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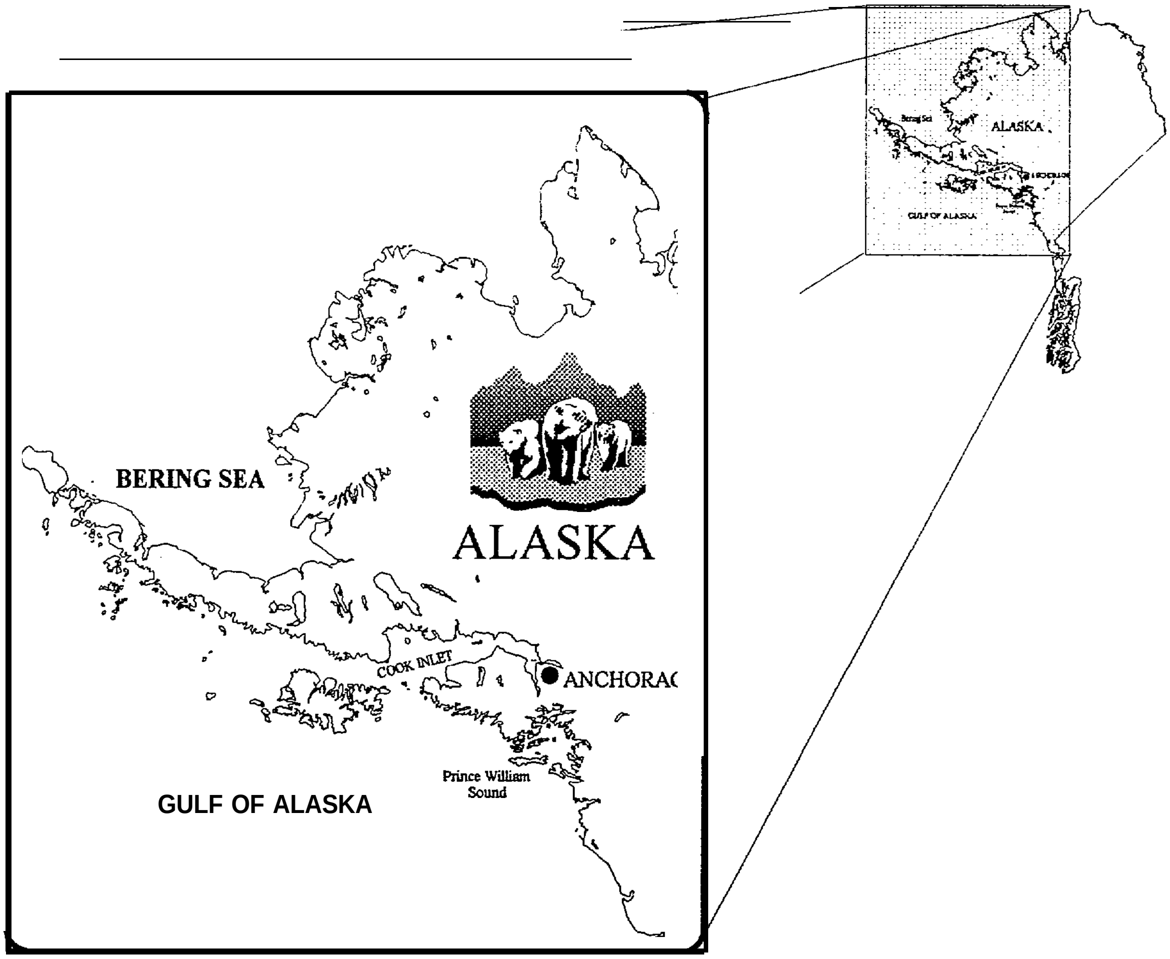
OCS Study
MMS 92-0046

Alaska OCS Region

FOURTH INFORMATION TRANSFER MEETING

Conference Proceedings



U.S. Department of the Interior
Minerals Management Service
Alaska OCS Region

OCS Study MMS 92-0046

ALASKA OCS REGION
FOURTH INFORMATION TRANSFER MEETING

Conference Proceedings

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MBC Applied Environmental Sciences
947 Newhall Street
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PROJECT STAFF

MINERALS MANAGEMENT SERVICE
Alaska OCS Region

Joy Geiselman, Ph.D.
Contracting Officer's Technical Representative

MBC APPLIED ENVIRONMENTAL SCIENCES

Kathryn L. Mitchell
Project Manager

Susan L. Dearn
Rapporteur

Charles T. Mitchell
Rapporteur

Madine Johnson
Word Processing

Carol J. Mitchell
Graphics

SHERATON ANCHORAGE HOTEL
Missy Hayes

Registration Assistance Provided By:
Pat Rivers
Marge Olson
ALASKA CONVENTION AND VISITORS' BUREAU

Audio-visual and Technical Support By:
Eric Imig
IMIG VIDEO, ANCHORAGE, ALASKA

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MARINE MAMMALS

Chair: Steve Treaty and Steve Landino, Minerals Management Service

FISH

Chair: Robed Meyer, Minerals Management Service

WELCOME

Robert J. Brock
Regional Supervisor
Leasing and Environment
Minerals Management Service
949 E. 36th Avenue
Anchorage, Alaska 99508

Good morning. My name is Bob Brock. I'm the Regional Supervisor for Leasing and Environment with the Minerals Management Services, Alaska Region Office.

I'd like to welcome you to the Fourth Information Transfer Meeting (ITM) that the Minerals Management Service has held. This year we are taking on a little different approach on this ITM by expanding the purpose of the ITM. This is also going to be the Information Base Review public input portion for the Gulf of Alaska and the Bering Sea. And, in addition, will be reviewing the information in Cook Inlet and Shelikof Strait,

I want to emphasize to start this meeting off is that it is a public meeting, it is part of the public input process. Every speaker will allow some time for questions, And if you don't get your chance to make your statement, or if you see some need for some additional studies, or have questions on the studies, in your packet, on the form titled "Information Base Review for Oil and Gas Lease Sales," please write us.

So, if the opportunity doesn't present itself here to express your concern, be sure and write that letter addressed to John Schindler in our office. And it will get incorporated into the Environmental Impact Statement (EIS) process, or the Information Base Review process.

The main thing I want to do is emphasize is that we are glad to see you all here. Don't hesitate to ask those questions that you've been wanting to ask.

With that, I'm going to end my welcoming remarks. And I'll go into the second item on the agenda, which is the Area Evaluation and Decision Process (AEDP), which is the decision making and the area evaluation process that the Minerals Management Service has adopted for each and every lease sale.

DECISION-MAKING UNDER THE AREA EVALUATION AND DECISION PROCESS

Robert J. Brock
Regional Supervisor
Minerals Management Service
Leasing and Environment
949 E. 36th Avenue
Anchorage, Alaska 99508

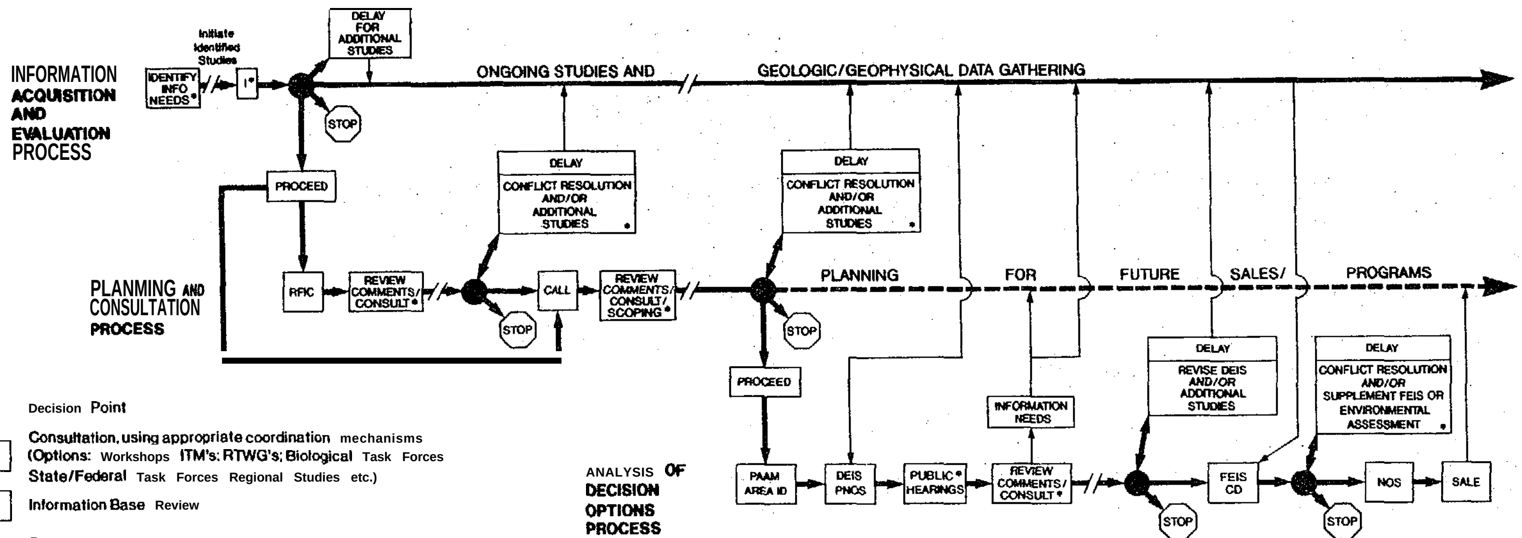
The Area Evaluation and Decision Process (AEDP) provides a framework for the activities which precede the decision of whether and under what condition to hold an individual Outer Continental Shelf (OCS) oil and gas lease sale. These activities include coordination and consultations, information acquisition, environmental studies, resource evaluations, decisions, and review and comment procedures under the OCS Lands Act and the National Environmental Policy Act (NEPA).

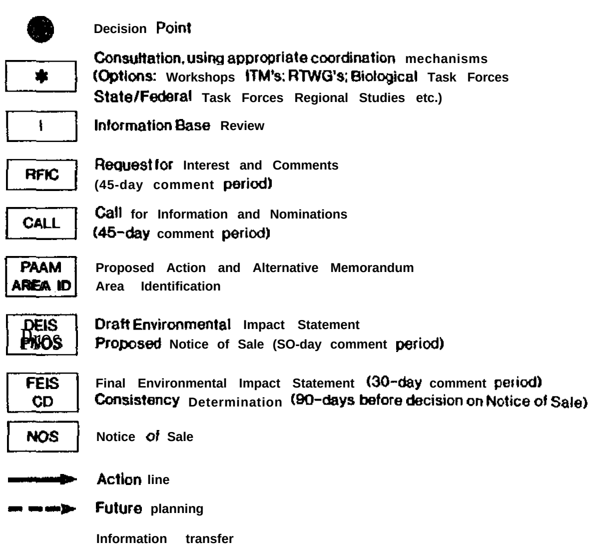
The AEDP has three interactive elements:

1. Information acquisition and evaluation process.
2. Planning and consultation process.
3. Analysis of decision options process.

Coordination with interested and potentially affected parties is a vital aspect of the AEDP. Extensive contact with federal, state, and local governments, universities, oil and gas industry, special interest groups, and the public assists in the acquisition and use of environmental and geologic information in offshore natural gas and decision processes.

We want to be sure that the OCS program management decisions are made with the benefit of the best available information, and in compliance with requirements of the statutes and regulations governing the OCS program. Decisions are developed and coordinated with potentially affected parties. Criteria for making decisions regarding leasing and management of OCS natural gas and oil resources and for acquiring information for these decisions are found in 1) applicable statutes and regulations, 2) judicial guidance resulting from OCS litigation, and 3) various Minerals Management Service publications developed for the aid of potentially affected parties.





TENTATIVE PLAN FOR THE AREA EVALUATION AND DECISION PROCESS

	I	RFIC	CALL	PAAM AREA ID	DEIS PNOS	FEIS CD	NOS	EARLIEST POSSIBLE SALE DATE
Beaufort Sea Sale 144	Completed	--	Completed	Late 91	Late 92	Mid 93	Late 93	Late 93
Chukchi Sea Sale 148	Completed	--	Late 91	Early 92	Early 93	Early 94	Early 94	Mid 94
Cook Inlet Sale 149	Completed	Late 91	Late 91	Mid 92	Mid 93	Early 94	Mid 94	Mid 94
St. George Basin or Hope Basin Sale 153	Mid 92	Mid 92	Late 92	Mid 93	Mid 94	Early 95	Mid 95	Mid 95
Gulf Of Alaska-- Yakutat Sale 158	Mid 92	Late 92	Early 93	Late 93	Late 94	Mid 95	Late 95	Late 95
Norton Basin or Navarin Basin or St. Matthew Hall Sale 159	Late 93	Early 94	Late 94	Early 95	Early 95	Early 96	Early 96	Mid 96
Beaufort Sea Sale 162	Early 94	--	Early 94	Late 94	Late 95	Mid 96	Late 96	Late 96
Chukchi Sea Sale 167	Mid 94	--	Late 94	Early 95	Early 96	Early 97	Early 97	Mid 97

Note: Provisions for compliance with the requirements of the Coastal Zone Management Act Reauthorization Amendments of 1990 will be incorporated in future depictions of this process.

Figure I. Alaska region area evacuation and decision process.

THE ENVIRONMENTAL STUDIES PROGRAM: CURRENT STATUS AND RESEARCH PRIORITIES

Jerry Imm, Chief
Environmental Studies Section
Minerals Management Service
949 E. 36th Avenue
Anchorage, Alaska 99508

I want to add my welcome to this Information Transfer Meeting (ITM) for those who have agreed to present papers or otherwise are participating, and for those who are attending as observers. We definitely appreciate these efforts. The ITM will focus on studies related to the Bering Sea, Cook Inlet and the Gulf of Alaska. The purpose of the ITM is to share Minerals Management Service (MMS) environmental, social and economic studies information and results gathered by MMS and other agencies, academia and industry consultants. We hope that this ITM will provide MMS and the public with more up-to-date information on the research that has been performed since our last major foray into the region. Again, we want to thank the many organizations and individuals for assisting us in this task.

The purpose of the Environmental Studies Program (ESP) is to:

1. Establish information needed for prediction, assessment, and management of impacts on the human, marine and coastal environments which may be affected by Outer Continental Shelf (OCS) gas and oil (1978 OCSLA Amendments),

2. Enhance the leasing decision process by providing information on the status of the environment pertinent to prediction of potential effects of gas and oil exploration and development,

3. Identify ways and extent that OCS development can potentially affect human, marine and coastal environment,

4. Ensure that information available or being collected is in a form useful to the decision making process, and

5. Provide a basis for future monitoring of post-lease OCS operations.

This basic purpose has not changed, even though program budgets, direction and focus has changed many times, but the overriding goal is to determine the effects of OCS gas and oil activities on the various environments on or associated with the OCS.

The ESP in Alaska is undergoing rapid changes due to several factors, such as, declining budgets, and for the time being, apparent dwindling interest in the OCS off Alaska by the oil and gas industry. Another significant program note is that we are in the process of phasing out National Oceanic and Atmospheric Administration/Outer Continental Shelf Environmental Assessment Program (NOAA/OCSEAP) which has been a mainstay of the program since its inception in Alaska, and in fact, this is the last week of that relationship. This action is in response to reduced funding and to recommendations made by the General Accounting Office subsequent to their review of the Alaska ESP in 1987. Another agent for potential change will be the forthcoming National Research Council/National Academy of Sciences review of the Alaska ESP in the Beaufort and Chukchi Seas and the Navarin Basin mandated by Congress. This review is scheduled to begin in March of this year with a letter report to be prepared for submission to Congress by June 1992. Significant findings of this review could affect the Alaska ESP, but as yet in unknown ways, We also may be entering into an era of increasing cooperation with state educational institutions, which could provide additional opportunities for innovative research and challenges for the program.

We still are focusing much of our efforts in the Beaufort and Chukchi Seas, but there appears to be increasing interest in sub-arctic areas such as Cook Inlet and the Gulf of Alaska, which could result in some shift of resources from the arctic.

Since 1975 we have expended in excess of $245,000,000 on studies of the Alaska OCS, and adjacent coastal areas, thus, many areas have been covered rather extensively in the collection of socioeconomic, physical, chemical, and biological baseline or ecosystem process information, and therefore, we will likely spend more effort on monitoring and site-specific investigations in the near-term.

SUMMARY OF LEASING HISTORY, EXPLORATION, AND PRODUCTION ACTIVITIES IN THE GULF OF ALASKA, LOWER COOK INLET, AND BERING SEA

Jeff Walker
Field Operations
Minerals Management Service
949 E. 36th Avenue
Anchorage, Alaska 99508

This paper discusses and clarifies some of the perceptions of what might be expected in postlease exploration and development and production activities in the event additional leasing occurs in southern Alaska,

There are 13 planning areas under the current 5-year plan. There have been 10 Outer Continental Shelf (OCS) lease sales in 8 of these planning areas; the Chukchi, Beaufort, Norton, Navarin, St. George, Shumagin, Kodiak, and Gulf of Alaska.

There have been almost 8000 tracts offered in these 10 OCS lease sales. In the sub-arctic only 553 leases were actually awarded, That represents about 7% of the tracts that were offered, While there is a lot of acreage in the Alaska OCS, very little of it has actually been leased and explored.

Almost all of the leases that were issued from the sub-arctic sales have expired or have been relinquished, There are 2 remaining leases in the Navarin Basin and 11 in St. George. These remaining leases are due to expire in 1994. There are also 23 remaining leases in the North Aleutian Basin. Further activity on the North Aleutian Basin leases is subject to a congressional moratorium until the completion of studies.

Exploration, or rate of exploration that occurs, is subject to a number of things that include:

1. the resource potential of an area,
2. the individual company's priorities, both on a regional level and on an international level,
3. the economics and the cost of drilling an exploratory well; and,
4. the results of each well.

There have been 49 OCS exploration wells and 14 deep stratigraphic test wells drilled in the southern planning areas. The number of wells drilled in each planning area ranged from 7 to 13 wells. if you took all the exploratory wells that the environmental impact statements (EIS') projected for analysis purposes in each of the sales areas, they would total 350 projected exploratory wells, compared to the 49 actually drilled. This reflects a couple of things. One is that there were no discoveries. All these wells were permanently plugged and abandoned. Second, the high cost of exploration activities in frontier areas, which range into the tens of millions of dollars, result in a conservative rate of exploration.

We would expect that, as seen with other lease sales, the rate of exploration resulting from future leasing will likely be one or two wells per year.

The type of drilling units that have been used for exploratory drilling in the past include jack-ups, which are bottom-founded structures. Jack-ups are generally limited to water depths of 300 to 350 ft and would be used in Norton Sound and portions of Cook Inlet, but not in the Bering Sea or Gulf of Alaska; drill ships, which are ship-shape type drilling vessels; and semi-submersibles are floating drilling units which can be used in any of the planning areas.

Drilling operations run about 30 to 90 days, depending on the depth of the well to be drilled. It is a-short-term activity, They are typically planned during the summer open water periods when the storm conditions are less to minimize down time and reduce the overall cost of the exploratory operation.

All exploration activities share a common need for onshore support facilities and air and vessel support. Logistical support typically encompasses one or two dedicated helicopters, a dedicated support vessel that stays in the vicinity of the drilling program, and another vessel that will make supply runs to the support base and back to the drilling operation, characteristically one or two trips a week. The major support bases which have been used during exploration activities include: Yakutat and Cape Yakataga in the Gulf of Alaska; Seldovia, Homer, Nikiski, and Kodiak in Cook Inlet; and Dutch Harbor, Cold Bay, St. Paul and Nome for operations in the Norton Basin and Bering Sea.

Exploration activities will be subjected to a technical and public review process. It involves submission of an exploration plan (EP) to the Minerals Management Service (M MS) which goes through a review process which includes public and federal and state agency review. In-house, the MMS will prepare an environmental assessment, taking into consideration any comments that are submitted. The EP is a detailed description of the type and timing of the proposed exploration, the type of facility to be used, when and where, and how the activity is going to be conducted. It is accompanied with other supporting information including an oil-spill-contingency plan and environmental information on the type and nature of environmental effects that are going to occur. The EP and associated documents are subject to review and analysis, including public review and comment. It is also subject to coastal zone consistency' certification by the state.

Lease stipulations and other mitigating measures are developed and designed throughout the leasing process to mitigate potential environmental effects. Some of the types of measures that have been adopted in the previous iease sales address oil spill contingency plans, surveys for archeological and biological resources, controls over shallow mud and cutting discharges, and endangered species. There have been many changes both in federal laws and regulations that have taken place since activities have been conducted in these subarctic areas. When the MMS starts developing and considering mitigating measures for new proposed lease sales, the MMS will take into consideration the new and existing laws and regulations which deal with environmental protection, and other previous experience in the area.

In the event of a commercial discovery in Alaska, another extensive permitting and review process will kick in, including the preparation of a project-specific EIS which will go through a process similar to the lease saie EiS, including scoping meetings and public hearings. A development and production plan will go through public review and approval and state coastal zone consistency.

The MMS retains, both for expiration and development and production, a very broad authority to approve, or conditionally approve, an activity to assure that it is conducted in a safe and environmentaliy-sound manner, or to disapprove an activity,

Exploration and development and production is not a new activity in Alaska. There has been OCS leasing and exploration in the past, and development and production is continuing in the Upper Cook Inlet on state submerged lands. In the event of future OCS leasing, the level of exploration activity and type of activity will be very similar to what has been done in the past. In the event of a major commercial discovery, there will be a more elaborate process kicked in and opportunity for additional public input.

Walker — Summary of Leasing History, Exploration, and Production Activities in the Gulf of Alaska, Lower Cook Inlet, and Bering Sea

---

Mr. Jeffrey Walker is a supervisory petroleum engineer with the Minerals Management Service (MMS). Over the last 14 years, Mr. Walker has been involved with administering the MMS'S regulatory program for oil and gas lease operations all over Alaska, from the Gulf of Alaska to the Beaufort Sea. Mr. Walker is responsible for processing proposed exploration and development and production plans, including technical reviews and coordination with other federal and state agencies, local communities, and other interests. Mr. Walker has a B.S. in geological engineering from the South Dakota School of Mines.

OIL SPILL RESPONSE PREPAREDNESS

Tom Murrell
Field Operations
Minerals Management Service
949 E. 36th Avenue
Anchorage, Alaska 99508

OIL SPILL CONTINGENCY PLAN REQUIREMENTS

Before conducting exploratory drilling or production operations on the Outer Continental Shelf (OCS), Minerals Management Service (MMS) regulations require each lessee to submit an Oil Spill Contingency Plan (OSCP) to the regional supervisor, field operations (RS/FO), MMS, for approval with, or prior to, the submission of an exploration plan (EP) or development and production plan (DPP). The OSCP is developed for the site-specific operations, based on the type, timing, and location of the proposed activities. The OSCP must satisfy the content requirements and provisions identified in 30 CFR 250.42 and the "Planning Guidelines for Approval of Oil Spill Contingency Plans" developed jointly by the MMS and U.S. Coast Guard (USCG) (herein called guidelines), Each OSCP is required by the regulations and guidelines to include:

1. A summary of all oil-spill trajectory analyses which are specific to the area of operations. The summary must identify environmentally-sensitive areas and biological resources, including birds and marine mammals, commercial fisheries, and subsistence resources which may be impacted by the spilled oil and the strategies to be utilized for their protection. The guidelines also require a risk analysis which indicates the number and size of spills that could occur during the proposed operation.

2. An identification of response equipment which is committed and available (on-site, locally, and regionally) and the associated response times, together with materials, support vessels, and procedures to be employed in responding to both continuous discharges and spills of short duration and limited maximum volume, The response equipment and strategies must be suitable for anticipated environmental conditions in the area of operations. The guidelines establish that equipment should be capable of operating in 8 to 10 ft seas and 20 kn winds, with deployment in the 5 to 6 ft range. The guidelines also establish that the quantity and capability of the equipment should be related to the risk analysis, A recovery rate of at least 1000 barrels of oil per day is considered appropriate unless the risk analysis suggests a higher rate is warranted. The response times established by the guidelines are 6 to 12 hrs for initial recovery actions, with prestaged equipment, depending upon location and weather. If the risk analysis indicates shoreline contact sooner than 6 to 12 hrs, response times must be accordingly adjusted. For extraordinary spills, the guidelines establish that additional equipment shall be available within 48 hrs.

3. A dispersant use plan including an inventory of the dispersants which might be proposed for use, a summary of toxicity data for each dispersant, a description of the types of oil on which each dispersant is effective, a description of application equipment and procedures, and an outline of the procedures to be followed for obtaining approval for dispersant use. The guidelines establish that the types and quantities of dispersants proposed for use must be related to the risk analysis taking into account toxicity, expected oil composition, and water temperature, A target response of 24 hrs or less from the time the spill occurs is established by the guidelines,

4. A plan for inspecting and maintaining response equipment.

5. Establishment of procedures for early detection and timely notification of an oil spill, including a current list of names, telephone numbers, and addresses of the responsible persons and alternates who are to receive notification of an oil spill and the names, telephone numbers, and addresses of regulatory organizations and agencies to be notified when an oil spill is discovered.

6. Well defined and specific actions to be taken after the discovery of an oil spill, including:

   - Designation by "name or position of an oil-spill-response operating team comprised of trained personnel available within a specified response time, and a description of the training such personnel will receive;
   - Designation by name or position of a trained oil-spill-response coordinator who is charged with the responsibility and is delegated commensurate authority for directing and coordinating response operations; and
   - A planned location for an oil-spill-response operations center and a reliable communications system for directing the coordinated overall response operations.

7. Provisions for the disposal of recovered oil, oil-contaminated material, and other oily wastes. This section must describe both the interim storage of such oil and mater, and the ultimate disposal options available.

8. Provisions for monitoring and predicting spill movement. The guidelines also require that, if electronic or mechanical instrumentation is used threshold detection sensitivities and limitations of equipment must also be provided.

9. Provisions for ignition of an uncontrollable oil spill and the guidelines to be followed in making the decision to ignite. The guidelines also require the identification of an operator's representative who has the authority to order the ignition of an uncontrollable well causing a massive spill event,

10. Identification of the location where inspection, training, and response-drill records will be kept.

All plans are reviewed by federal and state agencies, local government, and the public to ensure that each plan is appropriate for the type and scope of activities proposed, the environmental conditions of the area, and the biological resources at risk. The OCS plan must be updated at least annually,

TRAINING AND DRILLS

The MMS requires that operators conduct oil-spill-response drills to demonstrate their preparedness to implement an approved OSCP. These exercises include equipment-deployment drills and tabletop exercises. The drills are observed by the MMS, representatives of the US. Coast Guard, the State of Alaska, and local governments often participate in these drills,

RESPONSE CAPABILITIES

Historically, offshore exploration and development activities account for a very small percentage of oil that has been spilled, and large catastrophic spill events are rare from such operations. Even so, the MMS requires that operators be prepared to respond to large spills. The amount of oil that can be recovered or burned *in situ* varies greatly depending upon the amount and type of oil spilled, the ability of industry to respond to the spill before it has had a chance to spread over a wide are, and the oceanographic conditions during the spill-response

effort. Technology currently exists that is capable of containing, recovering, and disposing of oil spilled from offshore facilities. Strong winds, high sea states, dynamic ice conditions and emulsification of oil can greatly reduce spill-response effectiveness, Industry and government are working together to improve spill-response capabilities and the better understand existing technology.

Tom Murrell is a petroleum engineer and has worked for the MMS in the Alaska OCS Region since 1981. lie presently serves as the Operations Unit Supervisor in the Operations Review and Approval Section of Field Operations. This section is responsible for coordinating the review **of** *OSCP's submitted in conjunction with OCS EP's and DPP's.*

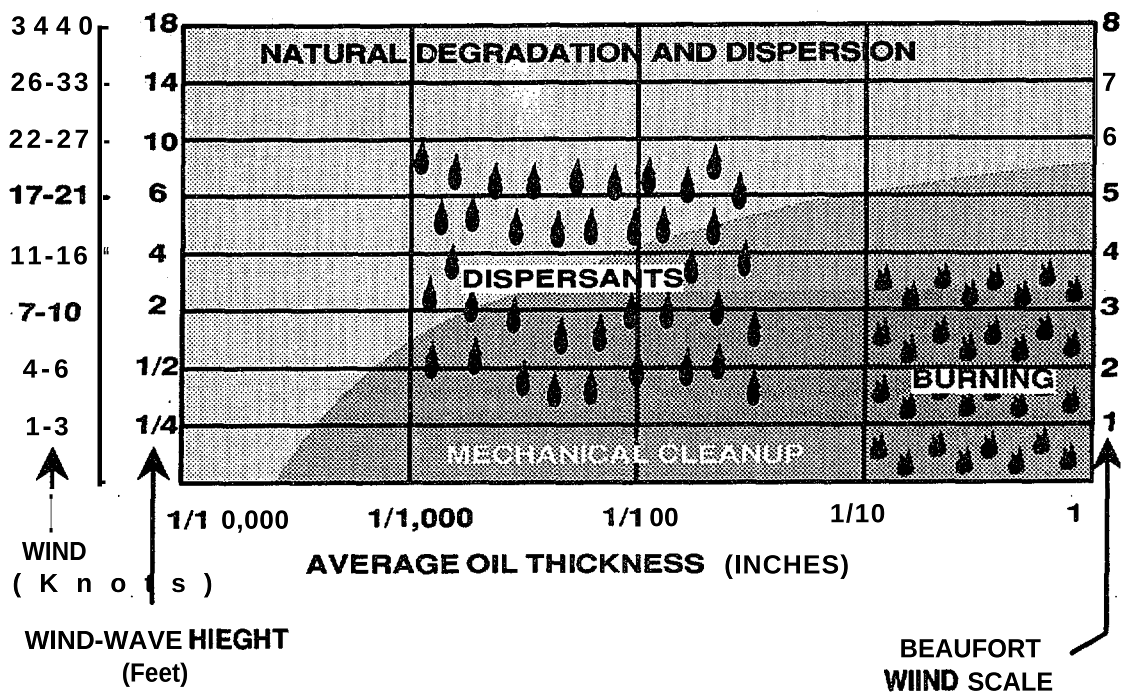


Figure 1. Spill response options under various wind/sea conditions (Source: A. Allen 1990).

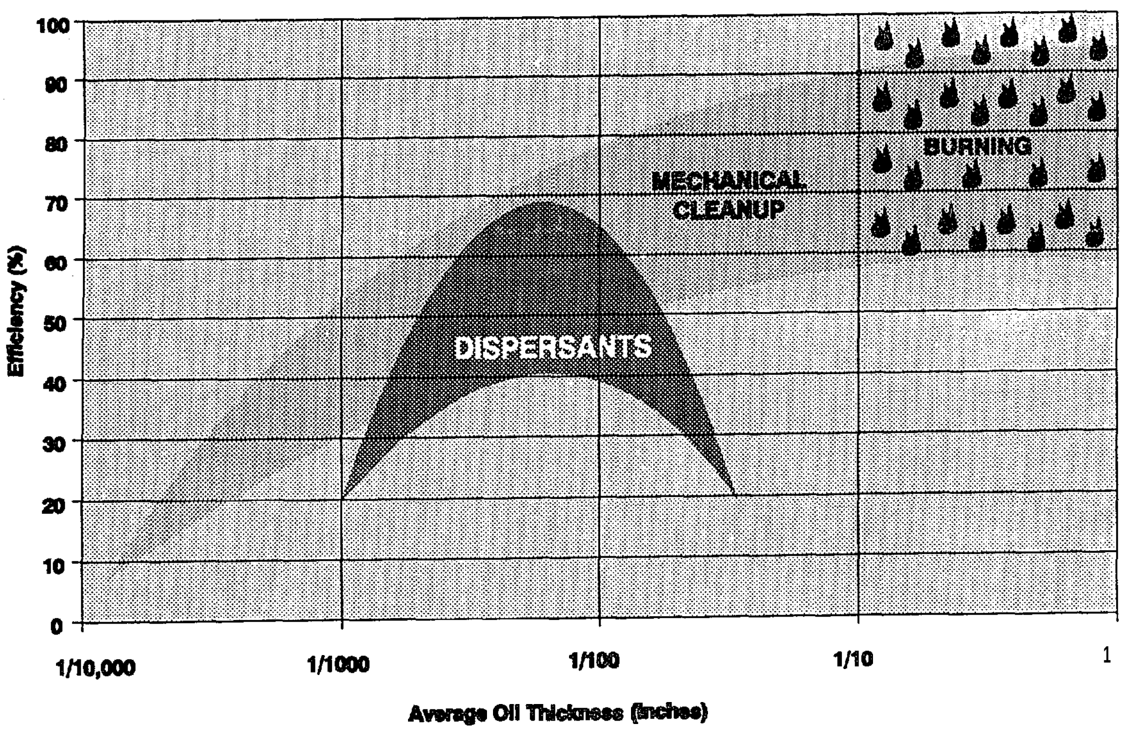


Figure 2. Selected performance efficiencies for response techniques over a range of oil film thickness (Source A. Allen 1990).

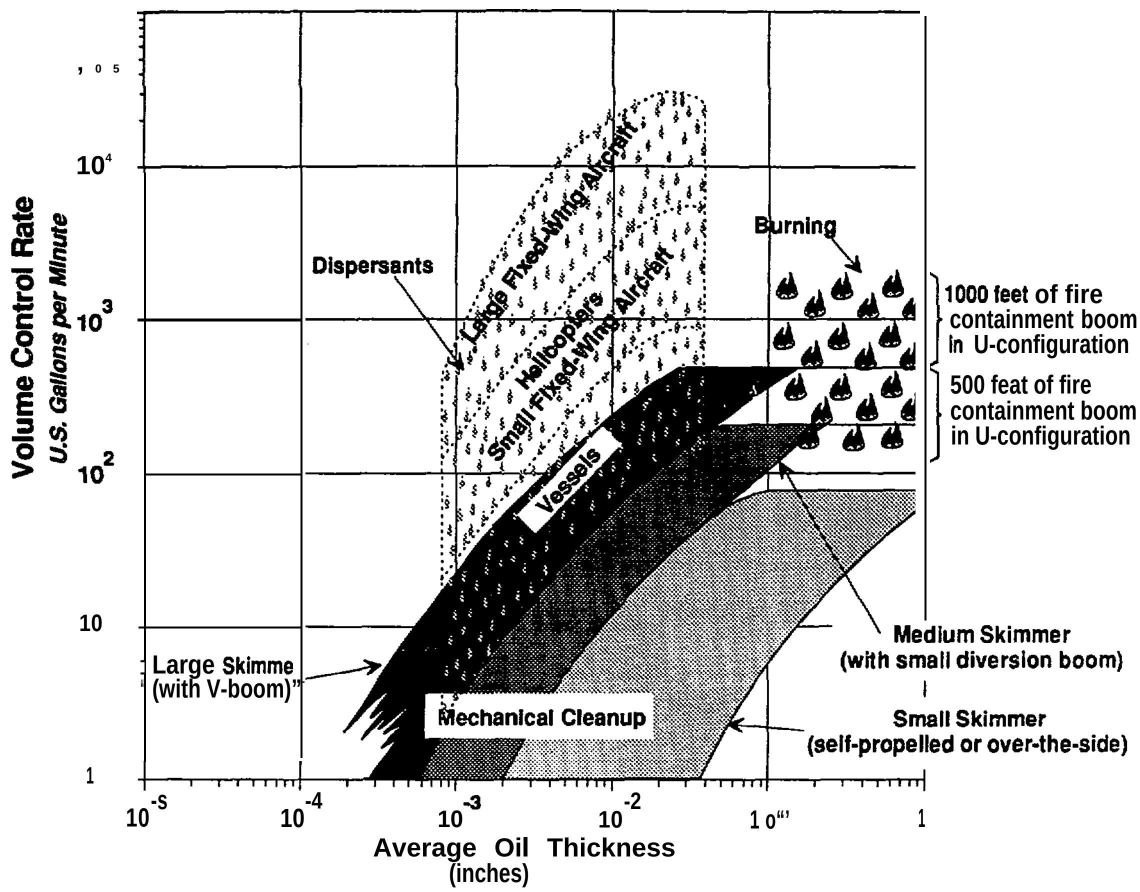


Figure 3. Comparison of potential volume control rates for selected spill response techniques (Source A. Allen 1990).

MMS OPERATIONAL AND REGULATORY PROGRAM REQUIREMENTS

James B. Regg
Field Operations
Minerals Management Service
949 E, 36th Avenue
Anchorage, Alaska 99508-4302

SUMMARY

Oil and gas operations on the Alaska Outer Continental Shelf (OCS) remain in an exploratory drilling phase. Offshore oil industry activities must be conducted in a manner which mutually exists with the other uses of the OCS, and which protects the Region's valuable resources, The challenges of operating on Alaska's vast OCS include dynamic (intense) weather conditions; remoteness and the lack of infrastructure; seismic (earthquakes, volcanos) activity; and subfreezing temperatures and associated conditions, The challenges of operating on the Alaska OCS have been met through over three decades of activities offshore Alaska and should not be viewed as unmanageable problems, They are being met through technology and the prevention of accidents and oil spills,

Offshore drilling in U.S. OCS waters has not been a significant source of pollution, There has never been a blowout resulting in an oil spill from drilling more than 10,000 OCS exploration wells — a record difficult to ignore (Minerals Management Service OCS Inspection Program), There are good reasons for this drilling safety record, not the least of which are continued experiences operating in similar environments with similar equipment (semisubmersibles, jackups, drillships, etc.), improvements in technology, a commitment by the oil industry to operate in an environmentally responsible manner, and a prevention effort which has evolved over many years of offshore operations.

The Minerals Management Service (M MS) regulatory program identifies special requirements of industry for the prevention of accidents: shallow hazards surveys, geotechnical evaluations, well planning, drilling mud, mud logging, drilling unit fitness, blowout prevention (BOP) systems, well control training and drills, and special contingency plans for suspending operations (referred to by the Alaska OCS Region as Critical Operations and Contingency Plans (COCP)).

A COCP details the criteria and structured procedures for suspending operations and ultimately securing the wellbore prior to environmental conditions which could exceed the operating limitations of the drilling unit. For floating drilling units, the COCP further details the conditions and procedures for disconnecting and moving the unit off location after the well has been secured, should the environmental conditions exceed the floating drilling unit's capability to maintain station.

A COCP relies on a combination of factors, including the monitoring and forecasting of meteorological/oceanographic conditions, the well status, and the type and mechanics of wellbore operations. These factors are analyzed onsite through a decisionmaking process outlined in the COCP. The emphasis is on making real-time, situation-specific decisions based on available information.

Ensuring adequate time to safely and efficiently suspend operations, secure the well, and if appropriate, move off location, is a key component of the COCP. Time requirements are reviewed and analyzed as environmental conditions and the types of wellbore operations change. Extensive monitoring of the environmental conditions is conducted to ensure early warning of potential and impending hazardous situations.

The MMS exercises a review and approval authority over a lessee's operations. The MMS employs a near-continuous inspection strategy in Alaska to ensure that drilling operations are conducted in a safe and environmentally sound manner. The MMS also actively inspects approved training facilities with both announced and unannounced inspections to ensure adequacy of the facilities and training programs.

Efforts following accidents such as the Piper Alpha incident in the North Sea are also improving safety offshore through safety management (including more workforce involvement in safety); new safety systems, equipment, and procedures; evacuation, escape, and rescue capability upgrades; communication procedures; platform design improvements; etc.

The MMS is continually assessing its regulatory program with an emphasis on accident and oil-spill prevention. Continued emphasis on prevention by the MMS and the oil and gas industry will ensure future operations are conducted in a safe and environmentally sound manner,

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James Regg **has** *worked at the Minerals Management Service (MMS) Alaska OCS Region for the past nine years. He presently supervises the Technical Support Unit in Field Operations and is responsible for the review of postlease operations for compliance with MMS pollution prevention requirements. Mr. Regg has offshore experience in drilling and production operations, and with the MMS offshore regulatory and inspection programs. Mr. Regg received his B.S. in Petroleum Engineering from the Pennsylvania State University.*

NPDES REGULATORY IMPACT ON OUTER CONTINENTAL SHELF OIL AND GAS ACTIVITIES

Brad Mahanes
U.S. Environmental Protection Agency
401 M Street, SW
Washington, DC 20460

The Clean Water Act and the subsequent re-authorization statutes mandate the Environmental Protection Agency (EPA) control and eventually eliminate the discharge of pollutants in and on the surface waters of the United States. Minerals Management Service (MMS) is charged with managing the efficient recovery and utilization of this country's mineral resources on the Outer Continental Shelf (OCS). These two apparently diverse missions are coordinated to some degree through an interagency Memorandum of Understanding and implementing regulations for the issuance of general National Pollutant Discharge Elimination System (NPDES) permits.

The EPA directly impacts MMS oil and gas leasing activities on the OCS through three principal mechanisms; participation in the Memorandum of Understanding (MOU), issuance of NPDES general permits for oil and gas activities on the OCS, and the development and promulgation of national effluent limitations guidelines (ELGs) for the oil and gas extraction point source category.

The Clean Water Act (CWA) (et seq.) has mandated that the discharge of pollutants to surface waters of the United States be controlled and eventually eliminated. The program to effect this control was set out in Section 402 of the Act as the NPDES program. Implementing regulations for the NPDES program can largely be found at 40 CFR 122, including the regulations addressing the development and issuance of general permits (see 40 CFR 122.28). The Act also provides that any NPDES permit issued for a discharge into marine waters be supported by a determination that the permitted discharge will not cause irreparable harm nor unreasonable degradation to the marine environment. This requirement is established at Section 403(c) of the Act and is commonly referred to as a 403(c) determination or Ocean Discharge Criteria Evaluation (ODCE). Sections 304 and 306 of the Act set up the requirements for the development and promulgation of national effluent guidelines for both existing sources and new sources. Section 306 also defines standards for these effluent limitations; these standards are Best Control Technology (BCT), Best Available Technology economically achievable (BAT), and New Source Performance Standards (NSPS). These terms will be described in greater detail later in this presentation.

THE MEMORANDUM OF UNDERSTANDING

The Memorandum of Understanding was signed in May, 1984 by William Ruckleshaus as Administrator of the EPA and Dan Clark as Secretary of the Department of the Interior for Minerals Management Service. The principal goal of the MOU is to better coordinate the exchange of information between the two agencies, related to offshore oil and gas activities, and to consolidate information gathering activities required under the National Environmental Policy Act (NEPA) where possible. Both MMS and EPA are to codify the major tenets of the MOU in their respective regulations. The MOU also implies that both organizations will seek formal cooperating agency status under the Council of Environmental Quality regulations. The MOU sets out the coordination of the major steps in the leasing process with related steps in the process of issuing a NPDES general permit. A later addendum to the MOU calls for coordinated on-site inspections through the establishment of regional MOUS between MMS offices and the EPA regional offices. These regional inspection MOUS serve to reduce duplication of effort and maximize the use of limited resources.

The memorandum's goal of information exchange is based on the knowiedge that the only way that the schedules for leasing and permitting can ever progress in concert is if information requirements of each program and existing databases were made known to the other program early in the process. This need for the early exchange of knowledge and data requirements is clearly reflected in the MOU. As part of information exchange, EPA is granted full participation in MMS environmental studies and is provided the resulting data. EPA is also included in the review and comment cycle for MMS leasing plans and study documents. Based on the insight these reviews provide, EPA then provides MMS with the information requirements for permit issuance for given iease offering.

A second goal of the MOU is the coordination of NEPA responsibilities where possible. As part of the MOU, EPA and MMS, as cooperating agencies, share information gathered from environmental studies in lease offering scoping studies and as part of NPDES permit issuance and monitoring efforts, EPA can adopt the lease sale Environmental Impact Statement (EIS) if it concurs with the findings or can prepare a supplemental Environmental Impact Assessment (EIA) as necessary. Generally though, this is not required as the MOU provides for differences, where they exist, to be both presented in the Lease Sale EIS.

The current schedule of coordination between lease sale activity and issuance of general permits for OCS activities centers around the principal stages of EIS preparation. Once MMS announces the Call for Information on a given iease sale, EPA should begin to determine their 403(c) planning needs. As the lease sale area is further identified and bounded, EPA deveiops their scoping comments for the planned lease sale EIS. Once the lease sale has been determined to be viable (i.e., industry interest is sufficient and no fatal issues were identified during the scoping process), EPA's regional permitting section begins to develop the draft general permit for the planning area and initiate an ODCE for the general permit. As an alternative, EPA can expand an existing generai permit's area of coverage to incorporate the new iease sale if the permit modification meets regulatory criteria for permit modification and is determined to be appropriate for coverage under the existing general permit limitations, Before such a permit modification is promulgated, a supplemental ODCE is performed to assure the protectiveness of the modified permit.

Once MMS publishes their draft EIS for a iease sale, EPA prepares comment on the draft EIS and schedules completion of the ODCE. The two documents are interlinked as often as the ODCE wili reference portions of the draft EIS and the associated research studies. Once EPAs comments on the draft EIS are addressed and EPA determines that the proposed permitted activity (within the bounds of proposed permit limitations and conditions) wiil not pose a potential for causing irreparable harm or unreasonable degradation to the marine environment, EPA can begin to further develop the basis for the NPDES general permit, The statement of basis, also known as the fact sheet, serves as the foundation (and explanation) of the permit conditions and limitations (the fact sheet will be described in greater detail later). The draft ODCE is provided to MMS for comment; these comments are then addressed as part of the response to comment for process for the draft ODCE document and development of the draft generai permit. Once the final EIS is published with EPA's comments incorporated, then the draft general permit is generally published for public notice and comment. As previously stated, where EPA has substantive differences with portions of the EiS, MMS is directed by the MOU to include those differences in the EIS is a clearly identifiable manner. Once public comments have been reviewed and resolved for the draft general permit, the general permit is ready to be published as a final rule near the time of MMS' final offering notice or the lease sale.

NPDES GENERAL PERMIT PROCESS

EPA regulations provide for the issuance of general NPDES permits when the Regional Administrator determines that a number of dischargers with similar operations and discharge characteristics are most appropriately covered under a general permit. The criteria for making this determination are found at 40 CFR 122.28. EPA regulations currently go on to require the Regional Administrator to issue general permits for oil and gas activities on the Outer Continental Shelf (OCS) unless there are extenuating circumstances. EPAs regional offices are the permitting authorities for activities requiring NPDES permits on the OCS. General permits, like individual NPDES permits, have a statutory maximum duration of five years; permits can and have been issued for shorter time spans.

As alluded to earlier, EPA must have sufficient information at hand to develop permit conditions and limitations necessary to protect the receiving water quality and allow completion of the ODCE. Part of this information base includes identification of all areas of biological concern within or adjacent to the intended permit's area of coverage. During the scoping stages of the permit development, decisions as to whether the permit will cover a single lease sale or an entire planning area are made. Other scope options, such as whether to cover exploration, production, or both, are considered in this phase of permit development. This decision is frequently influenced by the history of the permitting activities in the area of consideration, the more mature the field (and permitting history) the more likely a basin wide permit for both exploration and production will be developed.

The option of modifying an existing general permit to incorporate the new proposed lease area can be employed if the EPA region determines this to be the most appropriate permitting mechanism. EPA regulations allow a general permit to be modified under specific conditions; these conditions include: substantial changes to the permitted activity occur, if EPA receives new information not available when the permit was issued, promulgation of new regulations or standards, if the level of non-limited pollutants in the discharge exceed the current BAT levels of control, or receipt of a judicial or legislative mandate. New information can include information indicating that cumulative effects from the discharger are causing unacceptable environmental impacts, The permit may also be modified if it contains a specific clause setting out the conditions that initiate the modification and the general nature of the expected changes. Such a clause is called a “reopener clause”,

All the information needed to draft a permit is collected by the permit writer in the administrative record. In the draft general permit, the rationale for decisions on development of permit conditions and limitations, the statutory authorities for permit conditions and limitations, the basis of Best Professional Judgement (BPJ) determinations, the results of ODCE studies and similar evaluations, and any policy decisions are collected and presented in fact sheet. Factual information that serves as the foundation for permit decisions, such as the scope of coverage, types of operations the permit will cover, characterization of the covered discharges is included in the fact sheet. The fact sheet is also a regulatory requirement; it lays out the process of how the permit was developed and what procedures will be followed for issuing the final permit, Procedural information typically found in a fact sheet includes the name and telephone number of a contact for more information concerning the permit, the public review and comment cycle for the permit, and when the permit is expected to be issued as a final permit.

One of the specific determinations spelled out in the fact sheet is the technology basis for permit limitations and conditions controlling conventional, toxic, and nonconventional pollutants. NPDES permits issued after 1984 are required by the CWA to incorporate the Best Available Technology (BAT) for treatment or control of toxics and nonconventional pollutants which is economically achievable. A similar requirement exists for conventional pollutants, Best Conventional Control Technology (BCT). Where national effluent limitations guidelines for BAT and BCT have not been promulgated, the permit writer must exercise his BPJ to determine what BAT and BCT levels of control are appropriate for the permitted discharge (s). The process and criteria to follow in establishing BAT/BCT based on BPJ is codified in EPA's regulations. The evaluation of the applicable control technologies, the economic achievability analysis, and the economic impact considerations to support these determinations are summarized in the permit fact sheet.

After the technology based controls and limitations are developed, the permit writer must then address the potential water quality impacts resulting from the permitted activity, For oil and gas activities in the marine waters, this review is accomplished by implementing 403(c), the Ocean Discharge Criteria Evaluations. Again, the criteria to be evaluated and the process for performing the evaluation can be found in 40 CFR 125. There are ten factors which are to be considered in determining whether the discharge will cause irreparable harm or unreasonable degradation to the environment. The evaluation to support the ODCE findings will consider characteristics of the permitted activity and its discharges, the toxicity and persistence of pollutants in the discharges, current. condition of the receiving environment, the biota ambient to the discharge, and the structure of the balanced indigenous population in the surrounding environment. The evaluation will also consider any potential pathway for human health exposures which can elevate risks, examine any potential impacts on endangered or threatened species, and determine the potential for the discharge to exceed any federal water quality criteria. The results of these studies are summarized in the ODCE document and the permit fact sheet. The fact sheet also generally contains the Director's finding related to no irreparable harm or unreasonable degradation. Where the finding of no unreasonable degradation cannot be made with absolute certainty, the EPA can impress monitoring requirements into the permit to gain the information necessary to make that final determination. When such monitoring conditions exist, a reopener clause is also incorporated into the permit to allow modifications (for additional limitations or restrictions) if the monitoring data indicate environmental degradation. Examples of permit limitations that can result from 403(c) determinations are: shunting the discharge to depth, discharge rate requirements based on depth, no discharge buffer zones, and seasonal discharge restrictions. Examples of additional monitoring requirements that may become more commonplace in OCS permits are: analysis of produced water for naturally occurring radioactive material, toxicity and pollutant specific monitoring of produced water and drilling fluid system discharges, toxicity and pollutant specific monitoring of sediments contiguous to the points of discharge.

Other layers of constraint in the permitting process include direct involvement by the coastal states through Coastal Zone Management Act (CZMA) consistency determinations and state certification under Section 401 of the CWA where the discharges pass through or empty into state waters. Section 401 certification ensures that the permitted activity is in accordance with state water quality standards; CZMA consistency ensures the permitted activity is consistent with the state's approved Coastal Zone Management Plan. No NPDES permit can be issued until CZMA consistency has been resolved and state certification has been given or waived by the state. Where permitted discharges could impact wildlife, fish, or shellfish resources or the state has jurisdiction of such resources through rulemaking or coastal zone management plans, copies of the permit are mailed directly to the potentially effected states. Additionally, states like private citizens and industry groups, can raise issues on the permit during the public notice and comment period of permit issuance, EPA also has specific responsibilities under other federal statues such as the Endangered Species Act, National Environmental Policy Act, the Marine Protection, Resources and Sanctuaries Act, the Paperwork Reduction Act, and the Regulatory Flexibility Act. Where the U.S. is a signatory to international treaties, language reflecting such requirements (or the implementing regulations) is incorporated into the permit (e.g., prohibitions on the discharge of operational wastes based on MARPOL).

Once all these evaluations of potential impact and regulatory requirements have been performed, they are consolidated into the permit limitations and conditions. The permit will specify what waste streams are permitted for discharge and what quantities of pollutants in those waste streams are allowed. Monitoring schedules and enforcement penalties are generally found in the body of the permit. The scope and duration of the permit will be specified and the conditions under which permit conditions can be changed are spelled out. Once a general permit is complete, it is reviewed for accuracy, consistency with agency policies, and enforceability. The draft general permit is published for notice and comment; the Region then reviews and addresses the comments in the response to comment document, generally referenced or published with the final general permit. The response to comment document will indicate where changes were made to the final permit as the result of public comment.

Current Status of EPA Activities with Direct Impact

The Engineering and Analysis Division (EAD) in the Office of Science and Technology (OST) is responsible for the development and issuance of National Effluent Limitations Guidelines for the Offshore Subcategory of the Oil and Gas Extraction Point Source Category. The offshore subcategory is defined as including those facilities (by wellhead location) which are located immediately seaward of the baseline of the territorial seas. This baseline is generally described as the seaward most shoreline of any state's lands or barrier islands, but the actual lines are generally decided by the Department of State. Where there are "gaps" caused by inlets between barrier islands or large bays, closing lines are established, again by the Department of State. This definition of offshore does not directly correlate with the definition of OCS, which generally begins three miles seaward of the baseline of the territorial seas. The Offshore Effluent Limitations Guidelines for the Oil and Gas Extraction Point Source Category are in the latter stages of development and are currently scheduled to be issued final in June 1992. Some discussions are currently underway between EPA, the industry, and the public interest groups that are parties to the judicial consent decree which established the schedule for issuing this guideline for a potential extension of final promulgation. This extension is being requested by EPA to allow more adequate consideration of such inssues as produced water treatment technology, drilling fluid toxicity, and naturally occurring radioactive material in the discharges.

Coastal Subcategory National Effluent Limitations Guidelines are also currently under development by EPA. The current schedule for final promulgation of these guidelines (as set by the court) is June, 1995. The initial characterization of the facilities to be covered under these guidelines has begun and the information collection questionnaire (collected under Section 308 of the CWA) is in draft form. The questionnaire will be provided to public interest groups and industry trade groups for informal comment prior to actual issuance.

Cook Inlet General Permit Reissuance

The Cook Inlet planning area covers those federal OCS waters in the Cook Inlet in Alaska inside the Shelikof Straits. The current NPDES general permit for this area covers the 15 platforms and the associated treatment facilities in Upper Cook Inlet north of the Forelands. Based on the current definition of offshore and coastal subcategories this permit, though covering OCS facilities, is a "coastal" permit. As such, the permit is based on coastal effluent guidelines and the permit writer's Best Professional Judgement determination of BAT. The current permit expired in October 1991 and has been administratively continued. The new permit is currently in development and the draft is projected to be published for public comment around June 1992, The ODCE is currently under development; the Region is also reviewing industry performance on waste stream treatability.

Beaufort and Chukchi Seas Modification

The Beaufort and Chukchi Seas general permits are currently under modification to expand the scope of coverage to include recent MMS lease sales in those areas. Once the ODCEs for the new areas have been completed, the permit modifications will be published for notice and comment, As part of the planning for the reissuance of these permits, Region 10 is assessing the issuance of a "Global" OCS General Permit to cover all the current active MMS planning basins. This would be consistent to how other EPA regions approach permitting oil and gas activities on the OCS and would allow for a more holistic approach to impact assessment.

The coordination between MMS and EPA has undergone a learning curve with some occasional lapses which are expected during the initial phase of an interagency relationship. As the interaction increases and matures, the free flow of information should and must become the norm. Regulators and the regulated for the energy sector are operating in an increasingly environmentally sensitive arena. The general public is becoming more sophisticated on environmental and energy use issues; this is demonstrated almost daily on the nightly news. EPA is receiving more comments on our rulemakings and permitting activities and foresees new or revised environmental statutes being forged in the near future. This industry is going to be more tightly regulated as time progresses; it is the burden of those of us in the regulating community to craft controls in an coherent and rational fashion,

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Brad Mahanes has worked at EPA in the Office of Wastewater, Enforcement, and Compliance since **1990.** *He current/y serves as the Permits Division's lead on NPDES issues for energy sector industries, with emphasis on oil and gas exploration and production. Prior to joining EPA, Mr. Mahanes was a senior environmental scientist for an engineering consulting firm supporting Department of Energy and Department of Defense facilities. Mr. Mahanes received* **his** *B.S. in biology from the University of the State of New York.*

QUESTIONS AND DISCUSSION

Richard Ranger: I'm just wondering if I could get you to elaborate a little bit on the view of the clearinghouse approach that is underway as you're evaluating reissuance of the general permit? Will you elaborate on what you mean by that?

Brad Mahanes: Quite succinctly, the clearing house is the pm-approval process for drilling muds where there is no strict toxicity limit but it's based on a toxicity goal. One of the things we're looking at is that [this process] it is very time intensive and very, very resource intensive for EPA to go through with that process. And as we all know, in this era of budget constraints, we're running out of resources. And one of the things we're looking at is transitioning away from pre-approvals, at least the special mud authorizations, and possibly either fixing the table of pre-approved muds, or some other avenue. And right now that's very much just under consideration. There's nothing that's been clearly defined yet. As we move forward, that obviously will be discussed with both public interest and the industry to find out what is a rational and balanced approach.

Suzanne Winder: I have a number of questions, but I'll keep just one of them. The five-year NPDES permitting process is in review right now for the Nikiski Refineries. And I'm wondering if the decision that's going to be made will it have to comply with this lawsuit? And also, are you going to take the current OCS/MMS five-year lease impact on the Cook Inlet into effect when that permit is approved?

Brad Mahanes: Which lawsuit?

Suzanne Winder: The one that you just mentioned.

Brad Mahanes: Oh, the NRDC lawsuit? The NRDC lawsuit, the subject for that is the offshore oil and gas and coastal exploration and production facilities. The Nikiski Refinery is a separate industrial category and is not a subject specifically of that lawsuit.

Suzanne Winder: The lease sale 149 is OCS/MMS's is part of the five-year lease sale?

Brad Mahanes: Right.

Suzanne Winder: And it does take in Cook Inlet, as a matter of fact now extends into Shelikof Straits. And there are impacts to the Cook Inlet from the Chukchi, Beaufort Sea exploration, all the explorations going on, because it is my understanding the refineries in Nikiski are going to receive a lot of the North Slope crude. And, I'm wondering in the permitting process, in approving this permitting process and the discharge permits, if you're going to be considering that as well?

Brad Mahanes: For a refinery, which is an individual permit, which would be different from the type of permits we've talked about here. Routinely, the Nikiski permit, if it's a refinery, it would not be a general permit. It's routinely going to be handled as a individual NPDES permit. But characterizations of the discharge, flow, mass through the system, process design, all that should be considered as a part of determining what is the appropriate permit limitations and permit conditions. And if you want to talk about that further, we can do that.

Suzanne Winder: I guess I was just concerned because it was my understanding that if the NPDES discharge permits for Cook Inlet are approved, they're going to be another five-year approval. That concerns me, because this OCS/MMS falls under that five-year purview.

Brad Mahanes: Yes, routinely NPDES permits, both general and individual, last for five years. That's the maximum cycle for which an NPDES permit by law can exist. But as I said, there is a whole host of statutory and regulatory provided for modification processes. So if there is new information brought to the table after the permit has been issued, that was not available, the Water Management Division Director has the authority to reopen and modify the permit to incorporate that new information.

Suzanne Winder: Is EPA considering doing benthic community studies in the Cook Inlet to determine this 30-year, what we call a chronic spill in Cook Inlet from these discharges before you issue this permit?

Brad Mahanes: That probably would be best spoken to by the regional permit writer and the folks in the Ocean Program Section. As a routine measure, EPA takes a look at ongoing environmental studies and doesn't close their eyes to any of the current studies that are going on.

We are looking at chronic toxicity as a national strategy. We are looking at sediment toxicity as a national strategy. So as it is appropriate, we would consider those things. But again, specific questions about the Nikiski and the Cook Inlet permit would be best handled by the Ocean Program Section in Region 10, because they're the folks that are actually doing the work.

Dorothy Smith: I wondered if you could speak a little bit about why the States of Alabama and Louisiana no longer allow the discharge of drilling waste into state waters?

Brad Mahanes: Yes, it's a little bit beyond the scope of this discussion. Very briefly, the State of Louisiana does allow the discharge of some drilling waste in state waters. It's prohibited the discharge of certain types of drilling waste in fresh water and intermediate waters. They also have a fairly extensive program of monitoring a one-time event of drilling waste and the produced water.

Those issues are being addressed in the current Gulf of Mexico OCS permit and also in the currently considered draft coastal drilling permit. But states are clearly authorized under the

Clean Water Act to promulgate water quality standards and restrictions more stringent than those proposed by EPA. The converse is not true. They can never be less stringent, but they can certainly be more stringent. And the state has a lot more authority to act on local issues than EPA does. When we come up with a standard, it must be national in scope and consider national implications.

Dorothy Smith: When the EPA is issuing NPDES permits, is it considering the cumulative effect of these discharges in state waters that the state has now determined are too great to allow continued load of those pollutants in their state waters?

Brad Mahanes; Like I talked about earlier, in state certification, if the discharge is into state waters, the permit has to go to, the state for state review. And--

Dorothy Smith: What I'm trying to say is that it seems to me that the states have learned something over time, that these discharges have caused significant pollution in state waters. While the federal government is considering large permits for large areas of federal waters, it would seem to me that it would be appropriate for the federal government to consider what the states have learned in deciding whether or not discharges should be allowed in federal water,

Brad Mahanes: Well, we certainly consider any of the studies that have been done, including the studies that supported the Louisiana work, Kerrie St. Pe's study, Boesch and Rabalais' study that sponsored by MMS, all those studies have been considered. But understand too that the Louisiana, the LADEQ water quality standards that you're talking about are for coastal and inland discharges.

And what we were talking about today, was deep water, OCS operations, and the two do not necessarily parallel each other. In some instances they do, and you will see those paralleling sort of limitations reflected in the new general permits. Where they're not appropriate, you'll also see that discussed in the fact sheet. A good fact sheet will develop the rationale of why things are different. And if that's not there then you need to notice and comment that in the public comment, and bring people back on line, Thank you.

AIR QUALITY REQUIREMENTS AND JURISDICTIONAL ISSUES

David C. Bray
Permit Programs Manager
U.S. Environmental Protection Agency
Air Compliance and Permitting Section (At-082)
Seattle, Washington 98101

INTRODUCTION

Under the Clean Air Act of 1970 and the Clean Air Act Amendments of 1977, the Environmental Protection Agency (EPA) was responsible for regulating sources of air pollution on the Outer Continental Shelf (OCS). However, in the 1978 amendments to the OCS Lands Act, Congress placed the authority to regulate those air pollution sources authorized by the OCS Lands Act in the hands of the Minerals Management Service (M MS) of the Department of Interior. The MMS promulgated air pollution control regulations for oil, gas, and sulfur operations on April 1, 1988, and for minerals other than oil, gas on sulfur on January 18, 1989.

During the period between 1978 and 1990, air pollution sources on the OCS became a larger part of onshore air pollution problems in some areas of the country, Congress, in response to these growing problems, returned the authority for regulating sources on the OCS to EPA. In the Clean Air Act Amendments of 1990, Congress required EPA to promulgate air pollution regulations for sources operating on the OCS which ensure that on-shore air quality is adequately protected.

DISCUSSION

Section 328 of the Clean Air Act, as amended on November 15, 1990, requires EPA to promulgate regulations to control air pollution from OCS sources located offshore of the states along the Pacific, Arctic, and Atlantic coasts and along the Gulf coast off the state of Florida. The purpose of these regulations are to attain and maintain federal and state air quality standards and to prevent significant deterioration of air quality. For sources located within 25 miles of the seaward boundary of these states, the EPA requirements must be the same as would be applicable if the source were located in the corresponding onshore area, including, but not limited to, state and local requirements for emission controls, emission limitations, offsets, permitting, monitoring, testing, and reporting. Sources located more than 25 miles beyond state boundaries will be subject only to EPA requirements necessary to achieve the purposes of section 328.

On December 5, 1991 (56 FR 63774), EPA proposed regulations to control emissions from existing and new sources of air pollution located on the OCS. The regulations apply to all activities authorized or otherwise regulated under the OCS Lands Act, except those sources located adjacent to the states of Texas, Louisiana, Mississippi, and Alabama, In general, the regulations establish emission control requirements, permitting requirements, and procedures to delegate enforcement of the federal program to state and local agencies.

The regulations establish two regulatory regimes. One regime applies to sources located within 25 miles of states' seaward boundaries. In this "near-shore" region, OCS sources will be subject to the same state, local, and federal requirements that they would have to meet if they were located in the corresponding onshore area. The onshore area closest to the OCS source is assumed to be the corresponding onshore area. However, the regulations will establish procedures whereby a neighboring area may request to be designated as the corresponding onshore area, The petitioning area must demonstrate that its efforts to attain and maintain ambient air quality standards, or to prevent significant deterioration of air quality, are hindered by the OCS source, and that it has more stringent air pollution control requirements than the source's nearest onshore area.

An important aspect of this "near-shore" program is maintaining consistency between the OCS requirements and the onshore programs. The regulations establish procedures for EPA to update the OCS requirements to ensure that consistency with onshore requirements is maintained. However, it must be noted that state and local agencies cannot independently change the EPA OCS requirements,

State or local agencies may request delegation to implement and enforce EPAs regulations for OCS sources located in this "near-shore" region. However, the state or local agency must demonstrate that it has adequate legal authority before the Administrator will delegate the program.

The second regulatory regime applies to sources located more than 25 miles beyond state's seaward boundaries. In this "outer" region, OCS sources will not be subject to state and local requirements. Such sources will be subject only to EPA requirements, including new source performance standards (NSPS), prevention of significant deterioration (PSD) permitting, and operating permits, In this "outer" region, the OCS air regulations will be implemented and enforced solely by EPA.

In accordance with the provisions of section 328, new sources must comply with the EPA regulations on the date of promulgation, However, existing sources have 24 months after the date of promulgation to comply with all applicable requirements.

Under. either regulatory regime, OCS sources may request an exemption from complying with requirements that are technically infeasible or which present an unreasonable threat to health and safety. However, if such an exemption is granted, EPA must impose substitute requirements which are as close in stringency to the original requirements as possible, However, any increase in emissions due to the granting of an exemption must be offset by the source,

The proposed regulations asked for comment on two important issues. The first involves the treatment of vessel emissions. Section 328(a)(4) indicates that the emissions from any vessel servicing or associated with an OCS source, including emissions at the OCS source or enroute to or from the OCS source (within 25 miles) shall be considered direct emissions from the OCS source. While EPA proposed such that such emissions be considered direct emissions from the OCS source for applicability purposes, EPA did not propose to directly regulate emissions from vessels as part of these regulations,

The second issue involves the air toxics requirements of the Act. Because the stated purpose of the OCS regulations is to attain and maintain ambient air quality standards, EPA proposed only to require compliance with air toxics regulations which could be rationally related to the attainment and maintenance of federal or state ambient air quality standards. EPA will consider the public comment on these two issues to determine the treatment of vessel emissions and air toxics requirements in its final regulations.

The implications of these new regulations are both straight-forward and far-reaching. To date, sources on the OCS have been subject to just one set of federal regulations - those of the MMS. Now, they will be subject to the traditional array of federal, state, and local air pollution regulations established pursuant to the Clean Air Act, These will include emission limitations for most air pollutants, new source permits for construction or modifications, operating permits (including permit fees), monitoring and reporting requirements, and federal or state enforcement actions under the Clean Air Act. In other words, OCS sources will be treated no differently than any other sources of air pollution.

SUMMARY

The Clean Air Act Amendments of 1990 charged EPA with regulating air pollution emissions on the outer continental shelf (OCS), including sources authorized under the Outer Continental Shelf Lands Act. EPA is required to promulgate regulations which ensure that on-shore air quality is adequately protected. EPA proposed regulations on December 5, 1991 and intends to promulgate final regulations in the next few months. These regulations will require sources located between 3 and 25 miles off shore to comply with air pollution control requirements that are the same as the on-shore requirements. Sources located beyond 25 miles off shore will be subject to new federal requirements. Existing sources will have 24 months to comply with the new requirements, while new sources must comply immediately. The enforcement of the regulations for sources located between 3 and 25 miles can be delegated to a state or local air pollution control agency.

David C. Bray has worked for the U.S. Environmental Protection Agency (EPA) for the past 16 years and is presently the Permit Programs Manager in the Air and Radiation Branch at EPA's Seattle office. He is responsible for the development and implementation of state and local permit programs, including EPA's new regulations for control of air pollution on the outer continental shelf. Mr. Bray received his B.S. in mathematics from the University of Washington.

PROTECTION OF MARINE MAMMALS
(MARINE MAMMAL PROTECTION ACT - INCIDENTAL TAKE)

John W. Bridges
Marine Mammals Management
U.S. Fish and Wildlife Service
4230 University Drive, Suite 310
Anchorage, Alaska 99508

In Alaska, the U. S. Fish and Wildlife Service is responsible for the management of three marine mammals; polar bear (*Ursus maritimus*), sea otter (*Enhydra lutris*) and the Pacific walrus (*Odobenus rosmarus*). These mammals are not listed as threatened or endangered and therefore, are not provided protection by the Endangered Species Act. However, they are protected under the Marine Mammal Protection Act (MMPA) of 1972.

The MMPA placed a general moratorium on the taking of marine mammals. However, as with most of our laws, there are general exceptions. These exceptions include: 1) taking by federal, state, or local government officials, 2) Native exemptions, 3) scientific research permits and public display permits, collecting, 4) taking incidental to commercial fishing operations, and 5) Section 101 (a)(5)(A), which allows the small take of marine mammals incidental to specific activities in specific geographical regions.

The Service's involvement in the protection of marine mammals through Section 101 (a) (5) (A) is increasing. Section 101 (a)(5)(A) allows the Service to initiate rulemaking or develop regulations to authorize the taking of marine mammals. The Service initiates rulemaking after and only after receiving a petition from a U.S. citizen, in previous cases this has been the oil and gas industry. Section 101 (a) (5)(A) states that; upon request by citizens of the United States who engage in a specified activity (other than commercial fishing) within a specified geographical region, the Secretary shall allow, during periods of not more than five consecutive years each, the incidental, but not intentional, taking of small numbers of marine mammals if the Secretary, after notice and opportunity for public comment:

1) Finds that the total taking will have negligible impact on the species and will not have an unmitigable adverse impact on the availability of the species for subsistence; and

2) Takings are monitored and reported.

Take, in the context of the MMPA, means to harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill any marine mammal. 'Take" can be broadly interpreted to cover many encounters with marine mammals. The passive effect of harassing an animal is not as easily recognized as killing an animal. Any action that causes a marine mammal to change its behavior could be construed as a "take."

Oil related activities occurring on the north slope and off the coast of western and northern Alaska, will result in interactions between marine mammals and industry personnel. There has been only one documented case of a polar bear actually being killed by oil industry personnel in Alaska. This incident occurred in 1990 at an offshore exploratory well site. The actual shooting occurred early in the morning during the off loading of a supply train. The bear was a 2 year old female shot for the protection of human life. Incidents of this type are not specifically authorized by or exempt from the MMPA. The Service investigated this incident but chose not to prosecute.

Under Section 101 (a) (5) (A), the taking of marine mammals, such as the previous example, may be allowed provided regulations have been developed, based on the best scientific evidence available, and Letters of Authorization (LOAS) have been issued.

After the development of regulations, which must contain monitoring and reporting requirements, the Service may issue LOAS. To obtain LOAs for the incidental take of marine mammals, each person or company must submit an application describing the proposed activity, including the method of operation, dates and duration of activity and the estimated area to be affected, The application must aiso include a pian to monitor the effects of the activity on marine mammals and a pian of cooperation describing measures taken to minimize potential conflicts between the proposed activity and subsistence activities. After review of the application, the Service determines whether the proposed activity complies with the regulations and renders a decision on the request for a LOA.

LOAs may be withdrawn or suspended. If the Director determines, after notice and opportunity for public comment, that the activity is not being conducted in accordance with the regulations or that the taking is having or may have a more than negligible impact on the species, the Director may withdraw or suspend the LOA.

The Service has issued incidental take regulations for exploration activities in the Chukchi Sea. in 1991, Shell Western E&P Inc. (SWEPI) and Chevron were issued LOAs to take polar bear and walrus incidental to oil and gas expiration activities in state waters and the OCS during the open water season.

The LOAs are conditioned to require industry to avoid the species as much as possible. When an encounter is unavoidable, the conditions of the LOA direct the industry to actions that should be taken to protect the species. Also, data from the required monitoring plans allows the Service to improve monitoring plans from year to year.

Three petitions have been submitted by BP Exploration, on behalf of itself and 14 other companies, to develop regulations for the incidental take of polar bear and walrus during year round oil and gas activities in the Beaufort Sea area, onshore and offshore. The Service will evaluate the petitions and if they pass the test of negligibility, regulations will be drafted and released for public comment.

John Bridges has worked as a biologist for the past 12 years for the U.S. Army Corps of Engineers, the U.S. Air Force, and is now employed with the Fish and Wildlife Service. His area of responsibility for the Fish and Wildlife Service is Small Takes Coordinator working in the Marine Mammals Management Office. John received his B.S. in biology from the University of Alabama at Hunstville and his M.S. in biology from Memphis State University.

Questions and discussion follow Ron Morris' talk.

INCIDENTAL TAKE OF MARINE MAMMALS

Ron Morris
National Marine Fisheries Service
222 West 7th Avenue, Box 43
Anchorage, Alaska 99513-7577

Regulations authorize only the non-lethal incidental taking of bowhead, gray, and beluga whales and bearded, ringed and spotted seals by anyone engaged in oil and gas exploration in the Chukchi Sea or Beaufort Sea. This includes Alaska state waters and outer continental shelf waters that have been leased for exploration or that are being considered for leasing.

These activities include geophysical surveys and exploratory drilling and support operations (e.g., icebreakers, supply vessels, and aircraft).

It is unlawful to carry out an activity that disrupts the normal movement or behavior of a marine mammal. A disruption of behavior may be manifested by, but is not restricted to, the following: a rapid change in direction or speed; escape tactics such as prolonged diving or fleeing into the water, underwater course changes, underwater exhalation, or evasive swimming patterns; interruptions of feeding or migratory activities; aggressive postures or changes directed at intruders; attempts by a whale to shield a calf from a vessel or human observer; the abandonment of a previously frequented area; or other stress-related behavior that may include vocalizing, tail lobbing, or breaching,

INCIDENTAL TAKE PERMIT - REQUIREMENT

Monitoring Plan

When applying for a Letter of Authorization, the applicant must include a site-specific plan to monitor the effects on populations of marine mammals that are present during exploratory activities.

The monitoring program should document the acoustical effects on marine mammals and document or estimate the actual level of take.

A report documenting the activity and monitoring results are required,

Measures to Ensure Availability of Species for Subsistence

A statement that the applicant has notified and met with the affected subsistence communities to discuss proposed exploratory activities and to resolve potential conflicts regarding siting, timing, and methods of operation,

A description of what measures the applicant has taken and will take to ensure that exploratory activities will not interfere with subsistence whaling.

What plans the applicant has to continue to meet with the affected communities up to and during the exploratory operations to resolve conflicts and to notify the communities of any changes in the operation.

SITE SPECIFIC MONITORING GUIDELINES FOR 1991

The following elements should be considered in planning a monitoring program to comply with National Marine Fisheries Service Regulations 50 CFR 228 Subpart D (55 FR 29207).

Applicants for Letters of Authorization are strongly encouraged to informally consult with appropriate agencies and interests prior to submission of their request.

1. Monitoring Methods should be appropriate to determine distribution and behavioral responses of potentially affected species before, during, and after exposure to the activities. The area to be monitored must extend beyond the zone of potential influence. Proper design of the monitoring program must incorporate a control group outside this zone and prior to potential influence.

2. Numbers and Distribution of Marine Mammals
   - Group size (less than two body lengths apart will be considered a group for cetaceans)
   - Composition (gender, size, etc. when determinable)
   - Time, latitude, longitude

3. Behavior of Marine Mammals (observers should "flag" obvious changes in behavior without concision of take)
   - General behavior/habitat use (feeding, resting, traveling)
   - Respiration rates and surface/dive times
   - Relative heading of marine mammals
   - Vocalization of marine mammals (acoustical work will be required)

4. Noise
   - Ambient and animal
   - industrial - source - including identification of operational changes, frequency spectrum, transmission loss, received level (depth and substrate information should be included/added for analysis of sound propagation when necessary)

5. Other Environmental Factors During Sighting(s)
   - Visibiiity/weather
   - Sea state
   - Ice type and coverage

6. Other Activities to be Recorded
   - Transiting vessels, aircraft, indicating time, latitude, longitude

7. Monitoring Necessary to Evaluate Activity
   - Monitoring will include pre- and post-activity assessment
   - Adequate periodic sampling throughout the activities covered under the Letter of Authorization

QUESTIONS AND Discussion

Warren Matumeak: I just have a funny question.

John Bridges: That's the kind we like, funny ones.

Warren Matumeak: Did the walrus really come through that moon pool?

John Bridges: Yes, sir.

Warren Matumeak: So, what happened, did you kill it, or —?

John Bridges: As I understand it, he came up into the moon pool, hung around awhile, and went out, And then came up in it again, and then he was lifted out, and put outside, and swam away.

Warren Matumeak: Thank you.

Richard Ranger: Ron, I'd just like to ask you at this time does National Marine Fisheries have in mind any specific species that they are going to be seeking monitoring of in connection with the Lower Cook and the Shelikof Strait area?

Ron Morris: The way the rules are set up, the regulations only apply to the Chukchi and Beaufort Sea at this time, So, if industry was interested in the incidental take and getting a Letter of Authorization (LOA), they'd have to petition us, and then we'd go through the process of opening up the other areas,

It's very site-specific, and it's very specific to different activities, For instance, the Clean Seas Program to spill and burn some oil in the Beaufort Sea isn't covered under the LOA process. They're very specific. So any activities in that regard would have to be requested by the industry and we'd consider it. And since the law does allow it, we'd go through that process. That's right.

Unidentified Questioner: I was concerned or confused about how you asked — how you said that the LOA is not required?

Ron Morris: That's correct. The LOA is not a requirement, It's there and a company can either apply for an LOA or not apply for one.

Unidentified Questioner: But there can still be an incidental take?

Ron Morris: No, If they don't have an LOA, then they're in jeopardy, In other words, hypothetically, without an LOA, if they're out there operating, and we can prove a take, of course that can be up to at a $25,000 fine.

Unidentified Questioner: Okay. That was what was confusing me,

Ron Morris: Okay. I'm sorry I didn't make that clear.

Unidentified Questioner: I just would like some clarification from the Fish and Wildlife Service about why Chevron and Shell needed a 90-day extension. You said it was because of heavy activity, but I didn't know if that meant heavy interaction, marine mammal interaction, and that's why it's taking them longer to get their data together, or-- I may have misunderstood you. I just needed some clarification.

John Bridges: Well, they said they had not necessarily interactions, or harassment, or take, but a lot of sightings. They really weren't actually working that close to the ice edge, but a lot of, I guess, the helicopter work, and sighting from the boat, they had a lot of sightings,

Unidentified Questioner: And, do Fish and Wildlife and NMFS both have the industry monitoring themselves, or do both agencies have observers on the vessels, on the sites?

Ron Morris: Okay, it's the later part. The monitoring is done by a third party contractor that is hired by industry. And the handle we have on the monitoring effort is that we have a final say,

on who they hire as far as observers and monitoring. But I know what you're getting at, and that's true, yes, they watch themselves.

Unidentified Questioned And is that because NMFS isn't provided enough funding to do it themselves, or would you prefer to do it yourselves if you had staff?

Ron Morris: Do you beat your wife? (LAUGHTER)

It is one of those questions — Well, obviously, yes, I mean, we would rather do it ourselves. And although, in a spirit of cooperation I do go up there. I monitor the monitors, I fly with the monitors. And the second best way is, I think, the way we're doing it. We're getting reputable companies doing the work, people with very, very good backgrounds. It's my personal opinion. And I make an effort to go up with these contractors, fly with them, and look at the data, And I'm comfortable with what they're producing.

But there is the fox in the hen house theory. And 1 guess that's what you're getting at. But, yeah, we would rather do it ourselves, but we're talking about mega-dollars here. These companies are spending very large sums, And the government would have to spend it. Or of course, they could pass it on to us, and we could do it for them, 1 guess. But, yeah, that is the way it is done. Incidentally, just so everybody knows, lots of times I know I've been in this business a long time, and people have a tendency to think, well, all the bureaucrats are in cahoots. But in a case of these monitoring plans, when I was called up and told by industry that they wanted 90 days, I just laughed because I need the data by February 15th. And I'm going to get mine by February 15th, because it doesn't make any sense to wait 90 days when I'm going to have a meeting in March to come up with new plans. So, everybody gets treated a little differently, But there is a problem with waiting 180 days to get data to make plans with. And that will be changed in the new rules.

Linda Freed: — from some representative in Kodiak that there maybe a bill pending in Congress that will change the statutory requirements related to incidental take. And I'm wondering if you might be able to expand on that?

Ron Morris: Well, within the scope of the meeting, I really can't. I'll let you have some specifics. If I'm aware of it, I'd be glad to. I mean, in what regard?

Linda Freed: The concern in Kodiak was the upcoming lease sale 149, is that perhaps the oil industry would take precedent over the commercial fishing industry, with regard to incidental takes, specifically of sea lions.

Ron Morris: Oh, well, our dealing so far with sea lions and industry is to be very strict with them in the efforts we've seen so far. My own personal comment on that is that the oil companies get treated worse than anybody else does as far as marine mammals. I mean, if we ask fishermen to do what we make the oil companies do, I wouldn't have a job. But they're not going to be let off easy. They never have and nobody is going to start now. That's just the way it goes. That's the way it is.

Any other questions?

Oh, the only other thing 1 want to comment is you'll notice there aren't a lot of the big MMS bureaucrats around, and I think it's because, on the way over today, I heard on Paul Harvey a leak that all of the MMS people in Alaska the president is going to send them all down to Bogota, Colombia, and he's going to do away with them up here, and since all the oil companies are going down anyway, he killed two birds with one stone. We get project independence from South America oil and MMS budget goes--gets paid for by Colombia. So we probably won't have another one of these meetings, so enjoy the coffee and donuts.

John Bridges: Let me say something in defense of Fish and Wildlife and the extension we give them. We're just nice guys. But they did say they have a lot of information, plus they are willing to give us a summary of the monitoring program so we are able to present it in Seattie. Even they are willing to present what is ready to be present at that time.

OIL FISHERIES GROUP

Peter Hanley
BP Exploration
P.O. Box 196612
Anchorage, Alaska 99519

No Summary Provided.

QUESTIONS AND DISCUSSION

Doug Coughenhower: Can you identify the fishing groups that are on the Board?

Peter Hanley: Actually I don't have the list with me. We have Cordova Fishing United. We also have processing organizations, United Fishermen of Alaska. But most of the major fishing groups at one time or another have participated in our organization, We have sent mail outs to the Cook Inlet area fishing organizations, Loren Flagg (sic) was the fishing industry representative at the Norwegian conference that I just mentioned. But I have a list I can give you after the meeting.

CIRCULATION STUDIES IN SHELIKOF STRAIT, COOK INLET AND THE GULF OF ALASKA

Thomas J. Weingartner
Institute of Marine Science
University of Alaska
Fairbanks, Alaska 99775-1080

INTRODUCTION

Physical Setting

Circulation in the Gulf of Alaska is profoundly influenced by its geographic setting. The gulf's high-latitude location, coastal topography, and atmospheric circulation, affect the magnitude and phasing of winds and coastal freshwater discharge. These factors, in conjunction with shelf bathymetry, produce a unique shelf circulation regime of which the salient feature is the Alaska Coastal Current (ACC). The ACC originates on the British Columbian shelf, flows counterclockwise around the Gulf of Alaska, and finally enters the Bering Sea through Unimak Pass (Schumacher et al. 1982) - a distance of over 3000 km. The plan of this paper is to first describe the physical aspects of the gulf which affects flow in the ACC. Such a description will provide the framework for an understanding of the regional circulation in Lower Cook Inlet and Shelikof Strait to which the rest of the paper is devoted. Figure la is a location map for the northwest Gulf of Alaska and Figure 1 b is a surface circulation schematic of this region and depicts both the ACC and the Alaska Current. The latter exchanges waters with the shelf through meanders and eddy processes. The large scale pressure gradient associated with this current also contributes to circulation on the shelf,

Coastal topography affects the circulation by directly "steering" currents and by influencing the meteorology. The gulf is ringed by a vast coastal mountain range extending from British Columbia, around southcentral Alaska, to the Alaska Peninsula. Elevations typically exceed 4 km and are greater than the height of the tropopause. Hence storms propagating into the gulf are usually blocked from moving inland by these mountains. Adiabatic lifting of moisture-laden air masses causes very high precipitation rates along the coast, especially at high elevations. Along most of the coast annual precipitation rates range between 2 and 3 m, although extremes in excess of 8 m have been recorded in Prince William Sound and southeast Alaska. Because the coastal drainage region is narrow (< 100 km), the majority of the freshwater flows onto the shelf via a network of small, short streams rather than from large rivers. Low density freshwater, entering along the coastline, affects cross-shelf density and pressure gradients, thereby acting as a buoyant force. The distributed (or line source) nature of this discharge exerts a gradual and cumulative alongshore influence on the shelf circulation. In contrast, a single, large river discharging over a relatively small area (a point source) will produce an abrupt alongshore transition in the circulation.

Figure 2a, from Royer (1982), shows the estimated mean monthly freshwater discharge rates along the southeast and southcentral coast of Alaska. These vary fourfold over the year, with maximum runoff from September through November due to a combination of snowmelt and increased precipitation. Minimum runoff occurs in February and March because the precipitation, while still heavy, is stored as snow (a consequence of both mountain elevations and the high latitude location of the Gulf of Alaska). A secondary maximum is observed in May due to springtime snowmelt. Royer (1982) estimates the mean annual discharge here to be about 23,000 $m^3 s^{-1}$. By comparison, the mean annual discharge of the Mississippi River is about 19,000 $m^3 s^{-1}$.

The same storm systems that provide precipitation also provide wind stresses that create coastal convergence and downwelling of surface waters, Westward winds associated with these storms move surface water to the right (in the northern hemisphere) causing an accumulation of surface water along the coast. These storm systems (characterized by cyclonic or

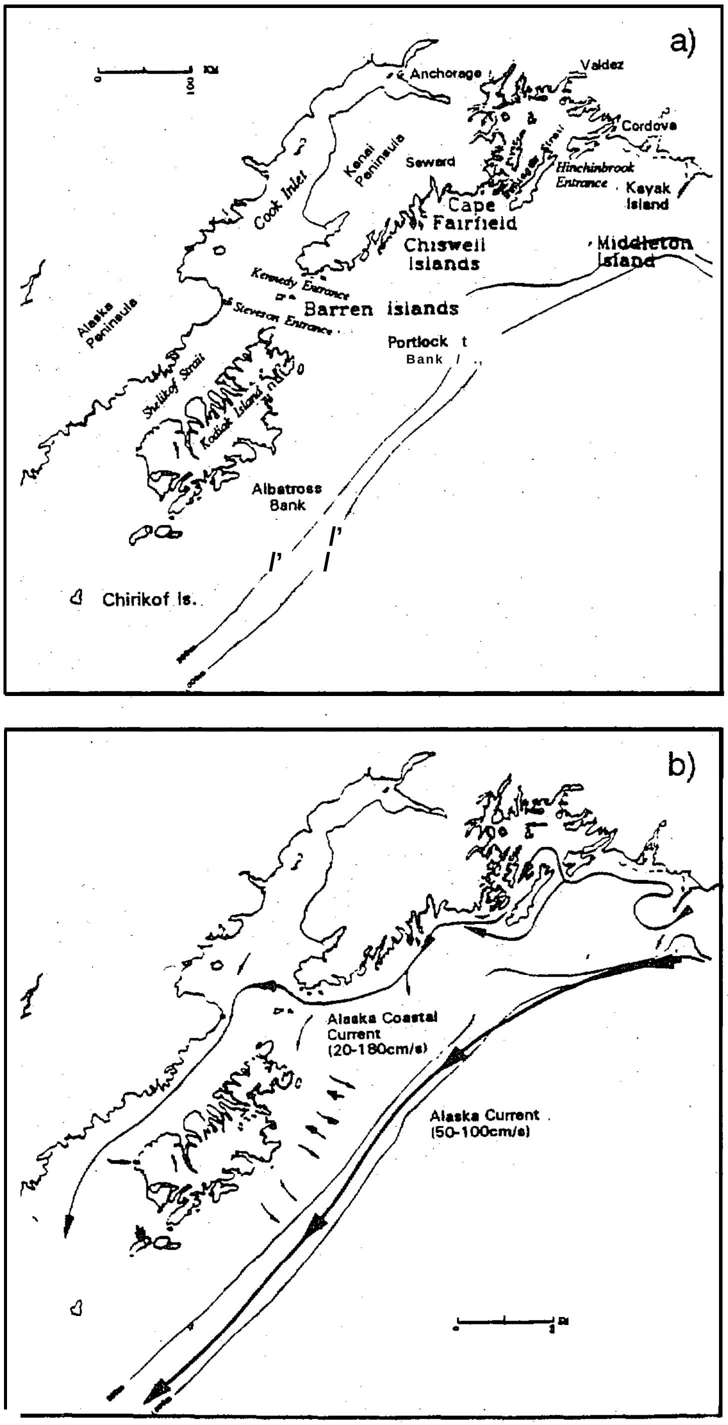


Figure 1. a) Northwest Gulf of Alaska and b) schematic surface circulation for the Northwest Gulf of Alaska.

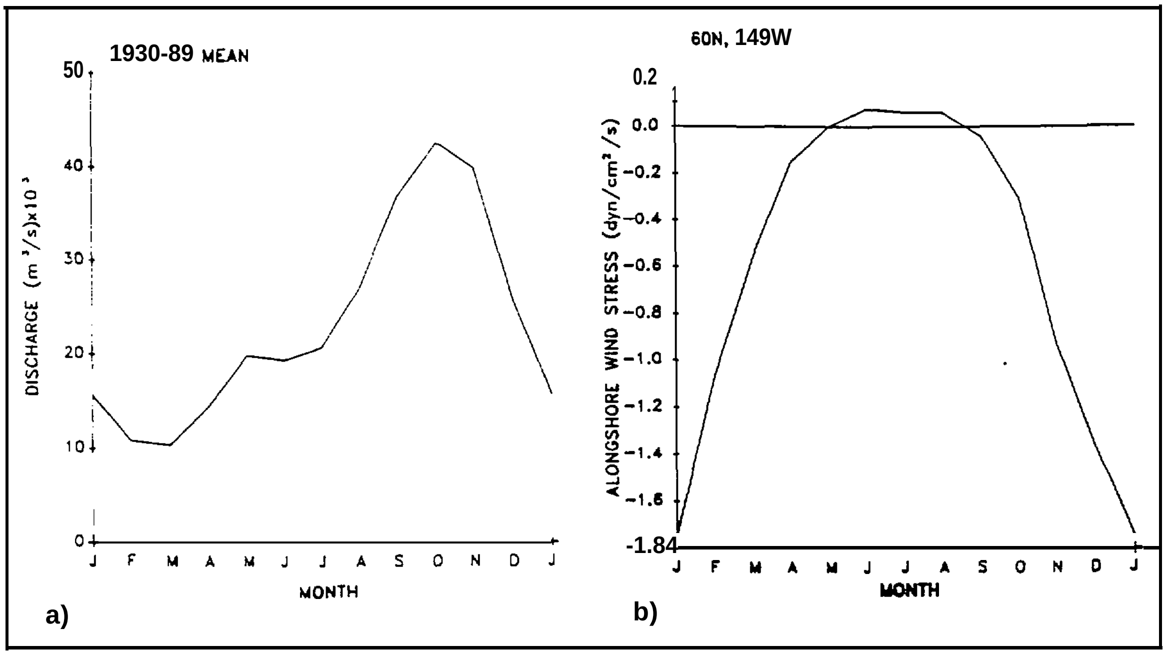
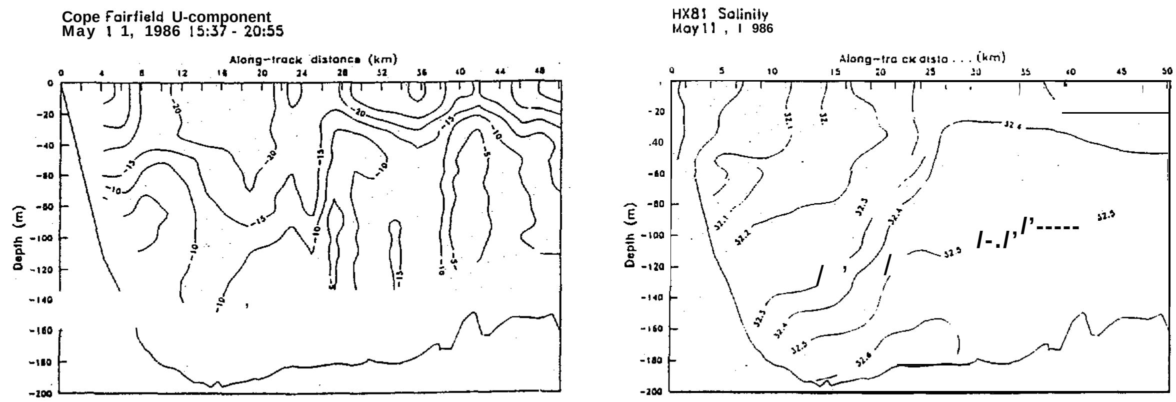


Figure 2. a) Mean monthly discharge of freshwater into the northern Gulf of Alaska using 1931-89 averages and b) mean monthly a longshore wind stress computed from surface pressure charts at 60°N,149°W. (Negative values denote westward wind stress and positive values denote eastward wind stress.)

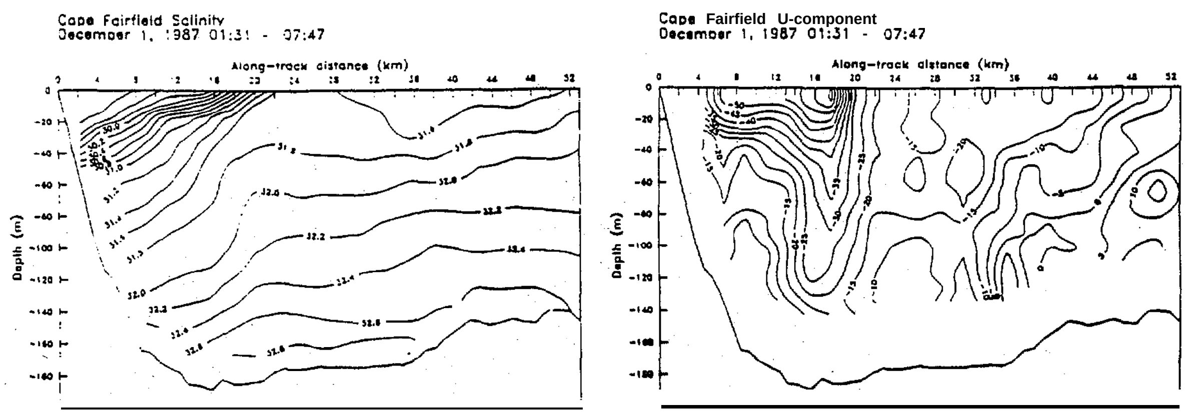
counterclockwise winds) are steered by the coastal mountains and fed by latent heat released during precipitation. Wind stresses and buoyancy flux exhibit large seasonal signals and are controlled by the North Pacific High in summer and the Aleutian Low in fall and winter. Figure 2b shows the mean monthly alongshore wind stress at 60°N,149°W along the southcoast of Alaska (evaluated from surface pressure maps). Westward wind stress (implies coastal convergence and downwelling and is given by negative values) occurs from September through April and attains a maximum in January. Eastward wind stress (implies coastal divergence and upwelling and is given by positive values) occurs from May through April and attains a maximum in June, Note that the maximum coastal discharge leads maximum westward wind stress by two to three months. Coastal convergence establishes a cross-shelf sea level slope and maintains the freshwater as a nearshore feature thereby enhancing the cross-shore density gradient. Both combine to accelerate the coastal flow.

GENERAL FEATURES OF THE ALASKA COASTAL CURRENT

Examples of the salinity and alongshore velocity (as measured from shipboard conductivity-temperature-depth [CTD] and Acoustic Doppler Current Profiler surveys) structure of the ACC are shown for May, 1986 (Figure 3a; when winds are weak and discharge below average) and December, 1987 (Figure 3b; when winds are strong and discharge above average). The plots were constructed from data obtained along a transect off the southcoast of Alaska which lies about 100 km east (upstream) of Shelikof Strait. In May, 1986 vertical and cross-shore salinity (and density) gradients are small and flow is westward but relatively weak across the whole transect. By contrast salinity gradients are strong in both the vertical and offshore directions in December, 1987. Relatively dilute water occurs in the upper 40 m of the water column and is bounded by a strong halocline which surfaces 20 km offshore to form a front. Vigorous westward flow is observed inshore of the front and maximum speeds of about 0,7 m s"' coincide with the front. Further offshore, the flow weakens and even reverses toward the end



a)



b)

Figure 3. Contour plota of isopleths of salinity and of the east-west velocity component obtained from a north-south transect off Cape Fairfield In a) May 1986 and b) December 19S7. Westward speeds are negative and eastward speeds are positive.

of the transect. Such a reversal is a common feature of the shelf circulation in this region (Niebauer et al. 1981, Johnson et al. 1988).

Johnson et al. (1988) current meter data collected within the ACC show that near-surface velocities are always westward at a mean speed of 0.35 m s-' with a seasonal range of from 0.2 m s-' in summer to 1.8 m s-' in fall. Their analysis also shows that on monthly time scales 1) alongshore winds (i.e., sea level slope variations due to coastal convergence and divergence) explain 68% of the variance of the alongshore flow and, 2) freshwater discharge explains 20% of the alongshore flow variance. Moreover, they find that the alongshore current response to winds occurs throughout the water column while the response to freshwater discharge is confined to the upper 50 m. With respect to the cross-shore flow component, alongshore winds account for about 36% of the variance while runoff accounts for about 31% of the variance. Here again, the cross-shore current response to winds is uniform over the water column while that due to runoff promotes offshore motion at the surface and onshore flow near the bottom. Their data

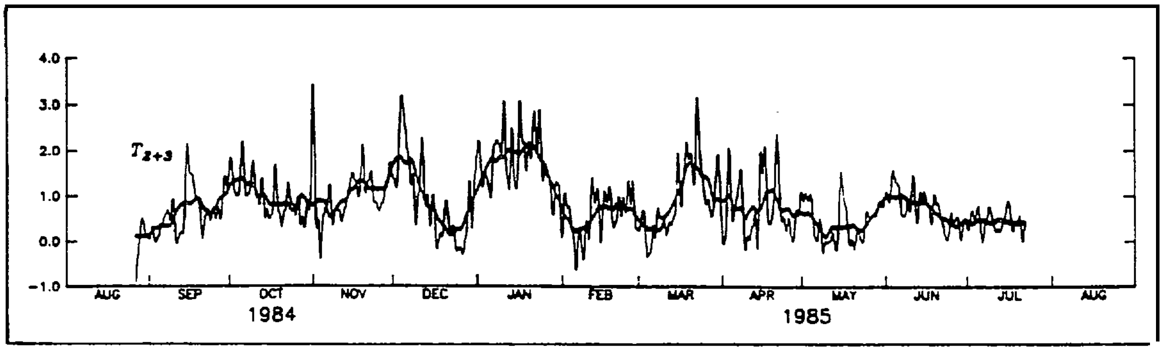


Figure 4. Time series of the ACC transport through lower Shelikof Strait. (The heavy line is a 10-day running mean.) Positive values denote outflow from Shelikof Strait. Units of transport are 106 m^3s^{-1} (Schumacher et al. 1990).

indicates a rapid increase in westward flow in fall (associated with increasing runoff) with a maximum attained in January (when westward wind stress is a maximum).

Figure 4 shows a time series of ACC transports (filtered to suppress the diurnal and semi-diurnal tides) as estimated by Schumacher et al. (1990) from current meter moorings in lower Shelikof Strait. (Figure 8 shows the positions of the current meter moorings used to construct Figure 4). They find a mean annual southwestward transport of 0.85 x 10^6 m^3s“'. The transport increases throughout the fall from a summertime minimum to its maximum in January. Superimposed on these seasonal fluctuations are shorter period fluctuations which often exceed the annual mean. Schumacher et al. (1990) find that approximately 50% of the variance in the seasonal and shorter period transport fluctuations are accounted for by the alongshore wind. Note also that flow reversals to the northeast are very rare and short-lived (<5 days).

To summarize, transport and velocities within the ACC are smallest in summer when winds are weak and runoff moderate, increase in fall as winds and runoff increase and are largest in winter when winds are strongest and runoff is least. It is also worth noting that, in terms of its extent, intensity, and persistence, the ACC is unique among North American coastal currents.

COOK INLET

Cook Inlet is a broad (N 80 km), shallow (-60 m depth) embayment extending 350 km northeastward from the Gulf of Alaska shelf. The mouth of the inlet, between the Kenai Peninsula and Cape Douglas, is bounded by an arcuate escarpment extending from Kennedy Entrance to Cape Douglas. Figure 5 shows the mean summer circulation in lower Cook inlet as proposed by Muench et al. (1978). The circulation consists of 1) the ACC, which is bathymetrically steered in a counterclockwise fashion around the mouth of the inlet and into the northern end of Shelikof Strait, 2) a strong southward flow of very dilute water concentrated along the western side of the inlet which joins the ACC off Cape Douglas and, 3) a weaker and more variable northward flow in the central and eastern regions of the inlet. The intensity of the southward flow varies seasonally with a maximum of 0.2 m S-l in summer to a minimum of 0.1 m s“' in winter. The current is driven by freshwater input from the rivers in upper Cook Inlet which is maximum in summer (in contrast to the fall discharge maximum along the gulf coast). Along its length, the southward flow laterally entrains saltier water from the east side of the inlet. The weaker northward flow (0.02 to 0.05 m S-l) in the central and eastern side of the inlet is derived from the ACC and replaces that lost by entrainment into the southward flow.

Figure 6 shows the distribution of surface temperatures and salinities in Lower Cook Inlet for three sampling periods between May and September, 1973. Salinities along the western side of the inlet are always lower those on the eastern side and, in general, temperatures are higher in the west than they are in the east. Maximum salinities are observed in the center extending north and then eastward from the mouth of the inlet. This feature is probably a consequence of localized upwelling induced by the ACC interacting with topography at the mouth of the inlet. Insofar as this upwelling resupplies the surface waters with nutrients, it might be important to biological production in Lower Cook Inlet, The intensity of vertical' density stratification is associated with the surface salinity distribution; strongest stratification occurs in regions of lowest surface salinities.

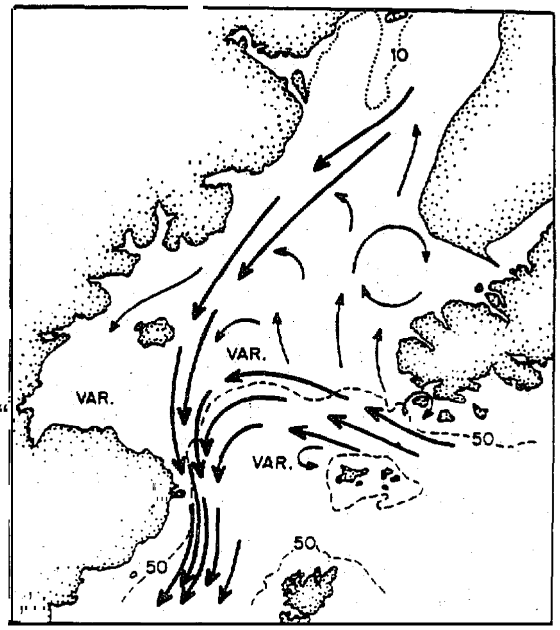


Figure 5. proposed mean spring-summer circulation In lower Cook Inlet. The dashed line shows the approximate position of the escarpment delineated by the 50 fathom isobath (Muench 't al. 1978).

Tidal processes might also play an important role in the circulation of Cook Inlet. Figure 7 shows the spatial variation in tidal current amplitudes for the semi-diurnal (M_2) tide which is the dominant tidal constituent in Cook inlet. Tidal currents are large (--I 1 m s-') on the eastern side of the inlet, weakest in the center, and about 0.05 to 0.1 m s-' on the western side. (For comparison tidal current amplitudes on the Gulf of Alaska shelf are about 0.05 to 0.1 m s-'.) These. variations imply that tidal mixing (both in the vertical and horizontal) varies throughout the inlet. Moreover, the intensity of the tides in the eastern part of the inlet suggests that, here, a mean flow might be produced by nonlinear interactions among the various tidal species and with the bathymetry.

Large, subtidal current fluctuations, persisting from 2 to 7 days, are also observed in Muench et al. (1978) data. While some are coherent with fluctuations in the ACC, others were unrelated to winds observed at coastal stations within the inlet. Limited wind data from the center of the inlet are poorly correlated with those at the coast because of topographic effects. Hence, wind measurements collected within the center of the inlet will probably be required in order to understand the nature of these fluctuations and to properly model the circulation within Cook Inlet.

SHELIKOF STRAIT

Shelikof Strait is a 450 km long by 40 km wide, deep sea valley between Kodiak Island and the Alaska Peninsula. Near its southern end the main channel veers southeastward across the shelf break. The bathymetric features are shown in Figure 8 along with the positions of Schumacher et al. (1990) current meter moorings discussed below. Figure 9 (from Reed et al. 1987) shows vertical sections of water density and nitrate along the axis of the strait during March and October 1985. In both months the water density and nitrate concentrations at depths greater than 150 m exceed those within the ACC and are characteristic of offshore waters. These observations led Reed et al. (1987) to conclude that the mean circulation is estuarine-like in that it consists of a southwestward (outflow) flow in the upper 150 m and a northward (inflow) flow at great depths. Figure 10 (from Schumacher "et al. 1990) shows the mean along-channel

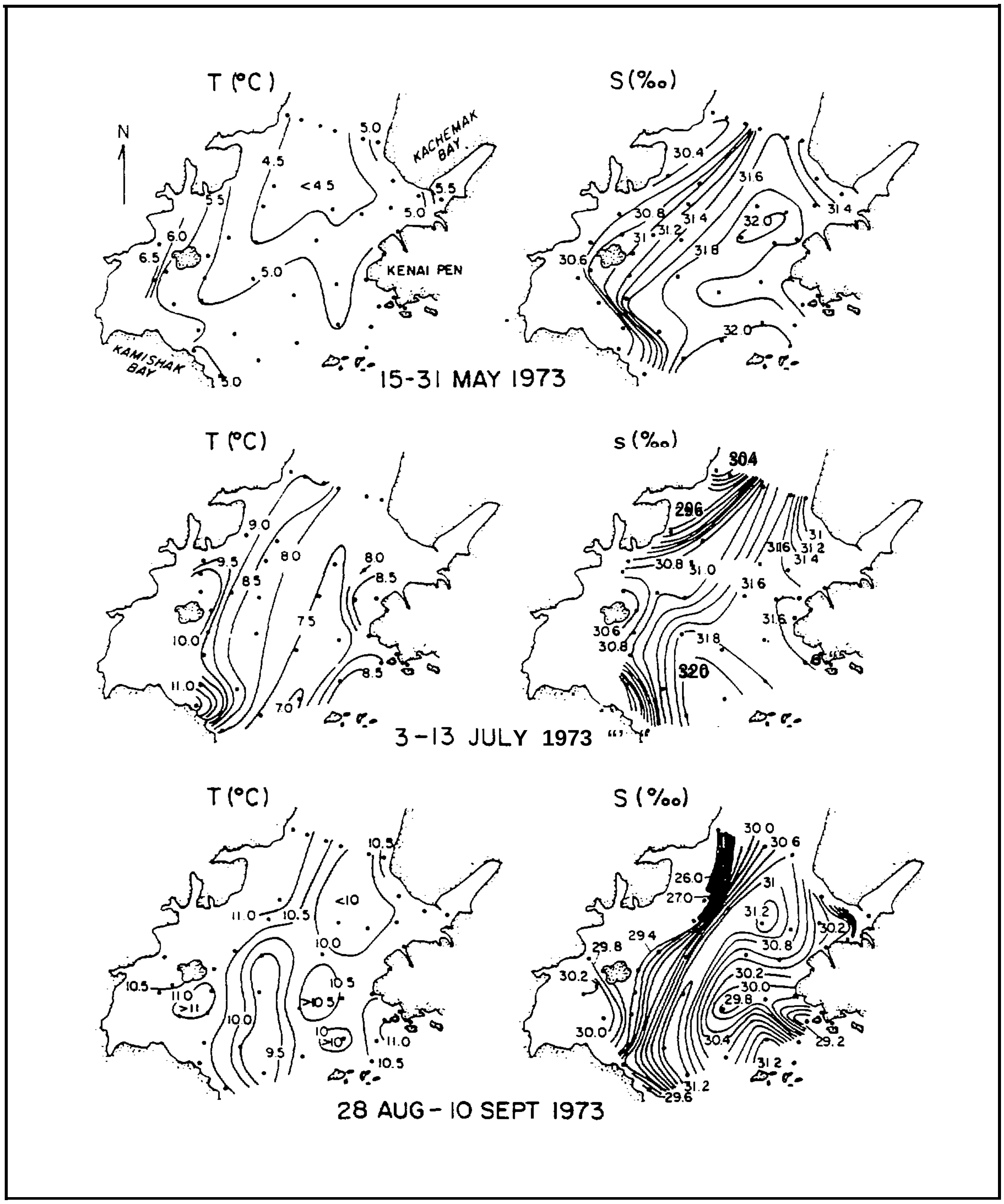


Figure 6. Surface distributions of temperature and salinity in lower Cook Inlet for three different periods during spring-summer 1973 (Muench et al. 1978).

currents for the three current meter mooring sections shown in Figure 8. Outflow of the ACC is strongest (>0.2 m s“') in the upper 150 m on the northwest and west sides of sections 1 and 3. Moderate (- 0.1 m s“') outflow is aiso observed along section 2, the shallow channel between Sutwik and Semidi Islands. Inflow is observed in the deeper waters across section 3 and adjacent to Kodiak Island in section 1, Approximately 75% of the transport through Shelikof Strait flows offshore across the mouth of the sea valley and the remainder continues along the shelf bordering the Alaskan Peninsula. Thus the bathymetry of Shelikof Strait exerts an important effect on the cross-shelf exchange of waters in the northwest Guif of Alaska.

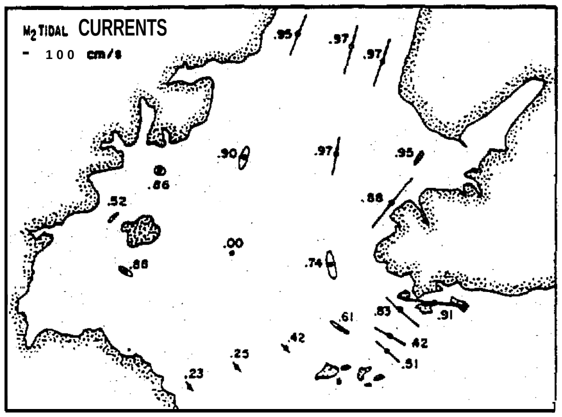


Figure 7. Distribution of M_2 tidal current amplitudes in lower Cook Inlet. Numbers are fraction of coherent tidal variance energy contained in the M_2 band (Muench et al. 1978).

As mentioned earlier, transport fluctuations in the ACC are largely related to fluctuations in alongshore wind stress, However, the complex bathymetry and orography of Shelikof Strait are an additional source of current variability and eddy formation. Mysak et al. (1981) have discussed how changes in bottom topography along the strait, in combination with seasonal variations in density stratification and flow, can lead to current fluctuations at time scales of from 3 to 6 days. Another mechanism affecting circulation variability is the interaction of storm systems with mountains which lead to gap winds and the convergence or divergence of the wind field within Shelikof Strait. Examples of these processes and their effects on the circulation will be shown using satellite imagery,

This discussion has briefly summarized aspects of the mean and seasonally varying circulation on the northwest Gulf of Alaska shelf. However, the gulf's high-latitude location cause it to be subjected to large interannual variations in freshwater discharge and wind stress. Roach and Schumacher (1991) discuss such interannual variability using five years of current and temperature data from Shelikof Strait. They find that variations in the currents and water temperatures are reiated to anomalies in the atmospheric pressure difference between Reno, Nevada (which has relatively constant pressure) and 50°N, 170°W (the mean position of the Aleutian Low). Lower water temperature and increased deep inflow occur when these anomalies are small and moderate temperatures and strong outflow occur when these anomalies are large. On a longer time scale (1910 to 1989) Royer (1989) has shown that sea surface temperatures in the northern Gulf of Alaska vary with a period of about 18 to 19 years and with an amplitude of about 0.5°C. Such variations are probably significant to the marine ecosystem of the Gulf of Alaska.

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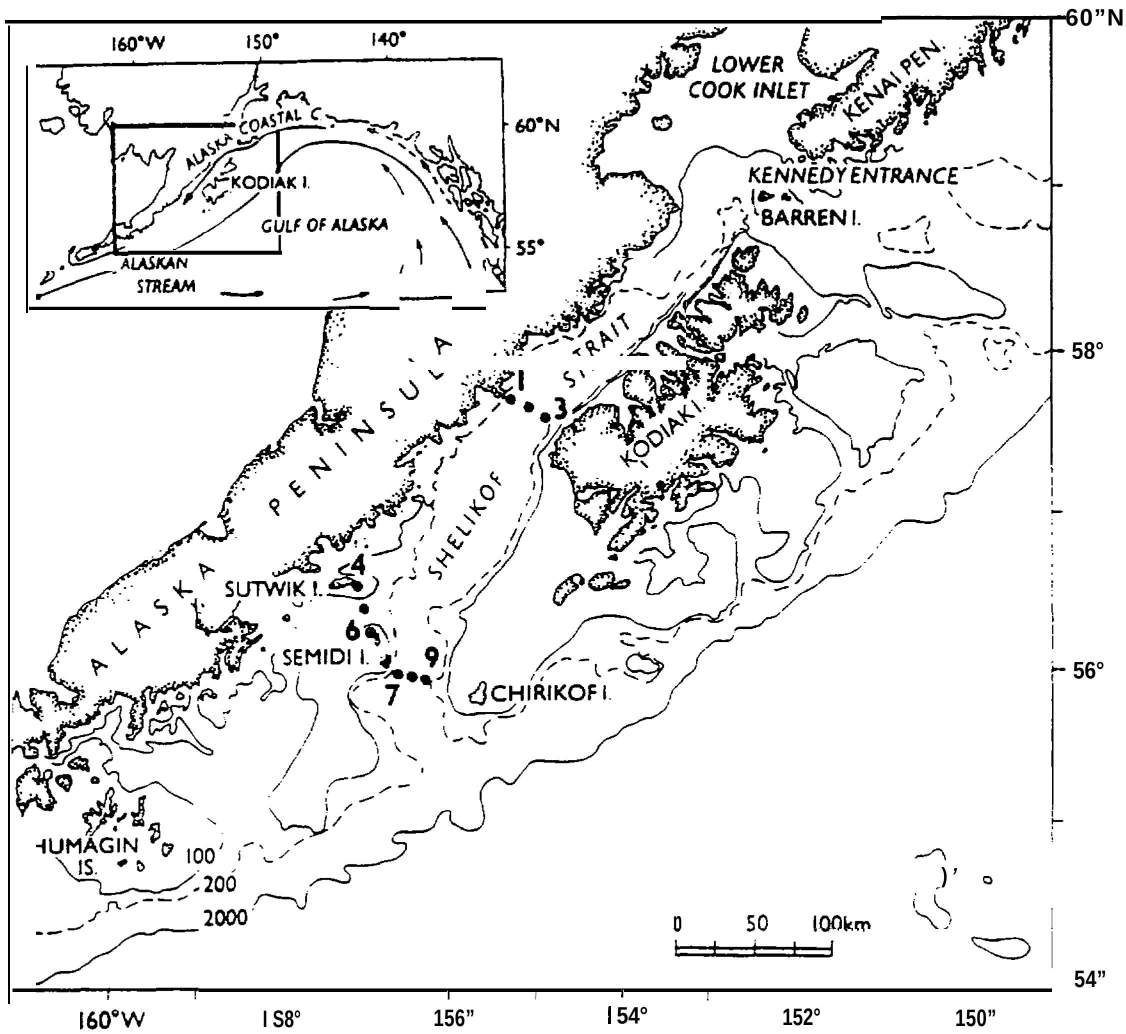

Figure 8. Shelikof Strait bathymetry and place names. Mooring positions are indicated by solid dots. Depths are in meters (Schumacher et al. 1990).

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Dr. Thomas J. Weingartner has been with the University of Alaska since **1988** *and is presently a Research Associate in the Institute of Marine Science. His research interests include buoyancy-driven circulation processes on high-latitude shelves. Dr. Weingartner received his B.S. in biology from Cornell University, his M.S. in physical oceanography from the University of Alaska, and his Ph.D. in physical oceanography from North Carolina State University.*

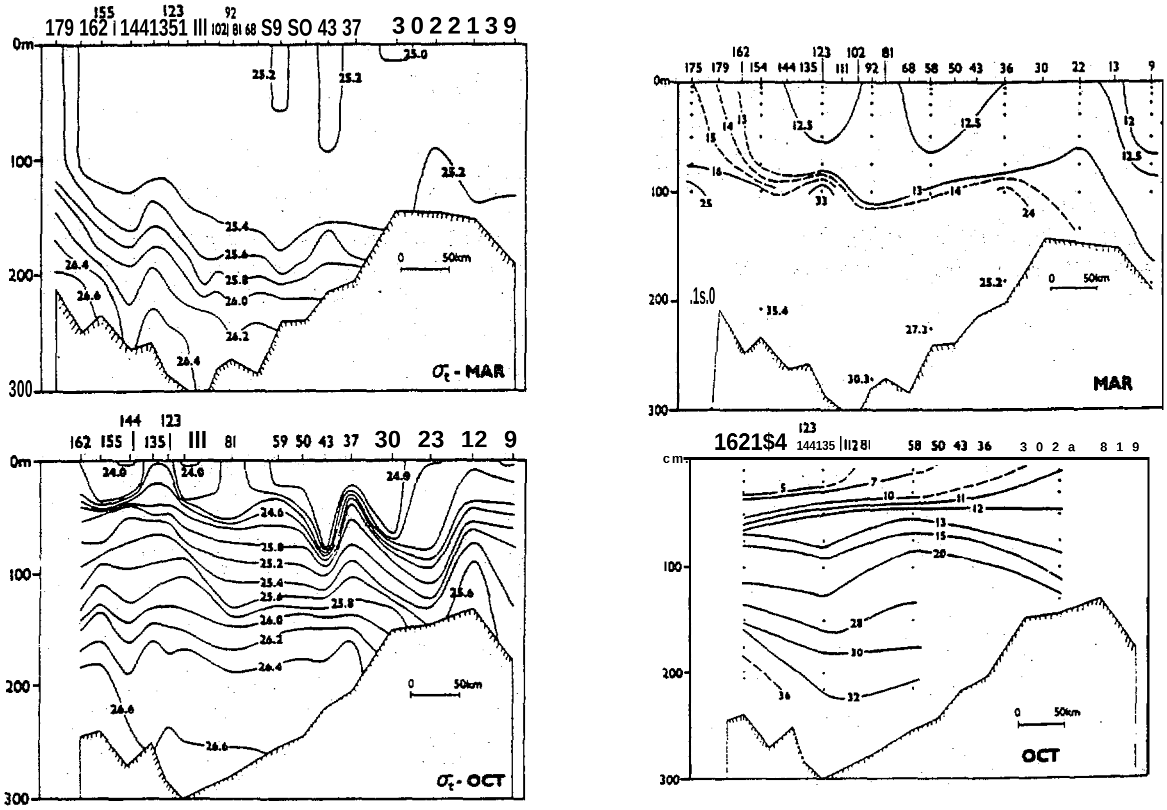

Figure 9. Contour plots of isopleths of sea water density (sigma-t) and nitrate concentration (μg at^{-1}) along the main channel of Shelikof Strait in March (upper panels) and October (lower panels). Lower Shelikof Strait appears on the left hand side of each plot (Reed et al. 1987).

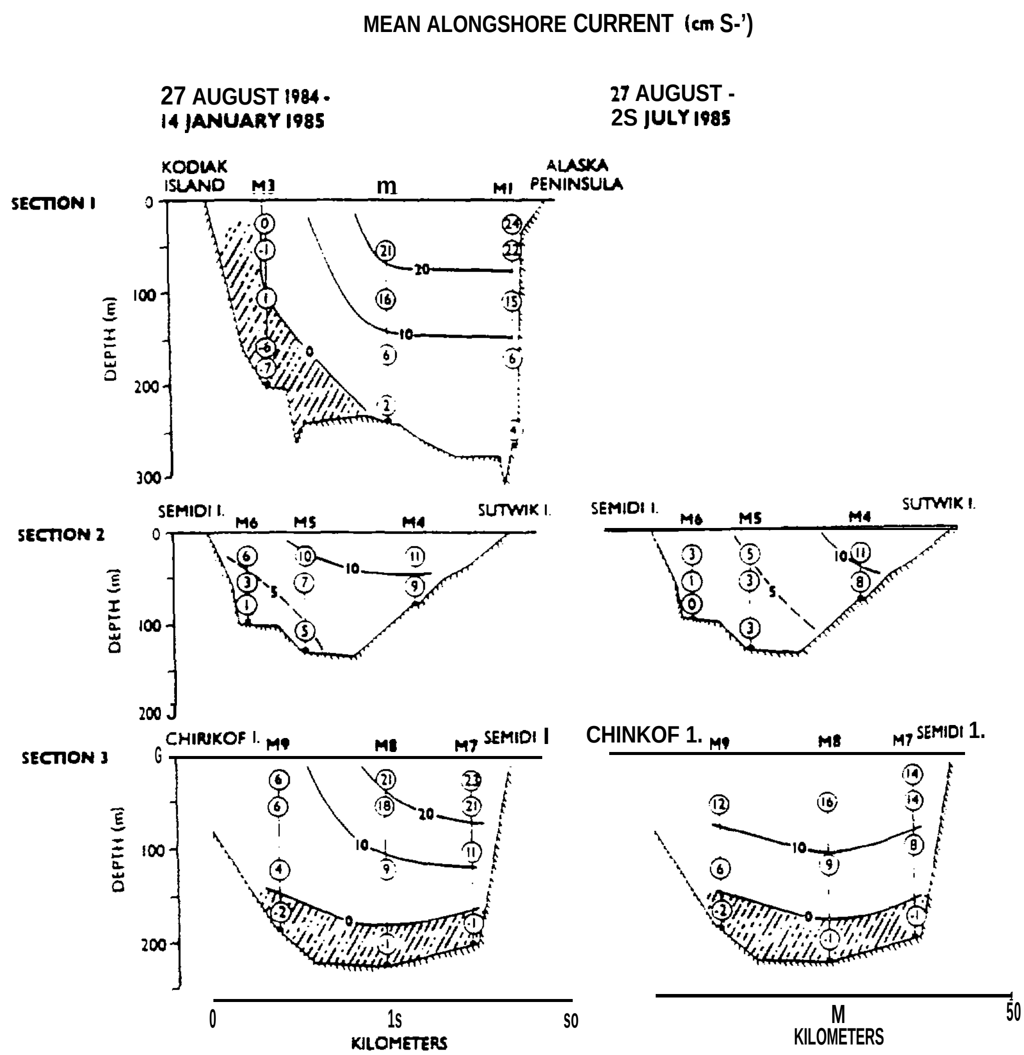

Figure 10. Isotachs of the mean alongshore current velocity observed at section 1 (top), section 2 (middle), and section 3 (bottom). Left column shows means for the period 27 August 1984 to 14 January '1985 and right column shows means for the period 27 August 1984 to 25 July 1985. Shaded areas represent inflow (Schumacher et al. 1990).

CIRCULATION AND FLUXES NEAR THE EASTERN BERING SEA CONTINENTAL SLOPE

J.D. Schumacher, R.K. Reed, and P.J. Stabeno
Pacific Marine Environmental Laboratory
7600 Sand Point Way, NE
Seattle, Washington 98115

INTRODUCTION

There are many schemes of general circulation over the Aleutian Basin of the Bering Sea (e.g., Sayles et al. 1979; Coachman 1986). These depictions are based almost entirely on inferences from water properties. In all of the data sets used to map geopotential topography, station coverage was sparse and typically lacked synopticity. Common to all schemes is mesoscale variability exemplified by eddies (most prominent in the southeastern corner of the basin) and a band of northwesterly flow contiguous along some portion of the eastern boundary of the basin (Figure 1). This latter feature has been called the Bering Slope Current (Kinder et al. 1975, Kinder 1976, Kinder and Coachman 1978, Kinder et al. 1986) and is described as a sequence of northwestward, southeastward, and northwestward flowing bands with a net transport of ~ 5 x 10' m's"' (Kinder et al. 1975). Over the outer continental shelf numerous direct measurements indicate a mean flow of 5 to 15 cm s"' toward the northwest (Schumacher and Kinder 1983, Muench and Schumacher 1985). There have been no moored current measurements over the slope.

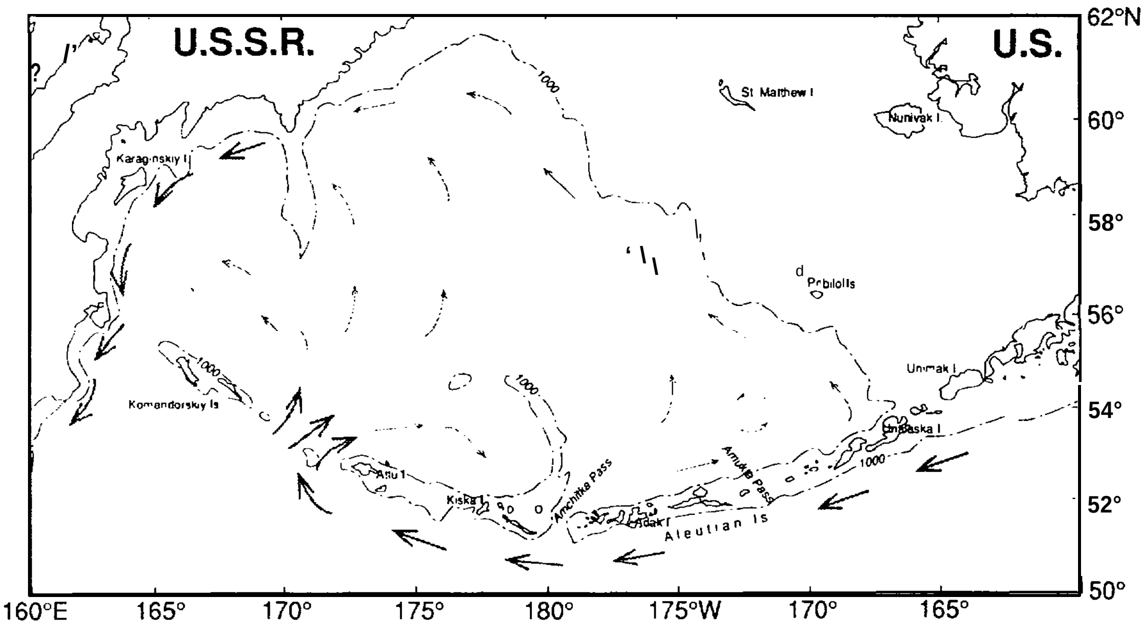

Figure 1. Schematic of general circulation.

The Bering Sea Shelf/Slope Exchange Study was conducted by personnel at the Pacific Marine Environmental Laboratory through sponsorship of the Department of the Interior's Minerals Management Service. The objective of the study was to enhance understanding of circulation and of property and momentum fluxes between the basin and shelf of the eastern Bering Sea. A major consideration was the effect of submarine canyons on exchange processes, Previous results from water property, nutrient, and total suspended matter data suggested that canyons acted as conduits for transport onto the shelf (Kinder 1976, Karl and Carlson 1987). Also, high primary production over the northern Bering Sea shelf is likely supported by nutrients which are transported from the Bering Slope Current onto the shelf (Hansen et al. 1989).

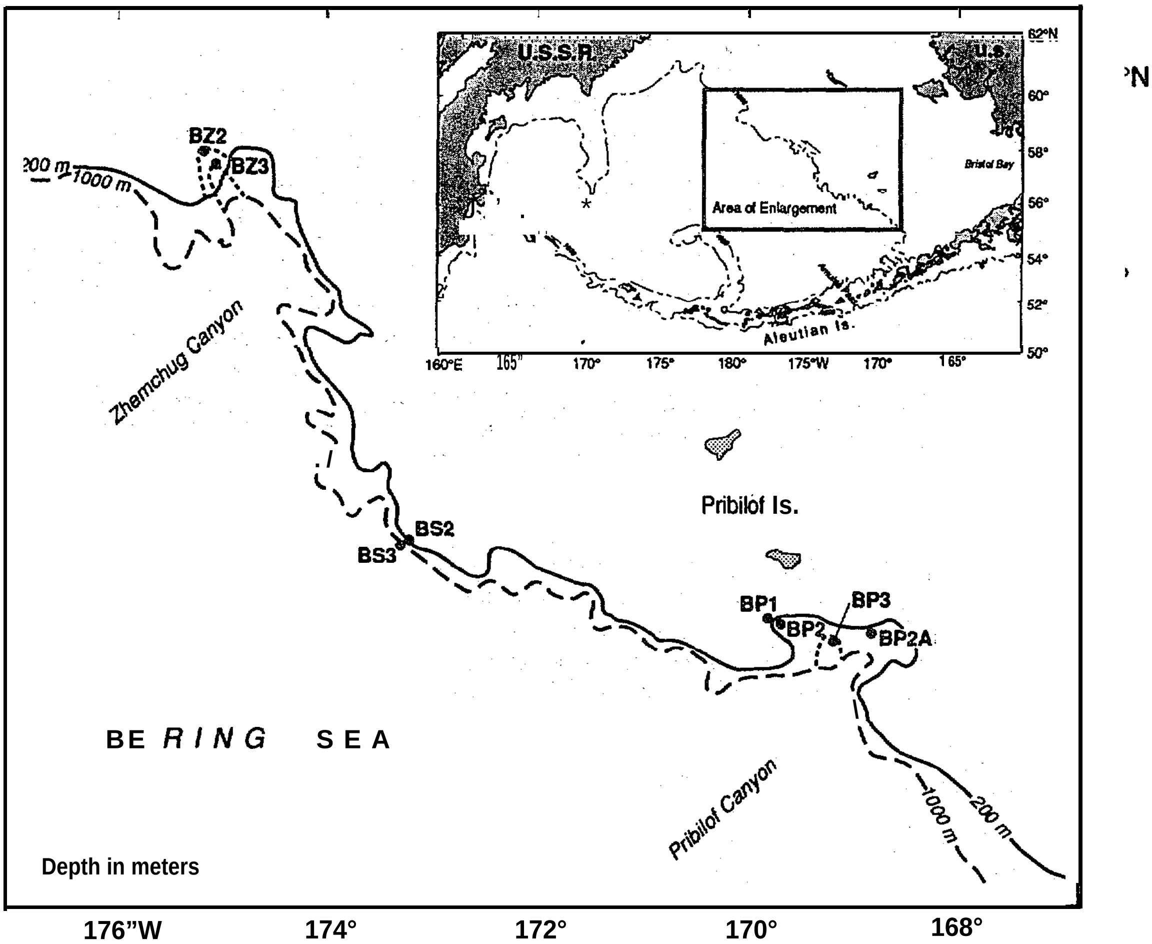

Figure 2. Study area showing the location of the current moorings. The general bathymetry is from standard NOAA/NOS charts. The dotted bathymetry is from ship soundings taken during operations. The insert shows the location of the eastern slope relative to-the Bering Sea. "

METHODS

CTD casts were taken with a Seabird SBE-9 system to 1500 m or, in lesser depths, to within about 10 m of the bottom. Data were recorded only during the downcast at lowering rates of 30 to 50 m rei"-'. Temperature and salinity corrections were derived from data taken on most casts. Various routines were used to eliminate spurious data and to derive 1-m averages of temperature and salinity, which were used to compute density and geopotential anomaly.

Currents were measured by both buoys and moored instruments. On the cruises during fall 1989 and spring 1990, two sets each of satellite-tracked buoys were released along a short southwest-northeast trending line (near 55.2° N, 167.8° W) at intervals of ~1.0 km, The buoys had tristar drogues centered at ~40 m. Typically 15 to 18 position fixes were received per day through the Argos location system. Eight moorings were deployed in Pribilof and Zhemchug canyons and at a location between the canyons {Figure 2, Table 1). All moorings were either taut-wire or Kevlar line. The upper current meter was located at approximately 50 m below the surface and had a paddle wheel rotor to limit contamination of the desired signal by surface

Table 1. Mooring locations, observation period and mean current.

Mooring name; location (N.lat., W.long.); and water depth (m)	Instrument Depth (m)	Observation Period (JD)	Mean speed ± RMS[1] error, direction (cm S-l, °T)	Axis of greatest variance and % of total variance (°T, %)
		Pribilof Canyon		
BP3: slope	52	89256-90131	5.6 ± 2.0, 277	296, 62%
56.12, 169.27	127	89256-90116	4.5 ± 1.4, 246	279, 52%
1002 m	262	89256-90109	1.7 ± 0.8, 246	142, 54%
	502	89256-90258	2.5 ± 0.8, 126	121, 85%
BP2A: mid-slope	49	90111-90245	10.3 ± 2.6, 266	272, 78%
56.16, 168.88	124	90111-90245	7.4 ± 2.6, 267	269, 89%
275 m	260	90123-90244	7.5 ± 2.0, 247	258, 92%
BP2: mid-slope	62	89256-90250	6.0 ± 1.8, 228	214, 81%
56.23, 169.70	137	89256-90250	3.9 ± 1.6, 237	206, 90%
287 m	272	89256-90250	10.8 ± 1.2, 189	190, 82%
BP1: outer shelf	50	90112-90279	6.7 ± 1.8, 240	223, 80%
56.27, 169.80	125	90112-90279	5.8 ± 2.8, 200	208, 91%
140 m				
		Central Slope		
BS3: slope	45	89257-90277	17.9 ± 6.0, 311	311, 93%
56.67, 173.29	120	89257-90251	11.2 ± 5.0, 301	301, 95%
995 m	255	89257-90187	5.9 ± 4.6, 309	304, 96%
	495	89257-90277	1.4 ± 1.8, 315	301, 97%
BS2: mid-slope	49	90112-90276	16.1 ± 3.7, 311	310, 85%
56.69, 173.25	125	90112-90276	16.0 ± 3.8, 311	311, 92%
274 m	260	90112-90276	11.2 ± 3.6, 318	313, 99%
		Zhemchug Canyon		
BZ3: slope	48	89259-90125	3.0 i 1.2, 288	228, 58%
58.55, 175.05	123	89259-90123	2.0 ± 1.4, 289	232, 61%
998 m	258	89259-90274	1.9 ± 1.6, 256	221, 68%
	498	89259-90274	0.9 ± 1.0, 234	233, 70%
BZ2: mid-slope	46	90114-90273	4.3 ± 1.2, 258	246, 75%
58.64, 175.12	121	90114-90273	5.2 ± 1.4, 240	241, 87%
271 m	260	90114-90273	1.8 ± 0.8, 230	219, 91%

[1] where RMS = 2 x [variance x integral time scale/record length]$^{1/2}$

waves. The instruments were Aanderaa-RCM-4 or -7 current meters which also measured temperature, pressure, and conductivity. The time series of temperature and salinity were compared to CTD casts; the recorded temperature and salinity are probably accurate to 0.2°C and 0.3 psu; random errors used for calculations of fluxes are believed to be ~ 0.02°C and ---0.04 psu.

All current records were first edited for time base problems and data spikes. To examine mean and low frequency characteristics, the current records were filtered using a cosine squared Lanczos filter with a half-power point of 35 h. This series was resampled at 6 hours and used to calculate correlations, rotary spectra, and coherence. Current vector plots and flux calculations used daily averages of the low-pass data. Surface winds were computed from the Fleet Numerical Oceanography Center surface atmospheric pressure grid. Geostrophic winds were interpolated to locations near the three array sites. To represent surface winds, the geostrophic winds were rotated 20° anti-clockwise and reduced in magnitude by 30%.

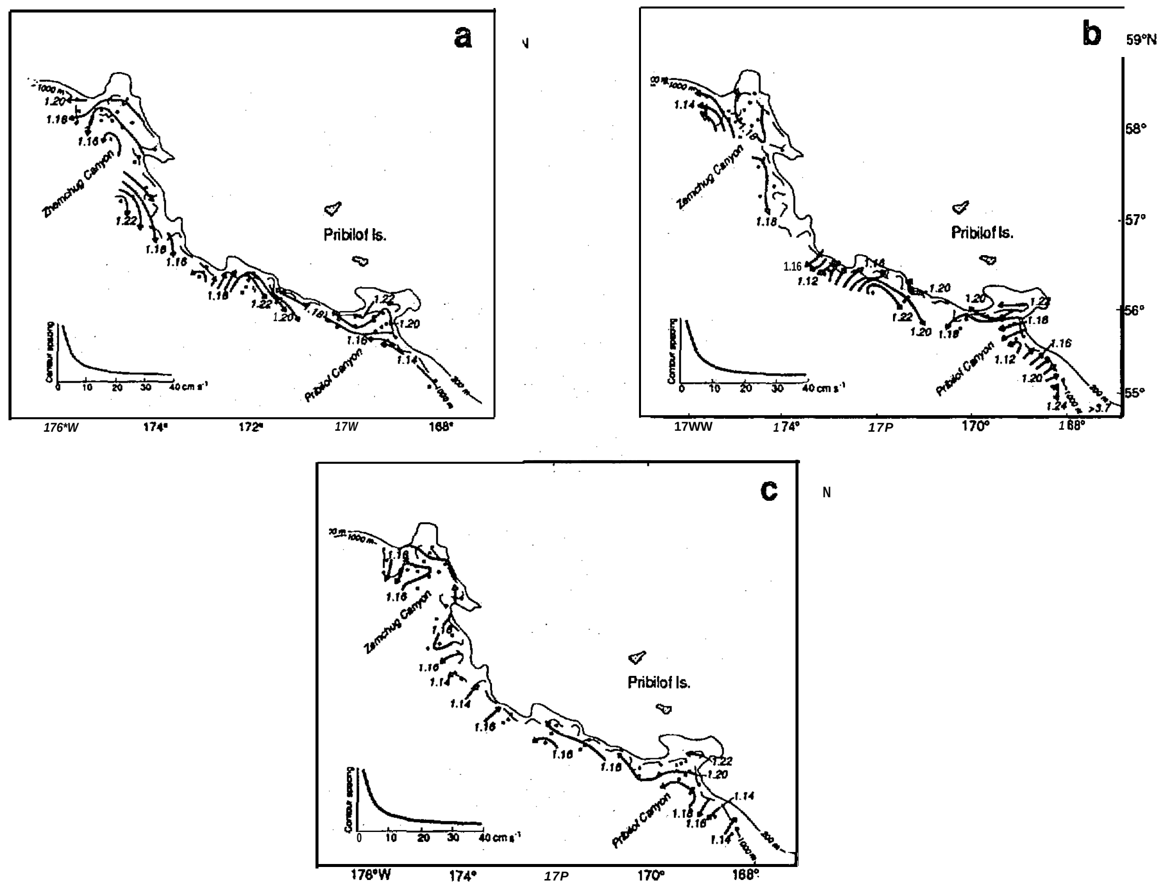

Figure 3. Geopotential topography (AD, dyn m) of the sea surface, referred to 1000 db: a) e-22 Sept. 1989, b) 21 April-1 May 1990, and c) 30 Sept. -9 Oct. 19e0.

RESULTS AND DISCUSSION

During fall 1989 (Figure 3a), geostrophic flow in the southern part of the region and in Pribilof Canyon was to the northwest or west. Between ~ 171° and 175°W, however, flow was mainly to the southeast (Reed 1991). Farther north' (in Zhemchug Canyon) flow was again to the northwest. In spring 1990 (Figure 3b), a well-developed onshore flow was present in the southern part of the area. (At the start of this cruise, 19 April, the flow had been to the northwest, however.) Westward flow occurred in Pribilof Canyon, and northwestward flow occurred near Zhemchug Canyon. In between the canyons, flow was southeastward or alternated between onshore and offshore. In fall 1990 (Figure 3c), westward flow occurred in the canyons, atthough it was relatively weak. Between the canyons, regions of weak onshore or offshore flow were present. In summary, over this 1-year period there was considerable variability in flow along most of the slope. In Pribilof and Zhemchug canyons, however, inferred flow was consistently northwestward.

The Bering Sea is characterized by a temperature-minimum layer, from the surface to near 200 db, and by a temperature-maximum layer below the minimum, typically centered at 300 to 400 db. The temperature-maximum layer is mainly affected by horizontal advection of water from the North Pacific through the Aleutian Island passes (Sayles et al. 1979). Kinder et al. (1975) concluded that the maximum occurred near the sigma-t density surface of 26.8, but Reed and Stabeno (1989) found the maximum occurred just south of the Pribilof Islands in spring 1988 at a mean sigma-t density of 26.62. Thus the depth and density of the maximum can vary considerably, presumably as a result of variations in the source waters.

Temperature near the maximum during this study and in spring 1988 is shown in Figure 4. In fall 1989 the coldest temperatures were in the northern part of Pribilof Canyon, and the warmest were in Zhemchug Canyon. The warmest temperatures in spring 1990 were in two zones of temperature >3.7°C, one near 170°W in Pribilof Canyon and one in Zhemchug Canyon. The coldest were near 173°W. In fall 1990 the coldest temperatures were north of Zhemchug Canyon, and the warmest were in the southern part of the study area. In general though, there was not a trend of decreasing temperature toward the north during the three cruises. The relatively cold temperatures present during all these cruises suggest there was an absence of warm (Alaskan Stream) inflow through the central Aleutian Island passes. During all three cruises, temperatures at sigma-t --26.8 were quite cold (generally <3.7°C). Conversely, during fall 1986 (Reed et al. 1988) and spring 1988 (Reed and Stabeno 1989) temperatures were >4.0°C in places (Figure 4d). During fall 1986, at least, there was clear evidence for an inflow of warm Alaskan Stream water through Amukta Pass (near 172°W) that produced the warm subsurface water. Relatively cold temperatures during the three cruises reported here, during August 1972 (Kinder et al. 1975), and during June 1987 (Reed et al. 1988), however, suggest the absence of inflow, or at least a weak inflow, through Amukta Pass. Thus there is appreciable variability in this inflow as well as variability in flow all along the slope.

The set of five buoys deployed on 10 September 1989 (Figure 5) initially moved westward across the 1000 m isobath at a speed of 15 cm s“'. The flow was essentially linear and was quite coherent. After 10 days a marked change occurred. Buoy numbers 7161, 7168, and 7169 rapidly spread away from the other two, and a complex, incoherent flow field emerged. The flow field was analyzed by Reed and Stabeno (1990) as an example of "Lagrangian chaos". Chaotic flow results from extreme sensitivity to initial conditions where non-periodic solutions exist. No simple flow field emerges from this buoy set. One buoy (7161) moved along the slope to the northwest in agreement with our expectations of flow in the Bering Slope Current. On the other hand, buoys 7165 and 7166 eventually moved back to the southeast, and buoy 7168 had little net movement. Thus the flow field appeared to have major inhomogeneities in space and time.

Three of the buoys deployed on 23 September 1989 moved westward, and only one (7166) looped back to the south and then moved along the slope and onto the shelf. The initial shear in the flow here was rather large. There was no convincing evidence in these data (Figure 6) of chaotic flow.

Seven buoys were released in the 19 April 1990 deployment (Figure 7). The initial flow was a weak drift toward the northwest. All of these buoys, unlike those in fall 1989, moved onto the shelf. The last half of these trajectories show a very weak, but persistent, flow toward the

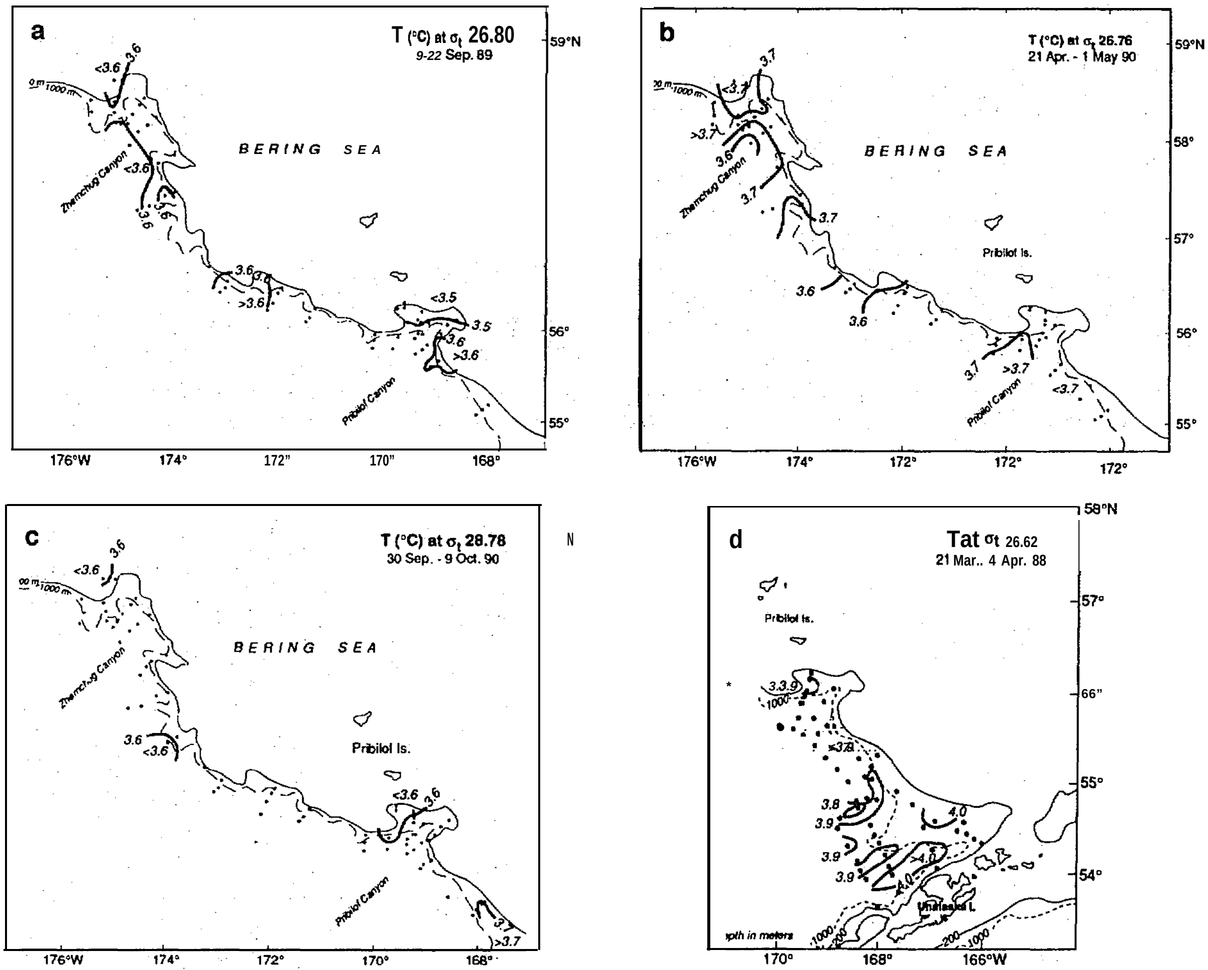

Figure 4. Distributions of temperature (°C) on the sigma-t density surface of a) 26.60 (S-22 Sept. 1989), b) 26.76 (21 April-1 May 1990), c) 26.78 (30 Sept. -9 Oct. 1690), and d) 26.62 (21 March-4 April 1S66).

north. The flow field suggested by surface salinity patterns .(Reed 1991), however, was more along the slope.

The final buoy release (1 May 1990) contained six buoys (Figure 8). At first, flow was across the shelf toward the northeast. The initial movement of this set, and the previous one, was very similar to the geostrophic flow (Reed 1991). Almost half of the duration of these data was spent in a small region near 55.6° N, 167.2° W (Figure 9). The buoys were virtually stationary there, with the only apparent force being weak horizontal diffusion. Apparently the buoys were in a small (<20 km diameter) eddy with rotational speeds of 10 to 15 cm s^{-1}. Finally a slow drii to the northwest occurred.

Considerable variability exists in the buoy paths. At times, Lagrangian chaos appears to be a major factor in the evolution of the flow field. These and other data are perhaps suqqestive of a seasonal change in flow. In fall-winter a relatively strong westward flow" across the eastern and central basin seems typical; in spring-summer of 1990,-at least, much weaker flow, mainly across the shelf, was present.

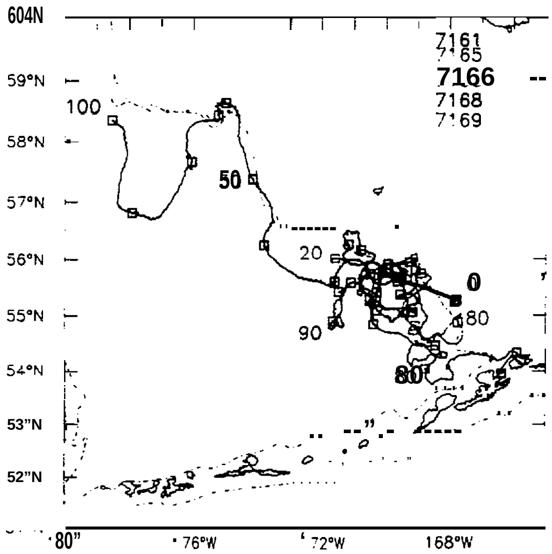

Figure 5. Trajectories of satellite-tracked buoys released on 10 September 1969. Date are shown for 100 days after release.

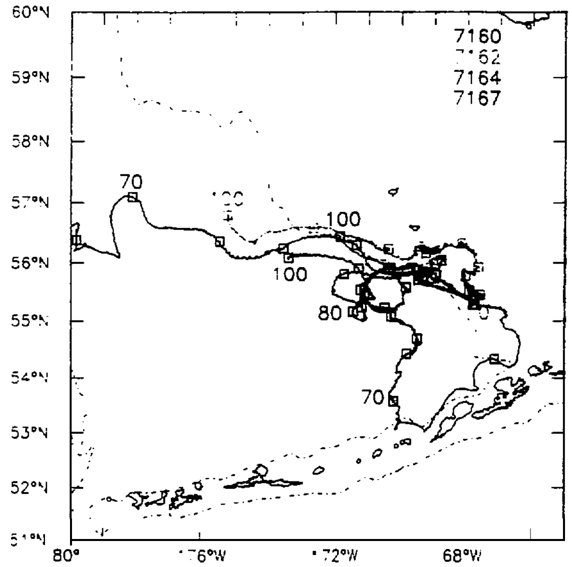

Figure 6. Trajectories of satellite-tracked buoys released on 23 September 1689. Data are shown for 100 days after release.

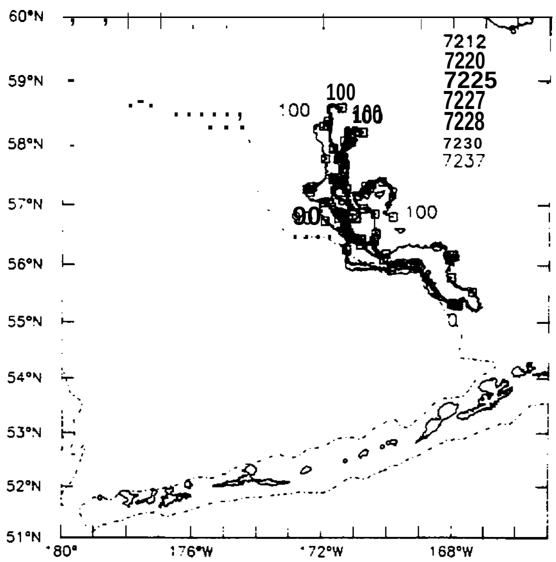

Figure 7. Trajectories of satellite-tracked buoys released on 19 April 1990. Data are shown for 100 days after release.

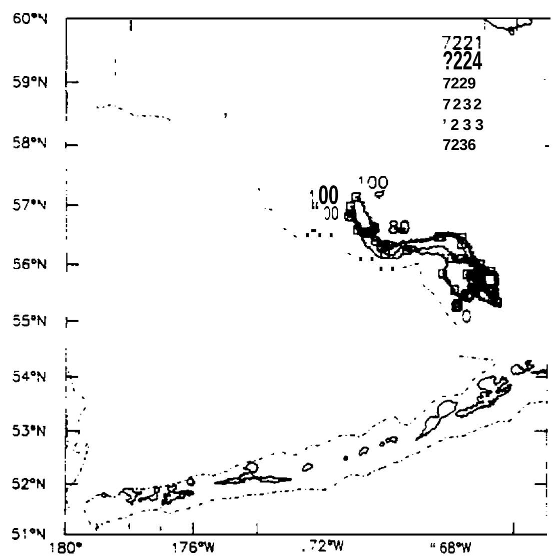

Figure 8. Trajectories of satellite-tracked buoys release on 1 May 1990. Data are shown for 100 days after release.

All of the current records from locations in Pribilof Canyon have statistically significant vector mean flow (Table 1). In general the direction of flow was aligned with the large-scale bathymetry and was generally toward the west or northwest. This supports observations from the adjacent outer continental shelf (Schumacher and Kinder 1983; Coachman 1986) and is consistent with general inferences made from geostrophic estimates. Where the slope is relatively straight (BS2 and BS3), mean currents were strong and toward the northwest. The mean flow at intermediate depths at BS2 was markedly greater than at similar depths at BS3. Mean flow in

Zhemchug Canyon was weak compared to flow elsewhere, but it was statistically different than zero in the upper 250 m of the water column.

Time-series of currents over the slope and wind are shown in Figure 10. The vector mean currents support the concept of a moderate flow generally toward the west or northwest along a large segment of the eastern Bering Sea slope.

Estimates of subtidal eddy kinetic energy per unit mass (KE′) were calculated from the along- and-across stream variances. There appeared to be a seasonal signal in KE' for both current and wind, with winter being more energetic than in summer. Although in a given season wind energy was nearly uniform at all locations, eddy kinetic energy was lowest in Zhemchug Canyon. For the nine winter/summer current record pairs, three had larger vector mean flow in summer, and six had means that were not statistically different between winter and' summer. This lack of seasonality in mean flow is consistent with results from the outer continental shelf (Schumacher and Kinder 1983).

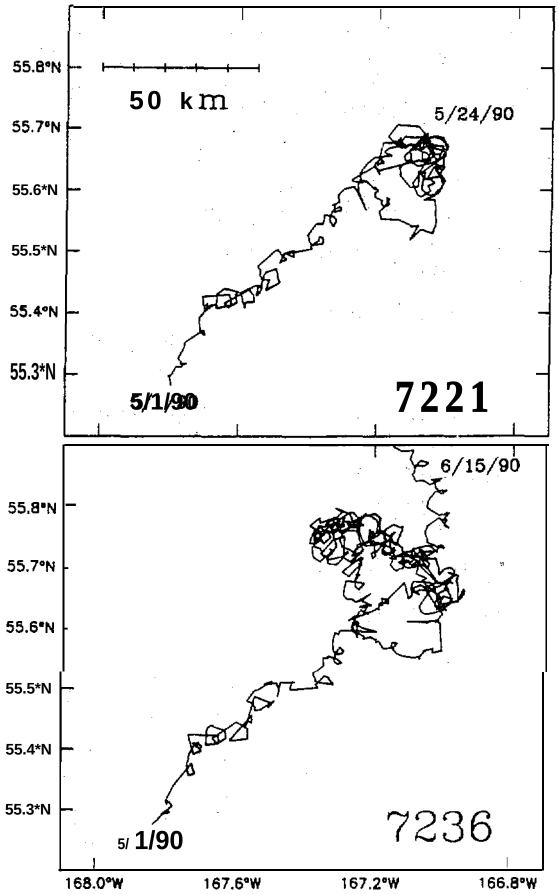

Figure 9. Enlargement of trajectories of two buoys deployed on 1 May 1990 (see Figure 8),"

There were significant (95% level) maxima at periods between 2.5 and 9.0 d in all the current records, The amount of fluctuating kinetic energy in any of these, however, was <5% of the total. In an attempt to account for peaks in current spectra, linear and vector correlations between wind and current were estimated for all records, None of the correlation coefficients were significant, likely because much of the KE' in the currents was at periods >12 d. Estimates of coherence between current fluctuations along the mean axis and both parallel and orthogonal wind components did yield some significant (95% level) values that account for many of the observed maximums (in bands between 2.5 and 7.0 d). The total energy accounted for, however, was <10% of the total KE′. The strong maxima (13.9 d) at BP2 was not coherent with either wind component. There were marked maxima (13.9 d) in the spectra at all depths at BP2. In the near bottom record this maxima contained 17% of KE'.

The strong bottom currents at BP2 were not accounted for by correlation with the wind. Their period (14 d) suggests that interaction between tidal currents and canyon bathymetry could be the forcing mechanism. A 4-month record segment from BP2 (272 m) shows a marked similarity between tidal current amplitude and the low frequency (subtidal) flow (Figure 11). During spring tides, low frequency current speeds approached 20 cm S-l, whereas during neap tides there were weak reversals in flow. The hourly current record from 272 m was demodulated to create daily and semidaily constituent time series, and estimates of correlation were calculated between these two new series and the three low-pass filtered series. The results showed significant (99% level) correlation between the demodulated series of daily frequency and the low-pass series (0.52, 0.43, and 0.36 at 272, 137 and 62 m respectively). The only significant correlations between demodulated semidaily and low-pass time series was at 272 m (0.30). Most

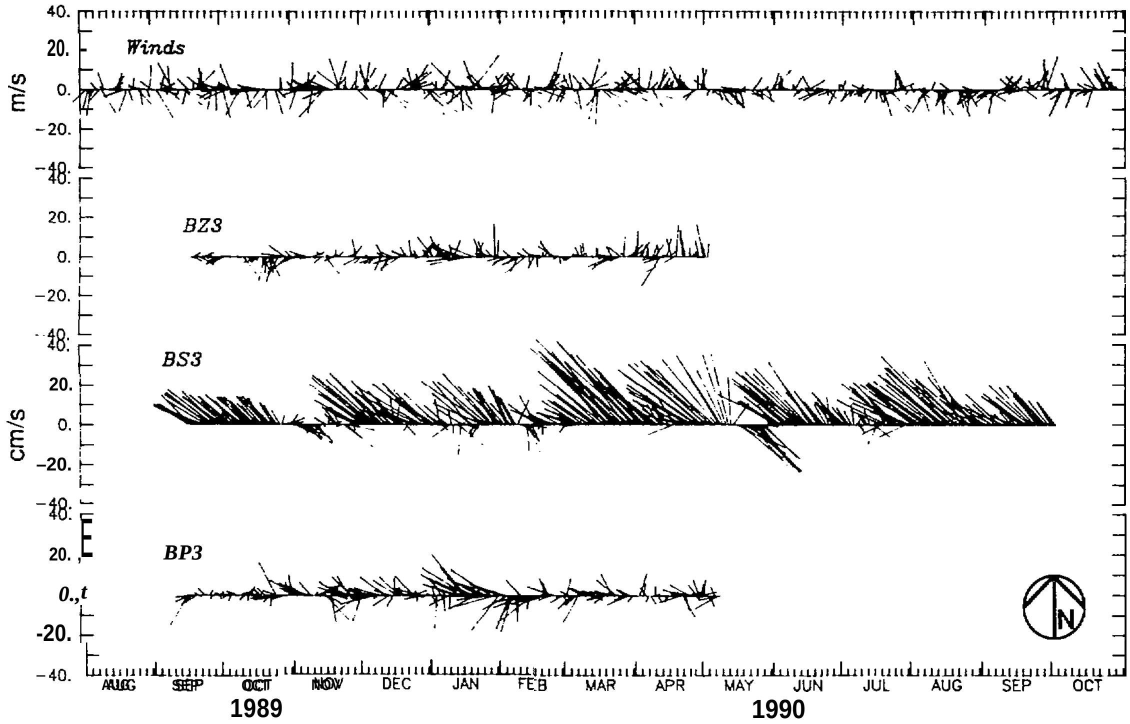

Figure 10. Low-pass filtered currents over the slope in Pribilof Canyon (BP3), at the central location (BS3), and in Zhemchung Canyon (BZ3). Also shown are synthetic winds for the central location.

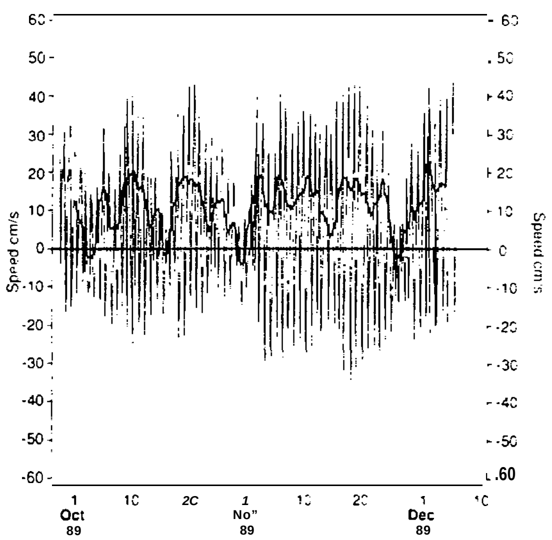

Figure 11. Four-month segment of current data from BP2 (272 m). The tidal component is resolved on the principal axis (135~ of the K1 constituent, and the low frequency component is resolved on an axis of 185°T.

of the low frequency fluctuations were accounted for by the demodulated K1 tidal current. Furthermore, the rectified bottom tidal current resutted in fluctuations throughout the water; these decreased with increasing height above the bottom, however.

The computed values of the fluxes, performed on daily net velocity components and daily mean properties after use of a 35 hr filter, are listed in Table 2. In general, the magnitudes of both the heat and salt fluxes are quite small. They are typically about half those measured at the shelf break in the Gulf of Alaska (Reed and Schumacher 1986). Furthermore, most of them do not exceed their standard errors. Only 5, 5, and 5 of the fluxes $\overline{u'T'}$, $\overline{v'T'}$, and $\overline{v'S'}$, respectively, out of 26 possible, are significant; these percentages are somewhat less than would occur by chance. On the other hand, 11 of the onshore salt fluxes ($\overline{u'S'}$) are significant, and all but one of these are positive. The momentum fluxes ($\overline{u'v'}$), however, tend to be more frequently significant and relatively larger than the property fluxes, except at moorings BZ2 and BZ3. Of the 19 remaining fluxes, 12 are significant; 4 out of 7 are significant at the open slope moorings (BS2 and BS3), and 8 out of 12 at the Pribilof Canyon sites. At BS3 the significant $\overline{u'v'}$ values are

Table 2. Fluxes of momentum ($\overline{u'v'}$, cm' S-l), heat ($\overline{u'T'}$ and $\overline{v'T'}$, cm "C s-'), and salt ($\overline{u'S'}$ and $\overline{v'S'}$, cm% s^{-1}) at the current moorings. The standard error (based on the variance and the Integral time scale) Is also given. v is In the direction of minimum variance (generally "alongstream"), and u Is 00° to the right of v.

Mooring	Depth (m)	Dir. of mex. var. (")	$\overline{u'v'}$	$\overline{u'T'}$	$\overline{u'S'}$	$\overline{v'T'}$	$\overline{v'S'}$
BP3	52	290	1.0±4.2	-0.2±1.0	0.3*0.6	1.2±0.7	0.5±0.4
	127		-0.5±2.4	0.5±0.4	0.1±0.I	0.2±0.4	0.1±0.1
	262		0.6±1.2	0.1±0.I	0.0±0.0	-0.1*0.I	0.0±0.0
	502		2.3±0.7	0.0±0.O	0.0±0.0	0.0±0.0	0.0±0.0
BP2A	49	265	4.1±4.0	0.7*1.I	0.3*0.2	-0.4±0.4	0.1±0.I
	124		2.6±1.9	0.1±0.2	0.1±0.I	-0.1±0.1	0.0±0.0
	260		-3.7* 2.2	0.1±0. I	0.1±0. 0	0.0±0.O	0.0±0.0
BP2	62	210	3.1*1.9	0.9*1.O	1.3*0.6	-0.3* 0.3	0.0±0.O
	137		-3.4* 2.2	0.2±0.5	0.3±0.8	-0.1*0.I	-0.2*0.I
	272		-7.7* 1.2	-0.2* 0.1	-0.8* 0.4	0.0±0.O	-0.2*0.I
BPI	50	210	5.4*2.3	3.1*1.1	0.2±0.1	0.6±0.5	0.0±0.1
	125		-1.9*3.1	0.2*0.2	0.3±0.2	0.0±0.I	0.1±0.0
3s3	45	310	3.6*7.5	-0.6±0.7	2.2±1.4	0.0*0.2	0.1*0.3
	120		-28.4±6.0	0.1±0.4	0.510.1	0.0±0.1	-0.1±0.0
	255		-13.6±3.6	0.1*0.2	0.2*0.I	0.0±0.0	0.0±0.0
	495		-6.9* 1.3	0.0±0.0	0.0±0.O	0.0±0.0	0.0±0.O
3S2	49	310	-0.6±6.5	2.0±3.8	0.3±0.3	-1.7±1.0	0.1±0.I
	125		2.9±4.0	-0.5*1.O	0.6±0.3	-0.2* 0.2	0.0±0.0
	260		9.1*3.1	0.3±0.2	0.5*0.3	0.0±0.0	0.0±0.0
323	48	230	0.4±2.8	0.7*0.9	0.0±0.1	-1 .8±0.9	0.0±0.1
	123		-0.1*3.4	0.2*1.2	0.0±0.I	0.5*0.4	0.0±0.I
	258		-2.4* 1.8	0.0±0.1	0.0±0.0	0.1±0.I	0.0±0.O
	498		0.3*0.5	0.0±0.O	0.1±0.0	0.0±0.0	0.0±0.0
3Z2	46	240	0.9*0.7	-1 .2±0.8	0.1±0.1	0.0±0.0	0.0±0.0
	121		0.0±0.I	-0.1* 0.3	0.0±0.O	0.1±0.1	0.0±0.0
	260		-2.3±0.5	0.0±0.I	0.0±0.O	0.0±0.O	0.0±0.0

negative; the one significant value at BS2, however, is positive. Use of the relation, $-\overline{u'v'} = A_h \partial v/\partial x$, where 4 is the horizontal eddy viscosity and $\partial v/\partial x$ is the cross-stream gradient of alongstream flow, allows an estimate of eddy viscosity. Using a mean $\overline{u'v'}$ at BS3 of –21 $cm^2 s^{-2}$ (Table 2) and $\partial v/\partial x$ of 6 cm s-'/3.3 km = 1 x 10^6 cm' S-l, which is a plausible, positive eddy viscosity. The significant positive $\overline{u'v'}$ at 6S2 would require a decrease in velocity inshore, which seems likely, for the eddy viscosity to remain positive.

SUMMARY

The current records show a northwestward flow which follows the bathymetry of the continental slope in the eastern Bering Sea. This flow primarily occurred in the upper 300 m of the water column and generally did not respond to the marked winter-time increase in wind stress. These results suggest that the observed flow was part of the basin-scale circulation that is modified by topography, integrating the seasonal wind signal (as in the Aiaskan Stream: e.g., Cummins 1989). The strength of the flow was weaker near Zhemchug Canyon than at the two other array sites. This suggests that the majority of the transport flows west over the basin rather than flowing northwestward past Zhemchug Canyon, which is consistent with previous results (e.g., Kinder et al. 1975). Finally, there appears to be appreciable variability in inflow through Amukta Pass. This has a marked influence on water properties along the slope.

Some of the current fluctuations were due to the passage of eddies. There were four current reversals which persisted for more than five days at BS3 (45 m). The most pronounced occurred between 16 and 27 May 1990. During this event, flow also reversed at BS2. Water property data from BS3 indicated that temperature at 45 and 120 m depths increased by 0.5°C and 0.3°C, respectively. Simuitaneousiy, salinity at 120 m decreased by ~0.2 psu. These changes suggest the presence of a clockwise rotating eddy. The mean along-slope speed during the passage of the eddy was 28 cm s“' (at 45 m) decreasing to 15 cm s“' at 495 m. Using estimates of translation speeds for eddies in the Bering Sea of 0.5 cm s“' (Kinder et al. 1980) or 1-2 cm s“' (Reed and Stabeno 1989), the radius of the present feature was between 5 and 20 km.

As expected, results from estimation of salt fluxes indicate a transfer of saltier waters toward the fresher waters inshore. Thus this process tends to equalize salinity gradients. It is interesting, however, that five of the significant fluxes occurred at the open-slope moorings (BS2 and BS3) and five were at the Pribilof Canyon sites. Thus there is no evidence that salt transfer occurs preferentiaily in the canyons.

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Dr. James Schumacher has worked at the Pacific Marine Environmental Laboratories (PMEL) for the past 18 years and is presently the program leader for the PMEL component of Fisheries Oceanography Coordinated Investigations in Shelikof Strait, Alaska. His ongoing area of research interest is describing and understand the forcing mechanisms for currents, volume transport and mixing over the Alaskan Continents/ Shelf. His present focus is on how physical processes influence recruitment of walleye pollock in the Gulf of Alaska and Bering Sea. Schumacher **received** *his B.S. and M.S. in physics from Monmouth College in New Jersey and his Ph.D. from the University of North Carolina, Chapel Hill.*

APPLICATION OF THE SMEAR (COZOIL) MODEL
USING THE MINERALS MANAGEMENT SERVICE HANDBOOK

Mark Reed
Applied Science Associates, Inc.
70 Dean Knauss Drive
Narragansett, Rhode Island 02882

A coastal zone oil spill (COZOIL, or Smear) model was developed by Applied Science Associates, Inc. (ASA) for the Minerals Management Service (MMS) in 1988 (Reed and Gundlach 1989, Reed et al. 1989). The model simulates the behavior of oil offshore, in the surf zone, and on and in the beach. Processes included are:

- spreading
- evaporation
- entrainment/dissolution
- emulsification
- advection (wind, currents, wave)
- deposition on the beach surface
- penetration into beach sediments
- long term storage in beach-groundwater system
- gradual release into surf zone
- reflotation from beach surface

Figure 1 shows the processes relating the various depositories for mass in a single coastal reach. Figure 2 shows an example study area for the model.

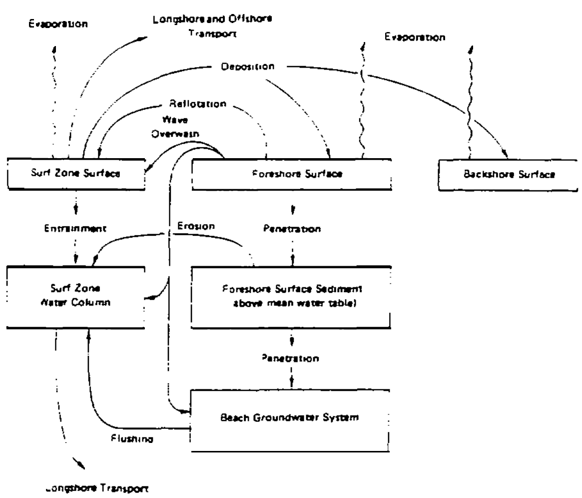

Figure 1. COZOIL mass transfer pathways in the coastal zone.

There are eight types of coastal reaches defined in the present version of the COZOIL model: 1) smooth rocky shore or sea-wall, 2) cobble beach, 3) eroding peat scarps, 4) sand beach, 5) gravel beach, 6) tidal (mud) flat, 7) marsh, and 8) coastal pond, lagoon, or fjord.

For each of the reach types 1 through 7, there are eight parameters required by the model: 1) reach length (m), 2) backshore width (m), 3) foreshore width (m), 4) offshore distance (m), 5) backshore slope (rise/run), 6) foreshore slope, 7) offshore depth (m) and, 8) reach orientation (degrees from north).

For reach type 8, the model requires four parameters: 1) pond surface area (m^2), 2) breachway (entrance) width (m), 3) breachway (entrance) depth (m), and 4) tidal range outside the pond (m).

Flow into and out of coastal ponds and lagoons is computed by simple conservation of mass principles, assuming uniform velocities over the entrance cross section, and neglecting phase lags inside and outside the pond.

The MMS Smear Model Handbook (Gundlach et al. 1990) consists of six volumes, 3,050 pages of tables of parameters for all of coastal Alaska, except Prince William Sound and the Panhandle. The handbook was compiled to provide complete environmental input parameters to run the model. The coastal parameters in the handbook are derived from the NOAA Environmental Sensitivity Index maps, with resolution varying from 50 to 500 m. This means that, in general, a user will have to perform extensive manipulation of the input data to produce data at any fixed model resolution. Estimated time to prepare a single model application is two days.

An alternative would be to build a graphical user interface to allow the user to:

- window and grid the application area,
- establish rules for combining coastal reach types,
- build current and wind data sets for input,
- run the model.

ASA has constructed a variety of mouse-driven graphical interfaces for oil spill models (e.g., Anderson et al. 1990). We anticipate that such an interface would allow model setup to be completed in 30 “minutes or less, for any arbitrary area.

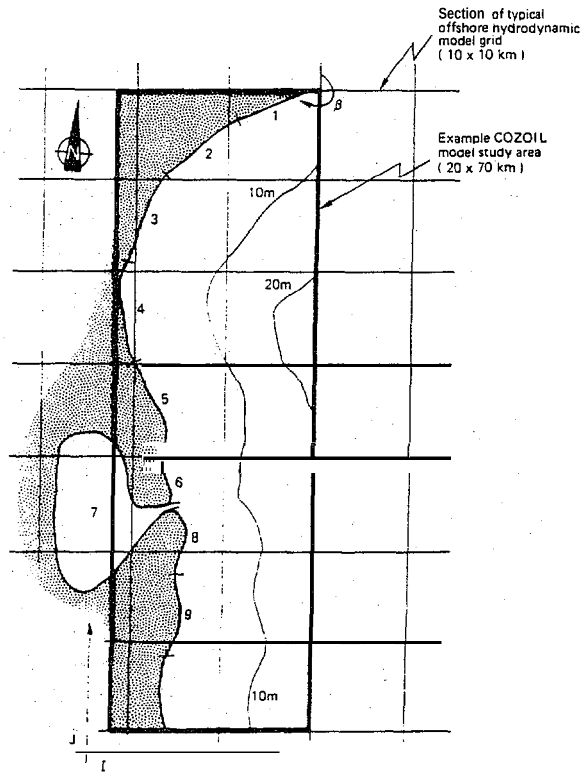

Figure 2. Example COZOIL model study area showing bathymetry and division of shoreline into reaches.

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Dr. Reed is senior scientist and project manager with Applied Science Associates, Inc. (ASA). Dr. Reed specializes in numerical modeling of the fates of oils and hazardous substances in aquatic environments.

QUESTIONS AND DISCUSSION

Cleve Cowles: Mark, on one of the last transparencies you showed was that an actual graphic from a COZOIL application or some other model?

Mark Reed: It was actually some other model because I don't have a graphics interface for the COZOIL Model yet. But this would work for that model. It works very much like that. The tools that we use to put together these interfaces we've used on several different models already,

Dick Prentki: I believe you gave us a test example for the Gulf of Arabia that we have in the office a while back,

Mark Reed: Yes, that has some of these same tools in it.

Dick Prentki: So if somebody wants to see those sorts of things in action, we do have an example — back at the MMS office.

Mark Reed: The main difference for the COZOIL Model is the sort of decision-making processes involved. If one cell has two-thirds sand and one-third gravel in it, what do you want me to do? You're going to have either program default rules, or ask the user every time. There are issues like that that have to be dealt with.

Dick Prentki: The handbook is also on diskette, by the way, too,

Gail Irvine: Have you designed some default parameter for that? For combinations of coastlines?

Mark Reed: No. I've actually only done — You know, the reason I know how long it takes to do one of these applications is that I did a hindcast of the Amoco *Cadiz*. We did three resolutions. It took about a week, really, to be happy with each one of those. But no, I haven't. And each case we had to go through and decide at this resolution, what's this piece of coastline going to be? What's the best representation for this length of coastline? I don't have fixed rules at this point, no.

Gail Irvine: Even though the experiences wouldn't lead you to some..,?

Mark Reed: Yes, I think I could probably sit down and work through some rules, but I haven't done that.

POTENTIAL SYNTHETIC APERTURE RADAR (SAR) APPLICATIONS FOR THE GULF OF ALASKA/LOWER COOK INLET - SHELIKOF STRAIT/BERING SEA

William J. Stringer, K.G. Dean, and J.E. Groves
Geophysical Institute
University of Alaska - Fairbanks
611 E. Elvy Building
Fairbanks, Alaska 99775

INTRODUCTION

The European Earth Resources Satellite (E) ERS-1 has been launched and data are being received. In addition to this, the Japanese Earth Resources Satellite (J) ERS-1 will be launched in the near future and the Canadian RADARSAT will be placed into orbit perhaps a little later. The siting of a receiving station at Fairbanks places a good portion of the Alaska OCS region within its station mask. It is therefore appropriate to ask what value these data might have to future studies. Perhaps the best way to do this is to examine some examples of the data already received and discuss their utility relative to previous existing data sets. Before doing this, it is worthwhile to note some basic principles of radar imagery in general and synthetic aperture radar imagery in particular:

1. image brightness results from the backscatter of the radar signal. This depends in part on the target's dielectric properties and in part on the target's roughness relative to the radar wavelength, taking the angle of incidence into account.
2. The radar signal is coherent radiation. Knowledge of the phase of the returning signal is lost. This leads to the phenomenon known as "speckle" that give radar images a very "noisy" appearance.
3. "One look", high resolution data are greatly limited in radiometric resolution by speckle. (Theoretical treatments show that one look data generally have as few as three independent gray levels).
4. Radiometric resolution can be gained at the expense of spatial resolution. Multiple "look" imagery is best for oceanography.
5. Motion of targets can cause their displacement on an image. Targets with differential motions such as wave fields will be distorted.
6. Bragg scattering from wavelets is often the dominant ocean surface scattering mechanism. Analysis of ocean backscatter can be difficult and subject to differing interpretations.

SAR DATA PRODUCTS

In addition to various image products, the Alaska SAR facility will produce a variety of derived data products. Table 1 describes the routine data products that will be available.

RESULTS

Example 1. Oil spills. Analysis of Landsat TM imagery led to the development of a nearly unique oil signature for the Prince William Sound spill (Stringer et al. 1992). However, the utility of the technique was severely limited by data availability partly due to cloudiness. Airborne radar was used with some success but both false positive and false negative identifications were reported. The airborne radar also required careful interpretation because of basic limitations due to aircraft yaw and radar illumination geometry. The satellite-borne radar will be free from these problems which will help to reduce (but not entirely eliminate) the interpretation difficulties. Thus, it should be possible to develop an all-weather methodology for identifying future - and relatively small - spills on SAR imagery that will be reasonably reliable.

able 1. ASF data products.

Product Type	Distribution Media	Data Characteristics
Standard Products:		
Computer Compatible Signal Data	CCT , DOD	12 second segment
Complex Image Data	CCT, DOD	8 m pixel spacing 30 x 50 km area 10 m resolution
Full-Resolution Images	CCT, DOD, Film	12.5 m pixel spacing 30 m resolution 8k x Sk pixels
Low-Resolution Images	CCT, DOD, Film	100 m pixel spacing 240 m resolution 1k x 1k pixels
Geo-Coded Products:		
Gee-Coded Full Res.	CCT, DOD, Film	12.5 m pixel spacing 30 m resolution 8k x 8k pixels
Gee-Coded Low Res.	CCT, DOD, Film	100 m pixel spacing 240 m resolution 1k x 1k pixels
Geophysical Products:		
Ice Mot ion Vectors	CCT, DOD	Ice Displacement Vectors 5 km grid 100 km x 100 km (nominal)
Ice Type Classification	CCT, DOD	Ice Type Image 100 m pixels 100 km x 100 km (nominal)
Ice Type Fraction	CCT, DOD	Fraction of Ice Classes 5 km grid 100 km x 100 km (nominal)
Wave Product	CCT, DOD	Wave Direct ion & Wavelength 6 km x 6 km subsections From Full -Res. Image
Other Geophysical Products	CCT, DOD	TBD

CCT: Computer compatible tape
DOD: 5.25” digital optical disks
Fi lm: 8"x10" format

Example 2. **Polynyas.** Recently, efforts have been made to analyze the growth of ice in Alaskan coastal polynyas (Groves and Stringer 1991) using Advanced Very High Resolution Radiometer (AVHRR) thermal and panchromatic imagery. These efforts were partly successful but problems arose because of the difficulty of determining a detailed ice configuration. It is anticipated that the higher resolution SAR imagery will provide this information. (The temperature of the ice surface is still determined using AVHRR thermal band imagery.) Combining SAR with thermal imagery should help provide much needed information regarding the growth and removai of ice from these features that appear to have significant influences on a number of oceanographic and atmospheric processes.

Example 3. ice Dynamics. ice motion has been studied using both existing satellite imagery and drift buoys. The buoys are never sufficiently dense to provide detailed motions and the previously existing satellite imagery have been cloud limited. SAR imagery should correct for this deficiency. Previously, Landsat imagery has been used to map ice displacements on a comprehensive scale in the Bering Sea (where there have been few buoys) during periods of prolonged cloudiness in the Bering Sea region (Stringer and Henzier 1982). SAR derived products should provide for the study of these ice motions during cloudy periods - times when there is evidence that the driving mechanism for the ice may be significantly different from cloud-free periods.

Exampie 4. Coastal Watermass Interaction Studies. Recently we have used Landsat TM and AVHRR visible and thermal imagery to study the interactions between lagoon and coastal waters for Kasegaluk Lagoon (Jiao 1992). The results provide some interesting insights regarding exchanges of waters between the two bodies, each driven largely by winds but having different response mechanisms. Examination of recentiy acquired ERS-1 imagery suggests that these data will add to our developing picture of physical processes in coastal areas. However some research wiii be required before meaningful interpretations of patterns seen on the imagery can be made.

Example 5. Coastal Transport Studies. During the weeks following the *Exxon Valdez* oil spill, there was a suddeniy renewed and intense interest in alongshore transport in the northern Guif of Aiaska, Lower Cook Inlet, and Shelikof Strait. There are many aspects to alongshore transport in this area, some of which are illustrated on existing satellite imagery. Now additional information that may be obtained from SAR imagery. Previously existing imagery provided evidence of transport through suspended sediment patterns and temperature distributions. SAR imagery is most likely to show evidence of modification of flow patterns resulting from sea floor topographical features.

SUMMARY

One of the greatest virtues of SAR imagery is its aii-weather capability. This wiil provide an opportunity to view a number of phenomena under conditions during which they previously were obscured from other sensors by clouds or darkness. In some cases SAR data reveai information not available from earlier sensors. However SAR imagery is not a replacement for data obtained by other sensors. instead, it should be considered a source of complementary information. in some cases SAR imagery is considerably more difficult to interpret than visible band, near infrared and even thermai Infrared data and debates continue among acknowledged experts over the competing mechanisms responsible for the patterns and textures seen on some SAR images. in many cases, other image data sets provide the training required to understand what is seen on the SAR image.

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Dr. Bill Stringer is an Associate Professor of Geophysics and the Coordinator of Remote Sensing for the Geophysical Institute of the University of Alaska, Fairbanks. He was responsible for the development of an image processing laboratory for the Alaska Synthetic Aperture Radar Facility. He teaches courses on remote sensing, including microwave remote sensing. He has been involved with the Alaska Outer Continental Shelf Environmental Assessment Program since its inception. This involvement has included the performance of studies based on remote/y sensed data sets and the provision of remote sensing assistance to OCSEAP investigators. Dr. Stringer received his B.S. in physics from New Mexico State University and both M.S. and Ph.D. from the University of Alaska.

QUESTIONS AND DISCUSSION

Keith Bayha: We just had a spill in the Cook Inlet. Was this equipment up there taking pictures at that time and could you tell the difference between oil and calm waters?

William Stringer: You know, I purposefully did not try to find out. (Laughter). If it had looked like it had been really bad, we would have had to do something. The last time we had a oil spill, I dropped everything and got involved and it disrupted my life considerably for quite a while.

Keith Bayha: It affected everybody.

William Stringer: Yes. That's right. And so, this time, I said, "Oh, I just hope it goes away,"

Now, that brings up something else interesting. This satellite has a relatively small field of view, and even if it is operating in a global coverage mode, it takes it about 27 to 30 days, I think, to cover the entire planet. Now, at high latitudes, you get some double coverage because of the convergence of meridians. But it turns out that at this particular time, the satellite was on a mode where it repeated every three days. They repeated the areas it covered every three days. Of course in this mode, it didn't cover everywhere. I'm pretty sure that that area wasn't in one of the zones it was looking at or there would have been images all over the place.

But I'm really not that closely involved with the operation of the system, and that's a good question. That's my honest answer. Had the spill turned out to be very large, we would have made a significant effort to map it. Fortunately it was even smaller than the original estimates,

OVERVIEW OF THE EFFECTS OF OIL ON MARINE MAMMALS

David J. St. Aubin
Department of Pathology
Ontario Veterinary College
University of Guelph
Guelph, Ontario, Canada NIG 2W1

INTRODUCTION

Exploitation of marine oil reserves, and marine transportation of oil from any source, carry the risk of accidental release into the ocean, with devastating consequences for many life forms. The threat to any particular species is as much a function of the animals' behavior, life history, and special anatomical or physiological adaptations, as it is of the inherent toxicity of any of the thousands of compounds that comprise crude petroleum or its refined products. For some species of marine mammals, we have enough direct evidence from field observations following oil spills to judge the risks associated with exposure to spilled oil. When such observations are lacking, we must rely on a patchwork of data extrapolated from other species, blended with limited experimental findings, and interpreted against an understanding of the animals' basic biology. This approach was developed in a recent review (Geraci and St. Aubin 1990), sponsored by the Minerals Management Service (MMS). In the interest of brevity, this summary will refer the reader to the review for detailed citations of original observations.

The March 1989 grounding of the *Exxon Valdez* in Prince William Sound once again raised concerns about the effects on cetaceans, seals, sea lions, fur seals, and sea otters. Oil was suspected as the cause of death of an estimated 200 or more pinnipeds, but no convincing link was established for the few cetacean carcasses that were found along the shore. By contrast, the effects on sea otters were immediate and devastating. In the short term, at least, the impact on each group of marine mammals could be predicted from past experience and scientific research.

CETACEANS

To address the large uncertainties about the effects of oil on cetaceans, MMS supported a five-year study (Geraci and St. Au bin 1982, 1985) which sought to answer several specific questions:

1. Can cetaceans detect spilled oil on the surface of the water, and if so, will they avoid it?
2. Do petroleum hydrocarbons damage cetacean skin?
3. Can the literature on inhalation and ingestion of petroleum hydrocarbons be used to predict the effects of such exposure in cetaceans?
4. Does oil interfere with the baleen feeding apparatus of mysticete whales?

The first two questions were investigated using bottlenose dolphins, *Tursiops truncatus*, as a representative cetacean. Under controlled conditions, the dolphins demonstrated that they could visually detect a 1-mm thick film of crude oil, and would avoid surfacing in sections of a seawater pen containing a 1 cm layer of innocuous mineral oil. The unmistakable reaction of the study animals contrasts to a handful of field reports of these and other cetaceans apparently swimming and behaving normally in the midst of spills of fuel and crude oil (Geraci 1990). In the wild, dolphins may be reluctant to avoid a spill because of some overriding attraction to the area.

Cetacean skin is unlike that of any other mammal, and might therefore be easily damaged by petroleum. To test this, we placed small devices containing crude oil- or gasolinesoaked sponges onto the skin of captive bottlenose dolphins for up to 75 minutes to determine the effects on epidermal cell integrity, growth, and function (Geraci and St. Aubin 1982). Some damage was observed histologically, but resolved within a week; no effect on growth or other cellular functions could be easily detected. The conditions of the experiment were thought to exceed those under which most cetaceans would be exposed to oil in the wild, except perhaps for animals restricted to leads in ice or within the confines of a complex coastline. Even so, without hair or fur to retain the oil, the wetted surface of their smooth skin would not allow oil to stick for long, thereby reducing the likelihood of significant damage to the epidermis.

Cetaceans in the midst of a fresh spill will inhale noxious vapors, and in a panic, might ingest-enough oil to cause illness. Acute intoxication by petroleum has not yet been established in a cetacean, and no laboratory study has been or will be undertaken to establish critical thresholds for toxicity. Published data for other species would suggest that the small amount of oil that a cetacean might ingest during the course of feeding would not present a significant threat. Concerns about transfer through the food chain are similarly overemphasized. Cetaceans, and most of their prey, have the enzyme systems necessary to metabolize and clear petroleum hydrocarbons, and as a consequence will not accumulate such fractions in their tissues.

Oil ingestion represents a different kind of threat to mysticetes, which feed using a sieve of baleen plates. Laboratory studies have shown that oil fouling the haired fringes of these plates restricted the flow of water. Heavy Bunker C oil at water temperatures below 5°C had the greatest effect, increasing the resistance to flow roughly two-fold. Continuous flushing with clean water removed most of the oil in less than 24 hrs, after which time no residual effects were noted. In a free-ranging whale, feeding could be interrupted for several days with consequences developing some months later if the animal were unable to store enough energy to meet its needs for migration and reproduction. It would be difficult to demonstrate such an association, considering the lack of verifiable evidence that baleen fouling occurs.

PINNIPEDS

The risk of exposure to oil is greater for pinnipeds, which are amphibious and traditionally favor certain "haul-out" sites where oil might accumulate. All but perhaps walruses have enough fur or hair to entrap oil as they venture between sea and rookeries. Some, principally the fur seal and very young phocid seals, rely on the pelage for insulation, which can be disrupted by oil. In most other pinnipeds, blubber serves as the principal insulator, and is unaffected by surface oiling.

A coating of oil can cause other difficulties, particularly in cold water. In the winter of 1969, a spill of Bunker C oil fouled 10 to 15,000 harp seals, *Phoca groenlandica*, (Sergeant 1991). Most were so encased in oil that they were unable to swim, and untold numbers probably died. The heavy toll reflected the disastrous combination of viscous oil in frigid water at a time when seals congregated to give birth and molt.

All other reports of oil fouling in phocid seals, including those in the aftermath of the *Exxon Valdez* spill, involved relatively few animals whose deaths were ambiguously linked to oil (St. Aubin 1990). This outcome is consistent with the findings of a controlled field study on ringed seals, *P. hispida*, held for 24 hrs in a pen containing a surface layer of light "crude oil (Geraci and Smith 1976). The seals developed corneal ulcers, and mild liver and kidney damage, but no functional impairment of these organs. By contrast, three ringed seals that had apparently not fully acclimated to captivity following transportation to a laboratory setting died with 71 minutes after exposure to oil under similar conditions. The acute deaths of these animals demonstrated that pre-existing stress may dramatically alter the ability to cope with an oil spill.

Pinnipeds can absorb hydrocarbon vapors across respiratory membranes, enough perhaps to cause systemic effects. Heavily oiled harbor seal pups, *P. vitu/ins,* rescued in Prince William Sound had blood hydrocarbon levels up to 260 ppm, but survived and were released (Williams et al. 1990). The effects might be greater in seals in which pulmonary function is already compromised by parasitic infestation of the lungs.

In the midst of a spill, pinnipeds might accidentally ingest some oil. Harp and ringed seals given small quantities of oil to duplicate this type of exposure showed no overt clinical signs, Some biochemical effects were noted, including changes in plasma and tissue enzymes, and increased cortisol secretion and turnover, but with no consistent pattern. It is unlikely that pinnipeds would consume enough oil to cause significant organ damage. A more serious threat is that viscous oil or tar in the mouths of small seals might interfere with feeding.

SEA OTTERS

To any sea otter, *Enhydra lutris*, oil is a pernicious threat. The animal is made vulnerable by behavioral, anatomical, and physiological adaptations that ironically are critical for survival. Sea otters rest and eat at the surface, where oil concentrates. Oil clings to their unimaginably thick coat, destroys its insulative value, and triggers compulsive grooming by which the animals ingest oil. The sea otter's intrinsically high metabolic rate, necessary for an animal its size to tolerate the rigors of a subarctic environment, is challenged to the limit, and cannot be sustained when feeding activities are displaced by grooming. There is little chance for a sea otter to reverse the chain of events that is initiated after its coat becomes fouled with oil.

For at least a decade before the grounding of the *Exxon Valdez* claimed an estimated 3500 to 5500 otters, laboratory research and sporadic observations from the north Pacific and the British Isles made clear the vulnerability of these animals to oil. Metabolic and behavioral disturbances had been described, and were addressed by those attempting to deal with the causalities in Prince William Sound. Other effects were unexpected (Williams et al. 1990). As the slick weathered and volatile components were lost, the incidence of respiratory distress and associated emphysema in the otters declined and survival improved, even when their fur was heavily oiled. It seemed that breathing hydrocarbon vapors was more harmful than consuming oil while grooming. The observation underscores the possibility that field studies will reveal effects that may not be apparent from laboratory experiments.

SUMMARY AND CONCLUSIONS

Marine mammals show a wide range in their sensitivity to oil as expected from the diversity of their morphology, behavior, and ecology. Sea otters are clearly the most vulnerable to any form of oil exposure, while odontocete cetaceans seem almost unaffected by casual contact. Pinnipeds can fall victim, especially if the spill occurs around rookeries or ice floes used for breeding.

Any marine mammal exposed to fresh oil will absorb volatile fractions across respiratory membranes, though the critical threshold for blood hydrocarbon levels appears to be lower in sea otters than in seals at least. Petroleum may be ingested incidentally during feeding, but probably not in sufficient quantities to be lethal. In the sea otter alone, grooming represents a potential route for ingestion of toxic quantities of oil. After the risk from floating oil has dissipated, benthic-feeding marine mammals may consume hydrocarbon residues concentrated in certain organisms, with unknown long-term consequences. The massive response that can occur in the wake of an oil spill may be as disruptive and threatening to marine mammals as the oil itself.

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Dr. David St. Aubin is an assistant professor in the Department of Pathology at the University of Guelph in Ontario, Canada, where he has been involved in studies on the effects of oil on marine mammals since 1974. His other research interests include endocrine physiology, stress and disease, and factors underlying natural mortality in marine mammals. He received his B.S. from the University of Michigan, and his M.S. and Ph.D. from the University of Guelph.

STATUS OF GULF OF ALASKA AND BERING SEA PINNIPEDS AND CETACEANS

Thomas R. Loughlin
National Marine Mammal Laboratory
7600 Sand Point Way, NE
Seattle, Washington 98115

I reviewed the current numerical status of pinnipeds (except walruses) and cetaceans (except belukha whales) that occur in the Gulf of Alaska and southeastern Bering Sea. The information used was from unpublished data at the National Marine Mammal Laboratory and from a recent workshop sponsored by the Marine Mammal Commission (Swartzman, G. L., and R.J. Hofman, Uncertainties and research needs regarding the Bering Sea and Antarctic ecosystems. NTIS #PB91-201731. 44 p).

The Pribilof Island fur seal stock numbers about 900,000 (Table 1) and is probably stable following a sharp decline during 1976 to 1981, Pup production on St. Paul Island is stable at about 200,000 pups born per year; St. George Island is declining at about 61%0 per year with about 25,000 pups born per year, Steller sea lion numbers continue to decline and the species was listed as 'Threatened" in November 1990. The Kenai to Kiska trend site area has declined to about 21,000 adults and juveniles in 1991 from about 90,000 in the 1970s (Figure 1). Harbor seal numbers in Bristol Bay have declined to about 9000 from a high in 1976 of about 18,000. Harbor seal numbers at Tugidak Island in the Gulf of Alaska have declined by over 85% from 1976 to 1988 (Figure 2); Prince William Sound (PWS) numbers are declining at trend locations. The remainder of PWS and the Copper River Delta were surveyed for the first time in 1991 and totaled about 5000 seals (Table 1). Historical estimates for ice seal numbers in the Bering, Chukchi, and Beaufort Seas include: ribbon seal, 90,000 to 100,000: rinsed seal. 1.000,000; spotted seal, 200,000 to 300,000; bearded seal, 2"50,000 to 300,0'00, '

Table 1. Pinniped populations In the Bering Sea and Gulf of Alaska.

Species	Population estimate	Current status	Seasona 1 usage
ribbon seal	90,000 to 100,000	stable?	Sp, u
ringed seal	1,000,000	stable	Sp, W
spotted seal	200,000 to 300,000	unknown	Sp, W
bearded seal	250,000 to 300,000	unknown	Sp, w
harbor seal	8500 (BB)	stable	Sp, S, F, W
	3500 (CRD)	unknown	Sp, S, F, W
	2500 (PUS)	declining	Sp, S, F, U
	1014 (Tug)	declining	Sp, S, F, U
northern	800,000 (Pribs)	stable	Sp, S, F
fur seal	1500 (Bogos)	increasing	SP, S, F
Steller's sea lion	48,000 (AK)	declining	Sp, S, F, W

Sp = spring; S = summer; F = fall; W = winter; BB = Bristol Bay; Bogos = Bogoslof Island; CRD = Copper River Delta; Pribs = Pribilof Islands; PUS = Prince William Sound; Tug = Tugidak Is Lard

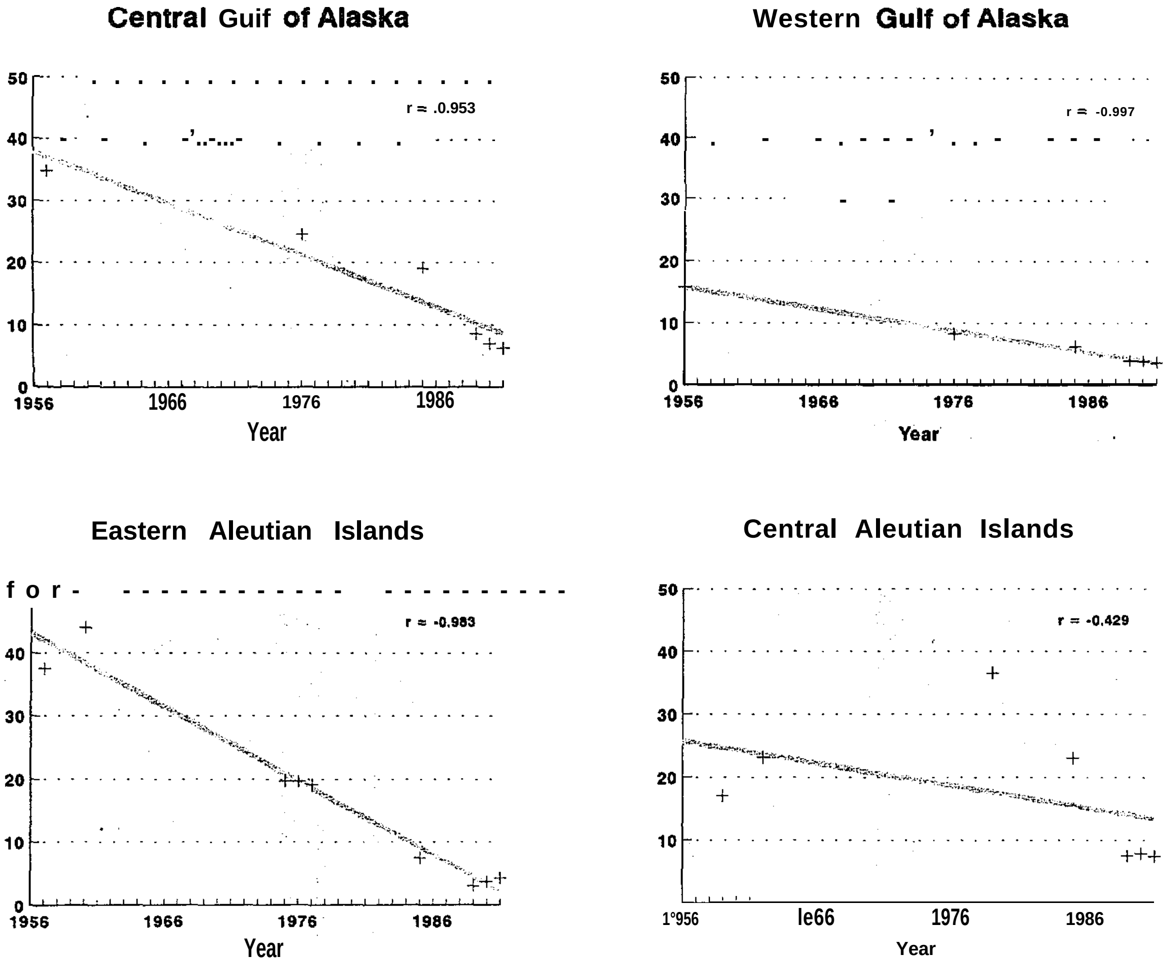

Figure 1. Counts of adult Steller sea lions in four geographic areas of Alaska, 1956 to 1991. The regression on the counts is shown as a shaded line; the r values of the regression are indicated in the upper corner.

Recent estimates of cetaceans are unavailable except for the following. Gray whale numbers are increasing and now total about 21,000 (Table 2); they are proposed to be taken off the endangered species list. Killer whales in PWStotai 260whaies andin southeastern Aiaska about 120 whales. Harbor porpoise in Bristol Bay and Cook Inlet number about 5,000 (±2,000) porpoise and in southeastern about 2,000 porpoise. There are about 1,300,000 Dali's porpoise in the North Pac'Hit; separate estimates for the Bering Sea and Gulf of Alaska have not been calculated. Historical estimates for other cetaceans in the North Pacific include: fin whale, 16,625; sei whale, >9,000; humpback whale, <2,000; blue whale, 1,600; sperm whale, 930,000; and bowhead whale, 7,800 (Bering, Chukchi, Beaufort Seas). There are no estimate of numbers for beaked whales, minke whales, or right whales.

Dr. Tom Lough/in has worked at the National Marine Mammal Laboratory since 1981 and is head of the Alaska Ecosystem Program. His research interest include marine mammal ecology and marine mammal/fisheries interactions. Dr. Lough/in received his B.A. in biology from the University of California, Santa Barbara; his M.A. in biology from Humboldt State University; and his Ph.D. in biology from UCLA.

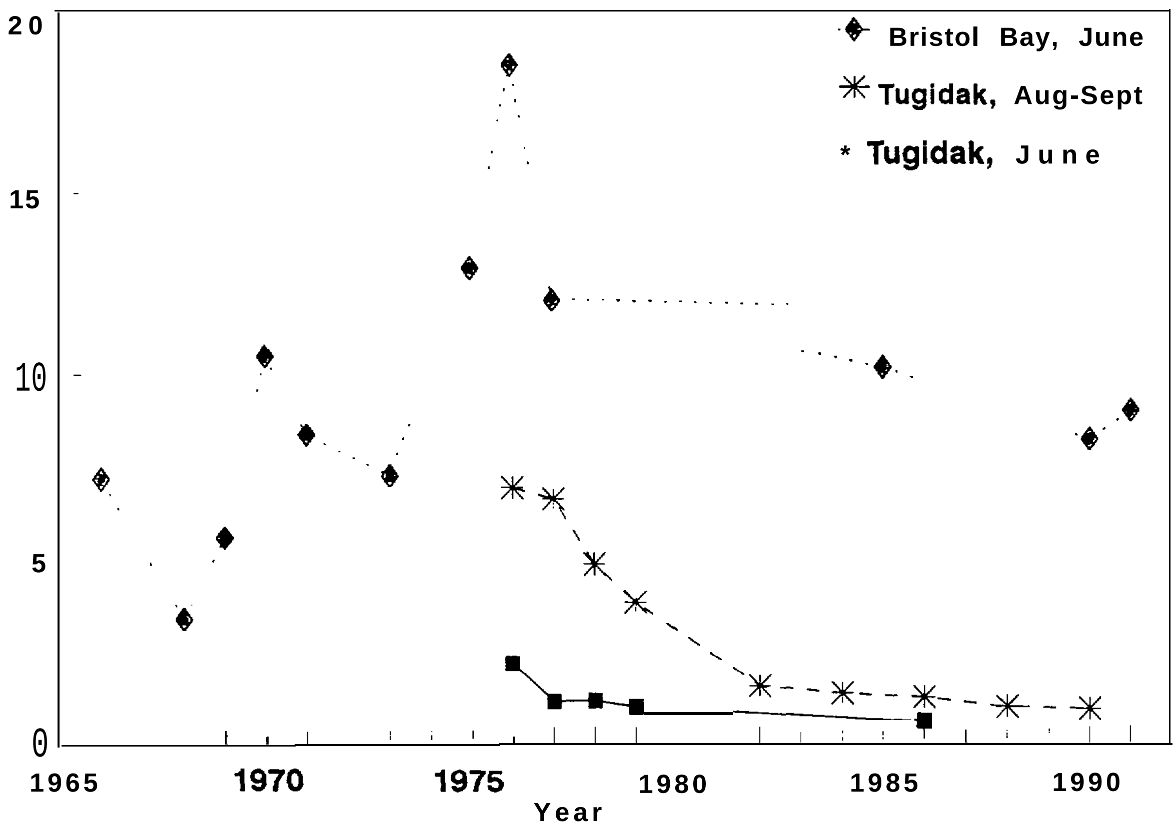

Figure 2. Counts of harbor seals (in thousands) at Bristol Bay and Tugidak Island (south of Kodiak), Alaska. Tugidak Island counts are from: Pitcher, K.W. 1991. Major decline in number of harbor seals *Phoca vitulina richardsi*, on Tugidak Island, Gulf of Alaska. Marine Mammal Science, 6:121-134.

Table 2. Cetacean populations in the Bering Sss and Gulf of Alaska.

Species	Population estimate	Current status	Seasonal usage
Gray whale	21,000	increasing	Sp, S, F
Fin whale	16,625	unknown	Sp, S, F
Sei whale	9,000	unknown	5P, S, F
Blue whale	1,600	unknown	s
Minke whale	?	?	Sp, S, F, U
Humpback whale	<2,000	unknown	Sp, S, F,
Bowhead whale	7,800	increasing?	Sp, W
Right whale	?	?	S, F,
Sperm whale	930,000	unknown	s
Killer whale	260 (PUS)	stable?	Sp, S, F, W
	120 (SEA)	declining	Sp, S, F, W
Beaked whales	?	?	?
Dan's porpoise	,300,000 (NP)	stable	SP, S, F, U
Harbor porpoise	2,000 (SEA)		
	5,000 (BS/Cook)	unknown	Sp, S, F, W

Sp = spring; S = summer; F = fall; W = winter

Table 2. Cetacean populations in the Bering Sea and Gulf of Alaska.

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Gray whale	21,000	increasing	Sp, S, F
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Sei whale	9,000	unknown	Sp, S, F
Blue whale	1,600	unknown	S
Minke whale	?	?	Sp, S, F, W
Humpback whale	<2,000	unknown	SP, S, F,
Bowhead whale	7,800	increasing?	Sp, w
Right whale	?	?	S, F,
Sperm whale	930,000	unknown	S
Killer whale	260 (PUS)	stable?	Sp, S, F, W
	120 (SEA)	declining	Sp, S, F, W
Beaked whales	?	?	?
Dall's porpoise	1,300,000 (NP)	stable	Sp, S, F, W
Harbor porpoise	2,000 (SEA)		
	5,000 (BS/Cook)	unknown	Sp, S, F, W

Sp=spring; S=summer; F=fall; W= Winter; PWS=Prince William Sound; SEA= Southeast Alaska; NP=North Pacific

STATUS OF POLAR BEAR, WALRUS, AND SEA OTTER IN THE GULF OF ALASKA/LOWER COOK INLET-SHELIKOF STRAIT/BERING SEA

Jon Nickles
Marine Mammals Management
U.S. Fish and Wildlife Service
4230 University Drive, Suite 310
Anchorage, Alaska 99508

INTRODUCTION

The U.S. Fish and Wildlife Service (FWS) is responsible for management of polar bear, Pacific walrus, and northern sea otter in Alaska, as provided by the Marine Mammal Protection Act of 1972 (MMPA). Populations of these species are healthy, and perhaps near historic high levels. Except for the sea otter, population information exists only for broad geographic areas. Precise estimates of population sizes and trends are lacking. Much of the ranges of polar bear and walrus are in the Chukchi and Beaufort seas, outside the area of focus of this paper.

The MMPA includes an exemption which allows Alaska Natives to harvest marine mammals for subsistence purposes, or for creating and selling handicrafts and clothing. There are no restrictions on the harvest, providing it is non-wasteful. The FWS monitors the Native harvest with a mandatory marking and tagging program, and through a walrus harvest monitoring program which will be resumed in 1992 after a two-year hiatus.

POLAR BEAR

Polar bears are circumpolar in distribution and generally occur in low density. They are associated with sea ice and this is reflected in their seasonal distribution and movements (DeMaster and Stirling 1981, Amstrup and DeMaster 1988). They range south in U.S. waters as far as St. Matthew Island and the Pribilofs (Ray 1971). Prior to 1900, some polar bears stayed on St. Matthew Island through the summer instead of remaining with the sea ice as it retreated north (Hanna 1920).

Alaska's polar bear population is shared with Canada to the east and Russia to the west. The population has increased over the past 20 years, but precise trend information is lacking (Amstrup et al. 1986). Conducting population surveys over vast offshore areas is difficult, and until recently the polar bear range within Russian territory was off limits to Alaskan researchers. It is thought there are two population stocks in Alaska, with the dividing line near Point Lay (Lentfer 1974). The Beaufort Sea "stock" was estimated at 1776 bears in 1986 (Amstrup et al. 1986) based on mark and recapture work. A total Alaska population of 3000 to 5000 bears was projected from average density estimates. The FWS plans to conduct a new population survey in 1993.

Recognizing the polar bear's increasing vulnerability to human activities, the five nations (U. S., U. S. S. R., Canada, Denmark, Norway) within whose boundaries polar bears occur negotiated the International Agreement on Conservation of Polar Bears, which was ratified in 1976. Each of the signatory nations has implemented management programs to protect polar bears and their environment. In the U.S. this has been done under the MMPA. Some provisions of the 1976 Agreement have not been adequately implemented.

Subsistence hunters in Alaska have harvested about 130 bears per year since 1980 (range: 75 to 296.) About 75% of these are harvested in the Chukchi-Bering Sea area, including about 45 bears per year taken from the Bering Strait south (Schliebe unpubl. data). No hunting has occurred in the Soviet Union since 1956, although hunting may be resumed there. Among the greatest concerns for the protection of polar bears and their habitat is increasing oil and gas exploration and development. The FWS and Alaska Department of Fish and Game routinely provide technical assistance to industry on siting and operation of facilities, measures to protect denning bears, and on detection and deterrence of bears around work sites. Monitoring studies required by the small takes regulatory program will provide information useful in refining mitigation measures,

WALRUS

The Bering-Chukchi walrus stock ranges from the eastern East Siberian Sea through the Chukchi to the western Beaufort Sea and southward over the continental shelf waters of the Bering Sea from Bristol Bay to the eastern Kamchatka Peninsula. The majority of the population congregates during the summer months in the southern region of the Chukchi Sea pack ice between Long Strait and Wrangel Island, Russia, and Point Barrow, Alaska. Major concentrations occur near the coasts of Chukotka and northwestern Alaska (Fay et al, 1984). The remainder of the population, primarily adult males, stays in the Bering Sea, especially along the Anadyr Gulf coast and in northern Bristol Bay and along the northern Alaska Peninsula (Sease and Chapman 1988),

In winter, walrus are found in two major areas where open leads, polynyas, or thin ice occurs (Fay et al. 1984). While the specific location of these groups varies annually and seasonally depending upon the extent of sea ice, one group ranges from the Gulf of Anadyr into a region southwest of St. Lawrence Island and a second group is found in the southeastern Bering Sea from south of Nunivak Island into northwestern Bristol Bay.

Female and young walruses travel from wintering areas in the Bering Seato summering areas in the Chukchi Sea starting in the last part of March or April, The fall migration starts as the pack ice begins to re-form, with females and subadult males swimming ahead of the ice edge toward the Bering Strait, Some adult males that remained in Bristol Bay during the summer move north toward Bering Strait to join the animals there,

Range-wide population surveys have been conducted cooperatively by the United States and the Soviet Union at five-year intervals since 1975. The fourth survey, conducted in fall 1990, was the first fully cooperative survey and involved an unprecedented degree of cooperation: pre-survey tests of methodology were conducted; the survey employed a common design; survey flights were flown concurrently in the U.S. and U. S. S. R.; U.S. biologists flew with the Soviet team; data were exchanged and cooperatively analyzed; and a survey report was prepared jointly,

During the 1990 survey, ice coverage approached a near record minimum in the Chukchi Sea and a record minimum in the East Siberian Sea. These conditions likely influenced walrus distribution and accounted for very low numbers of walrus overflown in the pack ice. Unusually large numbers of walrus were encountered on Russian haulout areas (total: 154,525, of which 76,702 were counted at Cape Blossom on Wrangel Island). The 1990 survey produced a minimal estimate of the total population size, 201,039, which is not comparable to estimates obtained from prior cooperative surveys (Gilbert et al., in press).

While survey data indicate that the population may be at or near historic levels and is stable or decreasing slightly, trends in life history parameters (e.g., age at first reproduction, sex/age composition, calf production, blubber thickness, and food habits) suggest the population may have exceeded carrying capacity and may be on the verge of a decline (Fay et al, 1989).

The Soviet walrus harvest is regulated under a quota system. Both a commercial and a subsistence hawest occur there but in the last several years the quota of 5000 has not been reached. The combined Soviet and Alaska harvest (including estimated loss) has increased over the past 30 years to about 10,000 animals per year (range 3000 to 17,000, Seagars et al.

1989; Fay and Fedoseev, unpubl. data). The retrieved U.S. harvest has declined over the last four years (Stephensen, unpubl. data). As with polar bear, there is concern about habitat protection in the face of oil and gas exploration and development activities. Additionally, there is concern about disturbance associated with fishing activity, particularly in the Bristol Bay area. In 1989, the Secretary of Commerce implemented a closure to prevent bottomfishing within 12 miles of Round Island and Cape Peirce haulouts. Action is pending to extend this closure for an indefinite period.

SEA OTTER

The history of exploitation and recovery of the sea otter is well known. Vitus Bering's voyage of discovery returned to Russia with 900 sea otter furs in 1742. There followed 126 years of Russian exploitation and then 44 years of exploitation by the United States. The pre-exploitation population in Alaska is thought to have been somewhat greater than 200,000 animals (Johnson 1982). By 1911, sea otters were nearly extinct, with only disjunct population remnants remaining. In 1911, the North Pacific Fur *Seal* Treaty (an international convention) gave sea otters protection from all hunting except by Alaskan Natives using aboriginal means. With statehood in 1959, a complete ban on harvest was implemented.

Sea otters are widely distributed in Alaska and with protection have re-occupied most of their historical range (Rotterman and Simon-Jackson 1988). Over 90% of the world's sea otters live in coastal Alaska. The population is thought to be nearing the pre-exploitation level, although population estimates are out of date for many areas. Sea otters in Alaska are distributed from Attu Island in the western Aleutians through the southeastern panhandle. On the north side of the Alaska Peninsula sea otters are commonly found as far north as Port Heiden. Sea ice limits their northward distribution and may limit population size as well (Schneider and Faro 1975). Gaps in distribution still occur at Kodiak Island, in the northeastern Gulf of Alaska, in southeastern Alaska, and perhaps in Cook Inlet. A state-wide population survey has never been conducted. However, following completion of survey work in the Aleutians in 1992, the FWS will develop a state-wide population estimate based on composite results of surveys conducted over the last several years.

Harvest records since 1982 indicate a maximum documented Native harvest of 555 animals in 1986. Following passage of the MM PA, there were several years of uncertainty about the legality of hunting sea otters. This probably served to keep harvest levels relatively low. In 1990, the FWS promulgated an interim regulation which made it illegal to sell handicrafts and clothing made from sea otter skins, although subsistence use was still legal. This regulation was recently overturned in court but an appeal by a coalition of private organizations is pending.

Sea otters are extremely susceptible to contamination of their fur, as evidenced by the impact of the *Exxon Valdez* oil spill. Unlike other marine mammals, they have no thick blubber layer and depend on their fur for insulation. Other sources of mortality and concern for sea otters include incidental take during commercial fishing, including mariculture operations; timber harvest, log transfer facilities, and related activities; and coastal development. After the near extirpation of sea otters, their prey species (sea urchins, mussels, clams, crabs) undoubtedly increased. Serious conflicts have developed in some areas because increasing numbers of sea otters have decimated these economically valuable shellfish resources.

SUMMARY

Populations of polar bear, walrus and sea otter are currently at healthy levels in Alaska. However, better and more frequent population surveys are needed and more attention should be focused on examining life history parameters that could provide more timely information on population status and trends. Better information is needed on habitat perturbations and effective mitigation measures. The FWS is currently developing new management plans for each of these species which will likely result in new management directions.

ACKNOWLEDGEMENTS

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Jon Nickles has worked as a biologist with the U.S. Fish and Wildlife Service for 18 years, 15 of those in Alaska. He has served as Supervisor, Marine Mamma/s Management since 1988. Jon received his B.S. and M.S. in zoology at Michigan State University and his M.S. in botany at Southern Illinois University.

GRAY WHALE AND WALRUS FEEDING EXCAVATION ON THE BERING SHELF, ALASKA

C. Hans Nelson, Kirk R. Johnson[1],
John H. Barber, Jr., and Robert L. Phillips
US. Geological Survey
345 Middlefield Road, MS-999
Menlo Park, California 94025

INTRODUCTION

Long, sinuous furrows unlike any known bedforms were observed during oceanographic surveys of the northeastern Bering Sea in the late 1970s (Larsen et al. 1981). Because of the presence of large numbers of marine mammals in this area, their interaction with the sea floor was suspected to be a cause for these features. Since then, sidescan sonar has been used successfully as a tool for the description and mapping of mammal feeding patterns on the sea floor (Johnson et al. 1983, Nerini and Oliver 1983, Johnson and Nelson 1984, Oliver et al. 1984),

Our study of sidescan monographs from the northeastern Bering Sea shows that extensive bottom disturbance is caused by benthic feeding of California gray whales (*Eschrichtius robustus* and Pacific walrus (*Odobenus rosmarus divergens*) (hereafter referred to as gray whales and walrus). In this study, we identify the features on monographs that result from gray whale and walrus feeding disturbance and relate their distribution to bottom-sediment types and faunal assemblages. We also quantify the area and volume of whale feeding. By correlating feeding features, substrate, and currents, we can estimate the quantity of sediment put into suspension and removed by unidirectional currents. The results show that volumetrically the mammal feeding disturbance may be the most significant sedimentary process in much of Chirikov Basin, the western part of northeastern Bering Shelf (Figure 1).

METHODS

Data used in this study are deriied from bottom samples, bottom photographs, underwater video, sidescan sonar (Johnson et al, 1983), and scuba-diver observation (Oliver et al, 1983a). Substrate and benthic community associations used in this study have been established qualitatively (Nelson et al. 1981, Johnson et al. 1983) and quantitatively (Stoker 1978, Nerini et al. 1980, Feder and Jewett 1981, Oliver et al. 1983b, Thomson 1986) and include an assessment from 683 sampling stations in Chirikov Basin and Norton Sound (Hess et al. 1981).

Bottom-current velocities from central Chirikov Basin have been compiled from long-term current-meter arrays (Cacchione and Drake 1979; J. Schumacher, NOAA, Pacific Marine Environmental Laboratory, writ. comm., 1982, 1984) and bottom-current measurements made during collection of bottom samples (Figure 1). These data have been used to identify locations where currents are strong enough to enlarge bottom features caused by whale feeding.

The detail of whale and walrus feeding features on the sea floor of Chirikov Basin is best observed by scuba diving (Nerini et al. 1980; Oliver et al. 1983a,b; Thomson 1986). Unfortunately, harsh weather conditions, poor visibility (c 1 m), and the large size and depth of the basin make it difficult for scuba divers to do extensive surveys. The regional distribution of these features is best mapped by sidescan sonar. The main sidescan coverage was provided by the EG&G 105-kHz digital Seafloor Mapper (Figures 2 and 3). Correlations of feeding traces on a high-resolution 500-kHz system have been accomplished at a number of spot localities in Chirikov Basin (Nerini et al. 1980, Thomson 1986). A total of nearly 4500 line km of sidescan data have been collected from Norton Sound, Chirikov Basin, and nearshore areas of St. Lawrence Island (Figure 3) (Nelson et al. 1978, Thor and Nelson 1978, Larsen et al. 1979a, Hess et al. 1981),

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[1]Present address: Denver Museum of Natural History, 2001 Colorado Blvd., Denver, Colorado 80205

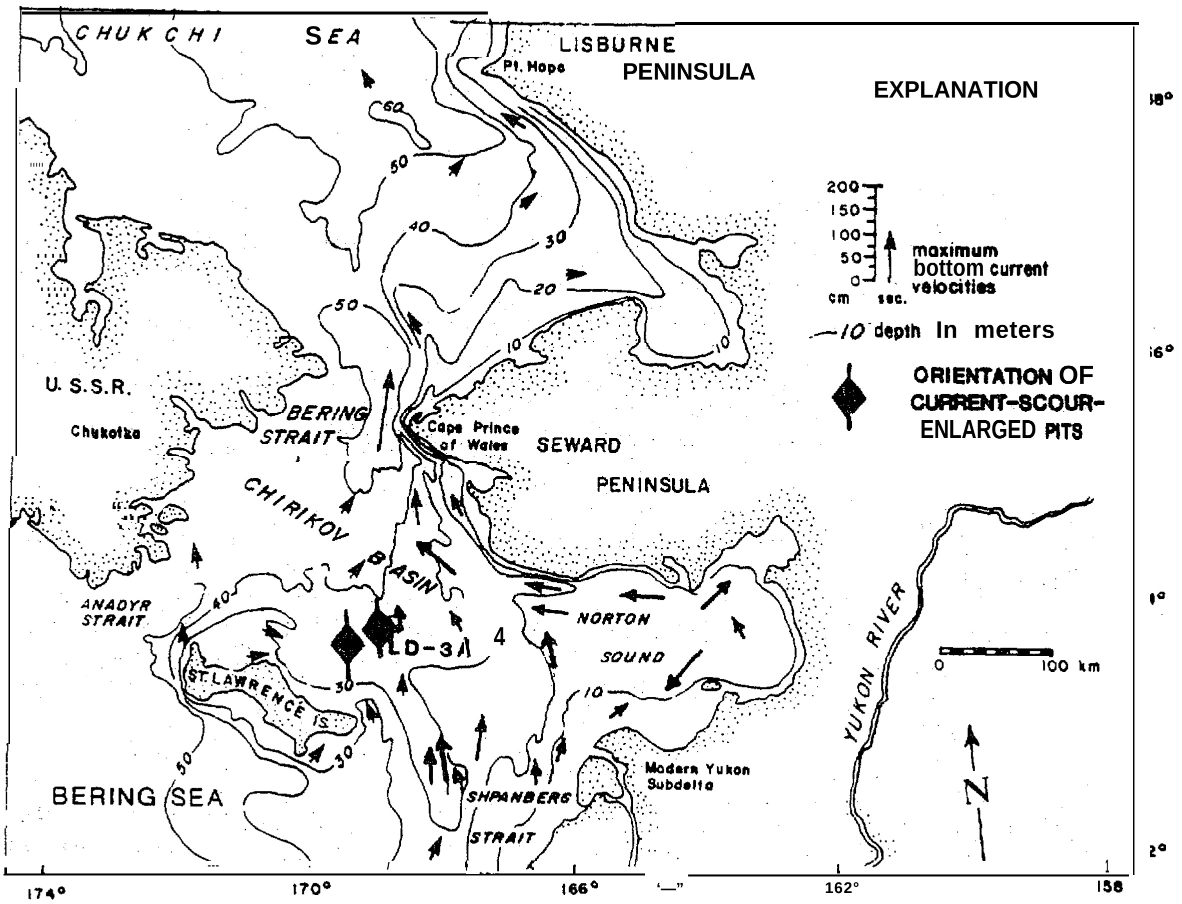

Figure 1. Direction and maximum bottom-current velocities from all available measurements in the northeastern Bering Sea and southern Chukchi Sea (after Nelson et al. 1 S81; J.D. Schumacher, NOAA-Pacific Marine Environment Lab., writ. comm. 1SS2, 1984). Also indicated are the location of long-term current meter LD-3A (see arrow above LD) and the long-axis orientation of pits thought to be excavated by feeding gray whales and enlarged by current scour toward the north.

The description of features from the monographs remains somewhat subjective and sensitive to weather and instrument conditions at the time of data collection. To minimize distortions, quantitative measurements in this report were made only from high-quality digital records taken during calm seas. Data from the nondigitized 100-kHz and 500-kHz systems were used for qualitative mapping, comparison with diver observations, and calibrations of larger-scale features with those of the 105-kHz digital records (Johnson et al. 1983).

All measurements of horizontal dimensions were taken from digital monographs lacking slant-range distortion. The bottom features have been quantified from the EG&G 105-kHz digital monographs in the following manner: 16 widely scattered areas were selected from high-quality monographs {Figure 2). In each area a minimum of 50, but usually 64 or more, features presumed to have been excavated by whales were measured for length, width, density of pits per 1,875 m^2 (a 25-m x 75-m block), and, for large features, orientation. From these numbers, area (area of an oval = length x width x 2/3) and length/width ratios were calculated (see Johnson et al. 1983 for a statistical treatment of these data). Percent total bottom disturbance was determined by multiplying average pit area (m^2) at a given station by pit density (see above), then dividing by 1,875 and multiplying by 100% (Johnson et al. 1983). Percentages for bottom disturbance should be considered minimum values because of the underrepresentation of small features oriented

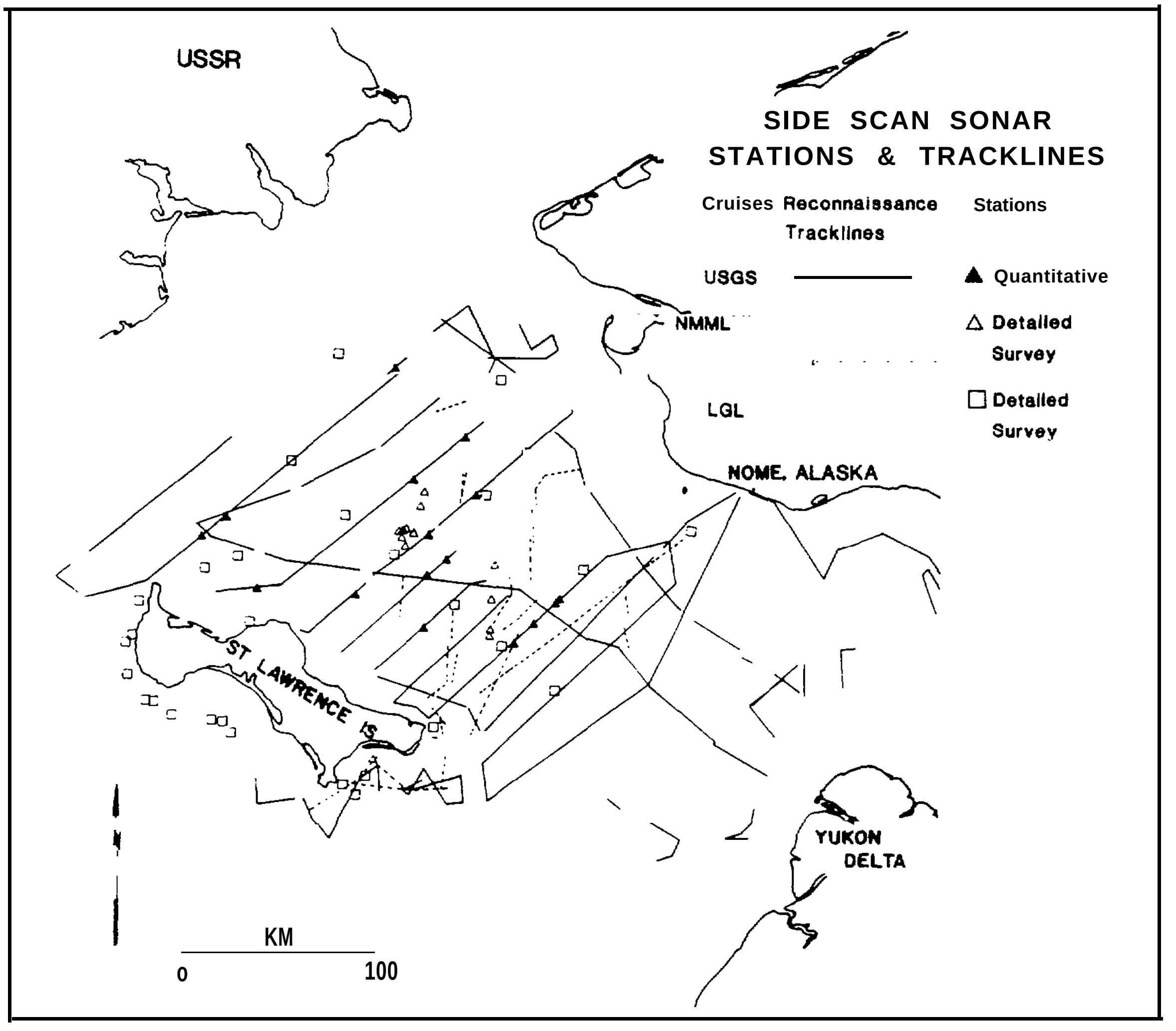

Figure 2. Location of tracklines with 100- and 105-kHz sidescan sonar and site-survey stations with 500-kHz sidescan sonar from USGS, National Marine Mammal Laboratory, and LGL Ltd. cruises in northeastern Bering Sea. Aiao shown are the locations of sidescan-sonar-quantification stations.

perpendicularly to the trackline. Scuba-diver observations also are needed to verify feeding pit depth, because the vertical dimension of the features is too small to be measured accurately from monographs.

No quantification of walrus feeding features has been attempted in this report because of their linear nature, possible rapid modification, and the inability of sidescan sonar to resolve the smaller circular feeding traces.

OCEANOGRAPHIC SETTING

Spot current-meter measurements in central Chirikov Basin exceed 30 cm/s, but at the basin margin, near Bering, Anadyr, and Shpanberg Straits, maximum speeds may be two to three times faster than this (Figure 1). In the northern half of the area and at its margins, mean current directions are generally northward (Fleming and Heggarty 1966, Coachman et al. 1976); in the southern half, directions are variable.

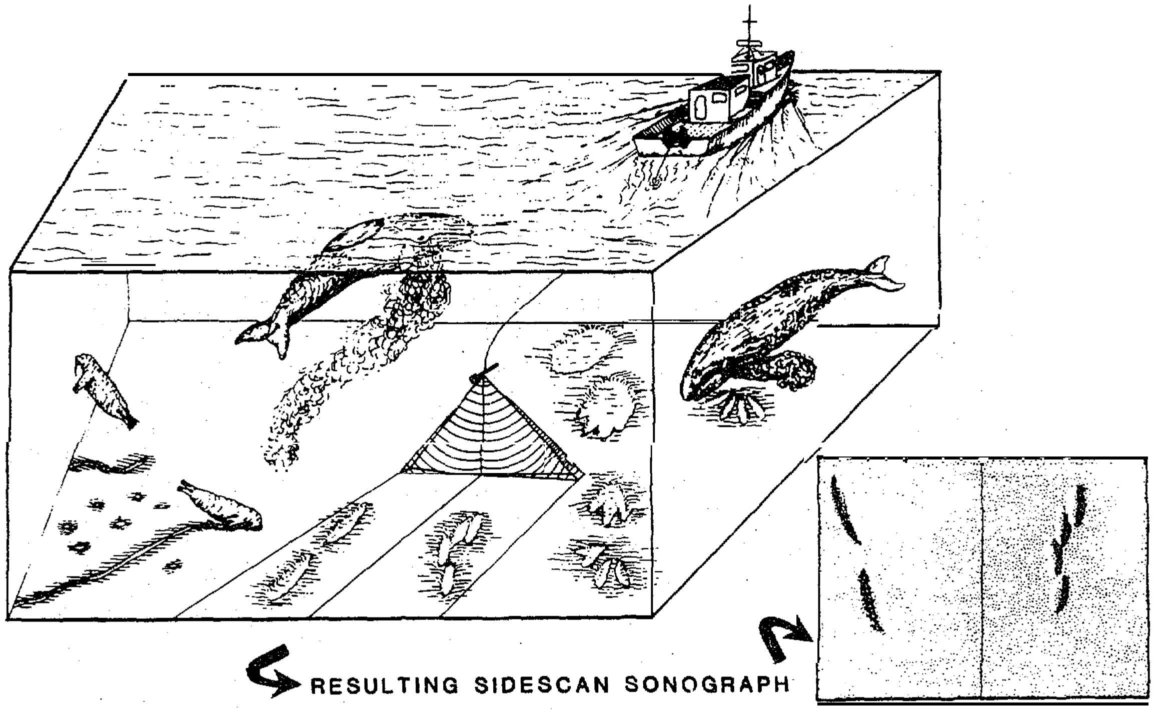

Figure 3. Schematic diagram of sidescan-sonar survey technique, showing whale and walrus feeding behavior and trackline-parallel feeding traces.

Long-term current-meter data are available for July-September 1978 from a mooring on the eastern margin of the Chirikov Basin (Figure 1). At this mooring, a mean current velocity of 10.7 cm/s and a maximum velocity of 30 cm/s were meaeured (Schumacher 1982, writ. comm.).

The current velocity at 1 m above the bottom necessary to mobilize fine sand (0.125 mm diameter) on a flat bottom is approximately 30 cm/s (Miller et al. 1977). A rough bottom significantly reduces the threshold velocity for erosion (Cacchione and Drake 1982). With a known minimum bottom roughness of 10 cm or more from whale pits and a grain size of 0.125 mm in whale feeding areas (Nelson 1982, Johnson et al. 1983), the velocity needed to erode sediment can be estimated at 18 cm/s (Cacchione and Drake 1982). Velocities greater than this were present about 10% of the time during normal weather in the summer of 1978 (Schumacher 1982, writ. comm.).

GEOLOGIC SETTING

The northeastern Bering Sea is a broad, shallow epicontinental shelf region covering approximately 100,000 km^2 between Seward Peninsula in Alaska and Chukotka Peninsula in the USSR (Figure 1), The shelf can be divided into four general morphologic and sedimentological areas (Figure 4): 1) the western part, an area of undulating, hummocky relief formed by glacial gravel and transgressive medium sand substrate (Nelson and Hopkins 1972); 2) the central part, Chirikov Basin, a relatively flat, featureless plain with a transgressive fine-sand substrate (Nelson 1982); 3) the northeastern part, a complex system of sand ridges and shoals bordering the coastline with a fine-to-medium-g rained transgressive sand substrate (Nelson et al. 1982); and 4) the eastern part, Norton Sound, a broad, flat marine reentrant covered by Holocene silt and very fine sand derived for the Yukon River (McManus et al. 1977, Nelson and Creager 1977, Nelson 1982).

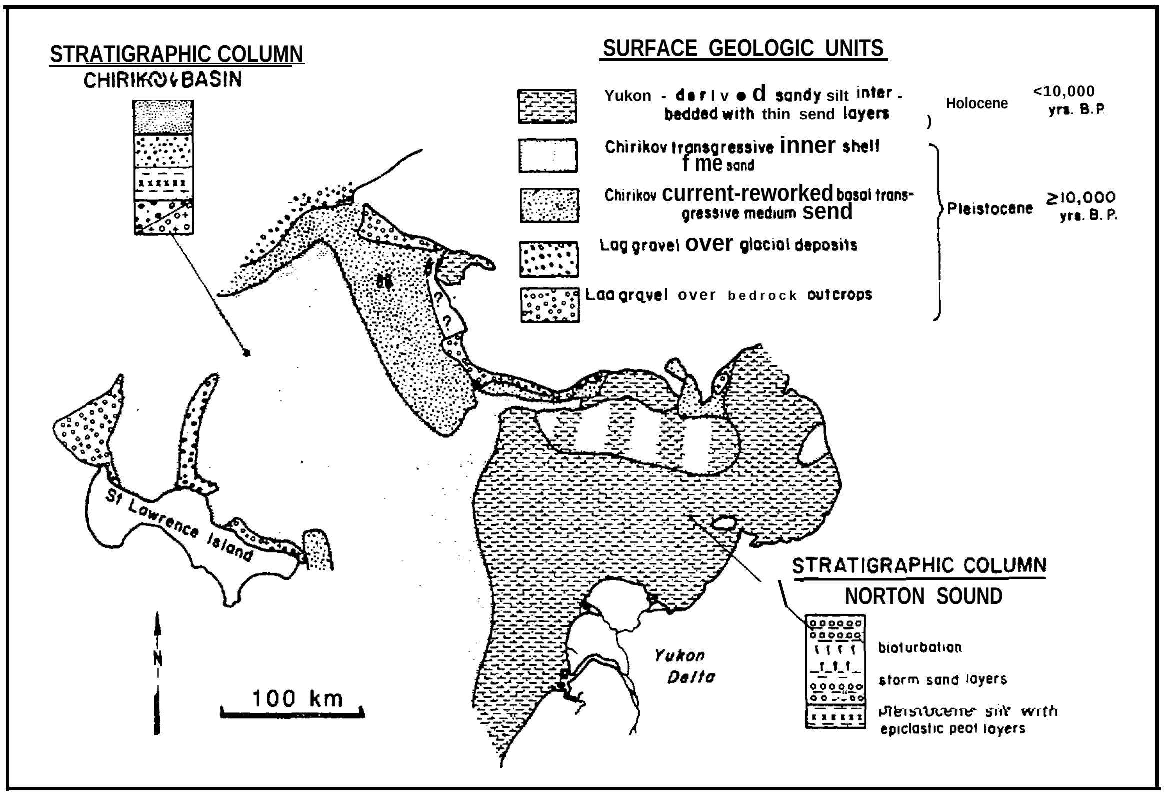

Figure 4. Map of the northeastern Bering shelf surficial geology showing major substrate typea (modified from Nefson 19S2).

At the end of the latest glacial maximum, 12-10 ka, melting ice caused a marine transgression over the Bering Land Bridge. First, basal transgressive sand and gravel were deposited over the silty tundra peat of the land bridge in the Chirikov Basin area (Nelson 1982). Then a thin (0.5 to 2 m), inner-shelf fine-sand sheet was deposited. Currents and, as we demonstrate here, whale disturbance in central Chirikov Basin have protected this inner-shelf sand sheet from burial by Holocene deposition. In contrast, recent inflow from the Yukon River has covered Norton Sound with silt and very fine sand, and the strong currents of Shpanberg Strait have reworked the sediment there into coarser lag deposits. Thus, Chirikov Basin is floored by a relict, laterally extensive, homogeneous, fine-sand sheet, while coarser-grained and muddier sediment exists on the margin of Chirikov Basin.

BIOLOGICAL SETTING

The benthic fauna of the Bering Shelf is characterized by low diversity, high density, and high substrate dependence (Nelson et al. 1981, Stoker 1981). The homogeneous fine sand of Chirikov Basin supports a community dominated by ampeliscid amphipods and the clams *Macoma calcarea* and *Astarte* *borealis* (Stoker 1981). The coarser-grained and muddier sediment of the northeastern margin of Chirikov Basin is the habitat for a fauna dominated by sand dollars, *Echinarachnius parma*, polychaete worms, ophiuroids, sea stars, and the clams *Tellina lutea*, *Serripes groenlandicus* (Stoker 1981), *Mya truncata*, and *Macoma calcarea* (Oliver et al. 1983a) (Figures 4,5, and 6). Consequently, the gray whale, which feeds primarily on amphipods, may be geographically restricted in its foraging to the amphipod-supporting fine-sand sheet, unlike the walrus, whose prey inhabit heterogeneous muddy and gravelly sand environments.

Both the gray whale and the walrus disturb Bering Shelf sediment while foraging for their main prey species, The gray whales create 1 to 4-m x 1 to 2-m pits by suction feeding of infaunal

amphipod crustaceans (Johnson et al. 1983, Nerini and Oliver 1983, Johnson and Nelson 1984, Nerini 1984). The walrus create 20 to 200-m-long x 30 to 50-cm-wide furrows and small (30 cm in diameter) pits white hydraulically rooting for infaunal bivalve molluscs (Fay 1982, Oliver et al. 1983a).

The gray whale population now numbers around 21,000 (Loughlin 1992). These whales annually migrate along a coastal corridor between their winter breeding and calving lagoons in Baja California, Mexico, and their summer feeding grounds in the Bering Sea and Arctic Ocean (Rice and Wolman 1971). Although the whales feed sporadically and opportunistically along their migration corridor (Nerini 1984), and small groups of whales occasionally spend the entire summer feeding season at selected areas along the migration route (Hudnall 1981, Oliver et al, 1984), the majority of the population feeds in the Alaskan shelf areas from May to November (Rice and Wolman 1971).

The gray whales feed on ampeliscid amphipods, mainly *Ampelisca macrocephala* (Rice and Wolman 1971). Ampelisca create shallow (<10 cm), mucus-lined burrows that, when densely packed, form a sediment-binding tube mat (Figure 5) (Nelson et al. 1981). They occur in the greatest density in the well-sorted, fine-sand habitat of central Chirikov Basin (Figure 6) (Nelson et al. 1981, Nelson 1982). The gray whales feed by sucking up patches of amphipod tube mat and filtering out the sediment through their baleen plates (Hudnall 1981). This method of feeding leaves shallow pits a minimum of 10 cm deep on the sea floor that are similar in size and shape to the average gray whale gape (length = 2 m) (Johnson and Nelson 1984), These pits are distinct and mappable on sidescan sonar.

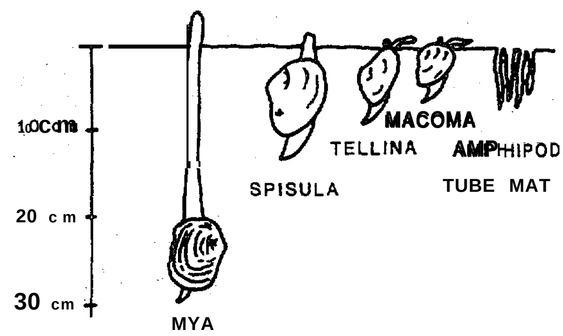

Figure 5. Substrate cross section and relative depth of penetration of the major food sources for gray whale and walrus In the northeastern Berlng Sea (modified from Fay 1982).

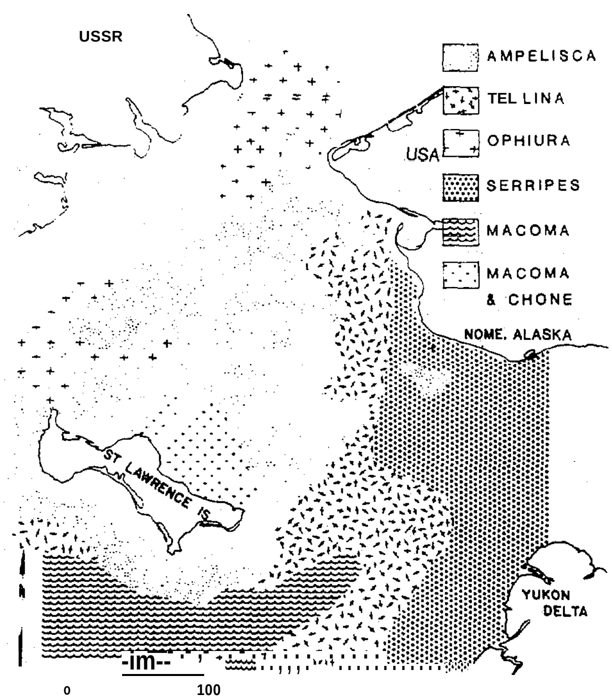

Figure 6. Benthic faunal communities on the Bering/Chukchi Shelf, showing *Ampelisca*-dominated and clam-dominated communities (modified from Stoker 1 s61).

There are about 234,000 walrus in the Bering and Chukchi Seas (Gilbert 1989). In general they stay near the edge of" the sea ice and in polynyas (ice-free areas) within the ice-sheet. Stomach content analyses show that walrus feed on at least 60 different genera of benthic fauna, including worms, soft-shell crabs, sea cucumbers, gastropod, octopus, and bivalve molluscs - the most common prey (Fay 1982). In the St. Lawrence Island to the Bering Strait region, the

main clam species exploited are *Mya truncata, Hiatella arctia, Serripes green/andica* (Fay 1982), and *Macoma calcarea* (Oliver et al. 1983a).

Tusk abrasion patterns indicate that walrus swim, head down, along the bottom while searching for their prey either visually or with the sensitive, bristle-like vibrissae that cover their snouts. Clams are probably excavated by a pulsating jet of water from the walrus' mouths (Oliver et al. 1983a). The walrus then clamp the clam between their leathery lips and remove the siphon, foot, or entire clam body from the shell by suction (Fay 1982). The clam shells are frequently crushed and almost always discarded.

This manner of feeding leaves long, sinuous furrows in the sea floor. The furrows are roughly the width of the walrus' snouts (25 to 40 cm) and are frequently associated with empty clam shells (Oliver et al. 1983a). These furrows have been observed by divers (Oliver et al. 1983a), from a submersible (Ray 1973) and on sidescan sonar (Johnson et al. 1983; Nerini 1984). Apparently walrus also feed on deep-burrowing clams such as *Mya truncata* (Figure 5) by visually identifying siphon necks and excavating discrete pits (Oliver et al. 1983a) .The resulting pits are small (<35 cm in diameter) and have not yet been detected by sidescan sonar.

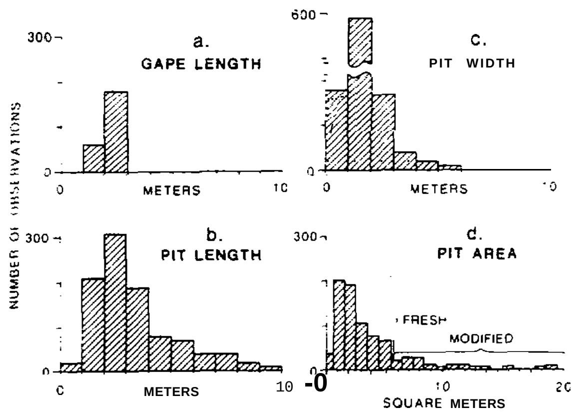

Figure 7. a) Histogram of gray-whale gape length measured from 240 whales. Histograms of feeding-pit b) length c) width, and d) area, based on measurements from 64 pits at each 16 sidescan-sonar-quantification stations In the Chirikov Basin (Johnson and Nelson 1964). Location of quantitative stations is shown in Figure 3.

Characteristics of Whale and Walrus Feeding Disturbance

We recognize small and large whale feeding pits, which we define as fresh and modified features, respectively. Histograms of whale-feeding-pit length, width, and area are all strongly skewed to larger sizes (Figure 7). The pit-length mode at 2 to 3 m closely matches the mode of measured whale gape lengths; this indicates that pits of this size show the least modification. We define pits 5,3 m' and smaller as fresh pits for the 1980 feeding season (Figure 7) (Johnson and Nelson 1984). Average total disturbance of the sea floor at the time of the August 1980 survey was 8.3% of the 22,000 km' total gray whale feeding area (Johnson and Nelson 1984). Fresh disturbance covered 3,4% of the total feeding area at the same time when the feeding season was only 60% complete for the year. Projected fresh disturbance for the entire feeding season is 5.6%.

Walrus feeding furrows were observed only on high-quality sidescan monographs. Because of their size and shape, they were only seen when nearly parallel to the towfish trackline. The feeding furrows were all less than 50 cm wide and ranged from 10 to nearly 200 m in length. They are sinuous, sometimes broken and restarted, and they may occur in subparallel groups (Figures 8A,B and 9). The irregularity of walrus furrows compared to straight and angular patterns of ice gouges, general lack of ice gouging at water depths greater than 20 m where the majority of furrows are common, width of furrows (40 cm) consistent with walrus snouts but not ice gouges (typically > 1 m), and broken clam shells associated with furrows all substantiate that the feeding behavior of walrus creates the furrows. Because their presence on monographs is so trackline dependent, no accurate estimates of walrus furrow density could be made. The furrows occur in areas totaling 6,600 km' along Shpanberg Strait between St. Lawrence Island and King Island, along Anadyr Strait, and around the southeastern cape of St. Lawrence Island,

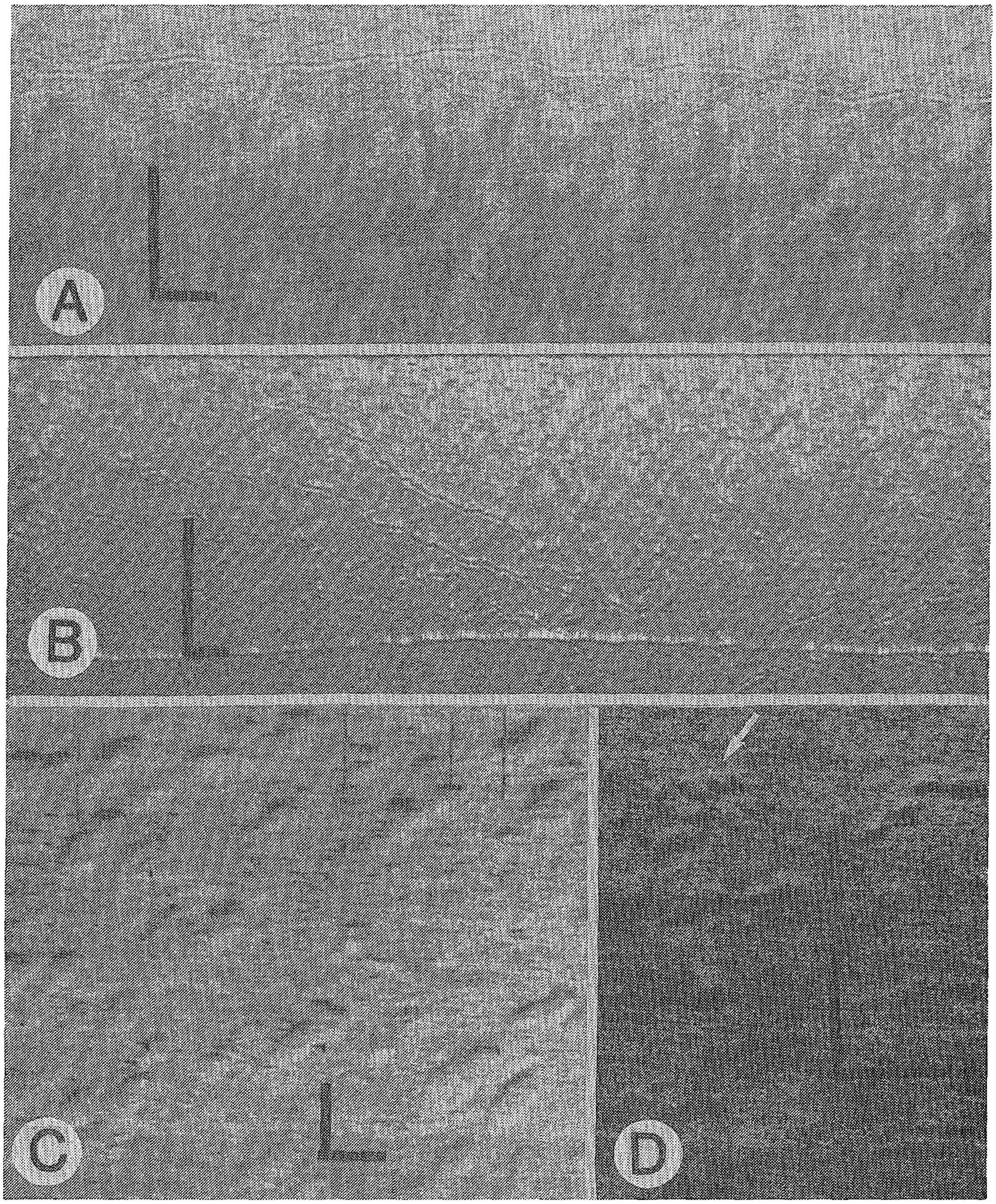

Figure 8. A) A long walrus feeding furrow, eastern Chirikov Basin, B) typical irregular and dendritic walrus furrows, C) current-modified whale feeding pits, and D) fresh whale feeding pits (see arrow). Ail photos are from 100-105 kHz monographs and have vertical and horizontal scale bars equal to 10 m each.

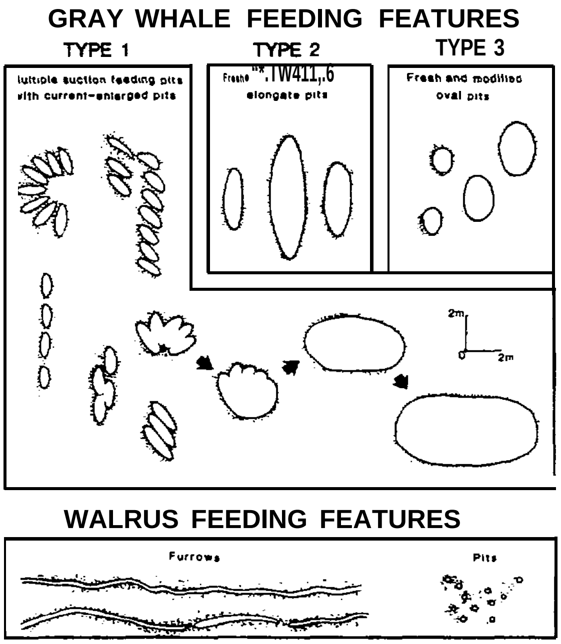

Figure 9. Sketches of gray whale and walrus feeding features. Sources of data are 105-kHz digitized sidescan (Johnson et al. 1983), 500-kHz sidescan (Nerini et al. 1980); (Thomson 1986), and scuba-diver observations (Oliver, oral comm. 1983; Thomson 19S6). Shown are three types of whale feeding traces and walrus feeding furrows and pits.

Controls on Distribution and Shape of Feeding Features

The distribution of whale feeding pits correlates closely with the distribution of the Chirikov sand sheet, ampeliscid amphipod population (Figure 6), and aerial sighting of feeding gray whales (Consiglieri et al. 1980, Nerini et al. 1980, Johnson and Nelson 1984). The area of highest feeding activity is the center of Chirikov Basin.

Modified pits larger than the 5.3-m^2 ‘fresh” pits (Figure 7) can form by whale feeding on existing pit margins (Kvitek and Oliver 1986), and by current-scour enlargement, or by both processes. The regional orientation of large pits (Figure 8C) suggests however, that unidirectional current-scour enlargement of pits is an active force similar to the process that produces scour enlargement of ice gouges in this region of Bering Shelf (Larsen et al. 1979b). If all large pits are assumed to be current-scour-enlarged, then pits caused by additional whale feeding will be underrepresented in statistical counts of fresh feeding. Because we count only pits smaller than 5.3 m’ as unmodified or “fresh,” and some fresh features perpendicular to the trackline may not be detected in monographs, our estimate of percentage of fresh disturbance is conservative and a minimum value.

Walrus furrows occur around the margins of Chirikov Basin in areas where the bottom-current speeds are higher and mean grain size is coarser (Figures 1 and 4) Because walrus features are smaller than whaie features and they occur in a higher-energy environment, they may be modified continually and rapidly by sediment infilling. Current-scour modification of walrus furrows is not commonly observed, perhaps because of the coarser grain size, lack of stabilizing amphipod tube mat, and raised relief of rims on the margin of walrus furrows.

Sediment Disturbance from Mammal Feeding

Assuming that the 1980 season’s fresh pits are the O to 5.3-m^2 class (Figure 7d), then their total area is the minimum yearly disturbance caused by gray whales (Johnson and Nelson 1984). Although little is known about the modification rates of fresh feeding pits, the larger pits seem to result from current scour that occurs regularly in the fall storm season after the feeding season each year (Larsen et al. 1979b, Dupré 1982). Repeated surveys at a site showed a change from spring walrus-furrow dominance to whale-pit dominance a month later (Johnson et al. 1983). This suggests that there is formation of a new set of fresh whale pits each new feeding season. In several locations there were no significant changes during one month between replicate sidescan surveys; this also argues against rapid modification of whale feeding pits prior to the fall storm season. Thus, we assume that larger pits are from previous feeding seasons and that the smaller fresh pits are not cumulative from year to year.

Using the percent area disturbed by fresh whale feeding pits, it is possible to calculate the total area of fresh feeding pits created each year in northeastern Bering Sea. An average bottom disturbance of 5.6% of the 22,000-km^2 feeding area, or 1,200 km', occurs each feeding season (Johnson and Nelson 1984). Using an average pit depth of 10 cm (Johnson et al. 1983), 120 x 106 m^3 (172 x 10^6 metric tons)' of bottom sediment is resuspended each year by whale feeding. To put this amount of resuspended sediment in perspective, it is almost three times the annual suspended sediment discharge (60 x 10^6 metric tons) of the nearby Yukon River, the fourth largest sediment source in North America (Milliman and Meade 1983).

it is evident that resuspension of material will tend to fill oid whale feeding pits downcurrent and wiii result in a significant net ioss of clay-sized material advected northward from the system (Figure 1). Because the clay content of sediment in central Chirikov Basin averages 2.5% (McManus et al. 1977, Hess et al. 1981), approximately 4.3 x 106 metric tons (2.5% x 172 x 10' metric tons) are resuspended by whales each year. This large amount of material either is transported from the region under average current speed conditions or is transported tens of kilometers even with low current speeds. The net long-term effect is the loss of most clay and also a large portion of the fine silt fraction from Chirikov Basin. The continual reworking of the entire Chirikov Basin sea floor by whales, a minimum of once every 20 years, inhibits any long-term deposition of modern mud. This, in part, may explain the presence of a transgressive inner-shelf sand with a low-mud-matrix content and no development of a Holocene mud blanket throughout central Chirikov Basin. The high amphipod productivity (Stoker 1981), bioturbation, and extensive whale and walrus excavation readily explain the iack of internal sedimentary structures noted previously in this region (Nelson et al. 1981),

Walrus feeding may resuspend a significant but indeterminate amount of sediment although the sediment excavated at the seafloor probably is not introduced into the water column as it is with whales. Because walrus feeding furrows may be preserved in some areas only prior to whale disturbance and because the smaller circular-type feeding pits are not within the resolution of our main reconnaissance grid of 105-kHz monographs, we cannot quantify the total area of excavation or estimate the amount of sediment resuspended because of walrus feeding activity. We can, however, outline the magnitude of feeding activity based on the following speculative model, if we assume conservatively that a single walrus may jet two average-sized (47 x 0.4 x 0.1 m^3) feeding furrows per day then annual sediment movement by the approximately 234,000 walrus transiting Bering Sea for an average of 100 days would amount to 88 x 10' m^3 or 126x 10^6 metric tons. Two important differences of walrus compared to whale feeding disturbance are that walrus rework or resuspend the sediment at the seafloor and not into the water column, and there is little evidence for current-scour enlargement of walrus furrows.

Geologic Significance

The majority of the 21,000 gray whale population passes through the main benthic feeding area in Chirikov Basin. This 2'% of their total northern feeding area provides about 5% or more of their total yearly food intake. In addition, nearly 234,000 walrus forage in this same area for shallow clams, mainly during the ice-covered winter feeding season. As a result, this benthic feeding by mammals may be the dominant sedimentary process in Chirikov Basin, The sediment surface microrelief of central Chirikov Basin is completely controlled by whale feeding. Walrus furrows are prominent in regions surrounding the whale feeding region,

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'One cubic meter of sediment with a bulk density of 1.88g/cm^3, which is an average value for the sandy area of the northeastern Bering Sea (Olsen et al. 1982), contains 1.43 metric tons of sediment.

Direct sediment reworking by whale feeding and subsequent modification by current scour resuspend more than 5% of the surface sediment in Chirikov Basin per year; perhaps a nearly equal amount of sediment may be reworked by walrus furrow and pit excavation. Of the approximately 172 million metric tons of sediment injected directly into the water column by whale feeding, as much as 4.3 x 10^6 tons of fines are winnowed and transported from the region by northward currents. This depletes the surface sand blanket of any clay component, prevents permanent deposition of any modern Yukon sediment, and prohibits formation of internal physical sedimentary structures in central Chirikov Basin.

Beoause the sand blanket is thin (generally 0.5 to 2 m) (Nelson 1982) over Chirikov Basin, a delicate balance exists between the substrate and whale-feeding ecology. The gray whales could eventually mine themselves out of a habitat as the thin sand blanket is injected into the water column and gradually advected northward, not to be replaced by present-day sedimentary processes. Similarly, any mining of this sand and gravel resource could also significantly disrupt this substrate that provides a significant portion of the gray whale food resource.

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Dr. Hans Nelson has worked at the U.S. Geological Survey for the past 25 years with 15 of those years spent studying geological oceanography of Alaskan Arctic Sea areas. His areas of research interest are epicontinental shelf and continental margin sedimentation and environmental assessment. Dr. Nelson received his B.A. from Carleton College in geology, his M.S. from University of Minnesota and his Ph.D. in geological oceanography from Oregon State University.

QUESTIONS AND DISCUSSION

Richard Ranger: I was just wondering if you could put up that overhead one more time" that showed how you calculated the biomass. I was just interested in how you calculated the biomass that they used from the side-scan data,

Hans Nelson: Certainly this is one where we got some help from the biologists. We took the biological numbers and a lot of data was done and a lot of specific studies for MMS on the production of amphipods. They took a lot of samples in and out of whale pits all around the feeding areas, so there are very good numbers on the biomass of amphipods per square meter. We took a whole series of random samplings all through the Chirikov Basin area, measured the size of whale pits, got their area, so we could tell that — and we could determine which were fresh and old pits — and we could determine that in 1980 there were 1200 km' that were

physically slurped up by the gray whales. Then we can calculate volume from that because we know pit depth is about 10 cm thick. We have amphipod biomass per square meter, so we can estimate the total amount of biota that whales have eaten in Chirikov Basin in one year, There have been a lot of other biological studies with numbers ranging from a 1000 to about 1200 in terms of kilograms of biomass that the whales require per day for feeding for a five-month feeding season in Alaska, because they coast the rest of the year. They get all their feeding essentially in Alaska.

Then, from this, by dividing total biomass consumed in one feeding season by 1100 kg/day, we get how many whale feeding days are provided by Chirikov Basin each year. Assuming the whole five-month feeding season was 1100 kg per day for 16,000 whales and now it seems to be up to 21,000, we get something like a total per year required of 3,150,000 whole feeding days. Divide the total by Chirikov Basin amount and we get the percentage of yearly food resource provided by Chirikov Basin.

I think that's a minimum number because we know the side-scan is underestimating a bit. Traces that are parallel to the beam could be missed. Several other things that would make me say this is the minimum amount. For example, grazing at the edge of prevous pits and opportunistic filter feeding (both observed behaviors) are not accounted for. Total percentage could be double the calculated, perhaps up to maybe 10, 12% in the Chirikov Basin.

Chuck Mitchell: I have just a comment actually. We've been experimenting over the last couple of months with a piece of equipment that's newly arrived on the market from the military, and it's a blue-green laser scanner. It's a towed vehicle and produces an extremely high resolution scan. It doesn't have the range that sonar has. But what you get is a scrolling across a video screen with quality probably equal to a high resolution black and white photograph. You don't need to interpret whether this is sand or rock from a side-scan sonar record. You can see the sand grains. You can see the broken shell. You can see biological. It's all on video tape, If you want a snapshot of a particular thing as it passes by, you can push a button and it's digitally recorded on laser discs. Then you can manipulate it directly into the computer with existing software for screen grabbers and that sort of thing. It looks like it's going to be a real exciting tool to use. You might think about the availability of it.

Hans Nelson: Yes. That would certainly be good for very site-specific things, monitoring aspects, perhaps. But you always want to worry about resolution versus what you're trying to do. But 1 haven't heard of that,

Steve Treaty: Just while you have the slide up there, I just was curious, you were trying to factor in the population today versus what it was earlier. Is that right?

Hans Nelson: Yes, I used 21,000 here when I redid this.

Mr. Treaty: Okay. Would that also affect the area of the pits per year?

Hans Nelson: No. No, this is what we actually saw. We physically looked at the side-scan records and that's what was there then.

Steve Treaty: I mean, there would be more pits up there now, I guess, with more whales, Is that right?

Hans Nelson: It could be. You just have to go out and see.

Steve Treaty: Okay,

Hans Nelson: I guess you would assume there would be yes,

Steve Treaty: Okay. Thank you.

Hans Nelson: But there has been nothing done iike that. If people wanted to monitor what's going on, this would be an ideal method of doing it. Take a site, go back each year and see what's happening.

Ray Emerson: And Steve asked me to ask the rest of that question. (Laughter). if these number of pits maybe increasing, could you, and I assume this is probably what you would say a critical habitat--

Hans Nelson: Yes, Definitely, sure.

Ray Emerson: --could you project a population size for the whale at which it could exceed the carrying capacity of that critical habitat? And if so, is there some kind of a progressional return to normal state for those amphipod beds that are gouged down?

Hans Nelson: There seems to be, although I certainly haven't investigated and I don't know-- Nobody has done a monitoring kind of thing to see actually how long this takes to return, I guess I've heard a little bit about amphipods that maybe, it takes about a year for the juveniles to come to adult age, I could be wrong on that.

Ray Emerson: Well, if the pits are being sand scoured to become larger--

Hans Nelson: Yes.

Ray Emerson: --there must be some sequence at which they become smaller.

Hans Nelson: Yes. They will tend to get filled in as well. There's a seasonal effect that's very strong in Chirikov Basin. They form during the summer when it's very cairn. Then you have these big storms that come in the fall and they get scour-enlarged. Now then you get a quiet season again when it ice-covered and lower speed currents. So you're getting a cycle effect, The fresh pits are forming, they're scouring out and enlarging, but then during the quiet season of the winter, they're probably filling in again.

Ray Emerson: So you wouldn't see the pitting from one year to the next?

Hans Nelson: Some you would. It's going to be a wide variety of what's going on.

Ray Emerson: If you had one area that was fed intensively one year and then the following year, it wasn't. Well, let's see, if it was the other way around, you might be able to see if they were still there but not any new fresh pits and follow that up.

Hans Nelson: Yes, this is the kind of thing that really hasn't been done. That's where monitoring could go in and follow up, take a few types of areas and then follow what happens. I think there certainly is a potential to do these kinds of things that you're suggesting.

Ray Emerson: But there is a potential for over-grazing by a population of size for this critical habitat?

Hans Nelson: I would certainly think so. Yes, now what that is--

Ray Emerson: There's no estimate from that number there?

Hans Nelson: No. I don't know-- You don't know how efficient are they, You'd have to have a monitoring program to see what happens as numbers increase, Does this just keep going on up? Does it suddenly (drop)? Yes, those are things that certainly aren't known but could be known. It's certainly a good future topic for biologists.

Cleve Cowles: This is just kind of a question or a reflection. About four or five years ago, we had a study done that looked at the carrying capacity question and came up with some numbers like yours. I'm just kind of curious. I haven't read the report recently. Do you know how your figures on the percentages would compare to the study that LGL did about the same time you did your work?

Hans Nelson: Roughly comparable. Of course, theirs was very site-specific, They had three or four sites. They anchored the ship. They dived. They did very detailed biological work. And ours was a broad reconnaissance of looking over the whole region. And the side-scan has to be used if you're going to do reconnaissance kind of thing and get a feeling for the whole area. You couldn't do the kind of thing they did throughout the whole region. I mean, it would take hundreds of millions of dollars looking that specifically. So, you've got different kinds of tools. So they looked at a few areas very intensively. We looked at the whole area in a broad reconnaissance way. But in general, we agreed, as I recall. I haven't looked at their report either for 10 years or so.

UPDATE ON ARCHIVAL OF TISSUES FROM GULF OF ALASKA/ BERING SEA MARINE MAMMAL SPECIMENS

Paul R. Becker
National Oceanic and Atmospheric Administration
Grace Hail, Suite 300
4230 University Drive
Anchorage, Alaska 99508-4626

INTRODUCTION

The Alaska Marine Mammal Tissue Archival Project (AMMTAP) began in 1987 as cooperative effort between the Minerals Management Service (MMS), the National Oceanic and Atmospheric Administration (NOAA) and the National Institute of Standards and Technology (NIST) to establish and conduct a program of collecting tissues from Alaska marine mammals and storing them under conditions which allow future analyses for substances indicative of contamination from offshore petroleum and mining activities. It was believed that such a collection of samples could be used to help establish a baseline against which future impacts associated with the development of Alaska's coastal areas could be evaluated. It was also realized that such a resource could provide samples for addressing questions regarding potential environmental problems outside of the petroleum and mining industries, such as the long-distance transport of persistent contaminants from lower latitudes.

Within the last 30 years, the development of cryogenic preservation techniques coupled with increased emphasis on biological research at the molecular levels has elevated the visibility of biological specimen banking as a routine and important part of research on systematic, genetics, pathology, toxicology, and environmental monitoring. For example, the updated draft proposal for the international Arctic Monitoring and Assessment Program recommends that the archival of biological specimens for retrospective analysis be part of the quality assurance procedures for environmental monitoring in the Arctic (State Pollution Control Authority Norway 1991). Canada has routinely banked biological specimens as part of its environmental monitoring programs for many years. Similar efforts are also underway in other northern nations (e.g., Finland, Norway, Sweden).

METHODS

The details of the design of the AMMTAP and protocols used for sampling and archival have been presented and discussed previously (Becker et al, 1988, 1991; Wise and Zeisler 1984). The intent of the protocols is to provide a consistent carefully documented procedure for sampling, to develop and maintain a detailed record of sample history, to insure that the samples are kept in the best condition for long-term storage without loss of original sample integrity, and to use procedures and equipment that minimize the chance of introducing artifacts to the sample that might bias future chemical analytical results. Equipment and materials used for sample excision, handling, and storage is limited to those of titanium and Telfon. As soon as possible after collection, samples are frozen in liquid nitrogen (LN_2), maintained in LN_2 vapor during shipment to the archive (located in the National Biomonitoring Specimen Bank, NIST, Gaithersburg, Maryland), and are stored in the LN_2 freezers (-150°C) until analyzed. Previous assessment of the long-term stability of environmental specimens in the National Biomonitoring Specimen Bank indicate no change following seven years of storage in LN_2 vapor (Wise et al. 1989) .

The principal tissues being archived by the AMMTAP are blubber, liver, and kidney. Blubber, due to its high lipid content, concentrates organic toxicants to relatively high levels. The liver is a major detoxification site for xenobiotics and is suitable for measuring all known environmental toxicants plus biotoxins. The liver generally has sufficient lipid content to be an accumulator of organic as well as inorganic substances and may also have a higher proportion of metabolizes than other tissues, Because of the tendency for several of the toxic metals (particularly Cd) to concentrate to relatively high levels in the kidney, this organ is also archived routinely. Muscle was originally included in the list of tissues to be sampied, but was deieted after the first year of sampling due to the difficulty in obtaining a uniform sample uncontaminated by intermuscular fat and connective tissue, as weli as the difficulty in arriving at homogeneous analytical aliquots during cryogenic homogenization of the samples.

Other samples that can aid in interpreting the results of chemical analyses of these principal tissues are collected periodically. These additional samples include liver and kidney subsamples in buffered formalin for histology, teeth forage determination, bile for PAH metabolize screening, stomach contents for food identification, and, more recentiy, subsamples of liver and muscle for genetics studies (University of Alaska Frozen Tissue Collection) and blood serum for pathology studies (Alaska Department of Fish and Game's wildlife serum library).

Two 150-g subsamples are collected for each tissue type from each animal sampled. Subsample A is maintained in the specimen bank for future retrospective analysis. Subsample B, although archived under the same conditions as subsample A, is available for dividing into aliquots for immediate analysis. For security purposes, subsamples A and B are stored in different LN_2 freezers,

As part of the specimen banking procedures, aliquots of 10 to 20% of the specimens (taken from subsamples B) are analyzed to determine the concentrations of selected organic and inorganic constituents, These analyses, the procedures of which are given in Becker etai.(1992), provide data for evaluating the stability of the specimens during long-term storage and for comparing with data obtained by other laboratories on subsamples from the AMMTAP, or similar samples collected at the time from the same sites (i.e., quality assurance). Samples to be analyzed are homogenized using a cryogenic grinding procedure designed to minimize sample contamination and reduce the likelihood of changes in sample composition due to thawing and refreezing (Zeisler et al. 1983).

RESULTS AND 'Discussion

All of the samples collected by the project are from animals taken by Alaska Native hunters. This has required coordination and close cooperation between the project staff and numerous Alaska native organizations and individuals. The sampling protocols deveioped by the AMMTAP have required careful consideration of the hunting procedures used and logistical problems in transporting sampling equipment and materials to remote locations having highly variable and often unpredictable weather and environmentai conditions.

A total of 196 tissue specimens have been collected and archived by the AM MTAP. These specimens were collected from 65 individual animals representing seven species from the following regions:

Northern fur seal, *Callorhinus ursinus* - Bering Sea
Ringed seal, *Phoca hispida* - Chukchi Sea and Norton Sound
Bearded seal, *Erignathus barbatus* - Chukchi Sea and Norton Sound
Spotted seal, *P. largha* - Norton Sound
Harbor seal, *P. vitulina* - Prince William Sound
Steller sea lion, *Eumatopias jubatus* - Cook Inlet
Beluga whale, *Delphinapterus leucas* - Chukchi Sea

Half of the specimens were collected from pinnipeds and cetaceans in the Arctic Ocean and the other half were collected from pinnipeds in the Bering Sea and Northern Gulf of Alaska (Figure 1).

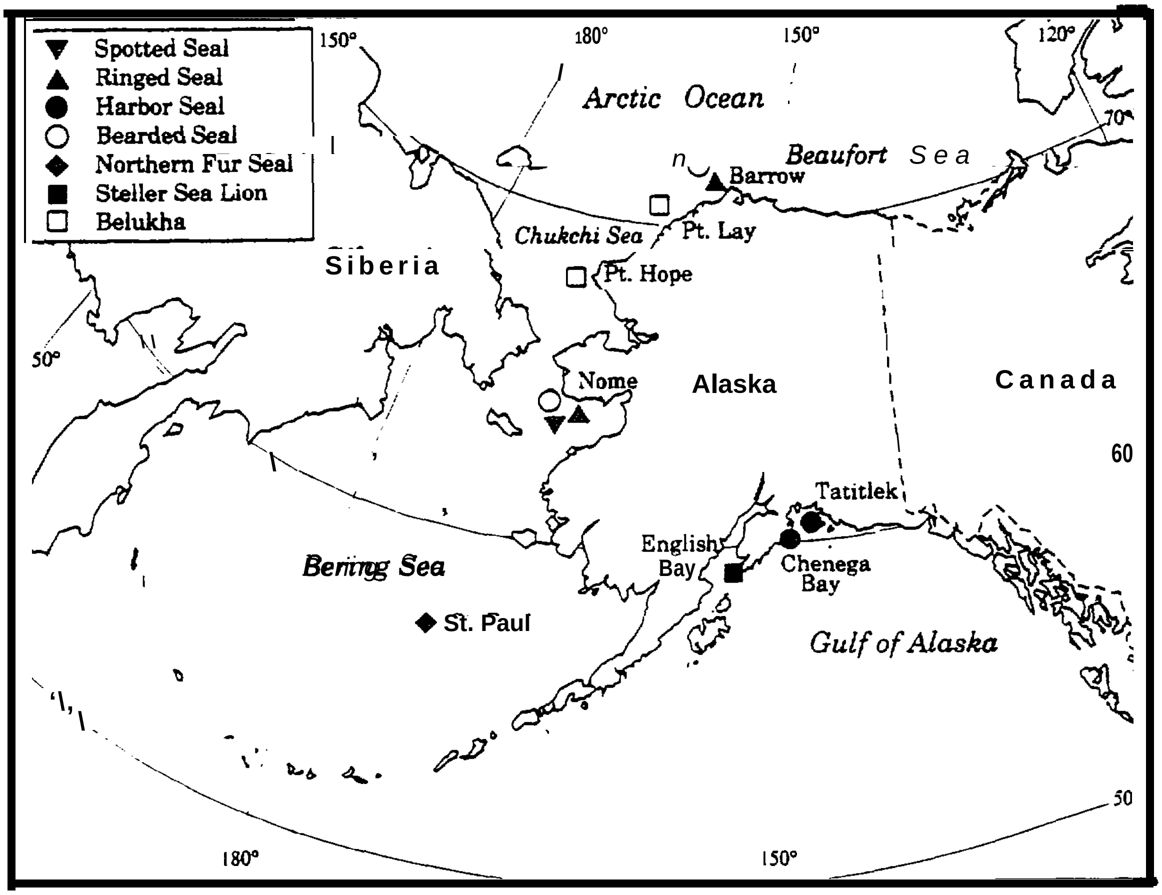

Figure 1. Marine mammals sampled by the Alaska Marine Mammal Tissue Archival Project.

Although initial analytical work was conducted on all tissue-types, analyses of specimens since 1990 have focused on analyzing oniy liver for trace eiements and oniy blubber for organic constituents. Constituents routinely anaiyzed by the specimen bank include aromatic and heterocyclic hydrocarbons, PCB congeners, selected pesticides, and 36 elements. A complete presentation of both the organic and inorganic analytical results are presented in Becker et al. (1992).

The original criteria used to select the species to be sampied have been presented and discussed by Becker et ai. (1988). Table 1 presents a matrix showing the animals sampled by the project as they relate to these criteria. it appears that the best candidates for comparisons and monitoring for environmentai contaminants are probably the ringed seal and the beluga whale. Both are widely distributed in the northern hemisphere. The ringed seai has been studied extensively and a relatively good contaminants data base exists for the species on a worid-wide basis. Although the data base for the beluga whale is not as extensive as that for the ringed seai, this animal has a high potential for concentrating contaminants in its tissues (it feeds at the top of the marine food web) and it has recently been the object of environmentai research across the Arctic from Greenland through Canada to the Bering Strait.

The AMMTAP is somewhat unique in that the nature of the resource being addressed and principal source of the samples require extensive coordination with many different organizations inside and outside Alaska. The AMMTAP has placed particular emphasis on establishing and maintaining a close working relationship with native organizations and international organizations in which Alaska natives piay a prominent role. To date, this has involved periodic and regular meetings with 14 different Alaska native organizations.

Table 1. Species selection criteria as related to those species sampled by the AMMTAP and those species which are candidates for future sampling.

Species	Geographic Range	Food Web Position	Subsistence Value	Baseline Bio-Data	Sampling Practicality
Sampled:					
Ringed seal	Circumpolar	Pelagic fish crustacean	High	Very good	Excellent
Habor seal	World-wide	Pelagic fish	Moderate	Very good	Excellent
Spotted seal	W. Arctic Bering Sea	Pelagic fish	High	Limited	Moderate
Bearded seal	Circumpolar	Benthos	High	Limited	Difficult
Steller Sea Lion	North Pacific	Pelagic fish	Low	Moderate	Difficult
Northern Fur Seal	North Pacific Bering Sea	Pelagic fish; Squid	Moderate	Very Good	Excellent
Beluga whale	Circumploar	Pelagic fish	High	Moderate	Excellent
Candidates for Future Sampling:					
Walrus	Broadly polar	Benthos	High	Moderate	Difficult
Bowhead whale	Broadly polar	Pelagic	High	Moderate	Moderate
Polar bear	Circumpolar	Top predator	High	Moderate	Moderate

Table 2. Programs with which the AMMTAP is collaborating or coordinating its work.

Program	Organization	Activity
National Marine Mammal Tissue Bank	National Marine Fisheries Service Silver Spring, Maryland	Protocol design
Circumpolar Distribution of Organochorine Compounds in Beluga Whales	Department of Fisheries and Oceans Canada Winnipeg, Manitoba, CANADA	Chemical analysis
Beluga Harvest Survey	North Slope Borough Deaprtment of Wildlife Management Barrow, Alaska	Cooperative field work
Alaska Frozen tissue Collection	University of Alaska Museum, Fairbanks, Alaska	Supplemental samples
Wildlife Serum Archive	Alaska Department of Fish & Game, Fairbanks, Alaska	Supplemental samples
Prince William Sound Foods Monitoring Program	Alaska Department of Fish & Game, Anchorage, Alaska	Supplemental samples
Environmental Specimen Bank Program	Nuclear Research Center Juelich, Germany	Chemical analysis
Global Baseline Pollution Studies	Dept. of Analytical Chemistry University of Ulm Ulm, Germany	Cooperative field work Chemical analysis

In addition, AMMTAP is collaborating and coordinating its work with several major research and marine mammal management programs both inside and outside Alaska (Table 2). This has included mutual field work during sampling (Beluga Harvest Survey; Global Baseline Pollution Studies), collaboration on protocol design (National Marine Mammal Tissue Bank), collection of supplemental samples for genetics research (Alaska Frozen Tissue Collection), pathology (Alaska Department of Fish and Game's wildlife serum library), and studies related to specific pollution events (Prince William Sound Subsistence Foods Monitoring Program), as well as collaboration on chemical analyses (Department of Fisheries and Oceans Canada, Nuclear Research Center, Jülich, Germany, and the University of Ulm, Germany).

SUMMARY

Most of the specimens have been collected from ringed seals, northern fur seals, and beluga whales. The present specimen inventory is relatively small. However, the careful nature in which the samples are collected and the rigorous protocols that are followed between sampling and analysis should make the collection of particular value for future analytical work on environmental contaminants of which we at present may know very little.

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Paul Becker (Ph. D., Texas A&M University) has been an ecologist with NOAA's Outer Continental She/f Environmental Assessment Program in Alaska since **1977.** *His principal research interest is the transport and fate of environmental contaminants and the biological/ecological response to contaminants and habitat alterations. He recently transferred to the National Marine Fisheries Service Office of Protected Resources, Silver Spring, Maryland, where he is working in the development of the contaminant monitoring and quality assurance part of the National Marine Mammal Tissue Bank Program.*

QUESTIONS AND DISCUSSION

Warren Matumeak: I like beluga muktuk; muktuk is what we call it. And I bought a piece of muktuk in here in Anchorage which was taken from Cook Inlet stock. Because we like it so much, we started cooking it right away here in Anchorage. After we cooked it, we just couldn't eat it, It was so tough, It was unlike all the others that we have had in the Chukchi stock. And so I just wondered what kind of muktuk these people have over here? (Laughter.)

Paul Becker: It's a lot tougher. But I don't know. It may have to do with the connective tissue within that muktuk. As far as what we're looking at in contaminants, I really can't answer that question, There may be some differences in individual stocks morphologically or it may be due to something else.

Ray Emerson: Have you been able to check to see when you homogenize your tissue sample-- I suppose that's to average out the variance to some extent?

Paul Becker: Right.

Ray Emerson: Is that the same kind of tissue you homogenize? In other words, muscle tissue or liver tissue?

Paul Becker: Yes.

Ray Emerson: You're not mixing them up?

Paul Becker: No, no. What I mean by homogenization, that's just to make sure-- One of the problems in chemical analysis of tissues is that, depending on what section of the tissue you get, you can increase the variability. If you homogenize the whole thing, you average that out,

Ray Emerson: I wonder though, on the homogenizing process itself, where you're probably lysing most of the cell structures, you're losing the internal content, or at least you're partitioning it somewhat. Do you think you'll get a lower average with a homogenized sample as opposed to a large number of individual samples and taking that average? Because how do you know you've got all the same content in the handling process, in the preparation of the homogenate? You lose vaporization potential from the internal content of the cell structure,

Paul Becker: There is a publication I could give you relative to homogenization of human tissues, which was done at the specimen bank in which that was looked at. As far as the loss of materials during the-- this was done at low temperatures, they found no differences in those particular things that they were looking at. Some of the aromatics, they were looking at organochlorines. They were looking at trace elements, methylmercury being one.

However, that is not to say that somewhere within that sample there is some compound which one might be interested in that we're not aware of now or they did not look at, which did occur.

Suzanne Winder: We're concerned about the closing of the NOAA office here, Dr. Hameedi's office, We're wondering what effect the closure of that office is going to have on your studies, particularly of the Cook Inlet? We're very concerned about the PAHs and the accumulation in the marine mammals. Is that going to affect your tissue studies?

Paul Becker: Well, it's my understanding that the funding for the project for Alaska will continue this year. The difference will be that before, over the last five years, I've been the one that's been doing the collections and working with the people to obtain samples. My understanding is the funding for it will continue. However, I'm going back to Silver Spring, Maryland, to work with the national program and also continue to work with this program from the standpoint of working with the National Institute of Standards and Technology. The collection of materials and all the things that involves will be conducted by the Minerals Management Service, is my understanding. What I will be going to be doing until the end of March is to try to set up all the contacts and the arrangements and so forth with the people that are going to be making the collections so that the program does continue.

There may be other impacts, but I really can't comment on that now,

Vivian Forrester: In my research on the walrus, I've come across several comments from the natives of the North Slope that the hides of the walrus in the past few years have been thinner than usual. In your studies, have you discovered anything of that nature?

Paul Becker: We haven't done any sampling of walrus, which I mentioned, We haven't seen anything like that in the animals that we've looked at. That sounds like it may be, perhaps, a food problem or feeding situation, a metabolic-type thing, based upon lower amount of food available, or maybe something else,

Jon Nickles: Yes, I'm with Fish and Wildlife Service. I haven't heard that comment, but we do *receive* comments occasionally about suspected problems or changes that are difficult for us to confirm or document. The Fish and Wildlife Service will resume a walrus harvest monitoring program with personnel in walrus harvesting villages in 1992. This may help address these comments.

SATELLITE TELEMETRY STUDIES OF NORTHERN FUR SEALS AND STELLER SEA LIONS IN ALASKA

Thomas R. Loughlin, George A. Antonelis
Richard L. Merrick, Masashi Kiyota[1]
National Marine Mammal laboratory
7600 Sand Point Way, NE
Seattle, Washington 98115

We used satellite transmitters (often termed platform terminal transmitter or PIT) to study migration and foraging ecology of northern fur seals and Steller sea lions in Alaska during 1990 and 1991. These studies are linked to our studies of the interaction of these pinnipeds with commercial fisheries and their potential occurrence in Minerals Management Service Alaska Outer Continental Shelf planning areas in the Gulf of Alaska and Bering Sea. Data on location, dive depths and durations, and water temperatures are collected by PTTs attached to the animal's back and the information is transmitted while the animal is on land or at sea. Results indicate that adult female sea lions forage close to land in summer (within 20 km), make short trips (<2 days), and dive to shallow depth (<30 m). During winter the trips are further offshore (>300 km), last longer (up to several months), and dives are deeper (often >250 m). Sea lion pups six months old range more than 250 km offshore, although their dives are shallow (<20 m) and brief (<1 rein). Initial results from male fur seals in winter show that they disperse widely from the Pribilof Islands but remain in the Bering Sea, and dive to depths exceeding 250 m. Female fur seals migrate through passes in the Aleutian Islands into the Pacific Ocean. Water temperature data (sea surface and at dive depth) do not indicate a preferred thermal regime for male northern fur seals or Steller sea lions.

Dr. Tom Lough/in has worked on Alaskan marine mammals since **1979** *and is present/y the Alaska ecosystem program manager at the National Marine Mammal Laboratory. His areas of research include behavioral ecology of marine mammals and marine mamma//fishery interactions. He received his B.A. in biology from the University of California, Santa Barbara; his M.A. from Humboldt State University; and his Ph.D. in biology from UCLA.*

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[1]**Far Seas Fisheries Resesearch Laboratory, Shimizu, Japan.**

STATUS OF ALASKA GROUNDFISH RESOURCES

James W. Balsiger
Alaska Fisheries Science Center
NOAA/NMFS
7600 Sand Point Way, NE
Seattle, Washington 98115-0070

The Alaska Fisheries Science Center is responsible for groundfish research in the Federal waters of Alaska. The mission of the Center is to plan, develop, and manage research programs designed to generate scientific data for the understanding and management of the groundfish resources of the region. In concert with researchers from state agencies and universities, annual status of stocks documents have been produced by the Center, and utilized by the North Pacific Fisheries Management Council in the management of the fisheries off Alaska. The status of stocks information summarized here is available in detail in two status of stocks documents (Low 1991, NMFS 1991).

Table 1. Recent average, current potential, and long-term potential yields in metric tons (t), for Bering Sea/ Aleutian Islands groundfish.

Species	RAY[1]	CPY[2]	LTPY[3]
Pollock	1,327,800	1,775,500	1,898,000
Pacific cod	178,800	229,000	192,000
Yellowfin sole	151,500	250,600	220,000
Greenland turbot	8,300	7,000	27,100
Arrowtooth flounder	2,200	116,400	59.000
Rock sole	43,900	246,500	160,000
Other flatfish	41,500	219,700	148,500
Sablefish	5,200	6,300	7,500
Pacific Ocean Perch	9,350	15,300	14,900
Other rockfish	850	1#300	1,300
Atka mackerel	12,400	24,000	24,000
Other fish	8,300	32,500	Unknown

-Recent average yield (RAY)= 1,790,100 t
2-Current potential yield (CPY)= 2,926,100 t
3-Long-term potential yield (LPTY)= 2,784,800 t

BERING SEA-ALEUTIAN ISLANDS GROUNDFISH

Groundfish populations are currently at high levels with an estimated long-term potential yield (LTPY) of about 2.78 million t. The current potential yield (CPY) of 2.93 million t for 1991 is slightly above the LTPY. Table 1 contains estimates of potential yield by species for Bering Sea/ Aleutian Islands groundfish.

Walleye Pollock

Pollock support the largest single-species fishery in the United States. Three main Bering Sea stocks in decreasing order of abundance are the Eastern Bering Sea stock, the Aleutian Basin stock and the Aleutian Islands stock. The Eastern Bering Sea and Aleutian Islands stocks are at moderately high levels and are fully utilized. A large pollock fishery occurs in the central Bering Sea outside the managed zones of the United-States and the Soviet Union. This fishery targets the Aleutian Basin stock. Although the status of the basin stock is not well known, it appears-to be declining rapidly.

Pacific Cod

Pacific cod abundance remained high and stable throughout the 1980s. Research in 1990 began to show a decline in abundance due to poor production over the last two years, The cod stock is fully utilized.

Flatfishes

Yellowfin sole is the most abundant of the flatfishes and is fully utilized. Greenland turbot, the only depressed flatfish stock is expected to remain low during the current decade due to poor spawning success in the 1980s. It is fully utilized. All other flatfish species are in good or excellent condition.

Sablefish

Sablefish is a valuable species caught mostly with longline or pot gear. Sablefish is managed as a single stock from the Bering Sea-Aleutian Islands region to the Gulf of Alaska. The Bering Sea-Aleutian Islands portion of the stock declined substantially in the early 1990s in part due to migration into the Gulf of Alaska. Current abundance is relatively high though recent recruitment has not been strong. Sablefish is a fully utilized species.

Rockfishes

The rockfishes are managed as two major groups in this area: the Pacific ocean perch (POP) group and "other rockfish." The POP group consists of five red rockfish species. Its abundance dropped sharply due to large foreign fisheries in the 1960s and has remained low into the 1990s. The POP group is recovering and considered fully utilized. The "other rockfish" group includes two thornyhead species and about 30 other species. Little is known about them, but they are considered fully utilized.

Atka Mackerel

Atka mackerel stocks exist mainly in the Aleutian region and are difficult to assess, Current potential yield is estimated from recent catch levels and the resource is considered fully utilized.

GULF OF ALASKA GROUNDFISH

Gulf of Alaska groundfish populations have been relatively stable, rising steadily between 1984 and 1990. Currently LPTY is estimated at 494,000 t. The current potential yield (CPY) of 773,600 t for 1991 is above the LTPY. Table 2 contains estimates of potential yield by species for Gulf of Alaska groundfish.

Table 2. Recent average, current potential, and long-term potential yields in metric tons (t), for Gulf of Alaska groundfish.

Species	RAY[1]	CPY[2]	LTPY[3]
Pollock	66,800	133,400	229,000
Pacific cod	50,700	77,900	39,100
Flatfish	10,300	514,900	168,600
Sablefish	29,000	22,500	26,600
Slope rockfish	16,300	17,900	21,350
Thornyhead rockfish	2,500	1,800	3,750
Pelagic shelf rockfish	1,300	4,800	4,800
Demersal shelf rockfish	500	400	400

1-Recent average yield (RAY)= 177,400 t
2-Current potential yield (CPY)= 773,600 t
3-Long-term potential yield (LPTY)= 493,600 t

Pollock and Pacific Cod

Pollock abundance is currently at an average level, but this species in the Gulf of Alaska has had wide fluctuations in abundance since the early 1970s. Pacific cod are abundant and fully utilized, and are expected to decline in the near future since reproduction has not kept pace with natural and fishing removals,

Flatfish, Sablefish, and Rockfish

Flatfish are very abundant in the Gulf due to the great increases in arrowtooth flounder. Most species of flatfish in this area are managed as deep-water of shallow-water categories, while flathead sole and arrowtooth flounder are managed in separate categories. The sablefish stock managed as a unit with the Bering Sea population is in good condition and fully utilized. "Slope" rockfish, those occupying the deep waters of the continental slope are in low abundance and are fully utilized, They are long-lived and grow slowly, and have not fully recovered from the heavy foreign removals of the 1960s, Thornyhead rockfish are also at low levels and are decreasing. Rockfish populations on the continental shelf are poorly understood and support fisheries at low levels.

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Dr. Jim Balsiger has worked at the Alaska Fisheries Science Center in Seattle since 1977. Until 1991 he led the Status of Stocks Task; he is now Deputy Director for the Center. Balsiger received his B.S. in forestry from Michigan Technological University, his M.S. in forest silviculture from Purdue University, and his Ph.D. from the University of Washington.

PETROLEUM EFFECTS ON HERRING EGGS AND LARVAE IN PRINCE WILLIAM SOUND, ALASKA, 1989

Michael McGurk
Triton Environmental Consultants, Ltd.
120-13511 Commerce Parkway
Richmond, B. C., Canada V6V 2L1

INTRODUCTION

On March 24, 1989, the oil tanker *Exxon Valdez* struck Bligh Reef in Prince William Sound, Alaska, spilling 250,000 barrels of Prudhoe Bay crude oil. The oil slick was transported southwest by the anti-clockwise surface current of the Sound. During its transit it washed around the Naked Island archipelago and the northern tip of Montague Island, both areas that contain spawning beaches for Pacific herring, *Clupea harengus pallasi*. It did not impact herring spawning beaches in the north, northeast and southeast.

Neff (1 991) reported that average concentrations of volatile aromatic hydrocarbons at 35 offshore stations (>0.4 km from shore) peaked at slightly less than 2 ppb (parts per billion) in early April and then fell to background level by June. Concentrations of polycyclic aromatic hydrocarbons followed a similar time trend. Of 1342 water samples collected at 51 inshore stations (<0.4 km from shore) between March and October, 1989, about 3 to 24% had concentrations above the detection limit of 1 ppb for volatiles and 0.01 ppb for polycyclics, and about 7% of the samples had concentrations of volatiles >4 ppb.

Prespawning herring were first observed massing near the four major spawning areas for herring between March 29 and April 1, 1989 (Figure 1) (Alaska Department of Fish and Game 1991). The first, and largest, wave of spawning began on April 2 and ended on April 15, and a second smaller wave of spawning occurred in the first week of May. Eggs incubated on vegetation in the subtidal zone for about 20 d. The mean dates of hatch for the two waves were May 5 and May 26.

Therefore, the majority of herring adults approached and spawned on the beaches of the Naked Island archipelago and Montague Island during the period of highest concentration of hydrocarbons in the water column. Eggs at these two areas incubated during the period of maximum hydrocarbon concentration. Larvae hatched out into water with an average hydrocarbon concentration higher than background levels.

What was the effect of exposure to these levels of hydrocarbons on the population dynamics of herring eggs and larvae? Rice et al. (1987) reported that the lowest concentration of the water-soluble fraction of Cook Inlet crude oil that produced a measurable acute effect on herring was 300 ppb for feeding larvae. However, they did not measure the viability of larvae that were exposed to oil in the egg. Pearson et al. (1985) reported that herring eggs exposed to a mixture of water-soluble fraction and a suspension of microdroplets of oil for only 1 to 2 d hatched significantly more deformed larvae than controls at concentrations as low as 4.4 ppb.

Since all hydrocarbon concentrations were in the ppb range and less than 10'% of the nearshore samples had concentrations greater than the lowest critical level for herring, we predict little or no effect of the *Exxon Valdez* oil spill on herring early life history in the Sound.

We tested this prediction with two studies. In the first study we tested the hypothesis that survival and viability of newfy-hatched herring eggs from oiled areas of the Sound was lower than that from non-oiled areas (McGurk et al. 1990b). In the second study we tested the hypothesis that growth and mortality of sea-caught herring larvae was lower in oiled areas than in non-oiled areas (McGurk et al. 1990a).

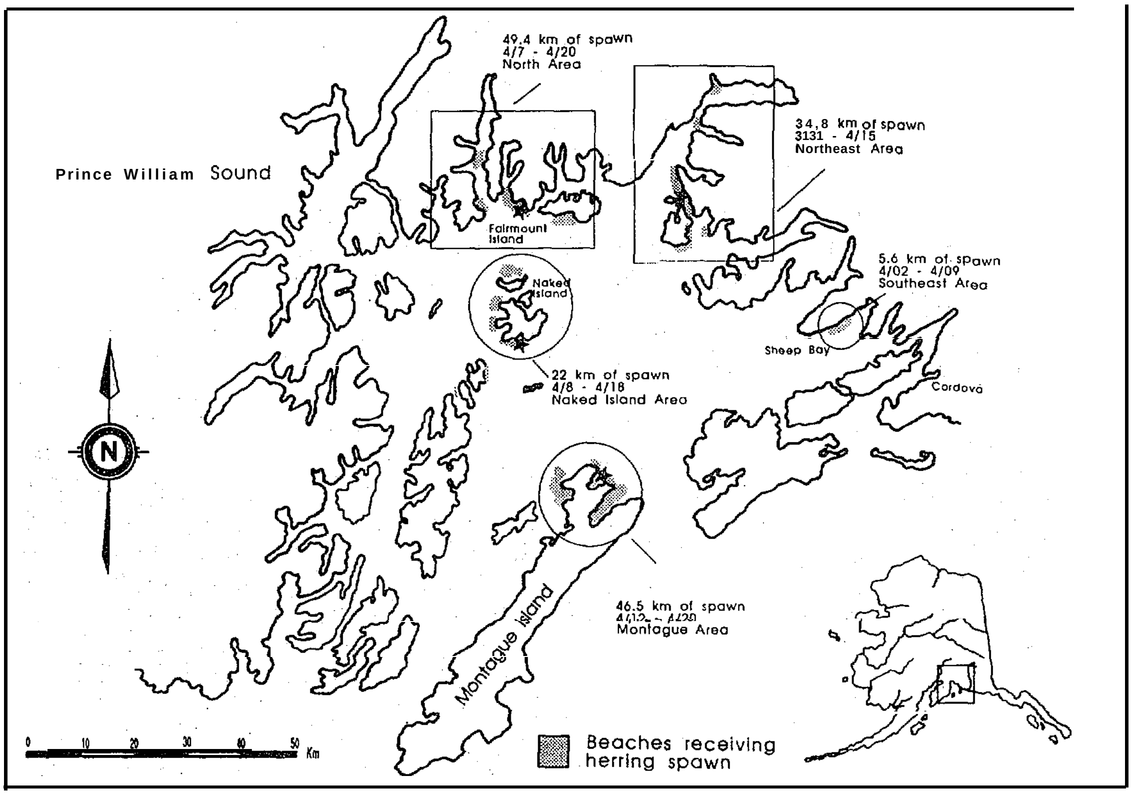

figure 1. Map of Prince William Sound, Alaska, showinq the four major spawning areas for herring (Sheep Bay was considered a minor site), the total length of spawn, and the range of spawning dates. Stars indicate locations of four plankton stations.

METHODS

Egg Incubation Experiment

Over 180 samples of live herring eggs were collected by SCUBA divers of the Alaska Department of Fish and Game from one control site (Fairmount Island) and five oiled sites (Bass Harbor, Outside Bay and Cabin Bay on Naked Island, the north shore of Story Island, and Rocky Bay on Montague Island). The eggs were flown to the Vancouver Public Aquarium and incubated to hatch. The number of live and dead eggs and the number of newly-hatched larvae were counted each 1 to 2 d. Larvae were preserved in 3% formalin, and classified as viable or non-viable from their external morphology, A sub-sample of 10 larvae from each date for each sample were chosen at random, and their length, yolk sac volume, and dry weight were measured.

Larval Herring Survey

In the second study, seven cruises of the Sound were performed each week from May ' 1 to June 22, 1989. On each cruise, four plankton stations were visited; two control stations (Tatitlek Narrows and Fairmount Bay), and two oiled stations (Bass Harbor on Naked Island and Rocky Bay on Montague Island). At each station wild herring larvae were collected with towed bongo nets dropped to a depth of 30 m. Auxiliary information was collected on the depth distribution of temperature and salinity and on the densities of zooplankton prey of herring larvae.

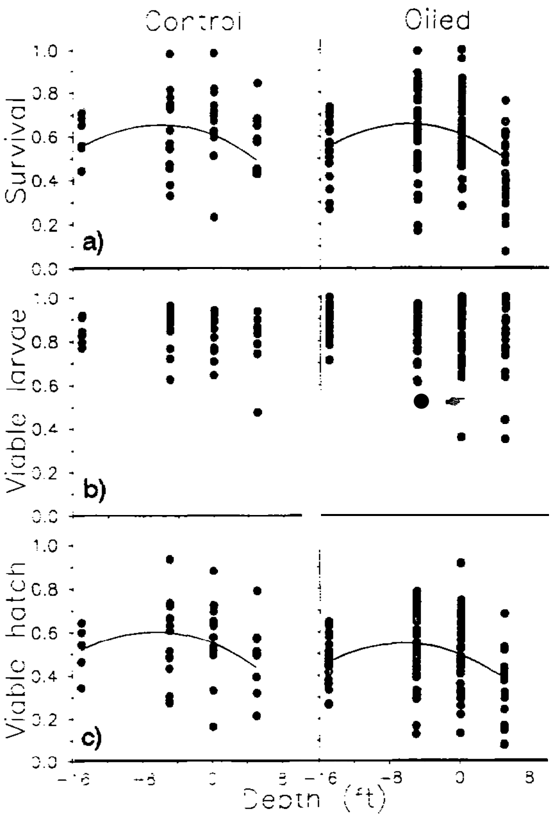

Figure 2. Fraction of control and oiled herring eggs that survived to hatch; fraction of larvae that were viable; and fraction of viable hatch at four depth classes. Solid lines are multiple regressions: survival = 0.8058-0.0159 depth - 0.0013 depth^2, n = 180, r^2 = 0.10, $P<0.001$; and viable hatch = 0.492 + 0.0577x -0.0159 depth - 0.0012 depth^2, n = 180, r^2 = 0.12, $P<0.001$, where x = 1 for control sites and zero for oiled sites.

Length of herring larvae was measured to the nearest 0.1 mm. Herring larvae were classified into cohorts by analysis of length frequency plots. Growth was calculated as the difference in mean lengths of each cohort at two successive sampling dates divided by the number of days between sampling dates.

Densities (numbers m^{-2}) of herring larvae were corrected for avoidance of the net by larvae with the use of a regression model developed from literature sources (McGurk 1992). Mortality and dispersion of herring larvae were estimated with two different models. The first model assumed constant radial diffusion and constant mortality, and the second model assumed constant radial diffusion and a mortality that decreased exponentially with age.

RESULTS AND DISCUSSION

Egg Incubation Experiment

An average of 59.2% (SD = 18, range = 7.1 to 99.9%) of the eggs survived incubation and hatched larvae (Figure 2a). The only factor that accounted for a significant ($P<0.001$) amount of variance in egg survival was depth - survival was greatest at a depth of 5 ft below mean low tide.

An average of 83.8% (SD = 11.7, range = 34.6 to 100.0%) of the newly hatched larvae were viable (Figure 2b). There were no significant ($P>0.05$) effects of oil treatment or water depth.

The mean percent of viable hatch, the product of percent egg survival and percent larval viability, was 50,0% (SD = 16.9, range = 7.1 to 88.2%). It varied significantly with depth ($P<0.001$) and barely significantly ($P = 0.033$) with oil treatment (Figure 2c).

These ranges of percent egg survival and larval viability are within the ranges reported for natural herring spawn not contaminated by hydrocarbons (Hourston et al. 1984; Johannessen 1986). A dome-shaped effect of depth on survival was not unexpected; previous research has shown that herring egg survival decreases with exposure to air (Jones 1972) and with increasing depth (Taylor 1971), so survival should be maximal at intermediate depths.

The most statistically significant effect of oil was an acceleration of embryo development. Hatching occurred significantly ($P<0.001$) sooner in upper depths than lower depths due to higher water temperatures in surface waters, and it occurred significantly ($P<0.001$) earlier in oiled eggs than control eggs, but only by 1 to 2 days.

It is common for a pollutant to shorten or lengthen incubation depending on concentration; low concentrations stress the embryo and stimulate early hatch whereas high concentrations narcoticize the embryo and cause delayed hatch (Westernhagen 1988).

These changes in hatching schedule led to small differences in mean length, yolk volume and dry weight of newly-hatched herring larvae between control and oiled groups. These differences were unlikely to have had significant effects on natural survival of larvae.

These results support the prediction of little or no ecologically meaningful effects of the *Exxon Valdez* oil spill on viable hatch of herring in the Sound.

Larval Herring Survey

One major cohort and several minor cohorts of herring larvae were found at each of the four plankton stations. Linear growth in larval length increased from 0.1 $mm \cdot d^{-1}$ in early and mid-May to 0.4 $mm \cdot d^{-1}$ in June due to an increase in water temperature from 5.5°C to 8.5°C over this period (Figure 3). Covariance analysis showed that there were no significant differences between stations in the growth-temperature relationship.

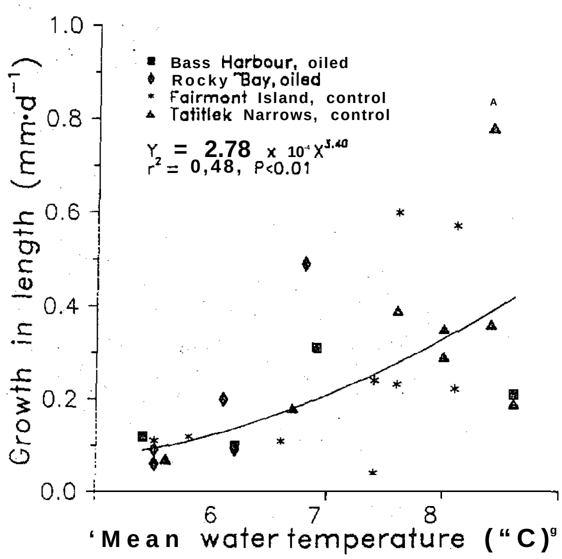

Figure 3. Regression of growth in length of herring larvae on mean water temperature for four plankton stations.

The simple population model described reasonably well the ascending left-hand limbs and the descending right-hand limbs of the four catch curves, but it underestimated the domes (Figure 4). The model with age-dependent mortality explained 6% more variance in ln(density) ($r^2 = 0.86$, $n = 42$, $P < 0.001$) by improving the fit to the domes. The most important result was that mortality did not differ significantly between stations, it was a constant 0.21 d^{-1} for all stations.

These results support the prediction of little or no effect of the *Exxon Valdez* oil spill on growth and mortality of wild herring larvae in the Sound.

SUMMARY

The coincidence in timing between the Exxon *Valdez* oil spill and major herring spawning in Prince William Sound, Alaska, led many to suspect that the spill may have caused reduced survival of herring eggs and larvae. However, laboratory incubation experiments and plankton surveys of the Sound found little evidence to support this hypothesis. Percent viable hatch of herring eggs was barely significantly different between oiled and non-oiled areas, and there were no significant differences in the growth and mortality of wild free-swimming herring larvae between oiled and non-oiled areas. These findings support the concision that despite the large volume of oil released in the spill, herring eggs and larvae were not exposed to sufficiently high concentrations of water-soluble hydrocarbons to affect their ability to survive in a natural environment.

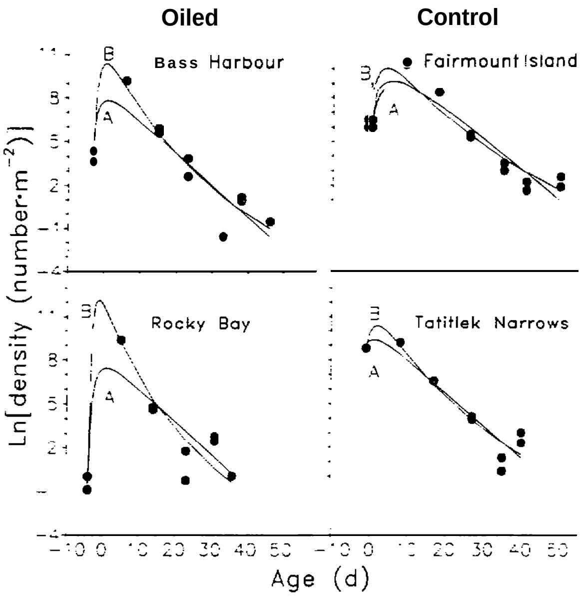

Figure 4. Densities of herring larvae at age and station in Prince William Sound. Solid lines are densities predicted from mortality-dispersion models. Model A. $N = b_0 exp[- b_1 t^{-1} - Zt]$, where N = densities (numbers m^{-2}), b_0 (number m^{-2}) and b, (d) are coefficients fit by multiple regression, t = age (d), and Z = mortality (d-'). Model B: $N = b_0 t^{-b_2} exp(-b_1 t^{-1})$, where b_2 = coefficient of age-dependent mortality.

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Dr. Michael D. McGurk is a fisheries scientist working for Triton Environments/ Consultants Ltd. of Richmond, B, C., Canada. He has been conducting research on the population dynamics of herring and sand lance larvae in Alaska since 1988. He received his Ph.D. in Zoology from the University of British Columbia, his M. SC. from Memorial University and his B.Sc. from McGill University.

STATUS OF STUDIES ON FORAGE FISH IN THE PORT MOLLER AREA

Michael D. McGurk, John E. Edinger,[1] Edward M. Buchak[1]
Triton Environmental Consultants, Ltd.
120-13511 Commerce Parkway
Richmond, B. C., Canada V6V 2L1

INTRODUCTION

The southeastern Bering Sea is the site of several sac-roe fisheries for Pacific herring, and a potential site for offshore oil and gas development. In response to concerns that herring eggs and larvae are vulnerable to coastal development of hydrocarbons, Minerals Management Service began a coastal fisheries oceanography study in 1988.

A one-year pilot study in Auke Bay, Alaska, led to the recommendation that a standard plankton survey should be combined with hydrodynamic modeling (McGurk 1989a). A reconnaissance survey of Port Moller in June, 1989, found that there were sufficient numbers of herring larvae to support a study of their population dynamics (McGurk 1989 b). Greengrove (1991) conducted a preliminary survey of the physical oceanography of the estuary.

An intensive fisheries oceanography study was performed in the estuary over May-July, 1990. It measured biological variables such as the densities of herring larvae and their prey, physical variables such as temperature, salinity and water pressure, and meteorological variables such as wind speed and direction, rainfall and barometric pressure. The physical and meteorological data was used to construct a computer model of water motion in the estuary.

In 1991, the study was expanded to investigate the population dynamics of Pacific sand lance, *Ammodytes hexapterus*, larvae collected in 1990.

METHODS

Twenty-three plankton stations were occupied once a week from May through July, 1990 (Figure 1), At each station temperature-salinity profiles were taken and an oblique bongo net tow was used to capture herring and sand lance larvae. They were preserved in 3% formalin and later sorted, counted and measured for length, At two stations each week the invertebrate prey and predators of fish larvae were sampled with large water bottles and small bongo nets. At the same time, extra bongo net tows were taken to collect fish larvae which were immediately frozen in liquid nitrogen for later measurement of RNA-DNA ratios. Three water pressure sensors were installed, two at the boundary of the estuary and one at the upper end of Herendeen Bay. An automatic weather station was installed at the tip of Harbor Point and a rain gage was installed at Entrance Point.

Physical and meteorological variables were used to drive a hydrodynamic model of the estuary. The model contained 151 square cells each with a length of 2100 m. Each cell was divided into vertical layers 2 m deep. There were between 4 and 51 vertical layers in each cell. The model was driven by water surface elevation, temperature and salinity at the boundary of the estuary. Computations proceeded inward and were modified by bathymetry, fresh water inflow, wind stress and solar heating. The model was verified by comparing its predictions with measured temperature and salinity and with water surface elevation measured by the third water pressure sensor at the head of Herendeen Bay.

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[1]J. E. Edinger Associates, Inc., Wayne, Pennsylvania

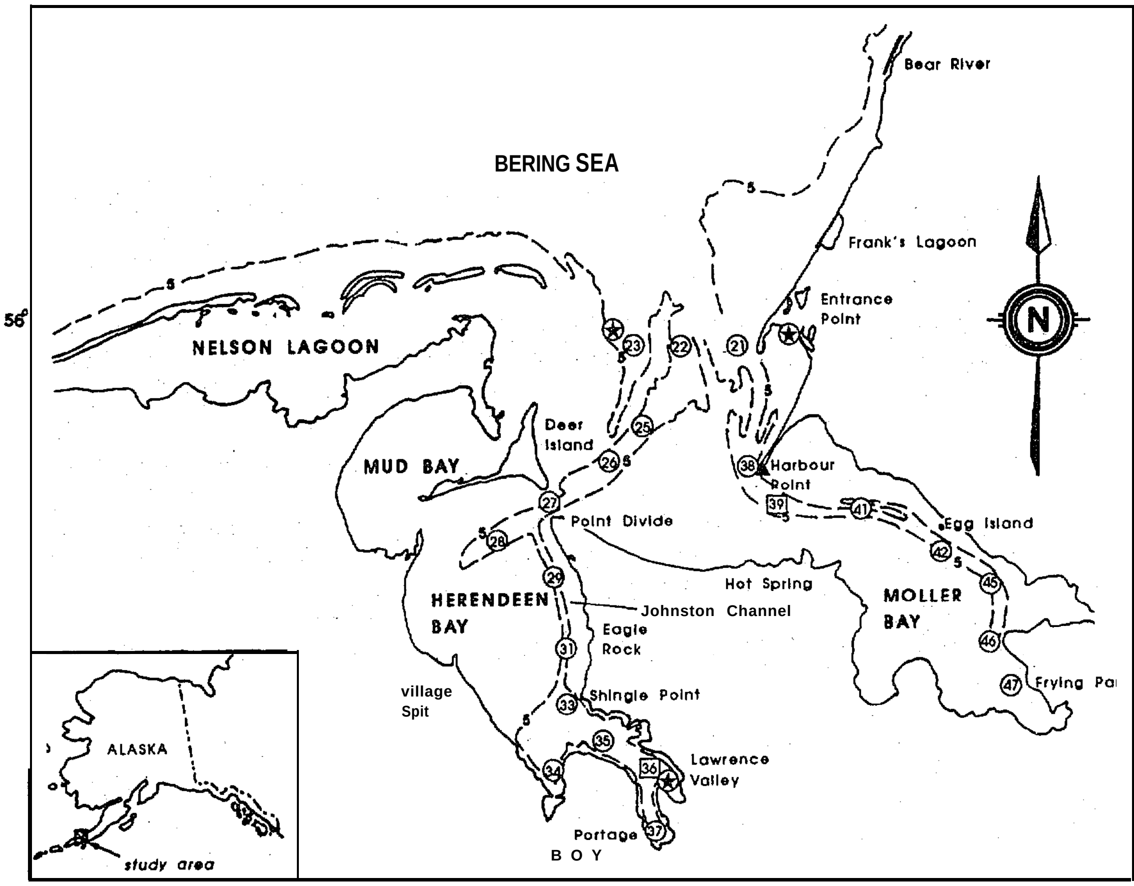

Figure 1. Map of the Port Moller estuary showing numbered plankton stations, the locations of three water pressure sensors (stars), and one meteorological station (solid triangle). Boxed stations were sites of zooplankton prey-predator sampling.

RESULTS AND DISCLESION

Hydrodynamic modeling showed that tidal flushing of the estuary decreases with increasing distance from the boundary. The outer estuary is rapidly flushed, but the head of Herendeen Bay is much more stable and vertically stratified. The estuary contains two areas of surface convergence, one near Harbor Point in Moller Bay and a second at the head of Herendeen Bay (Figure 2). These convergence act as barriers that retain fish larvae in the estuary.

All herring spawned within the zones defined by the convergence, and most herring larvae appear to be retained within these zones (Figure 3). In contrast, sand lance larvae moved into the estuary from hatching sites outside the estuary. Larvae of both species were found above the thermocline at 30-40 m depth. Their nutritional status, as indicated by RNA-DNA ratios, was high, indicating that the estuary is an excellent nursery area for both species.

We are currently testing the retention zone hypothesis (Iles and Sinclair 1982) by using the hydrodynamic model to simulate the dispersion of larval herring and sand lance in Port Moller.

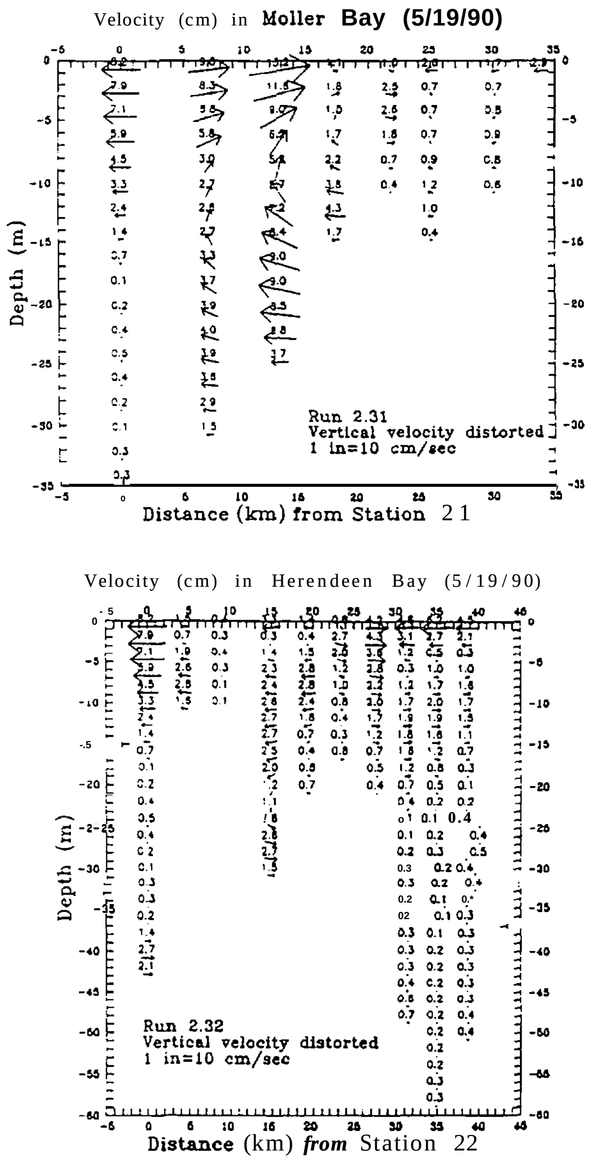

Figure 2. Longitudinal-vertical plot of water velocity in Moller and Herendeen Bays calculated for May 12-19, 1990, by a hydrodynamic model.

SUMMARY

A multi-disciplinary study of the early life history of herring and sand lance larvae in Port Moller, Alaska, shows that the estuary is a nursery area for these species because it contains two larval fish retention zones.

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Dr. Michael D. McGurk is a fisheries scientist working for Triton Environmental Consultants Ltd. of Richmond, B. C., Canada. He has been conducting research on the population dynamics of herring and sand lance larvae in Alaska since 1988. He received his Ph.D. in Zoology from the University of British Columbia, his M. SC. from Memorial University and his B. SC. from McGill University.

Dr. John E. Edinger is a physical oceanographer and the founder and principal scientist of his firm. His main area of research is the development and application of three-dimensional, time-varying computer models of waterbody dynamics. Dr. Edinger received his Ph.D. and his M.Sc. from Johns Hopkins University and his B. SC. from Union College.

Mr. Edward M. Buchak is a physical oceanographer with J. E. Edinger Associates, Inc. For the last 15 years he has collaborated with Dr. Edinger on the *development of hydrodynamic models. Mr. Buchak received his M. SC. from the University of Pennsylvania and his B. SC, from the Massachusetts institute of Technology.*

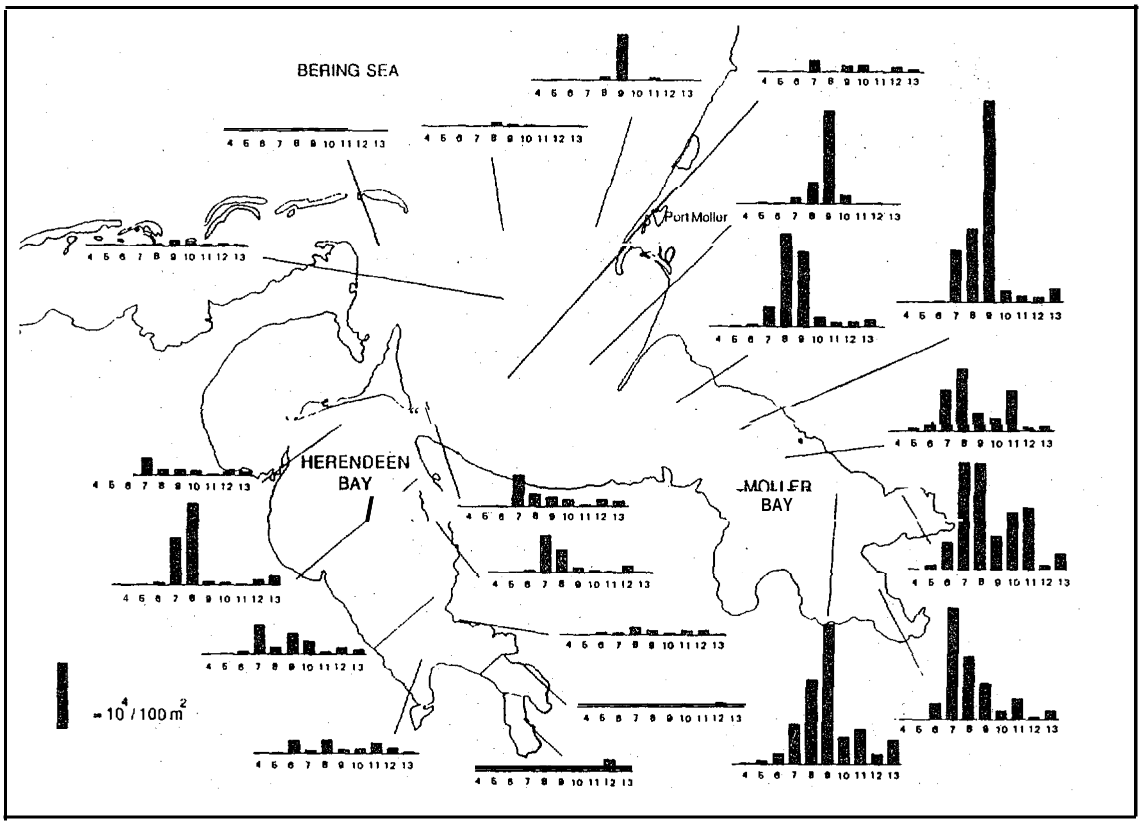

Figure 3. Density (numbers m^{-2}) of herring larvae in Port Moller over May-July 1980 as measured by bongo nets. Numbers on x-axis of bar graphs are weeks after May 1.

QUESTIONS AND DISCUSSION

Jonathon Houghton: A couple of observations. In Bass Harbor you gave the spawning times as through April 1 for the first wave, then beginning on the fifth of May for the second. There was no spawning in Bass Harbor in that first time period. I was there quite a bit. So I don't know if that is exactly where you were bringing that from. That might have been another part of the Sound.

Michael McGurk: This is the larval,..?

Jonathon Houghton: The actual spawning, eggs on the beach. We were there a number of times in late March and early April. When we left in early April on the 7th, there were a whole mass of herring just getting ready to spawn in Bass Harbor. When we got back at the end of April, they had spawned. So there was a major spawning in Bass Harbor between the 7th of April and probably around the 24th or 25th, So I don't know how that affects what you got?

Michael McGurk: I calculated age of the eggs from the aerial surveys done by the Alaska Dept. of Fish and Game. Here are the range of dates at which they observed any spawning biomass. What I did was take the median. I had no other information on age of eggs. I took the median and assumed that was the average spawn date.

Jonathon Houghton: Okay, that would agree. It didn't sound like that was what you had said earlier. The other thing is as far as 1 know Bass Harbor never really got oiled.

Michael McGurk: I am not surprised.

Jonathon Houghton: And Rocky Bay, 1 didn't spend much time there, but I don't know that it was very heavily oiled.

Michael McGurk: It was. There were some areas that were extensively oiled.

Jonathon Houghton: I am quite sure that Bass really never got oiled to any degree at all. So I wonder if what you see is differences in different subpopulations in the Sound.

Michael McGurk: We were given eggs from the Alaska Dept. of Fish and Game. They were labeled as "oiled" and "not oiled". In saying this, I am not questioning their observations, they were there on site, they took the eggs. They knew what was oiled and what was not oiled. The problem was in deciding what is oil treatment and what is not, Because when that spill came through it didn't wash around every square centimeter. It hit some bays and then missed entirely neighboring bays. I spent months talking to anybody in Alaska who had any knowledge of this trying to figure out a better index of treatment. But in the end, so much information was embargoed and so difficult to get that I had to go with simply "oiled" and "non-oiled". That was the best that was available.

Jonathon Houghton: Another thing, we also saw some schools of large, apparently mature herring around Knight Island in early May. I was wondering if there were any records of spawning in that area which was heavily oiled, Snug Harbor, Bay of Isles?

Michael McGurk: Again I would have to recommed you to the Alaska Dept. of Fish and Game who collected this information and know much better than 1.

Ray Emerson: You mentioned the survival rate of controls would be demonstrated as being typical of the 50% factor?

Michael McGurk: I think it was 59%,

Ray Emerson: Was that typical for what that laboratory usually does in a controlled situation for herring survival?

Michael McGurk: Vancouver Public Aquarium?

Ray Emerson: Yes.

Michael McGurk: I don't know what is typical for the Vancouver Public Aquarium. But when I say it is typical, 1 mean when you compare it with Hourston's work at the Pacific Biological Station. When you compare it with Johannessen's work in Norway, you find that it falls right within the range of values that they had published. So that is what I mean. Neither Hourston's eggs or Johannessen's eggs were oiled at all. They were natural spawned.

Ray Emerson: I am a little concerned about the application of your experiment to what is really going on in Prince William Sound. Because it seems to me that you are taking eggs that have been oiled at a point in time. Then we are putting those into a clean water system where we are flushing it or in this case aeration. It wasn't a flow through system, but it a static bioassay system. Basically you are aerating most of your volatile hydrocarbons which are going to cause the toxicity effect, if there is such. So, those larvae that are still in Prince William Sound that haven't had the opportunity to go to Seattle are still unfortunately going to have to find bed and breakfast there in Prince William Sound and it may not be quite that clean. So, how do you apply that?

Michael McGurk: In response to your question about flow through versus static, it wasn't exactly static because we had to count the eggs every day. What we do is take out the mesh bundle with the eggs and take them aside. Then empty out the water in that bucket, fill it up again with flesh seawater. Then when we finish counting the eggs we put them back in. So every day, the water was changed. But it is an enormous task, 180 separate aquaria is incredible. We had six technicians running virtually 24 hours a day.

Ray Emerson: But do you see what i am getting at? If you had the flow through system you would even then have to take your test eggs and expose them to your levels of fractional part per billion hydrocarbon to make some kind of extrapolation to Prince William Sound where the larvae are still hanging out, trying to survive. Do you understand?

Michael McGurk: Yes. The only thing I can say in response to that is that Dr. Pearson's work shows that simply exposure for only one or two days to a water soluble fraction with the suspension of microdroplets of oil is sufficient to result in the production of higher than average non-viable larvae, So 1 would say that that exposure that they had in the field for one to two weeks before we brought them into the lab was quite sufficient to show any significant statistical results.

Ray Emerson: Well, EPA's standard chronic bioassay methodology requires a 28 day exposure for, even let's say, eggs, larval development. The entire process of the egg to juvenile on up to adult in some cases can be captured within 28 days, but what would you say your exposure time was for these prior to the trip to Seattie?

Michael McGurk: I couldn't answer you right off the top of my head, I would have to go back to my notes and find the dates when they sampled.

Pamela Miller: i would like to ask you to expound a little bit on what you see as the significance of your work as it interfaces with that of Walt Pearson's especially in regard to what you call ecologically significant and also would you say something about what is known about the long term survival rates of herring, perhaps not from your work but from other work that has been done on oil impacts.

Michael McGurk: i don't know Dr. Pearson's results from his *Exxon Valdez* surveys because all of that information is under litigation, i have no access to it. i don't know very many people who do, So i can't say anything about his results. As far as survival, when I say ecologically meaningful, what I mean is that mortality rate of fish larvae is so high that small changes in mortality rate is an open question as to whether this has any meaningful effect on recruitment to an adult population. The whole question of the relationship between survival of eggs and larvae and recruitment to the adult population is an open question. We don't really know whether survival in the egg stage has anything to do with the number of fish that fishermen catch. That is all that i can say about it. it is unknown.

RESPONSE OF MIGRATING ADULT PINK SALMON TO A SIMULATED OIL SPILL[1]

Douglas Martin, Clifford Whitmus, Ian Austin,[2]
Lon Brocklehurst[3], and Ahmad Nevissi[4]
Pentec Environmental, Inc.
120 W. Dayton, Suite A7
Edmonds, Washington 98020

INTRODUCTION

The purpose of this investigation was to determine whether exposure to oil-contaminated waters would disrupt the migration of adult Pacific salmon. Previous research in the laboratory (Pearson et al. 1987) found that adult coho salmon had a detection threshold for the water-soluble fraction (WSF) of crude oil of $10^7 \mu g/\ell$ [parts per billion (ppb)]. This research also found that at WSF concentrations of 0.1 to 1.0 ppb, the chemosensory response to WSF is degraded but not irreversibly. Based on the findings of Pearson et al. (1987) a field investigation was designed to address the following questions:

- Will migrating adult salmon avoid oil-contaminated waters at concentrations near or above the chemosensory detection threshold?
- If adult salmon encounter WSF concentrations above 1.0 ppb, will they become disoriented?
- If adult salmon avoid or become disoriented by oil-contaminated waters, does either response disrupt migration to the home stream?

METHODS

The behavior of adult salmon exposed to oil-contaminated waters was studied by tracking pink salmon movements during periods with and without oil contamination as they migrated through Jakolof Bay, located near Seldovia, Alaska (Figure 1). Ultrasonic transmitters were attached to adult salmon, which were captured at the mouth of Jakolof Creek. During an ebb tide, the tagged salmon were released from a holding pen located 2 km from Jakolof Creek, and their movements were tracked by a fixed array of hydrophores as the fish returned to their home stream (Figure 1). The horizontal and vertical position of each fish within a test group was continually recorded. Plots of fish movements were used to identify fish behavior during coastal migration. These movement patterns were compared with movement patterns during oil exposure to determine behavioral characteristics indicative of either avoidance or disorientation.

A solution of aromatic hydrocarbons similar in composition to the WSF of Prudhoe Bay crude oil was injected into the water column from a 10-m long diffuser located midway between the fish holding pen and the mouth of Jakolof Creek (Figure 1). The diffuser was designed to create a vertically mixed hydrocarbon plume extending from the diffuser downstream and along the eastern one-half of the bay. Salmon were released from the holding pen when the hydrocarbon plume had extended approximately 300 m downstream. The salmon thus could move either into or around the plume, Hydrocarbon dispersion rate and concentration within the plume were estimated from a two-dimensional vertically integrated hydrodynamic model in combination with a water quality model. The hydrodynamic model was driven by tides, and the water quality model was calibrated by dye dispersion studies. Predicted hydrocarbon

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[1]This study was conducted by Dames and Moore under contract to NOAA.

[2]Dames & Moore, Los Angeles, California.

[3]LabCor Systems, Olympia, Washington.

[4]Laboratory of Radiation Ecology, University of Washington, Seattle, Washington,

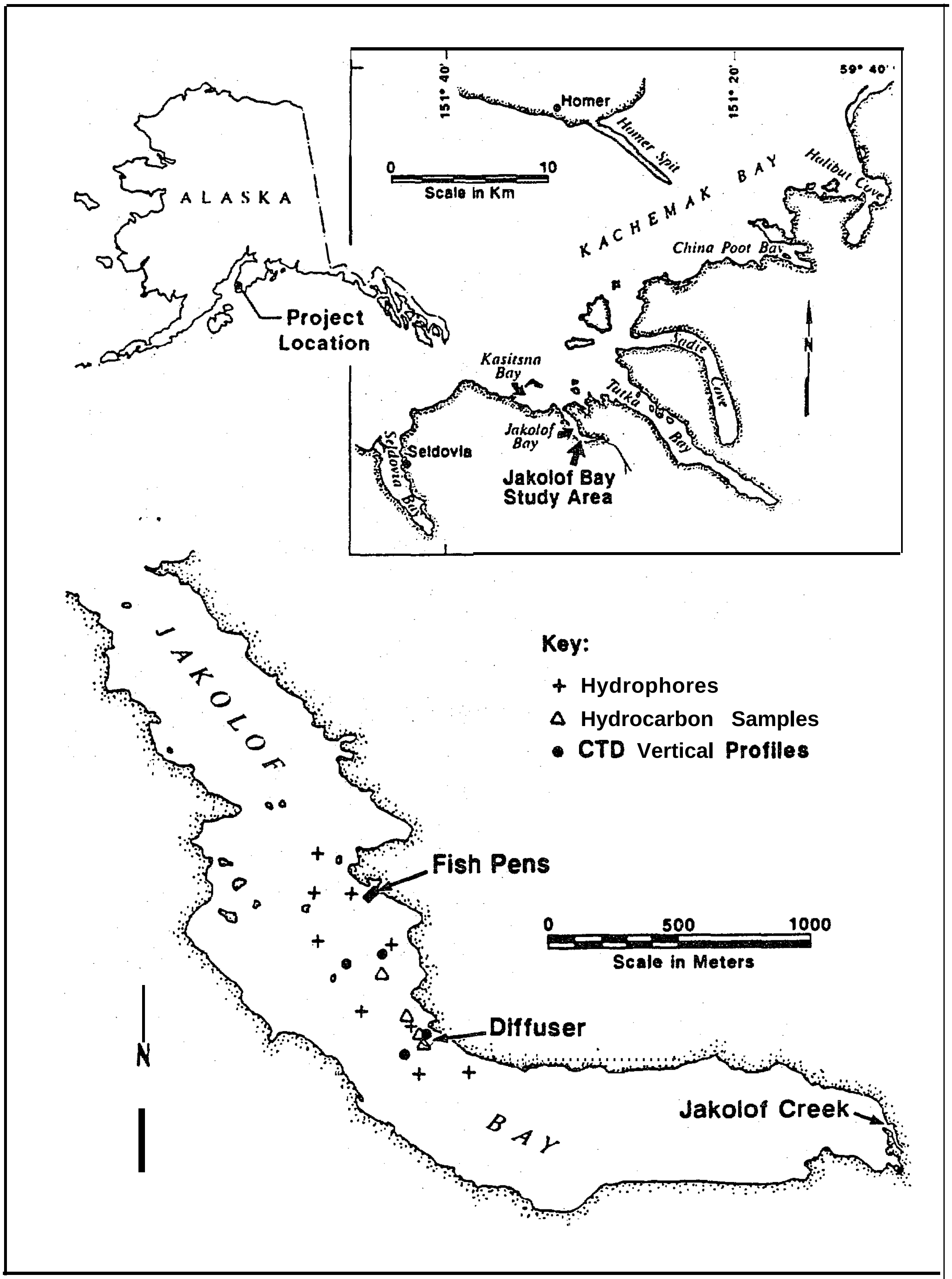


Figure 1. Location of Jakolof Bay study area (top) and locations of fish holding pen, diffuser and sample sites In Jakolof Bay (bottom).

concentrations were also veriied with analysis of water samples. The hydrodynamic model and diffuser design were developed from oceanographic data collected from a reconnaissance survey during April 1988.

The salmon tracking experiments were conducted during late July in correspondence with the spawning migration of pink salmon to Jakolof Creek. Ten to 20 tagged fish were released during each experiment. Tracking experiments conducted without hydrocarbon discharge were designated "controls," and experiments with hydrocarbon discharge were designated "treatments." Three control experiments and three treatment experiments were conducted on an alternating schedule from July 19 to July 29. Experiments were not conducted for a minimum of two days following each treatment run in order to allow time for the hydrocarbon plume to be flushed from the bay.

Total concentrations of hydrocarbons in Jakolof Bay prior to the experiments and during the control experiments ranged from O to 2.2 ppb. Concentrations during the experiments ranged up to 64.9 ppb at 25 m from the diffuser. The large difference between surface and bottom hydrocarbon concentrations indicated that the plume was not vertically mixed and was present only in the lower half of the water column. The plume model was adjusted to account for this variation, and the estimated hydrocarbon concentrations were verified by water samples. Plume shape was generally the same for all treatments, but the rate of development varied among experiments and depended on size of the tide.

RESULTS AND DISCUSSION

Salmon returning toward the home stream through uncontaminated waters exhibited two types of movement behavior. After release from the holding pen, salmon showed a searching behavior characterized by: variable horizontal movements generally directed upbay against the ebb current with short periods of movement either across or with the current (Figure 2); movement up and down in the water column with a higher frequency of large-amplitude compared to small-amplitude vertical movements; and slow speed swimming (mean ground speed 0,26 m/s) (Figure 3). The duration of the searching behavior was similar within an experiment but varied among experiments. When fish began to move along a straight horizontal course toward the home stream - behavior defined as active migration - the amplitude of vertical movement decreased and swimming speed increased (mean ground speed 0.46 m/s). The mean depth of fish during the period of active migration was variable among experiments and was associated with the depth of the interface between brackish surface waters and higher salinity bottom waters.

The identification of salmon migration behavior in the presence of oil-contaminated waters was successful, but the results are based on limited information. Two of the three treatments (i.e., 1 and 2) did not result in a test of exposure to oil because the plume did not intercept the homing fish. This problem was due to the absence of prior knowledge of the migration route and migration speed of salmon in Jakolof Bay in relation to the location of the plume. The location and timing of fish release relative to the location and movement of the hydrocarbon plume was critical for the successful exposure of salmon to oil. Salmon were exposed to oil-contaminated water only during Treatment 3.

Differences in movement behavior of salmon during Treatment 3 compared to the behavior of salmon during the control experiments indicated that hydrocarbon concentrations ranging from 1.0 to 10.0 ppb caused a temporary disruption of the migration to the home stream, Fish exposed to contaminated waters spent significantly more time conducting searching movements and showed negative rheotactic movements (Figure 4) resulting in movement downbay (out of tracking range). Following this behavior salmon displayed an active migration behavior (positive rheotaxis) and successfully returned toward the home stream by migrating

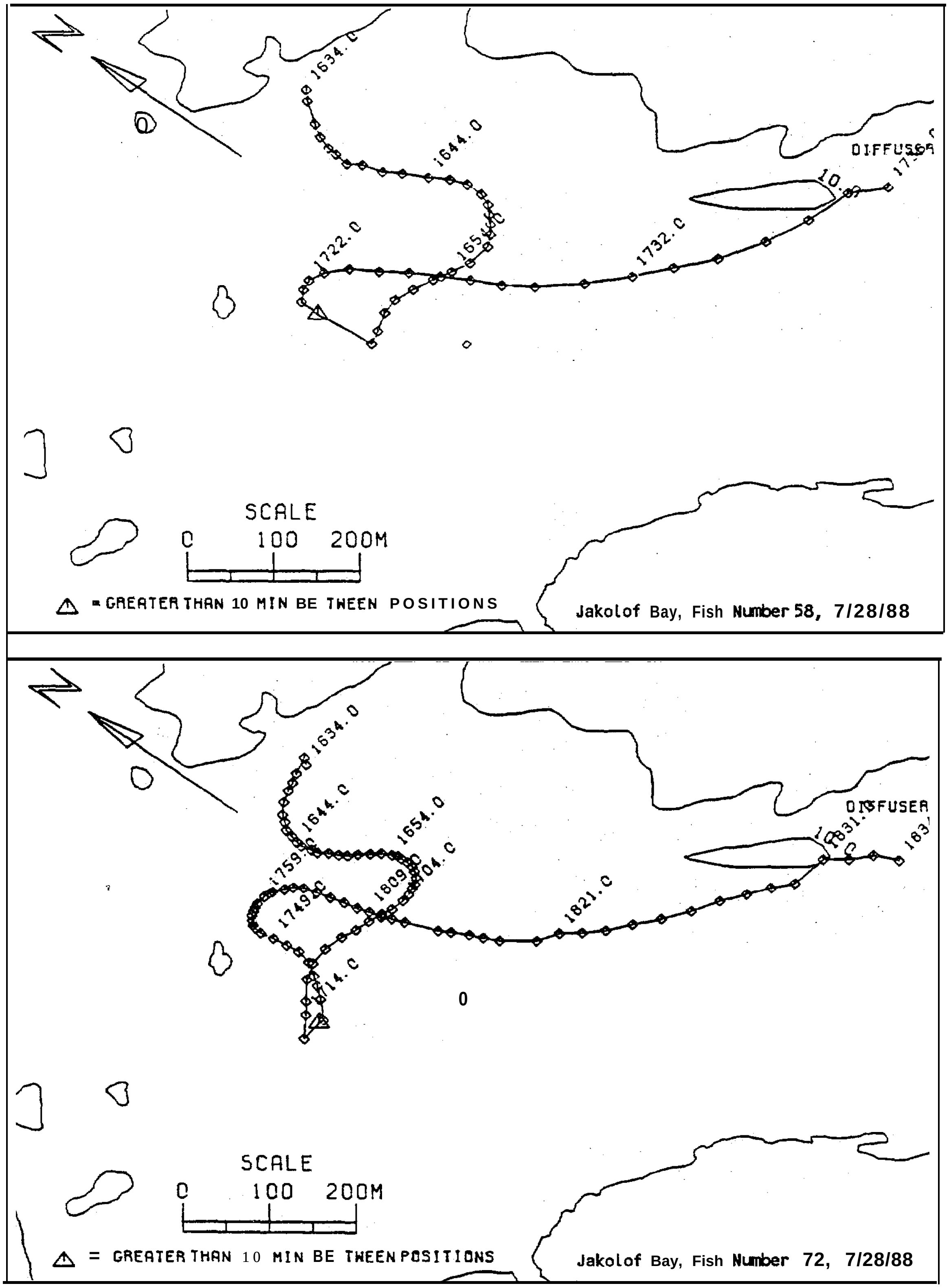


Figure 2. Horizontal movements of fish numbers 58 and 72 during Control 3.

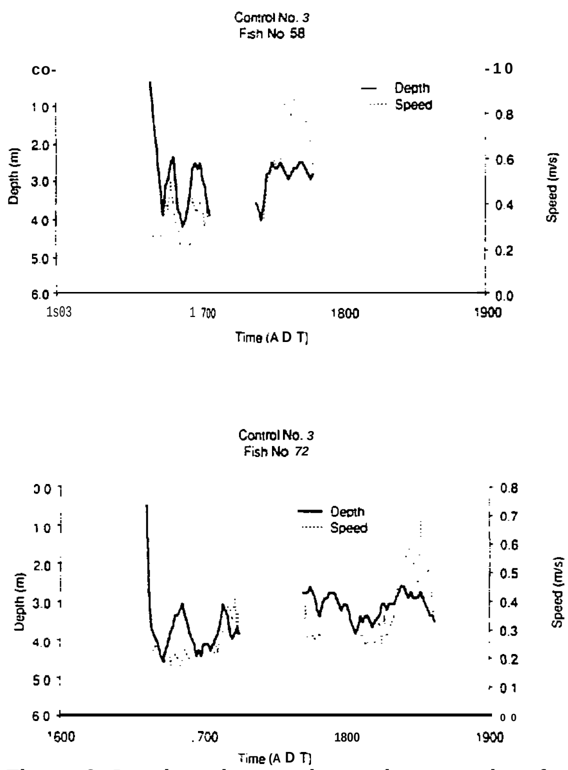


Figure 3. Depth and ground speed versus time for fish numbers 58 and 72 during Control 3.

initially through low hydrocarbon concentrations (i.e., near 1.0 ppb) along the plume edge and finally through uncontaminated waters outside the plume (Figure 4). The location of the return route was similar to the return route fish used during the control experiments, indicating that the home stream cue was not completely contaminated by the hydrocarbon plume.

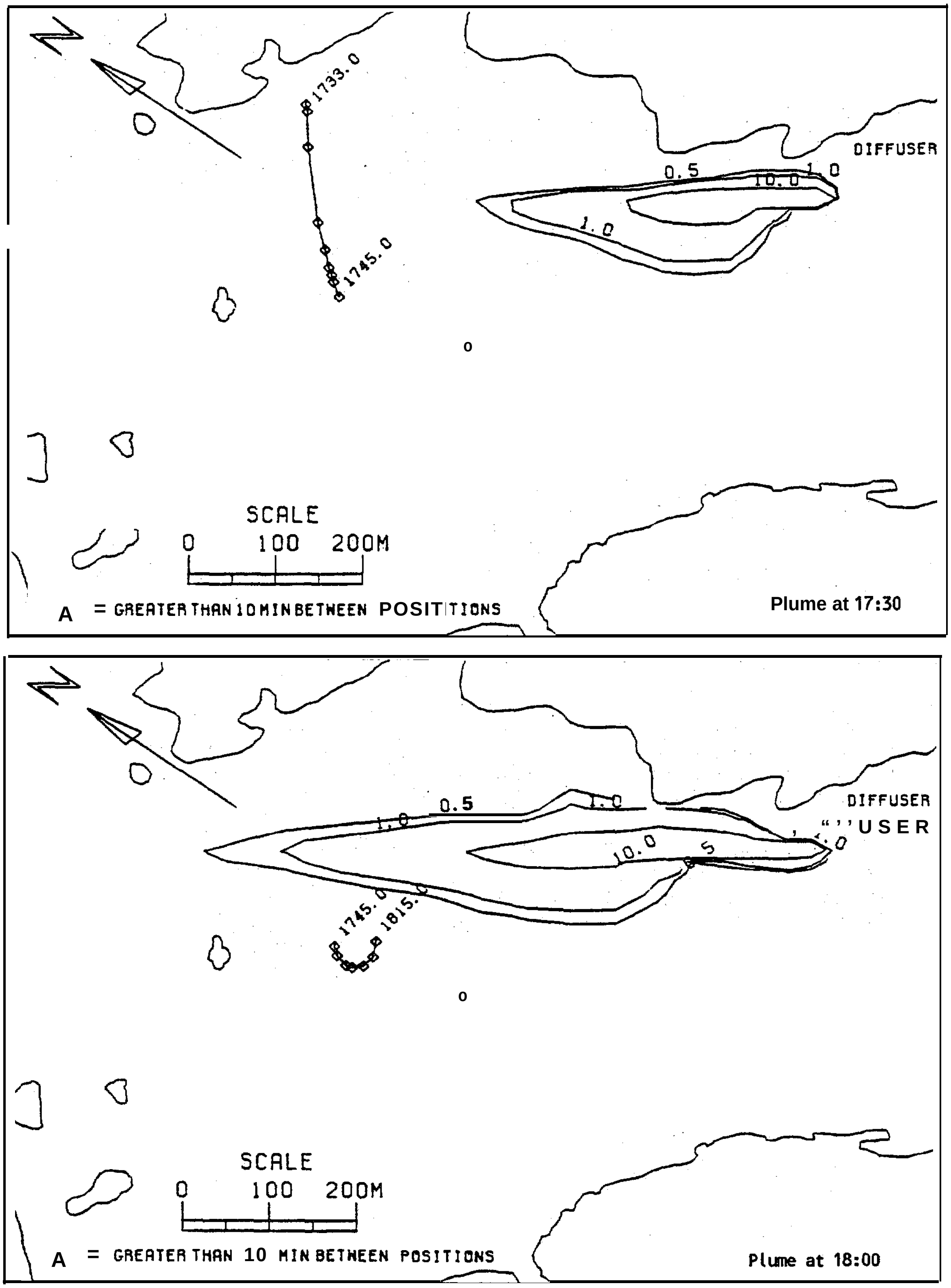
The change in movement behavior and the resulting delay of the return migration after oil exposure is thought to be a result of disorientation, which may have been caused by chemosensory impairment. This conclusion is based on the following evidence:

A consistent display of negative rheotactic movements by salmon exposed to oil suggests the fish were unable to detect the return route (home stream cue) and thus headed downbay in search of home water. Previous research has found that if salmon lose the home stream cue during upstream migration they will return downstream until they find the home water.

The inability of salmon exposed to oil to detect the home stream cue even though search movements outside of the plume crossed the eventual return route suggests that the chemosensory capabilities may have been impaired. The duration of impairment was temporary, as indicated by the eventual successful return toward the home stream. This type of response, however, corresponds with the chemosensory degradation seen in Phase 1.

These findings suggest that pink salmon encountering an oil spill along their migratory routes may not be exposed to levels causing tainting or mortality. Instead, disorientation from low hydrocarbon concentrations could cause the fish to retreat along the migratory route until orientation was re-established. Continued attempts to migrate through the spill would probably fail as long as the migratory route remained contaminated, This failure may result in a delay in migration that could have a significant effect on spawning time and subsequent survival of offspring, or it could cause straying to other streams where survival probability would be lower,

The conclusions of this study should be viewed with caution because they are based on a small amount of information. Further research is necessary to verify the consistency of the avoidance/disorientation response of salmon to low hydrocarbon concentrations, to determine the behavior and fate of salmon encountering a spill that contaminates either the entire width or a portion of the migratory route, and to investigate olfactory responses at exposure levels (concentration and duration) observed in this study.



Ftgure4. Horizontal movements of fish number 73 and plume trajectories at time intervals during Treatment 3.

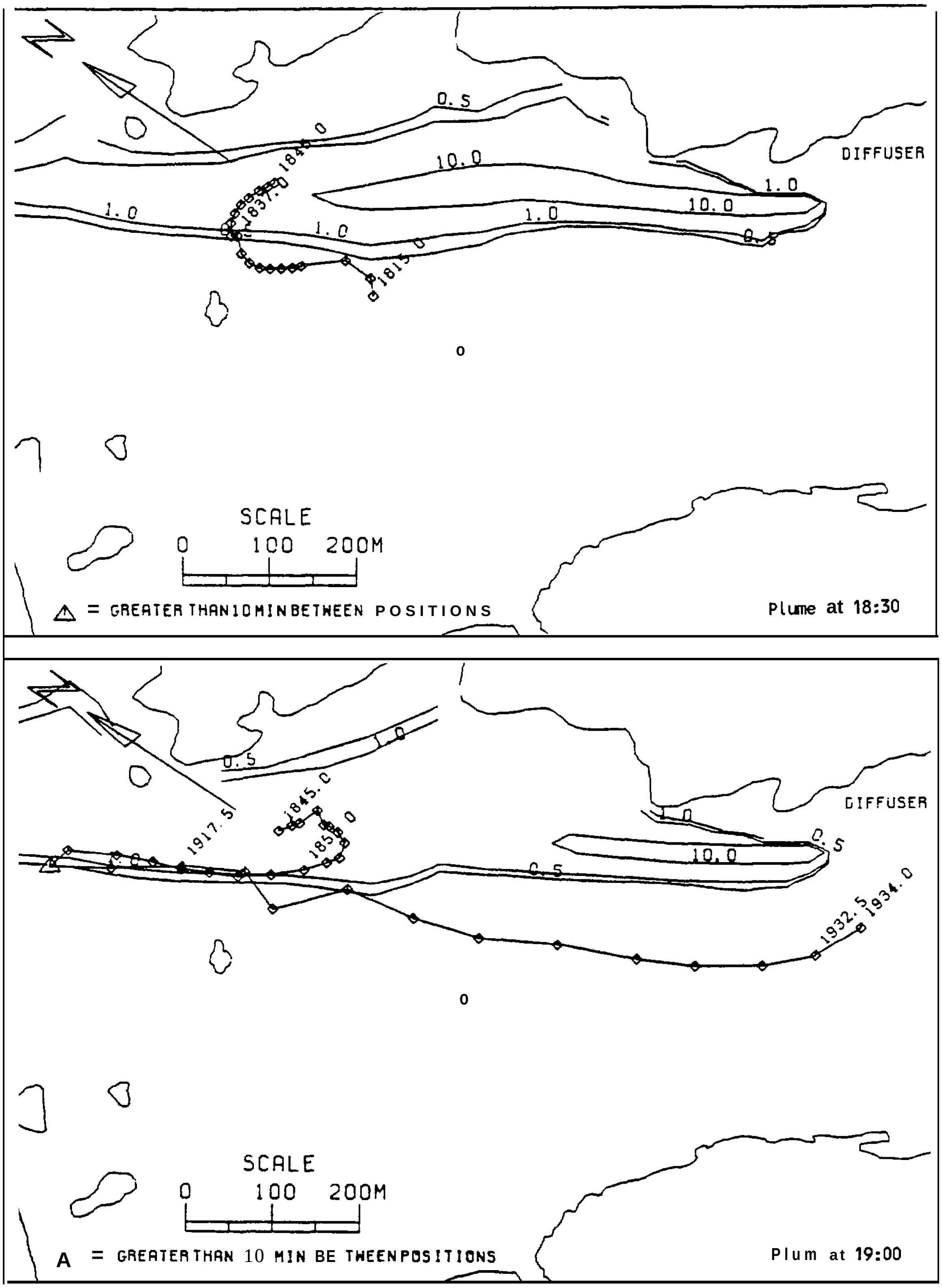


Figure 4. (Cent).

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Dr. Douglas Martin is an environmental consultant and principal at Pentec Environmental, Inc., Edmonds, WA. His research interests are in salmonid ecology and habitat restoration in freshwater and estuaries. He received his B.S. in water resource management from the University of Wisconsin, Stevens Point and his M. S.and Ph.D. in fisheries science from the University of Washington

Dr. Douglas Martin and Mr. Clifford Whitmus are fisheries biologists and environmental consultants for Pentec Environments/,inc., Edmonds, Washington.

Dr. Ian Austin is a physics/ oceanographer and consultant for Dames & Moore, Los Angeles, California.

Mr. Lon Brocklehurst is an electronics an acoustics expert with LabCor Systems, Olympia, Washington.

Dr. Ahmad Nevissi is a research chemist with the Laboratory of Radiation Ecology, University of Washington, Seattle, Washington.

QUESTIONS AND DISCUSSION

Rick Gustin: i was wondering what your ideas would be about a salmon stream that was heavily oiled before, during and after the spawning season? Do you have any thoughts about what that fish might do when the stream that it is actually going to go and dig redds in is emitting high levels of hydrocarbons?

Doug Martin: Yes, and that was one of the questions from the *Exxon Valdez* **obviously, the contamination of those intertidal spawning areas. You have to remember this particular experiment was done with the volatile fractions of crude oil, the benzenes, tolulenes, the types of things that are more soluble and can get into the water and they don't last a iong time. You'll have to find some chemists to give you some ideas, but i don't believe you are talking more than several days or maybe a week if it is a huge spill. I think when you get to something like Prince William Sound or something akin to that, that all of these volatiles are probably gone. But I couldn't teii you if those fish are going to respond to those other compounds that are there for a long period of time.**

Rick Gustin: So you think that it is mainly the volatiles they are responding to in your study and you don't really have any thoughts on what would be left after the volatiles have evaporated, how that might affect them?

Doug Martin: No, and we do know that types of compounds that are in the volatiles actually cause this narcosis of organs. i believe that the other types of the more heavy compounds that you find after longer periods of exposures of oiis don't cause that. Here, I believe the whole response that we saw was actually narcosis of the chemosensoty capability. That is why the fish became disoriented.

PUFFINS AS SAMPLERS OF JUVENILE POLLOCK AND OTHER FORAGE FISH IN THE GULF OF ALASKA[1]

Scott A. Hatch and Gerald A. Sanger
Alaska Fish and Wildlife Research Center
U.S. Fish and Wildlife Service
1011 East Tudor Road
Anchorage, Alaska 99503

INTRODUCTION

Puffins feed mostly fish to their young, and they usually depend on one or a small number of prey species for the bulk of the chicks' diet. Not infrequently, those key prey species are also subject to commercial harvest by man, leading to potential conflicts between fisheries management and seabird conservation. Capelin (*Mallotus villosus*) and Pacific sandlance (*Ammodytes hexapterus*) are important foods of puffins in Alaska (Wehle 1983, Hatch 1984, Baird 1990), but neither species is presently targeted by commercial fisheries. In contrast, walleye pollock (*Theragra chalcogramma*), a species of considerable importance to puffins, currently supports the world's largest single-species fishery (Lloyd and Davis 1989). A pollock fishery in the Gulf of Alaska developed rapidly after 1980, when a large spawning concentration was discovered in lower Shelikof Strait between Kodiak Island and the Alaska mainland (Figure 1; Kendall et al. 1987). Spawning peaks in early April, and the southwesterly drift of eggs and larvae is such that juvenile pollock are potentially available to puffins and other seabirds along the Alaska Peninsula in mid-summer (Kendall and Picquelle 1989, Hinckley et al. 1991).

We sampled puffins at colonies in this region over three years to determine patterns of prey use during the nestling period. The emphasis was on tufted puffins *Fratercula cirrhata*, but we also obtained material from homed puffins *F. corniculata* in two colonies.

METHODS

Between 1985 and 1987, we sampled the diets of nestling puffins in 13 colonies from Middleton Island, north-central Gulf of Alaska, to Tangagm in the Baby Islands near Unimak Pass (Figure 1). Collections were limited in 1985 to Suklik Island (Semidi Islands), where both puffin species were available for sampling. The following year we visited Suklik and 11 additional colonies of tufted puffins. In 1987 we reduced the sampling scheme to emphasize sites in the region of heaviest pollock use in 1986.

Most sampling occurred in 2 to 3 weeks from mid to late August. The principal method we used to collect chick meals was to block the entrances of puffin burrows with screens of galvanized hardware cloth. Puffins returning to blocked burrows dropped their bill loads at the entrances. Food samples were washed, fixed in 5% buffered formaldehyde solution for 12 to 24 h, then stored in 50% isopropanol for later examination in the lab. In the lab, prey were identified to the lowest possible taxon, measured to the nearest mm, and weighed to the nearest 0.1 g.

RESULTS AND DISCUSSION

Tufted puffins fed their chicks a greater variety of prey than horned puffins, the latter being primarily a sand lance feeder (Figure 2), In all, tufted puffins took 32 fish species and seven kinds of invertebrates, including two species of polychaetes, two euphausiids, shrimp, octopus, and squid, We found 13 species of fish and 2 invertebrates (euphausiids and squid) in homed puffin food loads. The average screen load in both species weighed about 7 g and contained 6 to 7 prey items.

[1]Condensed from Hatch and Sanger 1992.

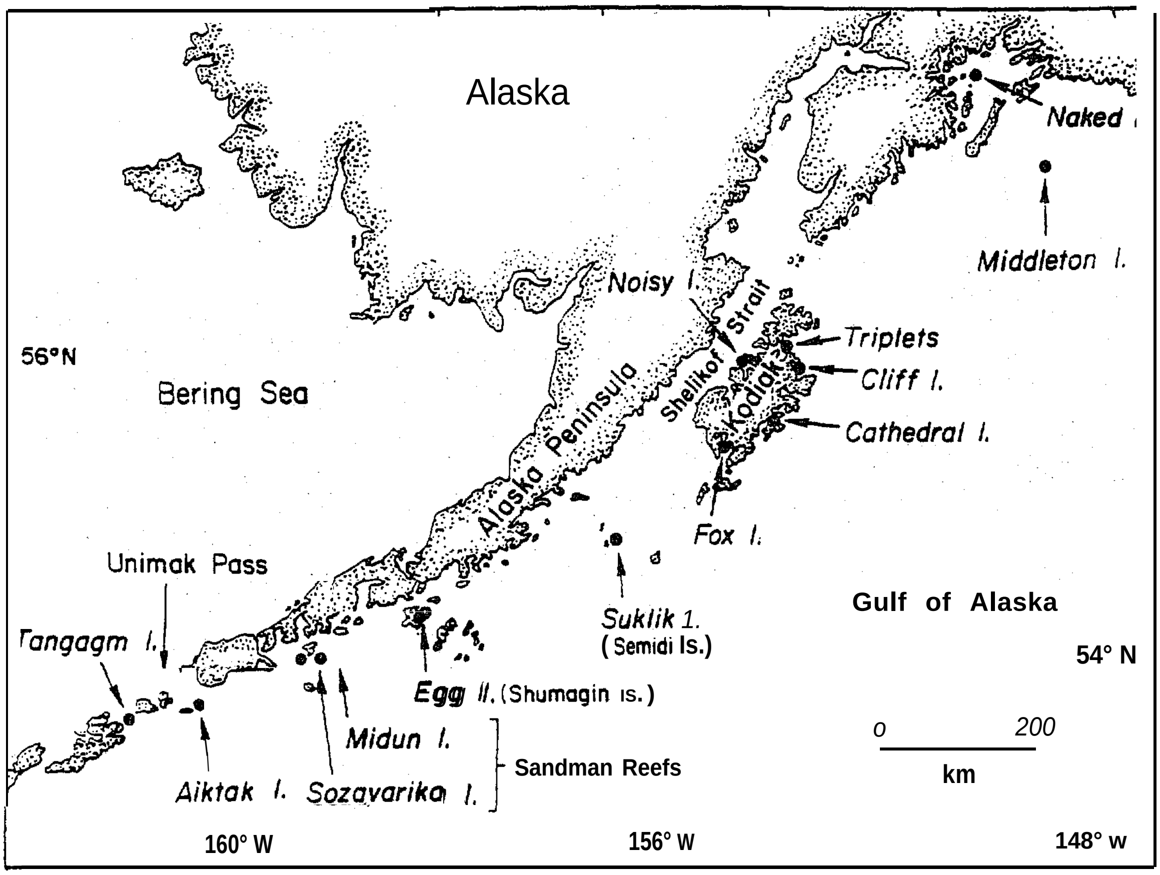
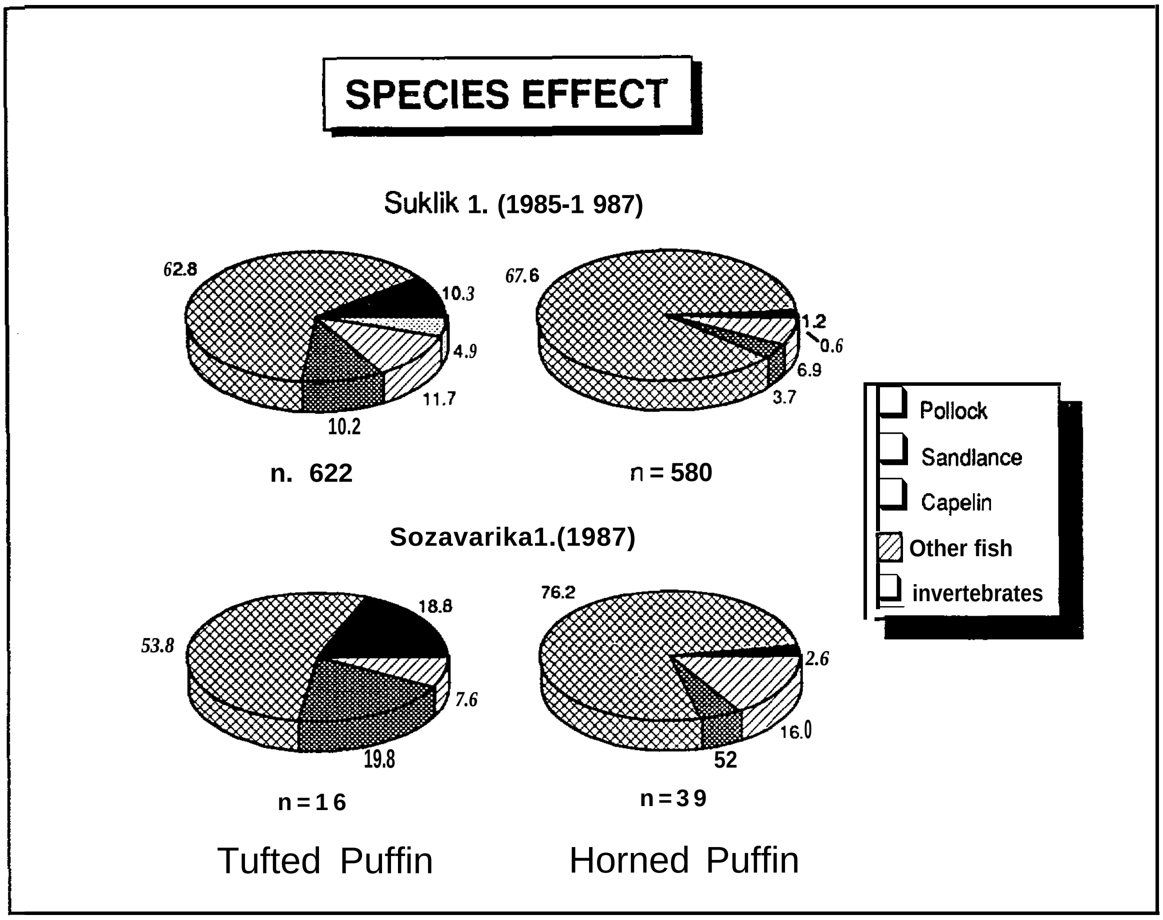


Figure 1. Wastern Gulf of Alaska and eastern Aleutian Islands, indicating sampling sites for puffin diet studies and other locations mentioned in the text.

The most important prey of tufted puffins were sandiance, capelin, and walleye pollock. The dominant prey species at a given colony was usually the same in different years, but differed markedly among sites: sandlance at Suklik (Semidi Islands), capelin at Egg Island (Shumagin Islands), and pollock at Midun and Aiktak (Sandman Reefs and eastern Aleutians, respectively) (Figure 3),

Combining data from four colonies (Suklik, Egg, Midun, and Aiktak islands) in 1986 and 1987, we found shifts in the relative amounts of sandlance, capelin, and pollock consumed by tufted puffins (Figure 4). Although these three species comprised about 87% of the diet in both years, the decrease in the proportion of pollock taken (20% in 1987 versus 40% in 1986) was compensated for by increased amounts of sandlance (1 O%) and capelin (1 0%).

To estimate total pollock consumption by tufted puffins during chick-rearing in the Gulf, we divided the region into areas of light, moderate, and heavy pollock use (Figure 5). Area 1 includes colonies from the north-central Gutf and Prince William Sound through the Kodiak archipelago, Area 2 is bounded approximately by the Semidi Islands and Shumagin Islands, and Area 3, with the heaviest pollock use and largest puffin population, extends from the Sandman Reefs through the eastern Aleutians. Our calculations make the assumptions that adult and nestling diets were similar and that a puffin's daily energy requirement i's consistent with the allometric equation for cold water seabirds using flapping flight (Birt-Friesen et al. 1989). Data on pollock use in ail three areas are available from 1986. About 25,000 mt of food were consumed in Area 3 over the chick-rearing period in 1986, of which about 17,600 mt were

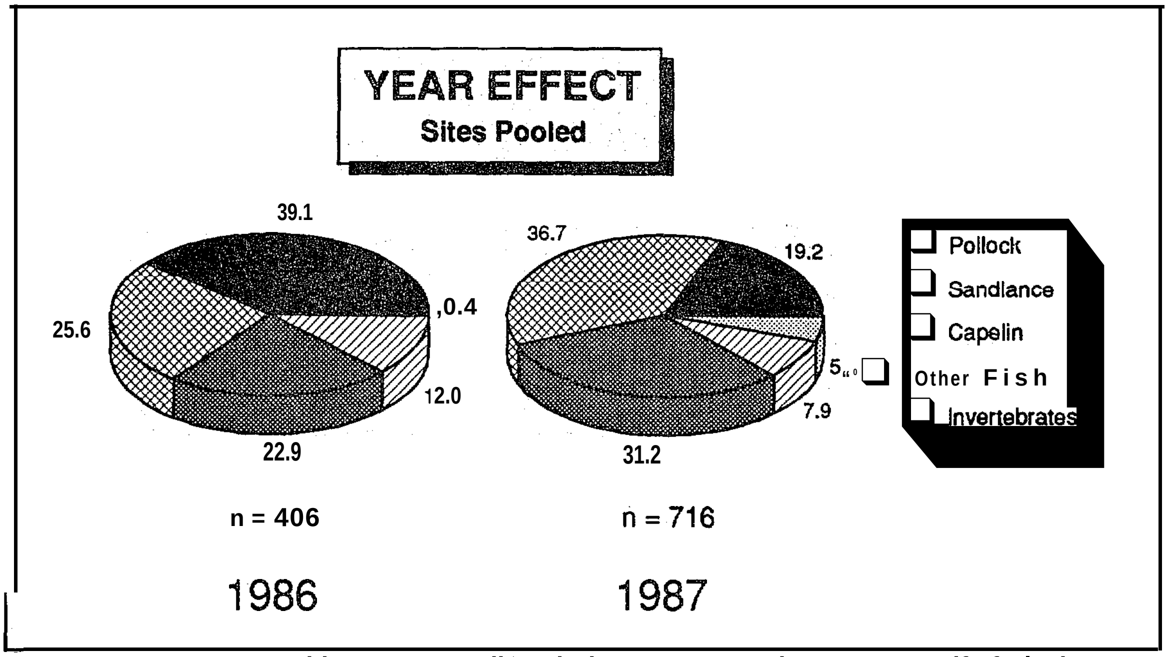


igure 2. Percent composition of tufted and horned puffin nestling diets at two colonies in the western Gulf of Alaska. Data from three years on Suklik Island are pooled for the comparison of species.

pollock. Based on the mean fresh weight of individual pollock observed in this study (1.6 g), that is equivalent to 10.7 x 109 juvenile pollock removed by puffins. Similar calculations for Area 1 (1 % dietary pollock) and Area 2 (6% pollock observed at Suklik and Egg islands in 1986) give respective estimates of 84 mt and 440 mt of pollock consumed from mid-July to mid-September. Total pollock mortality from tufted puffin predation throughout the Guif is estimated at 11.0 billion juveniles.

A provisional test of puffin diets as an indicator of juvenile pollock abundance uses data from the Semidi Islands, the only site visited in all three years. The Semidis are thought to be within the main nursery area for pollock produced in Shelikof Strait, and estimates of seasonal pollock abundance are available from recent fishery research in the area (Kendall et al. 1987, Kendall and Picquelle 1989, Schumacher and Kendall 1989, Hinckley et al. 1991).

The proportion of pollock in tufted puffin diets at the Semidi Islands was relatively high (21%) in 1985 and low (5%) in 1986 and 1987. Trawl surveys for young of the year conducted by the National Marine Fisheries Service in September 1985-1987 provide similar estimates of relative cohort size (Table 1). There is agreement as well with the results of a 1989 bottom trawl survey and with model estimates of pollock cohort size based on survey results and information on fishing mortality (Hollowed and Megrey 1990). Thus, the relative measures of fishable stock size were accurately predicted by puffin diets at the Semidis.



igure 3. Percent composition of nestling diets during two years in the western Gulf of Alaska. Data from four sites (Suklik, Egg, Midun, Aiktak) are pooled for the comparison of years.

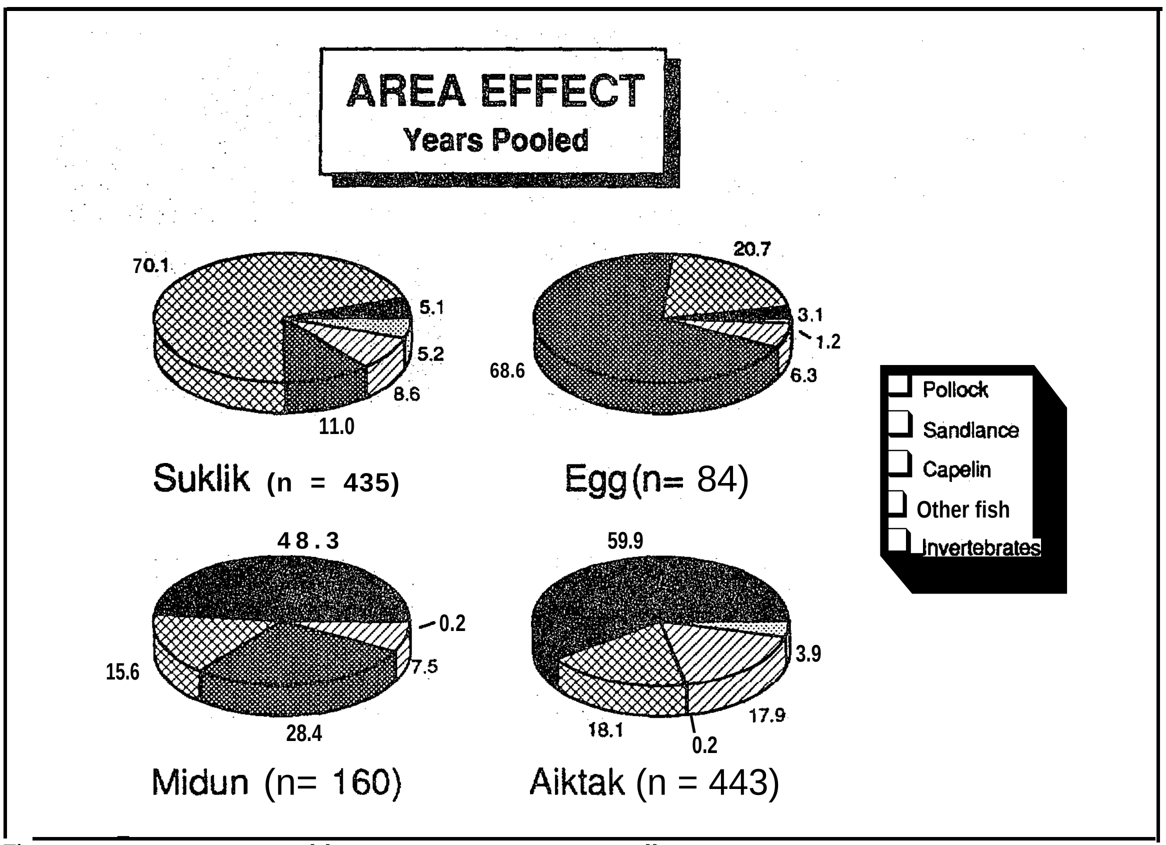


Figure 4. Percent composition of tufted puffin nestling diets at four colonies sampled in two years. Data from 1986 and 1987 are pooled for the Comparison of sites.

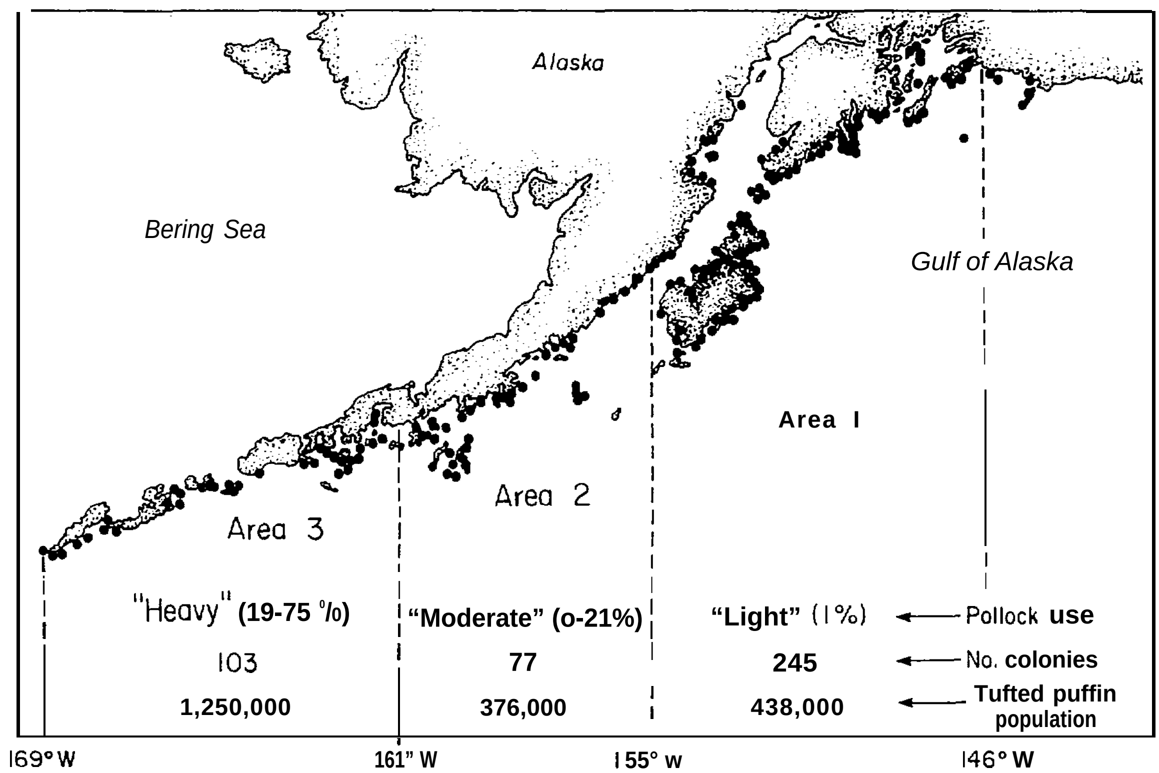


Figure 5. Distribution of colonies, abundance, and pollock use by tufted puffins in the western Gulf of Alaska. Information on puffin numbers from Sowls et al. (1978) and unpublished data of the U.S. Fish and Wildlife Service.

The use of seabirds as indicators of fish stocks is frequently suggested (Anderson et al. 1980; Sunada et al. 1981; Crawford et al. 1963; Cairns 1987; Montevecchi and Berruti, in press) but difficult to carry beyond the conceptual stage (Berruti 1985). We are optimistic that puffins can provide useful information on walleye pollock, including early indications of year-class strength. Because puffin colonies are numerous throughout the Gulf (Figure 5), there are many potential sampling sites for monitoring the distribution and abundance of juvenile pollock. By the middle of July, the emergence of schooling behavior makes it difficult to monitor juvenile fish by conventional acoustic or net sampling methods (Hinckley et al, 1991). In contrast, puffins appear to be effective samplers at this stage, The time frame for sampling afforded by puffins is good because Bailey and Spring (in press) found that of two alternative abundance indices they examined (larvae and Age-O juveniles) the cohort strength of first-year pollock in late summer was most effective for predicting recruitment at Age 2.

SUMMARY

We sampled the nestling diets of tufted puffins *Fratercula cirrhata* and horned puffins *F. corniculata* in three years at colonies from the north-central Gulf of Alaska to the eastern Aleutian Islands. The importance of juvenile pollock in the diet of tufted puffins varied geographically from little or no use in the north-central Gulf and Kodiak areas to moderate use (5 to 20%) in the Semidi and Shumagin islands to heavy use (25 to 75%) in the Sandman Reefs and eastern Aleutians. An estimated 11 billion pollock were consumed by tufted puffins throughout the region in 1986, The proportion of pollock in puffin diets at the Semidi Islands was strongly correlated 'able 1. Estimates of pollock year-class strength for the Gulf of Alaska, 1985 to 1987.

Year class	Tufted Puffin diet Semidi Is.. (% weight)	Fall Y-O-Y survey (abundance index, billions)[a]	1989 bottom trawl survey (% at age)[b]	Stock synthesis model estimates (billions)[b]	
				Model A[c]	Model B[d]
1985	20.7	22.1	21.4	2.010	0.589
1986	5.2	6.2	4.2	0.426	0.120
1987	5.1	9.7	5.6	0.406	0.089

[a] Young of the year (Y-O-Y) survey data" from Bailey and Spring (in press).

[b] From Hollowed and Megrey (1990).

[c] Model emphasis on bottom trawl survey results.

[d] Model emphasis on hydroacoustic survey results.

with independent estimates of cohort strength in three years, Puffins may thus provide a useful index of distribution and year-class abundance of first-year pollock, a species that currently supports an important commercial fishery in the Gulf of Alaska,

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Dr. Scott Hatch has worked for the U.S. Fish and Wildlife Service in Alaska for 17 years and presently serves as Team Leader for Seabird Research in the Alaska Fish and Wildlife Research Center. His main research interests are the feeding ecology and population dynamics of Pacific seabirds. Dr. Hatch received his B.S. in wildlife science from the University of Washington, his M.S. in wildlife management from the University of Alaska, and his Ph.D. in zoology from the University of California at Berkeley.

Mr. Gerry Sanger received his B.S. in fisheries from Humboldt State University and worked for 13 years as an oceanographer and wildlife biologist with the University of Washington and National Marine Fisheries Service in Seattle. In 1975 he transfered to the Fish and Wildlife Service in Alaska and served as a Supervisory Wildlife Biologist until 1986. He currently operates a water taxi business in Prince William Sound and continues his interest and involvement in marine bird research.

QUESTIONS AND DISCUSSSION

Tom Newbury: Do you know how deep they dive when they feed? You mentioned that they get the euphausiids, squid, and octopus. Squid in particular are usually down fairly deep.

Scott Hatch: Yes, except I would suppose that in the early morning, during the night certainly, squid are closer the surface and there is considerable crepuscular feeding, if you will. In puffins there tends to be a big mode of food deliveries early in the morning, just after first light, Although I have never tested for diurnal variation in the occurence of squid, I would suspect that you would have more squid early in the morning than in mid-afternoon. As far as how deep they go, I think 50 to 60 m might be fairly characteristic of tufted puffins, It depends on body size, The tufted puffin would be a deeper diver than the horned puffin, but 50 or 60 m would be about as deep they would typically go, John Piatt may be able to shed more light on that later. He's got some data on that point for these alcids and others.

Steve Treaty: When you projected that the fishery could be affected by the predation on small pollock by puffins, did that take into account sufficiently the non-puffin related mortality that would naturally occur between the time that they were this size and the time that they were the size that the fishery would take them?

Scott Hatch: No, it does not take account of that because I know of no way to do that. You are talking about the possibility of compensatory mortality; that if the puffins didn't get them, something else will. I suspect that is largely the truth, We are simply trying to assess what is the total take of juvenile pollock by puffins in a numerical sense and comparing that with total numbers of pollock out there. And again, I have to leave it to fisheries managers to comment on the importance of this predation. I might point out one statistic, I computed 12 billion pollock consumed by tufted puffins in the Gulf, as compared with 400 billion pollock, age O juveniles, that are thought to be cannibalized in a typical year in the eastern Bering Sea, Those seem like pretty disparate numbers, Of course the stock of pollock in the Bering Sea is a least ten times larger than in the Gulf, So the kind of figures that I am talking about have to be viewed in the context of a smaller population of pollock in the Gulf of Alaska, and also possibly less cannibalism. For whatever reason, adult pollock seem to be less cannibalistic in the Gulf of Alaska.

ADULT SURVIVAL OF BLACK-LEGGED KITTIWAKES ON MIDDLETON ISLAND, ALASKA[1]

Scott A. Hatch, Bay D. Roberts, and Brian S. Fadely
Alaska Fish and Wildlife Research Center
U.S. Fish and Wildlife Service
1011 East Tudor Road
Anchorage, Alaska 99503

INTRODUCTION

Black-legged kittiwakes are widely distributed in the subarctic North Pacific and adjacent seas, with a total breeding population of 2 to 3 million individuals. Since the mid 1970s this species has been studied more intensively than other seabirds in Alaska because its colonies are conspicuous and easy to observe. Population monitoring and studies of breeding biology have been conducted with some regularity at sites scattered throughout most of the species' breeding range in the northeastern Pacific.

Compared to their counterparts in certain areas of the northeastern Atlantic, kittiwakes in Alaska are notably unproductive (Hatch et al. in press). The mean of 160 colony-years of data available through 1989 was 0.31 chicks nest-' year-'. By contrast, annual productivity at some colonies in Britian averages over 1 chick nest-'. There appears, moreover, to be a declining trend in the productivity of Pacific colonies, as shown by recent 5-year means (Table 1), In the period from 1985-1989, productivity averaged only 0.19 chicks nest'. On Middleton Island, in the north-central Gulf of Alaska, breeding has been a virtual failure in 7 of the last 9 years (1983-1991), and productivity has averaged fewer than 0.2 chicks nest' in 12 years since 1978.'

Table 1. Productivity of black-legged kittiwakes in Pacific colonies since 1960.

Parameter	1960-1973	1975-1979	1980-1984	1985-1989	Overall
M (colony-years)	8	47	36	69	160
Failures[a]	3 (38%)	9 (19%)	16 (44%)	35 (51%)	63 (39%)
Productivity (young nest-')	0.51	0.45	0.36	0.19	0.31

[a]Failure defined as an instance in which a colony produced ≤ 0.1 chicks nest-'.

Our objective in this study was to answer the question whether low productivity in Pacific kittiwakes is offset by comparatively high adult survival and longevity.

METHODS

We measured adult survival rates in the colony of kittiwakes on Middleton Island. The Alaska earthquake of 1964 raised this island about 4.5 m, exposing large areas of previously submerged land (Figure 1). Today, kittiwakes nest on relatively gradual, soil-covered slopes on the east side of Middleton, where the accessible terrain made it possible to capture large numbers of birds with successive firings of a rocket net. We captured and marked about 700 individual kittiwakes during this study, Each bird was given a unique combination of three colored plastic bands on one leg and a standard USFWS metal band on the other leg.

During four years (1988 to 1991) we observed study plots closely over several weeks in spring to record the annual return of surviving kittiwakes. We present simple binomial estimates

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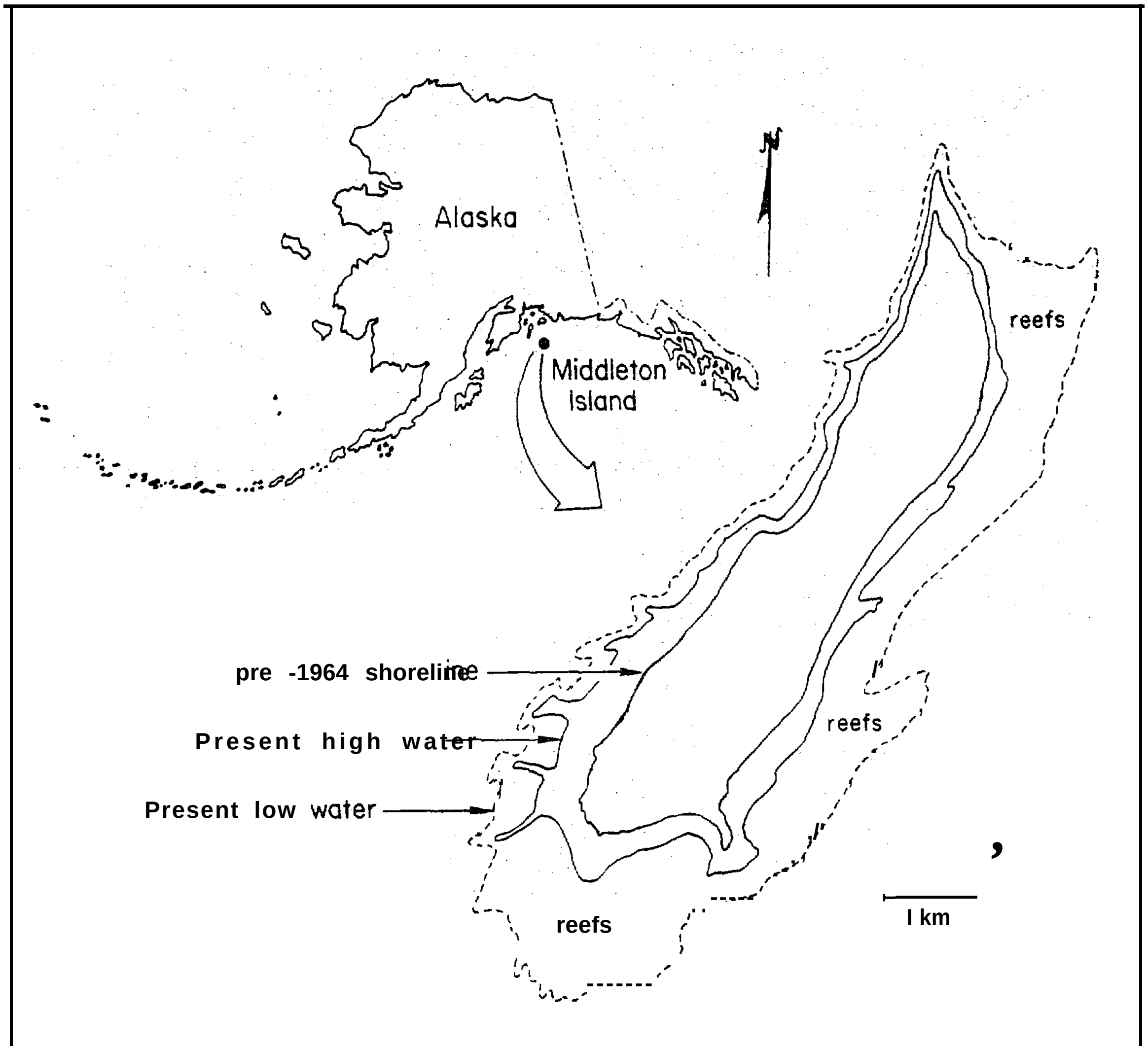
[1]Condensed from Hatch et al. (submitted).



gure 1. Location map of Middleton Island in the north-central Gulf of Alaska.

of survival, because our refighting effort was thorough enough (refighting probabilities >99%) as to obviate the use of Jolly-Seber or related models (Pollock et al. 1990).

RESULTS AND DISCUSSION

Kittiwakes averaged between 91% and 95% annual survival, with no significant differences between males and females (Table 2), There was a suggestion of a downward trend in survival rates over the years from 1988 to 1991, although even the lowest and highest of the annual estimates did not differ significantly.

When the return rates are broken down according to whether the individuals observed each year were breeding or not breeding the year before, the estimates of survival for breeders tend to be higher than the estimates for nonbreeders (Table 3). The apparent difference between groups is likely due to nonbreeders having a greater tendency to move off the study plots and thereby escape detection.

Table 2. Estimated annual survival of breeding black-legged kittiwakes on Middleton Island in four years (samples sizes in parentheses).

Year	Males	Females	Overa11
1988[a]	0.962 (159)	0.952 (125)	0.945 (292)
1989	0.934 (121)	0.941 (102)	0.938 (225)
1990	0.900 (100)	0.948 (77)	0.916 (179)
1991	0.904 (94)	0.920 (88)	0.913 (184)

[a] Samples include nonbreeders in 1988.

Table 3. Return rates of breeding and non-breeding kittiwakes, showing the effect of breeding status on the estimation of survival (samples sizes in parentheses).

Year	Breeders	Nonbreeders
1989	0.938 (225)	0.833 (42)
1990	0.916 (179)	0.902 (41)
1991	0.913 (184)	0.842 (19)

For life table calculations, we require a single best estimate of mean adult survival in this population of kittiwakes. That estimate is 92.5% of adults surviving per annum when we pool all the data for breeding birds of both sexes over a 4-year period. Annual survival of 0.925 gives a projected life expectancy of 12.8 years. With a productivity of just 0.168 chicks nest' year' (the 12-year mean from Middleton Island), a pair of kittiwakes would raise 2.16 chicks in a lifetime and, at equilibrium, 2 of those young (93%) would have to survive to breed at a mean age of about 5 years (Wooller and Coulson 1977). That requires an annual surival rate of juveniles averaging nearly 98% over the prebreeding period, which is higher than adult survival, and highly unlikely. We therefore conclude that this population should be declining.

There have been numerous censuses of kittiwakes on Middleton Island over the years, and counts have been done almost annually since 1981 (Figure 2). While there is considerable year-to-year noise in these counts due to annual variation in breeding effort, the population on average is showing atypical exponential rate of decline. Based on the 1981 and 1991 population estimates, we computed the instantaneous rate of decline using a simple model for exponential decay (Table 4). This also yields an estimate of lambda, the finite rate of population change per year over the last decade. The observed rate of replacement is 0,927, i.e., the population each year averages 7.3% smaller than the year before. This rate of decline is almost precisely as predicted for a population with mean adult survival of 0.925 and no recruitment. Given the poor fledging success observed on Middleton Island and the likelihood of high post-fledging mortality of juveniles, it is reasonable to assume little or no recruitment to this colony. Thus, the population trend of kittiwakes on Middleton is consistent with recent measures of productivity and survival.

Life table calculations for kittiwakes elsewhere in Alaska are equivocal. If survival rates observed on Middleton apply generally, then the near-term future of Pacific kittiwakes hinges on whether recent levels of productivity (19S5-1 989, Table 1) persist or improve. With an annual productivity of 0.19 chicks pair-', the Pacific population should decline, whereas productivity of 0.31 young pair' (the grand mean from Table 1) predicts a mean juvenile survival rate at equilibrium of 0.871 and a minimum first-year survival of 0.687. Those values are arguably within the expected range — e.g., Coulson and White (1959) estimated first-year survival to be 0.79 in one British colony.

SUMMARY

Black-legged kittiwakes in Alaska are conspicuously unproductive (0.31 chicks nest') compared with their counterparts in portions of the northeastern Atlantic (> 1.0 chick nest'). Some colonies are failing chronically (e.g., few or no young were produced on Middleton Island, north-central Gulf of Alaska, in 7 of the last 9 years). We measured adult survival rates on Middleton to see if low productivity is offset by long life in the Pacific. Breeding males averaged 92.8'% annual survival in 4 years; females averaged 93.7?! survival. Mean survival for the sexes

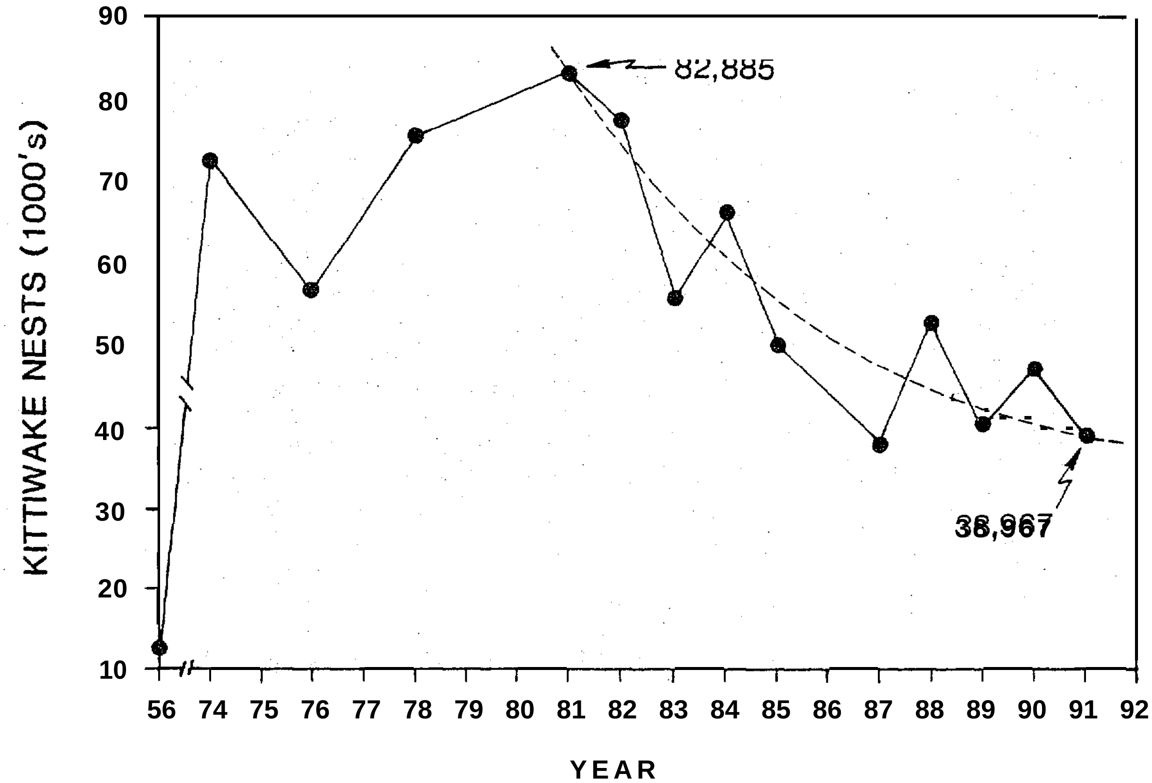


Figure 2. Nest counts of kittiwakes on Middleton Island showing a downward trend since 1981.

combined was 0.925, corresponding to 12.8 years adult life expectancy, Having little or no recruitment, the Middleton colony is expected to decline at a rate reflecting annual adult mortality. This was confirmed by an observed decline averaging 7.3% per year since 1981. The near-term future of other Pacific colonies depends on whether recent declines in productivity are temporary or persistent,

Table 4. Observed and predicted rates of decline for the population of kittiwakes on Middleton Island.

Observed rate of decline:

1) N_t = NO e^{rt}

2) NO = 82,8%5

N_{10} = 38,967

3) r = -0.0755

4) $\lambda = e^r$

5) A = 0.927

Predicted rate of decline:

With no recruitment, rate of decline = adult survival rate (γ)

$\lambda = \gamma = 0.925$

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Dr. Scott Hatch has worked for the U.S. Fish and Wildlife Service in Alaska for 17 years and presently serves as Team Leader for Seabird Research in the Alaska Fish and Wildlife Research Center. His main research interests are the feeding ecology and population dynamics of Pacific seabirds. Dr. Hatch received his B.S. in wildlife science from the University of Washington, his M.S. in wildlife management from the University of Alaska, and his Ph.D. in zoology from the University of California at Berkeley.

Ms. Bay Roberts received her B.A. in biology from the University of California at Santa Cruz and her M.S. in biology from UC Santa Barbara. Since 1988 she has worked as a Wildlife Biologist with the U.S. Fish and Wildlife Service, Alaska Fish and Wildlife Research Center. Her main interests are seabird population dynamics and behavioral ecology.

Mr. Brian Fadely worked as a Wildlife Biologist at the Alaska Fish and Wildlife Research Center (USFWS) from 1988 to 1991. He received his B.S. in biology and M.S. in marine science from the University of California at Santa Cruz, and is currently enrolled there as a doctored student in marine science. His principal area of research interest is the physiological ecology of marine mammals and birds.

QUESTIONS AND DISCUSSION

Tom Newbury: You didn't say what you thought caused the increase of the number of nests on Middleton and what is causing the decline?

Scott Hatch: The increase is something that is historical and we weren't thereto observe. I can make a speculation: one intervening event was the Alaska earthquake which changed, 1 suspect, not only the physiography of the island but also of the surrounding areas. That is a fairly shoal area in the north central Gulf of Alaska, as you may know. It was uplifted, as I said, about 4.5 m, which created considerable shoal area around Middleton Island that may be attractive to spawning populations of sand lance, for instance. Fish populations were attracted suddenly to an area that didn't exist before. It had to have been, 1 think, a change in food supply that happened rather suddenly, and the birds responded to that. I have done some calculations elsewhere that suggests there is no way intrinsically that this population could have grown so quickly, It was immigration of adult kittiwakes from other colonies, homing in on a drastically changed food supply. Again the only dramatic event that occurred would be the Alaska earthquake. But that is pure speculation, and we don't have any of the details, As far as the decline, we have a lot of circumstantial evidence that the poor breeding productivity of kittiwakes, and certain other species in the northeastern Pacific these days, is food related. It is a food stress problem. So we can't go into too much detail, we have just a lot of circumstantial evidence. Looking at their time budgets, in particular, looking at their food habits, phenology, suggests they are not finding enough food to raise young. But as far as a physical explanation or more details as to what precisely is wrong with the food supply, we are not yet in a position to say. In talking about seabirds generally, it is food supply almost always, unless there is something else well known, that is regulating populations. So on the one hand we had a dramatic change allowing an increase, and now sort of an attrition, apparently in the food supply, that is causing a gradual decline.

Don Hansen: You said that these differences between the Atlantic and Pacific kittiwakes, that there aren't genetic differences or they haven't looked at genetic differences?

Scott Hatch: The populations are considered to be distinct subspecies. That has been questioned on the basis of considerable overlap in morphology, I would suspect that if one looked at mitochondrial DNA that one might find demonstrable differences in the gene systems between them. I am simply saying that I doubt that it is a genetically determined difference in life history characteristics that we are seeing. I think that those differences arise from differences in the environment. But the equation is there, it has got to be one or the other, My speculation is that it is environment. But no, there haven't been studies of kittiwake genetics that I am aware of.

Ray Emerson: Could you just transplant a few from each side and see how they turned out?

Scott Hatch: An exchange experiment would be a lot of fun. I don't know if that is feasible or not. I suspect that it would be difficult. You might be able to transplant young that would become established in the different populations, but to move adults back and forth, I doubt would work,

Ray Emerson: Life history changes to that particular geography would be quite interesting.

Scott Hatch: That would be the critical experiment to do.

Pamela Miller: I was just wondering what is happening with predator populations on those colonies?

Scott Hatch: Middleton Island is a very dynamic place in terms of not only seabird populations, but we have an expanding population of dusky Canada geese, And also, in respect to the other question, what is causing the decline of kittiwakes, I have to be careful here. The proximate cause of failure in kittiwakes is predation by glaucous-winged gulls. They are the primary predator on kittiwakes on Middleton Island, And that population is exploding. It is a case of classic exponential increase. If you ask what happens to all the eggs and young, well it is a simple answer, They all get eaten by glaucous-winged gulls, there is no doubt about that, But we have to be careful, because I view that as a proximate cause only. Ultimately it is a problem with the kittiwakes' food supply that is causing adult kittiwakes to not be effective breeders, They are not assiduously guarding their nests. They are not effectively defending their nests against predators. So I think that it is a food supply problem for kittiwakes, and that the gulls are just opportunistic predators. But as an important predator on seabird eggs and young, the gull is increasing dramatically on Middleton Island. When Robert Rausch was there in 1956, he had zero glaucous-winged gulls breeding on the island, and only a few non-breeders loafing on offshore rocks. By the mid-1970s, you had a population of 800 to 1000, 1400 was a census figure I got in 1978. At the present time, I forget the exact value, I believe it is 16,000 to 18,000 glaucous-winged gulls. We have a number of censuses that when plotted show an exponential rate of increase, and the line now is heading straight up with no end in sight.

Steve Treaty: Let's assume that it is food that explains some of the differences between the Atlantic and Pacific populations. If you knew that for sure, how would you phrase it in terms of size classes of fish, or what would it mean in terms of size classes of fish or the types of fish that the nestlings eat versus the adults?

Scott Hatch: What might be wrong with the food supply in the northeastern Pacific? One possibly illuminating observation is that when we make a comparison between surface feeding birds, the kittiwakes being the prime example, and diving species which feed on much the same prey,' such as puffins, cormorants, and murres, we find in many years in the same colonies, those diving species are doing fine, raising young while the kittiwakes are failing miserably. So it seems

to be availability at the surface of key prey species at times in the breeding season when the kittiwakes rely on them. Not necessarily the total abundance of those prey, but availability. It may have to do with environmental parameters, such as sea surface temperatures affecting the vertical distribution and vertical migration patterns of some of these prey populations. That is a hypothesis that we tend to carry around and to review now and then.

MAPPING PELAGIC SEABIRD DISTRIBUTIONS IN ALASKA

John F. Piatt
U.S. Fish and Wildlife Service
Alaska Fish and Wildlife Research Center
1011 E. Tudor Road
Anchorage, Alaska 99503

INTRODUCTION

An enormous amount of data on the pelagic distribution of seabirds in Alaskan marine waters was gathered during the 1970s and 1980s under the Outer Continental Shelf Environmental Assessment Program (OCSEAP). In more recent years, private and government investigators have continued to add to this database, funded by the Minerals Management Service, U.S. Fish and Wildlife Service, and other research agencies. Recent assimilation of this data, and development of software (CAMRIS) to map seabird distributions by Ecological Consulting Inc., with support from NOAA and MMS, now makes it possible to develop integrated interpretations of seabird distribution on the continental shelf of Alaska, An example of distribution maps for tufted puffins (*Fratercula cirrhata*) and horned puffins *(F. corniculata)* on the continental shelf in the northern Gulf of Alaska are presented and discussed with regard to colony locations, oceanography and feeding ecology.

FACTORS INFLUENCING THE DISTRIBUTION OF PUFFINS

Oceanography

The physical oceanography is well-defined in the northern Gulf of Alaska (e.g., Emery et al. 1985, Johnson et al. 1988), especially along the Alaska Peninsula (Reed et al. 1980, Reed and Schumacher 1989) and in the eastern Aleutians (Favorite 1974, Truett and Kertell 1991). The system is a relatively simple one: The Alaska Current circulates in a counter-clockwise direction in the northern Gulf of Alaska. Nearshore, the Alaska Coastal Current flows southwest over the Alaska Peninsula shelf at an average rate of about 20 to 30 cm/sec. Water is deflected south to the shelf-edge near the Semidi, Shumagin, and Sanak islands. Upwellings occur around these islands, along the coast, and at the shelf edge, where the Alaska Stream also flows southwest at 100 cm/sec. The Alaska Coastal Current enters the Bering Sea through several passes in the eastern Aleutians, and currents there vary markedly (O to 400 cm/see) with tides and wind-stress. Marked seasonal and annual variations in transport, temperature, and salinity occur nearshore and offshore because of variations in baroclinic transport of the Alaska Current, and locally because of wind-stress.

Prey Fish Abundance and Distribution

The major spawning center for walleye pollock (*Theragra chalcogramma*) in the Gulf of Alaska is located in Shelikof Strait between the Kodiak Archipelago and the Alaska Peninsula (Megrey 1991). Pollock spawn in deep waters of Shelikof Strait in late March and April. Larvae hatch at depth and rise to concentrate in the upper 50 m, where they are often found in large, distinct patches. These patches are carried southwest by the Alaska Coastal Current, although some larvae are advected off the shelf and into the Alaska Stream (Kendall and Picquelle 1989). By late June and July, the center of distribution of Age-O larval and juvenile (ea. 30+ mm) pollock is between the Semidi and Shumagin islands. By August and September, juvenile pollock (ea. 50 to 130 mm) are distributed mostly southwest of the Shumagins, although the onset of schooling behavior at this time makes it difficult to map distribution and abundance patterns with confidence (Hinckley et al. 1991). Juvenile pollock are the most abundant forage fish in the eastern Aleutians in fall (Truett and Kertell 1991). Age-1 pollock (ea. 140 to 250 mm) are also widely distributed during summer and fall throughout the shelf nursery area from Kodiak to the eastern Aleutians, Knowledge of other forage fishes in this region is sparse compared to pollock, but better described than in many other areas of Alaska (e.g., Aron 1962, Trumble 1973, Dick and Warner 1982, Rogers et al. 1983, Pahlke 1985). Sandlance (*Ammodytes hexapterus*) and capelin (*Mallotus villosus*) are the dominant forage fishes in the region, where they tend to aggregate in shallow shelf waters during summer, particularly near shores of the Kodiak, Semidi, Shumagin, and eastern Aleutian islands. Juvenile Pacific cod (*Gadus macrocephalus*), greenling (Hexagrammidae), sculpins (Cottidae), and rockfishes (Sebastes spp.) are among the most abundant of some 70 fish species found on the shelf. At the shelf edge and in oceanic waters, lanternfish (dominated by the myctophid *Stenobrachius leucopsaurus*) and squid (Gonatidae) are superabundant and widely distributed throughout the area. Finally, several invertebrates, including especially *Thysanoessa* euphausiids and nereid polychaetes are often locally (e.g., Shumagin Islands, Unimak Pass) important prey for marine birds and mammals.

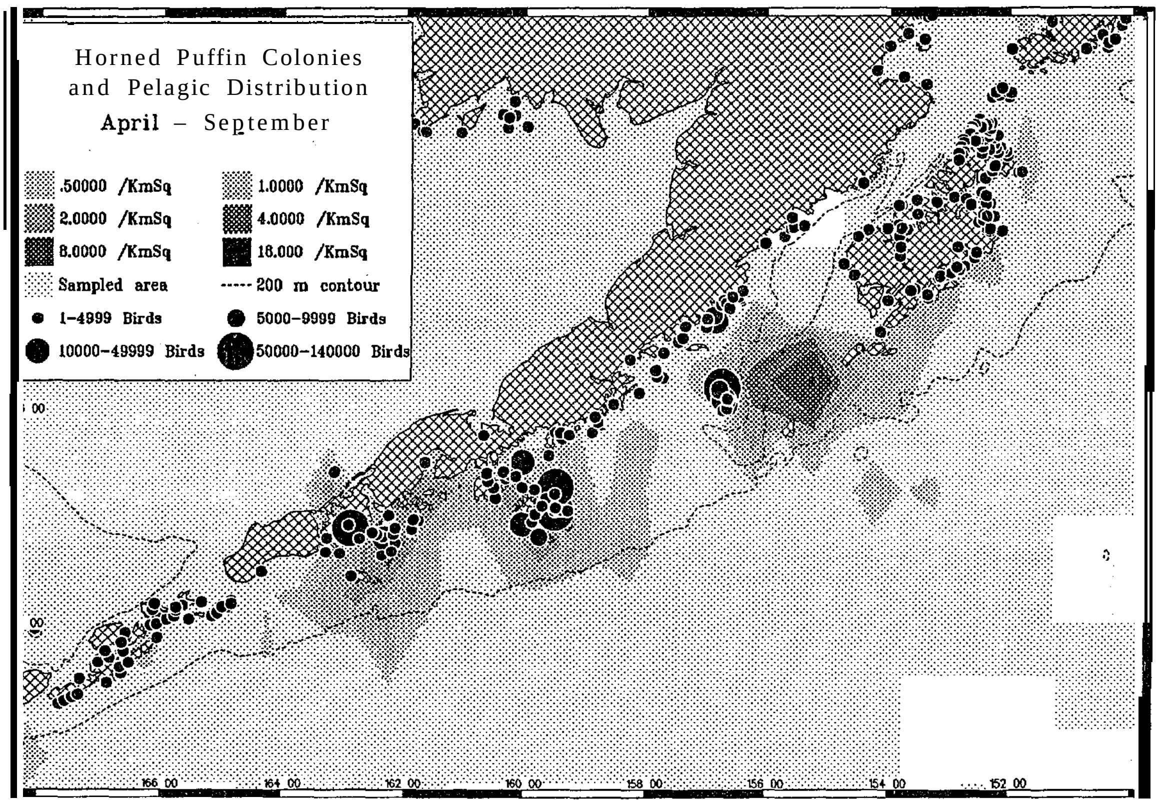

Figure 1. The distribution of horned puffin colonies (black circles) and distribution of horned puffins at-sea (shaded contours) in the northwest Gulf of Alaska. Computerized colony data providedby Art Sowls from USFWS data files. Pelagic distributions mapped with CAMRIS and using OCSEAP data collected by the USFWS and others in the 1970s and 1980s (provided by Glenn Ford, Ecol. Consult. Inc.).

PUFFIN DISTRIBUTION

Puffin colonies are widely distributed in Alaska (Sowls et al. 1978), but large populations are concentrated south of the Alaska Peninsula and in the eastern Aleutian Islands (Figures 1 and 2). Using CAMRIS to plot the available OCSEAP data on pelagic distribution of puffins, it is possible to determine where major concentrations of puffins occur at sea in this region during

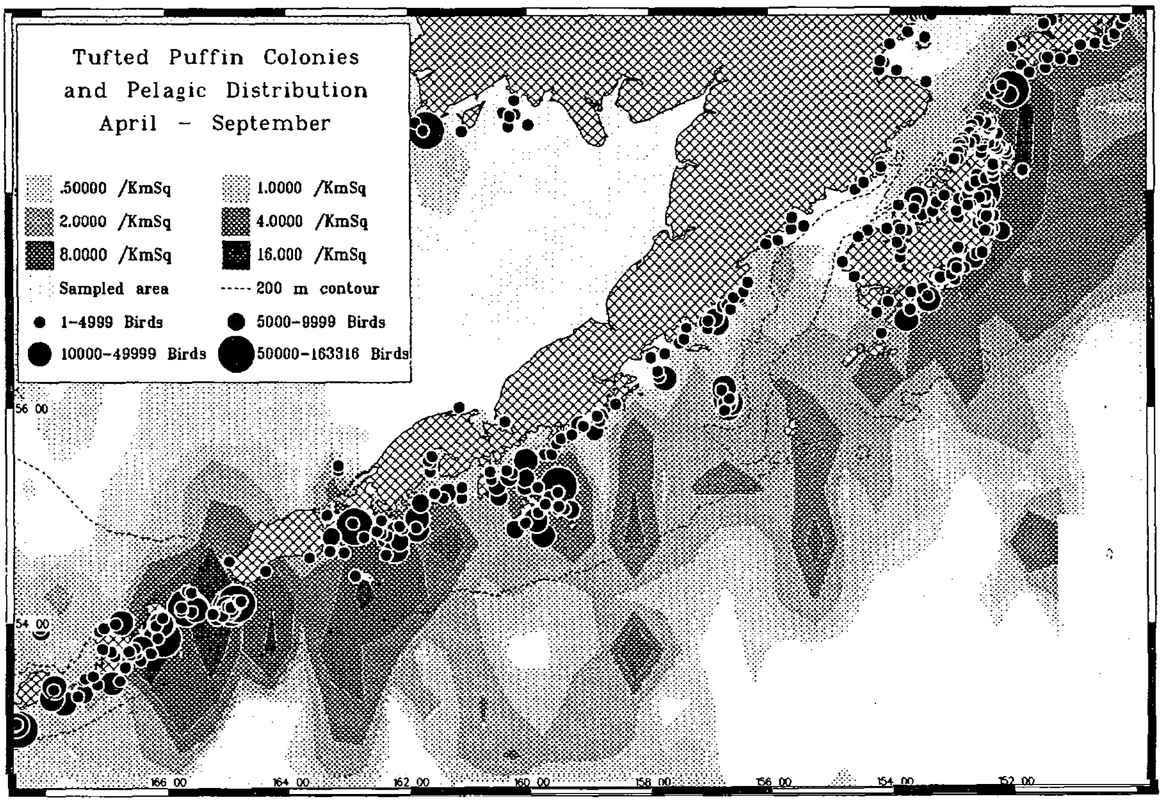

Figure 2. The distribution of tufted puffin colonies (black circles) and distribution of tufted puffins at-sea (shaded contours) in the northwest Gulf of Alaska. Computerized colony data provided by Art Sowls from USFWS date fries. Pelagic distributions mapped with CAMRIS and using OCSEAP data collected by the USFWS and others in the 1970s and 1980s (provided by Glenn Ford, Ecol. Consult. Inc.).

the summer breeding season (Figures 1 and 2). Tufted and horned puffins forage mostly on the continental shelf of the Alaska Peninsula, but venture into oceanic waters at the Semidi and Shumagin islands, and west of the Sanak Islands (Figure 2). Summer foraging populations are segregated geographically. Homed puffins are most abundant on the large section of shelf bordered at each end by the Semidi and Sanak Islands, whereas tufted puffins dominate to the east and west.

AN INTEGRATED PICTURE: PUFFINS AND MARINE FOOD WEBS

The biology, distribution, abundance, and feeding ecology of tufted puffins (*Fratercula cirrhata*) and horned puffins (*F. corniculata*) in the North Pacific are well-described, particularly in the northwest Gulf of Alaska (Sowls et al. 1978: Wehle 1980, 1982, 1983; Hatch and Hatch 1990; Baird 1990, 1991; Hatch and Sanger 1991; Byrd et al. 1991). Puffins are flexible in their choice of prey. Important criteria for selection include size (ea. 40 to 180 mm length), nutritive value, school density, and ease of capture, Because tufted and horned puffins dive to capture prey at maximum depths of about 110 and 80 m, respectively (Burger 1991), they are capable of sampling most pelagic and demersal fish populations on the shelf,

At colonies located in shelf habitats, the predominant prey of puffins include sandlance, capelin, juvenile walleye pollock, and juvenile Pacific cod, although dozens of other prey are

Table 1. Puffins and major food-webs found in the northern Gulf of Alaska.

Type	Area	Dominant Species		Habitat
I	Kodiak Arch.	tufted puffin	capelin	Shelf/islands
I	Semidi Is.	horned puffin	sandlance	Shelf
1	Shumagin Is.	horned puffin	capelin	Shelf /is Lands
II	Sanak Is.	tufted puffin	pollock	Shelf/shelf edge
11	E. Aleutians	tufted puffin	pollock	Pass/shelf edge
III	Bogoslof 1.	tufted puffin	myctophid	Shelf edge/oceanic

taken less frequently. Horned puffins have a narrower diet of fish than tufted puffins, and consume fewer invertebrates. At colonies located in shelf-edge or oceanic habitats, puffins consume more oceanic prey including squid, myctophids, and Atka mackeral (*Pleurogrammus monopterygius*). Overall, geographic variation in diet of puffins (and other seabirds) appears to reflect different marine habitats and three fundamentally different types of food webs in Alaska (Table 1).

Type-1 Food Web

The Kodiak Archipelago and Shumagin islands are characterized by large, shallow banks and numerous indented bays which provide suitable and sheltered benthic substrates needed by capelin (for spawning), sandlance (spawning and burrowing), and a variety of small coastal fishes. Puffins at the Semidis are surrounded by large, shallow banks dominated by sandlance. These three areas are similar in that the predominant forage fish are immature and mature bank species that reside locally during summer (Type-1, bank residents), Whereas these resident species may undergo seasonal migrations from wintering to summering areas, they use the same habitats throughout their lifetimes (typically 3 to 6 years), Thus, larval survival, recruitment, cohort dynamics, and adult mortality are influenced by local oceanographic and feeding conditions, Type I food webs are relatively complex. Pollock are a minor component of puffin diets in this area, but the proportion of pollock consumed appears to vary directly with year-class strength (Hatch and Sanger 1991). The Semidi-Shumagin bank forms the core of a community characterized by horned puffin, sandlance, and capelin abundance, and supports millions of other predominantly fish-eating seabirds (common murres *Uria aalge*, black-legged kittiwakes *Rissa tridactyla*), a once-large population of northern sea lions, and historically, a large Pacific cod fishery. As indicated by seabird communities elsewhere (Springer 1991), the Type-1 food web appears to be typical within the inner domain of the Bering Shelf and around some of the Aleutian islands with substantial banks (e.g., Attu; Agattu).

Type-ii Food Web

West of the Sandman Reefs — near the Sanak Islands, and in the eastern Aleutians — the continental shelf narrows and there is less bank habitat for capelin and sandlance. Pelagic juvenile (Age-O) pollock are usually the dominant prey of tufted puffins in this area during August and September. Most of these juvenile pollock probably derive from the transitory pulse of larval pollock that originates in Shelikof Strait, although juvenile pollock from Bering Sea stocks may also use this nursery area. In any case, transitory juvenile pollock represent a fundamentally different food base for puffins in this area (Type-n, bank transitory). In contrast to Type-1 food webs, the abundance of prey in Type-n webs depends on the oceanography and initial survival of larvae in a distant region. Only Age-O to Age-2 pollock are important for seabirds and mammals in Type II food-webs, so what happens to pollock after they recruit to the breeding population (aged 3 to 14 yr) is not of direct importance to local predators (except to the extent that the biomass of spawners determines larval production). The eastern Aleutians area is notable for its dominance by only a few superabundant species (e.g., euphausiids *Thysanoessa* spp.;

pollock; tufted puffins; and short-tailed shearwaters *Puffinus tenurostris*), a conspicuous scarcity of predominantly bank seabirds (common murres, black-legged kittiwakes), a once-large population of northern sea lions, and a dynamic marine environment in the passes between the Bering Sea and Gulf of Alaska. The relatively simple Type-n food web also appears to be typical of the middle and outer domains of the Bering Shelf. Adult pollock spawn in deep waters of the southeastern Bering shelf edge, and larvae are carried east and north by currents onto the outer and middle shelf domains. Ages-O, 1, and, 2 pollock completely dominate the fish fauna in these domains, and are the overwhelmingly dominant prey of seabirds and marine mammals breeding at St, Paul Island.

Type-III Food Web

Bogoslof Island is a small volcanic island located just north of the eastern Aleutian continental shelf edge and surrounded by deep (> 1800 m) oceanic waters. It provides a sharp contrast to adjacent bank food webs. Mesopelagic lanternfish and squid are the dominant prey for tufted puffins at Bogoslof, and their availability depends on the regular vertical migration of these prey from inaccessible depths (300 to 500 m) during the day to within foraging range (O-100 m) at night. Thus, a third basic food web (Type-ill, shelf edge) is found at Bogoslof Island, and it is typical of other shelf-edge domains in Alaska that support regionally significant populations of marine birds and mammals (e.g., St. George and Buldir islands). Type-III food webs appear to be relatively simple. Shelf-edge communities are notable for their abundance of pelagic seabirds (e.g., red-legged kittiwakes *Rissa brevirostris*; thick-billed murre *Uris lomvia*), and marine mammals (fur seals), and dominance of the food web by only a few species (Springer 1991),

CONCLUSIONS

The maps of puffin distribution at sea tell us where important foraging areas for these species are during the breeding season — and this is useful for interpreting the potential impacts of a variety of environmental perturbations. More importantly, however, they offer new insight into the biology of these species. When integrated with existing knowiedge on oceanography, fish distribution, colony locations, and feeding ecology, we can begin to develop an overall picture of puffin behavioral ecology in the region.

From this analysis, for example, we may conclude that the distribution of puffins in the northwest Gulf of Alaska is profoundly influenced by the interaction between local oceanography and physical features of the continental shelf, which in turn determine the nature of food-webs in the area. Horned puffins are largely restricted to the banks where a Type-l food web predominates. In contrast, tufted puffins are most abundant where a Type-n food web predominates, and they essentially rely on a conveyor belt of juvenile pollock swept downstream by the Alaska Coastal Current. Whereas horned puffins forage largely on the banks, tufted puffins range up to and beyond the shelf edge in search of prey, particularly in areas where the coastal current is deflected into the Alaska Stream. It is clear that tufted puffins are more flexible in their choice of prey than horned puffins and they are apparently successful over a wider range of feeding and oceanographic conditions.

Mapping the pelagic distribution of all the common seabirds in Alaska is now possible because of an enormous historical effort in gathering data and the development of appropriate software to analyze that data. This offers exciting new opportunities for integrating existing information on marine birds in Alaskan continental shelf waters with different aspects of their environment.

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Dr. John Piatt has been studying the feeding ecology and marine distribution of seabirds in Alaska for the U.S. Fish and Wildlife Service since 1987. Prior to this, he spent 10 years studying seabirds and marine mammals in Newfoundland and Labrador, and obtained his Ph.D. in marine biology from Memorial University of Newfoundland in 1987.

QUESTIONS AND DiSCUSSiON

Ray Emerson: Where did the composite of plankton come from?

John Piatt: i am not sure how they did that. That is obviously a satellite image. The oniy information that I have on it was that it was a six year composite. i have seen other ones iike it but they have been one month or one year. It must be computer generated, then averaged out and regenerated.

Steve Treaty: One of the slides you showed earlier had a white-hot pixel there for murres, it looked to be southeast of Diomedes, you didn't show any murres from this past summer's work. Did i read that right?

John Piatt: That is one of the interesting things about this, Those are two really different data sets. The OCSEAP data is actually grouped into 30 minute blocks for this analysis so that somewhat limits the scale of resolution that you can get. At the same time, it can take something

that is in the corner of the block and put it in the middle, sort of averaging that sort of thing. But we now have 5 minute information from that data set and we are going to look at that in more detail and go back to the Bering Strait and look at the actual OCSEAP data to see what it shows. I did do that for the OCSEAP data but it was at 30 minute resolution and in the Bering Strait that tends to put everything on one side or the other. The other thing that we learned and even with our own data, is that things change so rapidly in the Strait. You've got currents of two, three, and four knots fairly steadily whipping through there; things move through fast. We would do surveys and discontinue a line, start them over the next day, and the oceanography, the birds, the fish, everything was completely different. So it is a very dynamic area. Those OCSEAP data are nice, They represent long term averages probably. But occasionally you can have some point sampling that could represent only a day that somebody happened to be there. Similarly short term data is not as comparable, but it is more interesting in some respects because it is a real short time sort of picture.

Suzanne Winder: Are the black kittiwakes in the Lower Cook Inlet on a decline as they are in Prince William Sound like that gentleman said?

John Piatt: In Lower Cook Inlet? I think Scott Hatch could better answer that question.

Scott Hatch: I don't think we have a record of a decline such as we saw in Middleton for say, Chisik Island.

Suzanne Winder: He just indicated that there is an overwintering population in Lower Cook Inlet of the black legged kittiwakes. I am wondering if they are on the decline as well as they are in Prince William Sound?

Scott Hatch: The sites that have been monitored to some degree include Gull in Kachemak Bay, Chisik Island, Barren Islands. I don't think we have a similar decline at those sites like you saw at Middleton Island.

SPRING MIGRATION HABITATS OF GEESE IN UPPER COOK INLET

Jerry Hupp
U.S. Fish and Wildlife Service
Alaska Fish and Wildlife Research Center
1011 E. Tudor Road
Anchorage, Alaska 99503

INTRODUCTION

Several species of arctic geese accumulate reserves of fat and protein during spring migration (Raveling 1979, Ankney 1982). Geese build reserves by feeding intensively in spring staging areas along migration corridors. Arctic geese rely on body fat and protein to meet the energetic and nutritional costs of reproduction at high latitudes (Raveling 1979, Ankney and MacInnes 1978). The quality and availability of feeding habitats in staging areas may affect physiological condition of birds and thus influence reproductive success at higher latitudes (Thomas 1983). Because geese consume large amounts of forage during periods of fat and protein deposition, it is important that feeding habitats receive maximum protection from human impacts.

The tidal wetlands of Upper Cook Inlet (UCI), Alaska provide important feeding habitat for up to 100,000 geese and swans during spring migration (Butler and Gill 1987), These include snow geese (*Chen caerulescens caerulescens*) from the Wrangel Island population. This population is of international importance because it is the only nesting population of snow geese in Russia. Wrangel Island snow geese use wintering areas in the United States and Canada. Approximately 60% of the population winters near the estuaries of the Skagit and Fraser rivers in Washington and British Columbia. The remainder of the population winters in the Central Valley of California. Management of the Wrangel Island population requires that migration habitats be identified and maintained to insure that birds arrive on nesting grounds with adequate endogenous reserves for reproduction,

We have conducted preliminary studies of the migration ecology of Wrangel Island snow geese in UCI. Our objectives were to determine migration chronology and to evaluate the distribution of geese among tidal estuaries. We also assessed wintering ground affinities of snow geese, measured diurnal activity patterns, and determined vegetative composition at feeding sites,

METHODS

Aerial surveys of staging snow geese in UCI were conducted weekly from mid-April through early May in 1985 through 1988 and in 1990. Surveys were flown at approximately 200 to 300 m above ground level using either a Cessna 206 or Cessna 185 aircraft with one or two observers and a pilot. Areas within approximately 5 km of the coast were searched for staging flocks. During 1985 to 1988, all coastal areas north from Redoubt Bay on the west, and the Kenai River on the east side of UCI were surveyed. In 1990, estimates of the numbers of geese on the Kenai River estuary were made from ground observations.

A total of 2056 snow geese was marked with individually-coded neck collars on Wrangel Island and on the Fraser River wintering area during 1986 through 1989. Observers in UCI used spotting scopes to locate neck-collared geese within flocks, We recorded the alphanumeric code on each collar observed. Codes were compared to sightings on the wintering grounds to determine whether snow geese that migrate through UCI primarily originate from the northern wintering area near the Skagit and Fraser rivers, or from the southern wintering area in California.

We measured diurnal activity patterns of snow geese by approaching to within 200 to 300 m of flocks and classifying behaviors of individual geese. Activity patterns represent the proportion of the daylight hours that geese spend in a particular type of behavior, We measured activity patterns of geese to determine whether birds were actively feeding or whether they were merely using UCI as a resting area,

In 1991 we marked 14 sites where geese where observed to feed. We returned to those sites in mid-summer to classify plant species composition at the feeding area. We measured plant composition by estimating percentage cover of each species in 20, 25 X 50 cm plots systematically located along a transect through the feeding site.

RESULTS AND DISCUSSION

Snow geese are usually first observed in UCI approximately 15 April. However, numbers of geese do not reach a peak until the last week of April and the first week of May (Figure 1). Between 12,000 and 34,000 snow geese have been observed at the peak of migration. The largest number of geese seen in UCI occurred in 1985, when as a consequence of delayed snow melt geese remained in the Inlet for a longer time period while waiting for feeding areas to be exposed by melting snow, Snow geese tend to first use areas near the Kenai River estuary because it becomes snow-free earlier than other areas. Areas on the west side of UCI (Susitna Flats, Trading Bay, Redoubt Bay) are used later in migration.

Of 134 neck-collared snow geese seen in UCI, most (101) had been marked on Wrangel Island and 95% had been previously observed on wintering areas (Figure 2). Most previous sightings (765 observations of 126 marked birds) occurred on the northern wintering area near the Skagit and Fraser rivers. Only 11 individuals seen in UCI had previously been observed on the southern wintering area. Thus, Wrangel Island snow geese that use the northern winterina area follow a coastal 'migration route that includes UCI during spring migration.

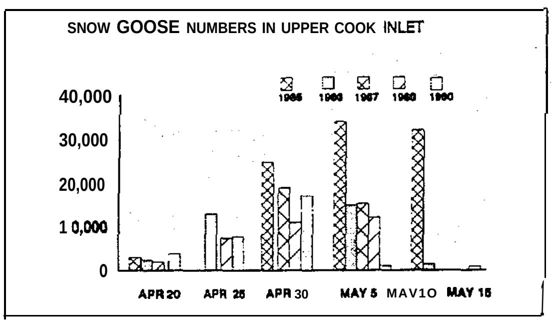

Figure 1. Total numbers of snow geese observed In Upper Cook Inlet during aerial surveys, 1985 through 1990.

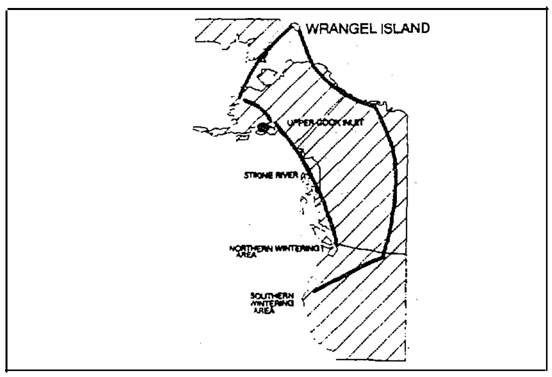

Figure 2. Migration routes of Wrangel Island snow geese (Syroechkovskiy and Litvin 1986).

Snow geese spent a high percentage of the daylight hours feeding (72 and 76% in 1990 and 1991, respectively). The intensive feeding activity suggests that geese were likely accumulating endogenous reserves required for further migration and reproduction on Wrangel Island. Feeding sites were dominated by arrowgrass (*Triglochin maritimum*) and *Carex ramenskii*. Feeding primarily occurred in plant communities that were adjacent to unvegetated mudflats along the coast and river edges. Few flocks were observed in more inland communities.

These results provide preliminary information on the importance of UCI as a spring migration area for snow geese, However, additional information is needed. While preliminary studies of feeding habitats have been conducted, the ecological relationships between geese and forage resources remains unknown. The plant communities that provide important feeding habitat to be determined to insure that important areas receive maximum protection from human disturbance.

SUMMARY

Tidal wetlands of Upper Cook Inlet, Alaska annually provide migration habitat for up to 100,000 geese and swans during spring migration. Included are up to 34,000 lesser snow geese that nest on Wrangel Island in Russia. Snow geese that migrate through UCI originate from wintering areas in the Skagit and Fraser river estuaries of Washington and British Columbia. Snow geese spend a high proportion of the daylight hours feeding in areas dominated by arrowgrass (*Triglochin maritimum*), and *Carex ramenskii*. Birds likely accumulate body reserves of fat and protein that are needed for further migration and reproduction. Further research is needed to identify important feeding habitats of geese in UCI.

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Jerry Hupp is a research biologist with the Alaska Fish and Wildlife Research Center of the U.S. Fish and Wildlife Service. For the past three years he has studied migration ecology of arctic geese on the North Slope and in southcentral Alaska. He received his B.S. from the University of Missouri, his MS. from South Dakota State University, and his Ph.D. from Colorado State University.

QUESTIONS AND DISCUSSION

Jonathon Houghton: I might have missed this. Do you know if there are additional staging areas that are used by the Skagit/Fraser flocks enroute or is the Cook Inlet the only one?

Jerry Hupp: That is a good question. Where are the other links in the chain so to speak? We know Stikine Flats in southeast Alaska gets used by this population. There is some indication that birds are stopping in the Copper River Delta area, Also some use of the Yakutat area. After leaving Cook Inlet, there may be some sites on the Yukon Delta. After that it is kind of a mystery where snow geese from this population stop prior to arrival at Wrangel Island. Cook Inlet is not the only one, But I think that when we are speaking of migratory birds we need to really look at ensuring quality of habitats in all links of the chain. And Cook Inlet is certainly one of those links not only for snow geese but also for cackling Canada geese. It is very interesting that Cook Inlet may be the last site that cackling Canada geese use as a spring staging area before their arrival on nesting grounds on the Yukon Delta. It is possible that the reserves that those birds ultimately rely on for reproduction or at least partially rely on for reproduction are at least due in part to their ability to acquire forage in Cook Inlet.

Ray Emerson: It sounds like we don't know too much about the snow geese here in the Anchorage area. I am wondering how difficult would it be to determine stomach contents of a few snow geese in the Anchorage area to find out what they are feeding on? And then you would map the habitats associated with that stomach content? Is that pretty straightforward?

Jerry Hupp: Yes I think it would be quite a straightforward project. I think it is feasible. Funding is always a question..,

Ray Emerson: Logistics wouldn't be too tough.

Jerry Hupp: Logistics would be interesting. It is not far away compared to some of our work on the North Slope, It ought to be pretty easy to work over there, Breakup is a bit of a problem. There is an in-between period where it is difficult to land an aircraft to get into some of the sites where we would like to work. I think a project to assess forage selection by snow geese and other species of geese, projects which would assess the distribution of the species that they are using and really map out the communities of interest would be appropriate,

Ray Emerson: That isn't a high priority for Fish and Wildlife right now?

Jerry Hupp: I would say it is probably not the highest priority by any means, I think some of us have interest in it but I think spring migration habitats have really not been an area of great focus as perhaps they should be.

Suzanne Winder: I have been here since 1981 except for a short time outside and I do watch the geese on the Kenai Flats. That seems to be the thing that everyone does down there. I am concerned about what I think is a decline in the number of snow geese, at least, that are coming through that area since 1981. Can you address that at all or are they going somewhere else or are they being impacted in the Skagit Valley?

Jerry Hupp: Well actually that population has grown from about 25,000 to 34,000 in the last ten years. It is possible that geese you have previously seen on Kenai Flats are going elsewhere in Cook Inlet. There is quite an amount of year to year variation, We do see that in times when the Kenai Flats may be covered with snow, birds used Susitna Flats or Goose Bay or some other area in Cook Inlet, So what we really need to do is look at Cook Inlet as a whole, obtain counts from all areas at one time, which we have done. Those data don't really seem to indicate an overall decline of the numbers of migrating geese in the area,

INTERANNUAL AND INTERCOLONY VARIATION IN BERING AND CHUKCHI SEA SEABIRD COLONIES

Vivian M. Mendenhall
U.S. Fish and Wildlife Service
1011 E. Tudor Road
Anchorage, Alaska 99503

INTRODUCTION

Populations and productivity of cliff-nesting seabirds have been studied for 15 to 30 years at sites in western Alaska. Estimates of populations at seabird colonies started at Little Diomede Island in the Bering Straits (Kenyon and Brooks 1960) and at Cape Thompson in the Chukchi Sea (Swartz 1966). Work continued in the Bering and Chukchi Seas under the U.S. Fish and Wildlife Service and the Outer Continental Shelf Environmental Assessment Program (Hickey and Craighead 1977, Drury et al. 1981, Springer et al. 1985).

In recent years, although descriptive studies have continued, the emphasis on monitoring of population trends in seabirds has increased. The U.S. Fish and Wildlife Service is responsible for keeping track of seabird population trends, which requires frequent monitoring at selected colonies throughout Alaska. Study plots have been monitored for up to 15 years at several colonies in western Alaska, and frequent or yearly revisits to monitoring sites have been initiated, in order to establish and maintain a reliable data baseline, Methods that have been standardized allow results to be compared among years and colonies. We monitored both populations and productivity of seabirds at our study colonies in order to ensure that both long-term and short-term changes can be detected in time for further study and corrective actions,

Minerals Management Service has cooperated with the U.S. Fish and Wildlife Service since 1987 in monitoring colonies in the Bering and Chukchi Seas. This report covers four colonies: Cape Thompson (1988 and 1990), St, George (1989), Cape Peirce (1989 and 1990), and Bluff (1989 and 1990). The colonies were selected because each is a major colony that is representative of the marine avifauna in a portion of the state, Each colony also had a baseline of monitoring data which we could use for analysis of population trends.

METHODS

Locations of the four study colonies are shown in Figure 1. St. George is accessible by commercial aircraft; the other three colonies are reached by chartered small aircraft that land on unmaintained tundra airstrips or on floats. At Cape Thompson, equipment is then ferried 7 kilometers to the camp site by inflatable boat.

Two seabird genera were selected for monitoring at our study colonies: common and thick-billed murres *(Uris aalge* and *U. lomvia*) and black-legged kittiwakes (*Rissa tridactyla*). These species were chosen because they nest on open cliffs and therefore can be censused reliably; are widespread; and represent groups of species with similar feeding ecology (murres feed by diving for fish, kittiwakes on fish at the surface). Both species of murres were monitored at St. George and Cape Thompson (the species were not differentiated in censuses at Cape Thompson); only common murres breed at Cape Peirce and Bluff. Black-legged kittiwakes were monitored at all 4 colonies; red-legged kittiwakes (*R. brevirostris*) were also monitored on St. George, the only colony in our study where they occur.

Populations were monitored by two methods. From 1960 through 1976, all colonies were censused in their entirety from boats offshore. Boat censuses were continued at Cape Thompson through 1982, and at Bluff in some years when plots were also censused. We repeated offshore counts in 1990 at Cape Thompson, and also at Bluff for kittiwakes, to facilitate long-term comparisons.

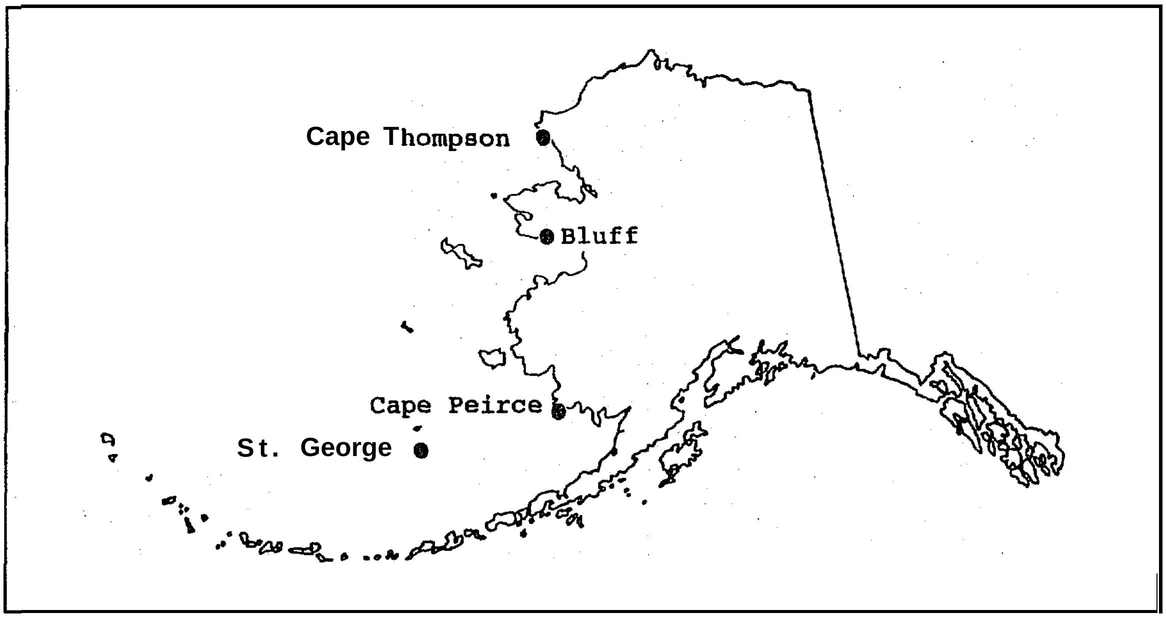

Figure 1. Location of colonies selected for monitoring in 1989 through 1990.

Populations are now monitored at all four colonies primarily by censusing plots that are viewed from the top of the cliff. Plots were established at St. George and Cape Peirce in 1 976 (Hickey and Craighead 1977, Petersen and Sigman 1977), at Bluff in 1979 (Drury et al. 1981), and at Cape Thompson in 1988 (Fadely et al. 1989), More precise counts can be obtained for land-based plots than boat plots, and land-based counts can be replicated several times each season, which allows calculation of confidence limits, Fifteen to 57 plots containing 20 to 1500 birds are distributed in representative areas of each colony, Plot boundaries are marked on photographs of the cliffs to ensure that they are recounted accurately. Five to 10 counts of all plots are made each season, Birds are counted during the period when their numbers are most stable, between the completion of egg-laying and the first fledging of young birds, Calculation of mean population indices from plot censuses for each year allow us to detect a change between years of 12% to 20% (Hatch and Piatt 1987). Data from years of monitoring prior to our study were analyzed for comparison with our data; only plots censused in each year were used in analyses of trends.

Productivity of murres and kittiwakes is monitored on smaller plots containing 5 to 100 pairs of birds. Plots are demarcated on photographs, and the location of each nest is mapped on a photograph or sketch so that its progress can be followed throughout the season. Kittiwakes build nests on the cliff, whereas murres lay eggs directly on a bare ledge, Each plot is observed every 2 to 4 days throughout the season if possible, and the presence or absence of a nest, eggs, or chicks at each breeding site is recorded, We try to initiate observations each year before the birds establish their nests and continue until the last young have fledged. However, this schedule must be modified in some cases due to weather; our arrival at Cape Thompson is delayed because of sea ice, and autumn storms require that we depart from all colonies before fledging is complete. Estimates of productivity tend to be biased slightly high when we cannot observe from first laying throughout fledging. The index of productivity is the sum of young fledged on all plots in the colony divided by the sum of nest sites observed.

RESULTS

Murre populations (Figure 2) declined significantly before approximately 1984 at Cape Thompson (Springer et al. 1985), Bluff (Murphy et al. 1986), and at St. George in the case of thick-billed murres (Byrd 1989). No significant decline occurred in common murres at St. George (Byrd 1989) nor at Cape Peirce before approximately 1987. Since the mid-1980s, murre populations have been stable at St. George, Bluff (Mendenhall 1991), and Cape Thompson (Mendenhall, in prep.). However, common murres at Cape Peirce declined significantly from 1985 through 1989 (regression coefficient = -174., t = 4.199, $P < 0.05$; Mendenhall, in prep.).

Black-legged kittiwake populations (Figure 3) have been stable at Bluff and Cape Thompson throughout the period analyzed (Springer et al. 1985, Murphy 1991), and populations of this species increased significantly on plots at Cape Peirce from 1976 through 1990 (t = 3,748, $P < 0{,}01$; Mendenhall, in prep.). At St. George, black-legged kittiwakes declined significantly from 1976 through the mid-1 980s, but were stable thereafter (Byrd 1989). Red-legged kittiwakes at St. George were the only population in this study that declined significantly throughout the period of this study (Byrd 1989, Mendenhall 1991). The St. George population was approximately 50% smaller in 1989 as in 1976.

Mean productivity of murres was similar among all four colonies, and variability within each colony was low (Table 1). Mean productivity of kittiwakes varied both between and within colonies (Table 2).

DISCUSSION

Murre populations at Cape Thompson, Bluff, and St. George declined significantly between 1960 approximately 1984 (Figure 2), The two species of murres were not affected equally, Common murres declined more severely at the northernmost colony (Cape Thompson, Fadely et al. 1989); in contrast, only thick-billed murres declined in the southeastern Bering Sea (at St. George), while common murres showed no trend in the south during that period (at St. George and Cape Peirce). The reason for declines of murres in the 1960s and 1970s is unknown; changes in populations of forage fish in the wintering areas of the central Bering Sea have been suggested as a cause (Murphy et al. 1986).

The decline of common murres at Cape Peirce during the late 1980s (Figure 1) also is unexplained. There is no reason to suspect breeding failure in this colony; mean productivity of murres at Cape Peirce was similar in 1988 through 1990 to productivity of both species at St. George during 1985 through 1989 and selected earlier years (Table 1). It is important that our monitoring program for murres be repeated annually at Cape Peirce until we can confirm whether the long-term trend is stable, as suggested by increasing numbers in 1989 through 1990, or for a decline, We need reliable description of the current trend in murre numbers at Cape Peirce to provide a baseline for assessing impacts of possible future development, and also to determine whether intensive work is needed into the causes of a decline.

Black-legged kittiwake populations at Cape Thompson, Bluff, and Cape Peirce have been stable or increasing during the period of our study (Figure 3), Mean annual productivity at these northern colonies (Table 2) was higher than the 0.31 suggested by Hatch et al. (in press) as necessary to maintain kittiwake populations in the north Pacific. The decline of black-legged kittiwakes during the late 1970s at St. George was associated with low productivity during this period, possibly as a result of reduced stocks of juvenile walleye pollock (*Theragra chalcogramma*), which form a major portion of the species' diet during the breeding season (Springer and Byrd 1989). Other trends in kittiwake populations in the southeastern Bering Sea are difficult to explain in terms of productivity, particularly the stable numbers at Cape Peirce, which has the lowest productivity of any colony studied in Alaska (Table 2; Hatch et al. in press), It is possible that Cape Peirce numbers are maintained by immigration from nearby colonies.

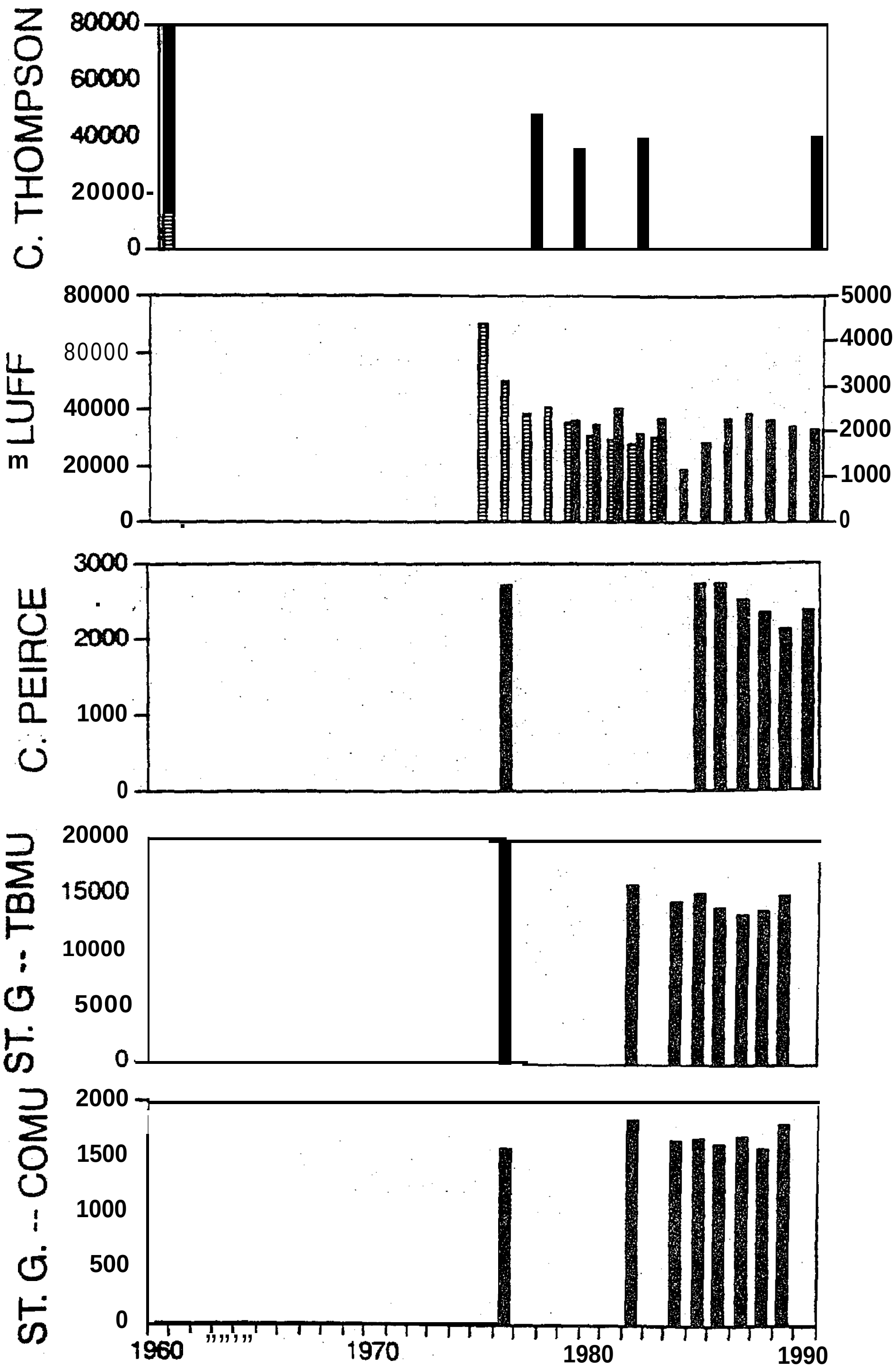

Figure 2. Populations of common and thick-billed murres on monitoring plots at four colonies. Common murres at Bluff and Cape Peirce; data for both species are combined for Cape Thompson. Black bars represent plots counted from land, cross-hatched bars plots counted from boats.

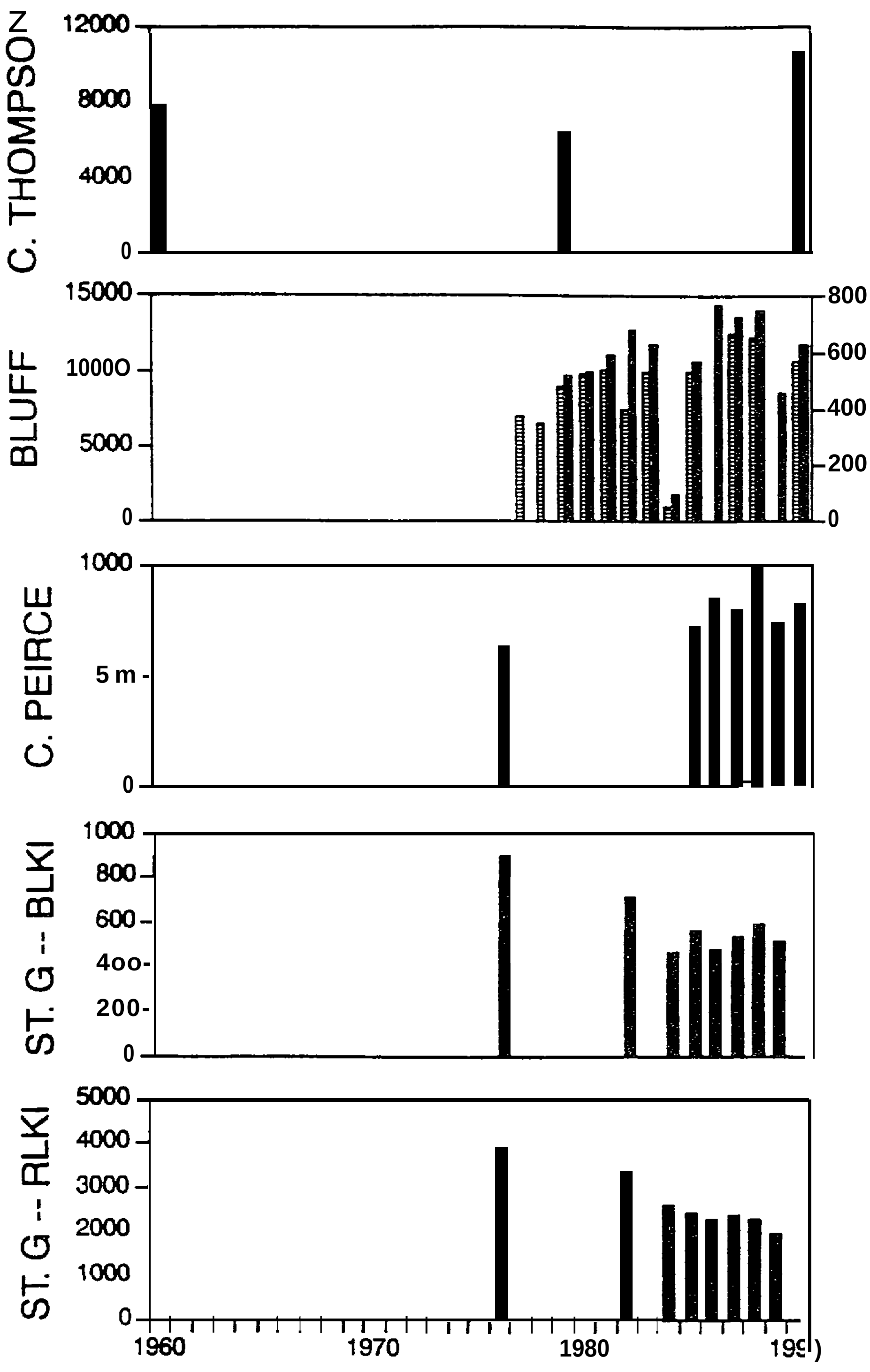

Figure 3. Populations of black-legged and red-legged kittiwakes on monitoring plots. All data are for black-legged kittiwakes except at St. George. Conventions as In Figure 2.

Table 1. Mean productivity' of murres at four colonies through 1990².

	St. George³	Cape Peirce	Bluff⁴	Cape Thompson
CoMu	0.60 ±0.19 (7)	0.53 *0.057 (3)	0.64 *0.094 (4)	0.73 ±0.18 (2)
TBMu	0.50 ±0.17 (9)			0.69 *0.11 (2)

[1]Fledglings per pair with egg(s).
[2]Mean ± SO (N).
[3]Through 1989
[4]Only for years observed from laying until most fledge.
[5]Observations started mid-laying.

Table 2. Mean productivity' of kittiwakes at four colonies through 1990².

	St. George³	Cape Peirce	Bluff⁴	Cape Thompson⁴
BLKi	0.22 ±0.20 (14)	0.087 ±0.080 (12)	0.42 ±0.36 (15)	0.70 ±0.43 (9)
RLKi	0.20 ±0.18 (14)			

'Fledglings per nest start.
'Mean ± SD (N).
'Through 1989.
[4]Includes some years with short field seasons.

it is important to evaluate the adequacy of our monitoring program for revealing trends in populations and productivity of seabirds throughout the eastern Bering and Chukchi Seas. Monitoring is influenced by the adequacy of baseline data, the degree to which the colonies we have selected are representative of others in the region, and the schedule on which monitoring will be repeated.

Baseline data for population monitoring are sufficient at St. George, Cape Peirce, and Bluff, with at least consecutive years of data at each; we could detect significant departures from populations estimated at these colonies. At Cape Thompson, where we have only three population estimates for kittiwakes on boat or land plots (as of the end of 1991), our baseline data are not yet adequate. Baseline data on productivity of kittiwakes are probably adequate at all colonies. Murre productivity also has been adequately characterized at all colonies, but one or two additional years' data at Cape Thompson (in addition to the three years' data on hand) would improve reliability.

Monitoring must be repeated at each colony at frequent intervals after baseline data have been obtained. Strict standards for monitoring intervals have not been developed, but gaps longer than three years may prevent timely detection of trends. St. George populations have not been monitored since 1989.

If a seabird colony is to be considered representative of others in the area, trends should be correlated with those at nearby colonies. Productivity of black-legged kittiwakes usually does not vary similarly among years in different parts of Alaska (Hatch et al., in prep). Black-1 egged kittiwake productivity at three of our colonies (Hatch et al., in prep,) was highly correlated with that of others located no more than 60 km away (Figure 4), although more data are needed to confirm the relationship between Round Island and Cape Peirce. Three other pairs of colonies located 350 to 450 km apart showed no significant correlations in productivity (Figure 5). The common factor shared by colonies that exhibited similar productivity is probably oceanographic, with similar water masses and sea temperatures influencing the availability of forage fish in each year. Colonies likely to be affected by different temperature regimes must be monitored separately.

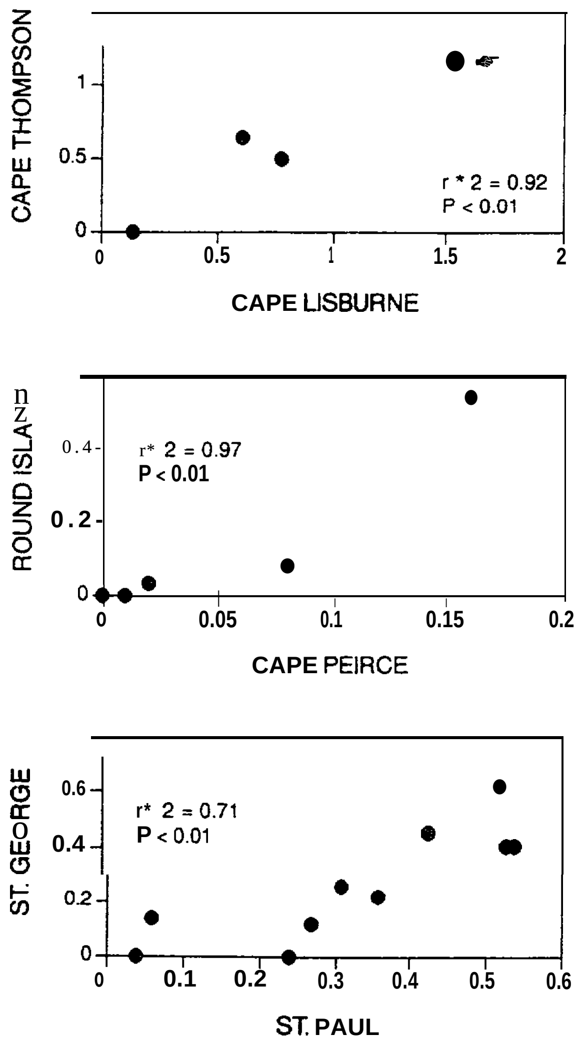

Figure 4. Correlations between yearly productivity of black-legged kittiwakes (young fledged per nest) at three pairs of colonies In Alaska. Data from Hatch et al., in press.

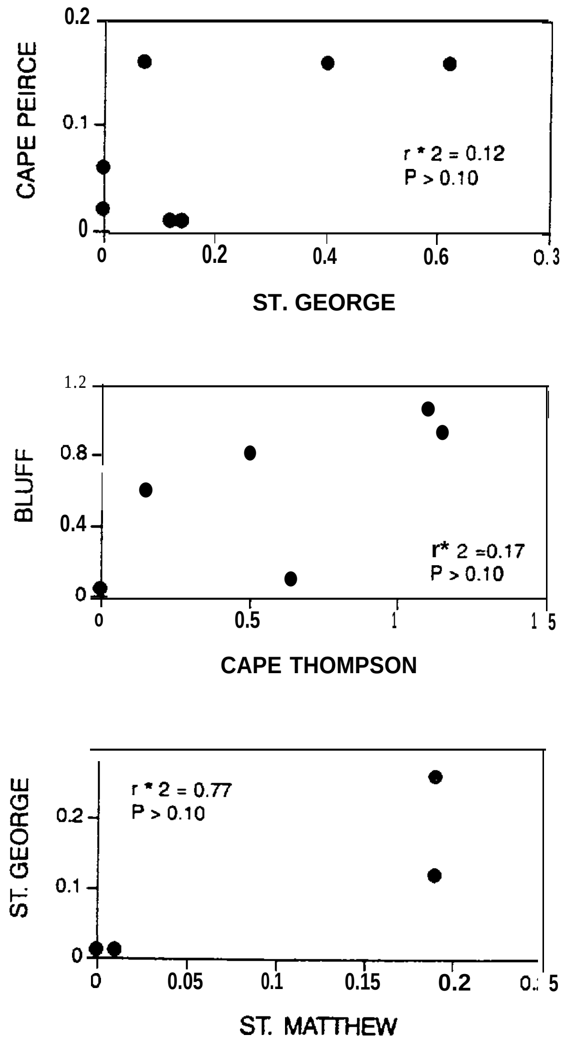

Figure 5. Correlations between yearly productivity of black-legged kittiwakes (young fledged per nest) st three pairs of colonies In Alaska. Data from Hatch et al., in press.

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Dr. Vivian Mendenhall is Marine Bird Coordinator for the U.S. Fish and Wildlife Service in Alaska. Besides seabirds, she has worked on the ecology of shorebirds and sea ducks. Dr. Mendenhall received her Ph.D. from the University of *Aberdeen, Scotland.*

QUESTIONS AND DISCUSSION

Declan Troy: Have you seen any indications of productivii telling you in advance what the populations are going to do?

Vivian Mendenhall: Not at our colonies, but it has been seen elsewhere in the world, Middieton Island is one case. There is one colony of Atlantic puffins in Norway that declined precipitously 10 or 15 years after productivity went to pot due to overfishing completely. I can't remember what they were feeding on, capelin or herring, but it was gone. The productivity was good in one year out of 10 or 12 and as the life span of the existing adults was exceeded the population suddenly started to disappear.

Declan Troy: . ..anything other than a catastrophic case, do fluctuations occur?

Vivian Mendenhall: We don't have any productivity data for any reasonable time before the declines we saw either in the iate 1970s or early 1980s in some of these colonies or for the murres more recentiy in Cape Peirce. So the answer is I don't think we have the data to address that. But it is worth looking over it again to see if we do.

Declan Troy: So in the mid-1980s didn't high populations..,

Vivian Mendenhall: No the oniy colony where we had population decline that was significant was murres at Cape Peirce. We only started really looking at murre productivity properly in 1988.

ALASKAN SEABIRD COLONIES: TWO COMPUTER DATABASES

Vivian M. Mendenhall
U.S. Fish and Wildlife Service
1011 E. Tudor Road
Anchorage, Alaska 99503

Arthur L. Sowls
U.S. Fish and Wildlife Service
Alaska Maritime National Wildlife Refuge
202 Pioneer Drive
Homer, Alaska 99603

Censusing of seabird populations at Alaskan colonies began in 1960, but most colonies were first located and counted in the 1970s by the U.S. Fish and Wildlife Service and the Outer Continental Shelf Environmental Assessment Program. The first atlas of these data, the Catalog of Alaskan Seabird Colonies (Sowls et al. 1978), contained records on 35 species at approximately 1000 breeding sites. Additional colonies were located during the next few years, particularly in the Aleutian Islands and Prince William Sound, and updated estimates were obtained for other colonies. The published catalog therefore was soon out of date.

An automated database of Alaska seabird colony information was developed in 1986 by Art Sowls and Roger Slothower of the Fish and Wildlife Service on a DataGeneral mini-computer. In 1991 the database was revised for desktop computers. Two different databases containing Alaskan colony records now exist on IBM-PC and Macintosh computers.

The IBM-PC database was developed by Dr. Steve Klosiewski of the U.S. Fish and Wildlife Service in Anchorage. The database contains 8500 records on more than 1350 colonies. Data records are stored in Paradox, a commercial relational database system. The program incorporates menus that allow rapid selection of data according to area, colony, and/or species of interest. Reports can be produced giving the number, name, and location of each colony, current estimates of numbers for each species in the colony, historical estimates (if desired), date and method of census, observers, and literature reference, Several codes are provided for each record to indicate the quality of the data, which varies with observer, species, and type of survey. The mapping program Atlas GIS allows the user to select any area for output. Maps can be made of large areas, with colonies represented by dots of various sizes, or detailed maps can show the extent of shoreline that each colony occupies.

The Macintosh database was developed by the National Oceanic and Atmospheric Administration Strategic Environmental Assessments Division, Rockville, Maryland, with the assistance of Art Sowls and George Divoky. This database contains the same current estimates for each Alaskan colony as are stored in the IBM-PC database, as well as data for British Columbia, Washington, Oregon, and California. Historical data are not available, Supporting information is provided for each census record on colony location, census, observers, data quality, and so forth. Data are selected and listed in Macintosh HyperCard. The mapping program Atlas MapMaker allows colonies to be displayed as dots of various sizes for any area selected (detailed maps of shoreline extent are not available). The Macintosh database contains two features not provided on the PC. An additional file summarizes life-history information for each species in each of 11 biogeographic areas, including timing of the breeding season, nesting habitat, food habits, and body size; this information can be included on maps. An analysis program compares and population data for any two areas selected by the user and displays histograms.

Printouts or maps of Alaskan seabird colony data from either database can be requested from the U.S. Fish and Wildlife Service in Anchorage. The Macintosh database can be obtained from the National Oceanic and Atmospheric Administration in Rockville; a run-time version of the mapping program is available commercially for a modest price.

New and updated colony censuses are entered into the databases regularly. Contributions of colony data are welcome; blank data forms and information on census methods are available from the U.S. Fish and Wildlife Service, Anchorage.

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Dr. Vivian Mendenhall is Marine Bird Coordinator for the U.S. Fish and Wildlife Service in Alaska. Besides seabirds, she has worked on the ecology of shorebirds and sea ducks. Dr. Mendenhall received her Ph.D. from the University of Aberdeen, Scotland.

Art Sowls has 15 years of experience censusing seabirds of all species in Alaska and California. He has published seabird atlases and created automated databases for both areas. Mr. Sowls received his B.A. from the University of Arizona.

QUESTIONS AND DISCUSSION

Steve Treaty: In ten words or less what are some of the advantages of the first data base over the second data base?

Vivian Mendenhall: Good question. The Alaska Data Base which in on the PC, if you have PCs and not Macintosh, it makes it easier to run. It contains historical data where those are available for colonies as well as current data. It doesn't mean you can always do trend analysis. That is only true where the data are of particularly good quality, but you often want to see what the past history of the work is. The maps contain information on the actual extent of the colony on the shoreline or island. That data base can also construct maps using colored dots of various sizes, if you want, Or it can produce maps that can be overlaid exactly on another map like a topographic map. The Macintosh Catalog is on Macintosh. It contains the rest of the West Coast if you are interested in other areas, It contains life history information summaries which allow you to combine that with the colony data in various ways. Ours is available for nothing and the other one is $100.00 for a one time version of the mapping program. Actually 1 am not sure because we haven't really gone that far in to it. We plan on making ours available, either the data which you can get right now from either one in electronic form or print outs. Or we will make ours available at least on a limited basis because we have never been in this business before. They are both quite large and it is the mapping routines that make them so large. The PC data base is about 800 kb for just the tables and a one time version of Paradox. The maps are about another 20 mb. The West Coast Data Base is comparable in size, larger if you want the rest of it, not just Alaska.

Steve Treaty: Is the mapping information here bonafide traditional maps or are these images of particular map areas? Do you have the ability to zoom in on any particular area?

Vivian Mendenhall: There are genuine base maps you can zoom in on. There is the same base map for Alaska, They were digitized from 1:250,000 maps. And in the close of my talk one I showed you for the first data base, Petrel Island, Forster Island and so forth, the total length of those islands is about ten miles.

So you have pretty good resolution. It will get a little jagged if you go down to one mile for the entire screen probably.

LATE WINTER AND EARLY SPRING SEABIRD POPULATIONS IN THE BERING SEA

George Divoky
Institute of Arctic Biology
University of Alaska
Fairbanks, Alaska 99775

While the Bering Sea shelf avifauna has been well studied from late spring to early fall (June to October) there has been little systematic seabird research for the remainder of the year. From June through September the eastern Bering Sea shelf supports one of the most abundant and diverse seabird communities in the world and comprehensive preliminary assessments of the summer populations have been published. The summer and fall pelagic seabird distributions have been reported on by Gould et al. (1982) and the size and location of breeding colonies has been documented by Sowls et al. (1978). With the exception of the late winter and early spring observations reported here and in detail in Divoky (1991), little has been done for the remainder of the year.

Beginning in December pack ice begins to form on the northern Bering Sea shelf and at the time of maximum ice extent in late March and early April the pack ice edge is typically near the edge of the continental shelf with ice cover of shelf waters being almost 90%. The Bering Sea shelf has been divided into three hydrographic domains described in detail in McRoy et al. (1986). These domains and the isobaths that delineate them are the Outer Shelf Domain (200 to 100 m), Middle Shelf Domain (100 to 50 m) and Coastal Domain (50 to 10 m). At the time of maximum ice extent in March ice cover is essentially complete in the Coastal Domain and Middle Shelf Domain with coverage of the Outer Shelf Domain showing high annual variability. The pack ice begins to decompose in April when leads and other openings formed in the ice by wind and currents no longer refreeze. This manner of decomposition makes open water areas available in all domains in the spring.

Shipboard censusing of seabird populations on the Bering Sea shelf from March through June were conducted on six cruises from 1976 to 1981. Over 460 hours of observation were conducted resulting in over 1600 15-minute observation periods. For each of these observation periods a density of birds/km^2 was obtained as well as information on ice coverage.

During March bird densities at the edge of the pack ice were extremely high with average densities in the Outer Shelf Domain averaging over 400 birds/km^2 while the other two domains had densities of less than 20 birds/km^2 (Figure 1). The densities found in the Outer Shelf Domain in March are extremely high for seabirds not associated with breeding colonies. They are twice the average density for the Bering Sea shelf in summer (Gould et al. 1982). In April and May densities in the Outer Shelf Domain decline precipitously while the Middle Shelf and Coastal Domains increase slightly. This is due to increasing open water in the latter two domains and the initiation of migration from wintering areas to breeding colonies in the Middle and Coastal Domains. In June densities in all domains showed an increase over April and May as migration of breeding birds to the Bering Sea is complete and extremely high densities are found adjacent to colonies.

Determining the ice conditions associated with bird densities was a major part of the study. Figure 2 shows the average densities of seabirds on the Bering Sea shelf in relation to ice cover by month. In March densities were highest on transects in the ice fringe with 10% ice coverage or less. In April and May densities were relatively uniform in a range of ice conditions indicating that habitat selection plays less of a role during this period of migration. In June densities increased with increasing ice cover up to 30% ice coverage. This is due to remnants of the pack ice persisting near the auklet colonies at Saint Matthew and Saint Lawrence Island.

The principal species or species groups found in association with ice from March to May are murres *(Uris* spp.), black-legged kittiwake (*Rissa tridactyla*), northern fulmar (*Fulmarus*

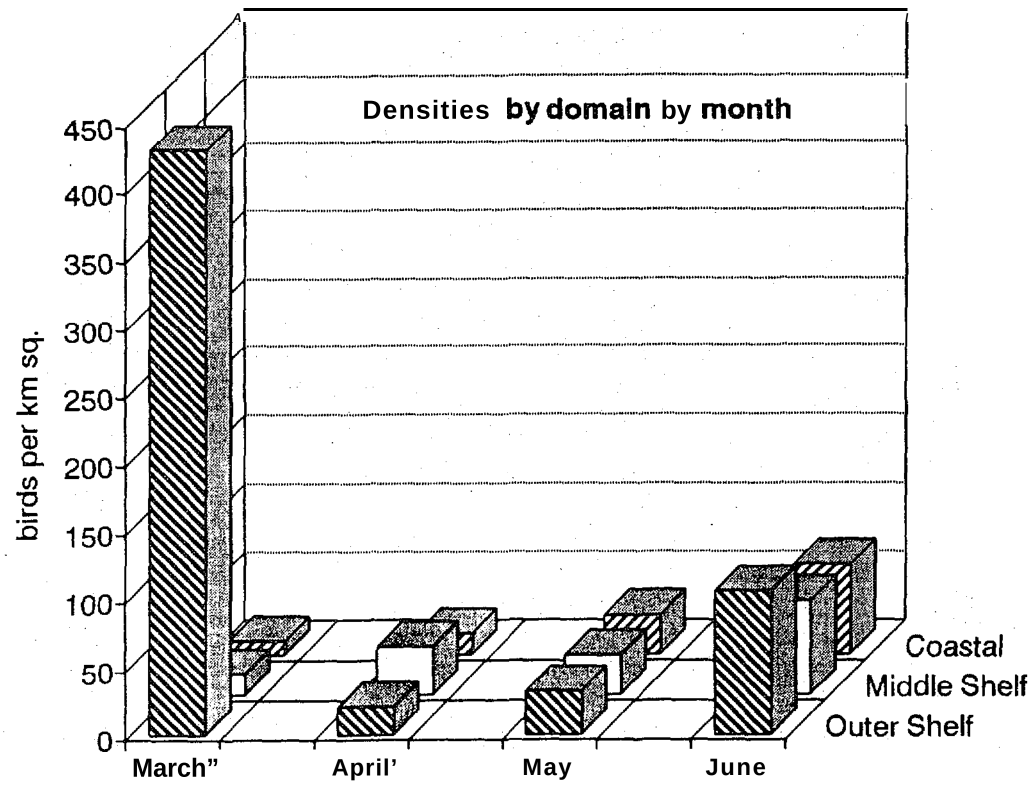

Figure 1. Bird densities by oceanic domain on the Bering Sea shelf from May to June.

glacialis), and Larus gulls (*Larus* spp), Murres constitute over 90% of the birds present at the ice edge in March and April. In June, in addition to the above species, least auklets (*Aethia cristatella*) are also common in waters with ice cover adjacent to breeding colonies. Walleye pollock (*Theragra chalcogramma*) appears to be the primary prey consumed by species at the pack ice edge in late winter. Planktivorous species do not become common on the shelf until late May and early June with the arrival of least auklets. The size of the murre population wintering in the Bering Sea may exceed the summer population. The wintering population's apparent dependence on walleye pollock would make it vulnerable to the reductions in pollock stocks caused by commercial fisheries,

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George Divoky has worked *on Alaskan* ***seabirds*** *for the past 20 years and is currently working as a private consultant while completing* ***his*** *doctorate at the Institute of Arctic Biology at the University of Alaska in Fairbanks. His research interests have included pelagic* ***distributions*** *of seabirds at ice edges in the* ***Beaufort, Chukchi*** *and Bering seas and his doctors/ research has* **been on** *the* **demographics and breeding biology** *of* ***Black*** **Guillemots in** *northern* **Alaska.** ***Divoky*** *received his masters degree from Michigan State University and anticipates receiving his doctorate in* **1992.**

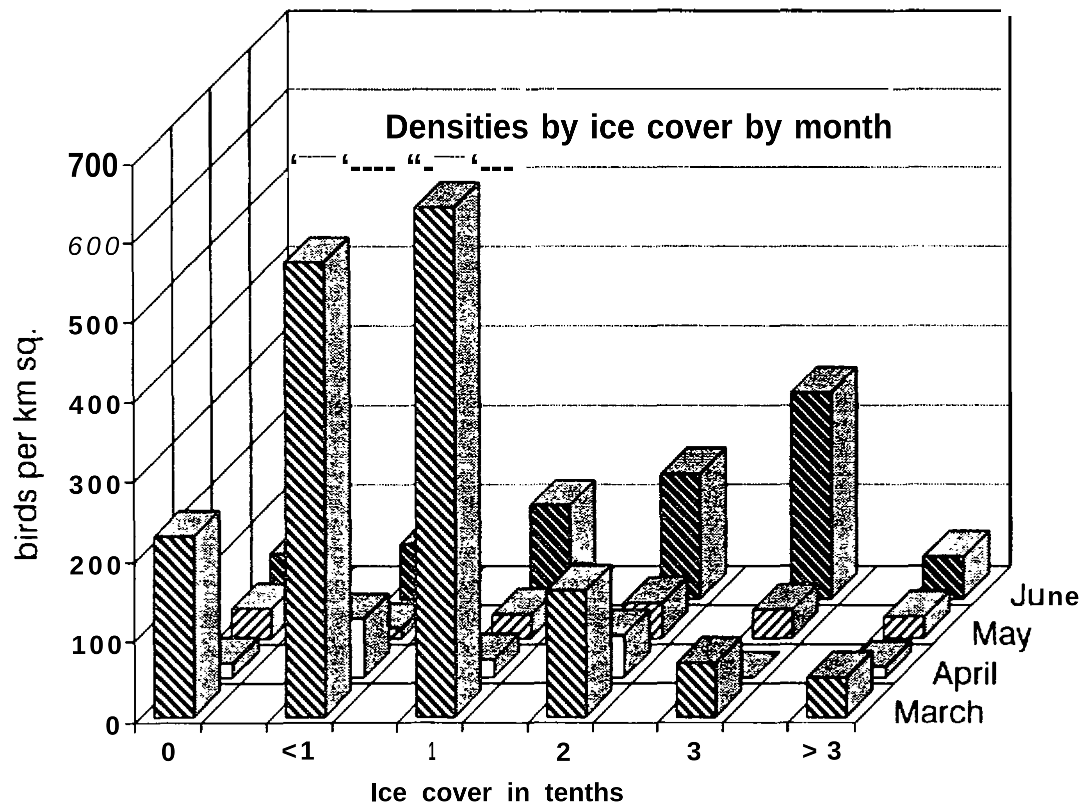

Figure 2. Bird densities on the Bering Sea shelf from March to June in relation to ice cover.

SEABIRD AND MARINE MAMMAL USE OF THE UNIMAK PASS REGION[1]

Declan Troy
Troy Ecological Research Associates
2322 E. 16th Avenue
Anchorage, AK 99508

INTRODUCTION

Unimak Pass is the major passage linking the northeastern Pacific Ocean to the eastern Bering Sea. large numbers of commercial cargo vessels, fishing boats, seabirds, and marine mammals regularly transit this pass. During periods of migration millions of birds and thousands of marine mammals migrate through the pass. In summer, well over one million seabirds nest on islands in the area.

Portions of the Bering Sea - St. George Basin, North Aleutian Shelf, Navarin Basin, Norton Sound - have been or are being considered for leasing for petroleum exploration. In the event of a major oil discovery off western Alaska, tanker and support vessel use of the passage will intensify, increasing the probability of accidents that could result in oil spillage and damage to regional biota. The Unimak Pass area is thus somewhat unique in that it is of considerable biological importance, potentially at risk from Outer Continental Shelf (OCS) activities, yet it is spatially removed from the actual lease areas.

A lack of quantitative information on the nature and extent of use of the Unimak Pass area by marine birds and mammals prompted National Oceanic Atmospheric Administration (NOAA) and Minerals Management Service (MMS) to obtain additional data. This report describes some of the results of efforts to fill these gaps.

STUDY AREA

The study area encompassed Unimak Pass and adjacent waters within a distance of approximately 50 km, including the Krenitzin Island group, The study area is bounded by latitudes 53°30'N and 55°00'N and longitudes 164°00'W and 166°30'W (Figure 1.)

RESOURCES OF CONCERN

The species of interest fall into three groups: 1) species that are numerous in the area, 2) species that are very rare, and 3) species for which we are unsure of their status.

The abundant species were predictable based on prior investigations in the region. Short-tailed shearwater, tufted puffin, and crested auklet were expected to occur in large numbers within the boundaries of our study area.

Rare species, especially endangered species, are of concern because these are species for which special measures are being taken to increase their population. Several endangered species occur (or formerly did) in the Unimak Pass area. These include several of the great whales including the right, gray, blue, humpback, and fin whales; and the short-tailed albatross.

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[1] The final report for this study is: Marine birds and mammals of the Unimak Pass area: Abundance, habitat use, and vulnerability. Prepared by LGL Alaska Research Associates. OCS Study MMS 91-0038.

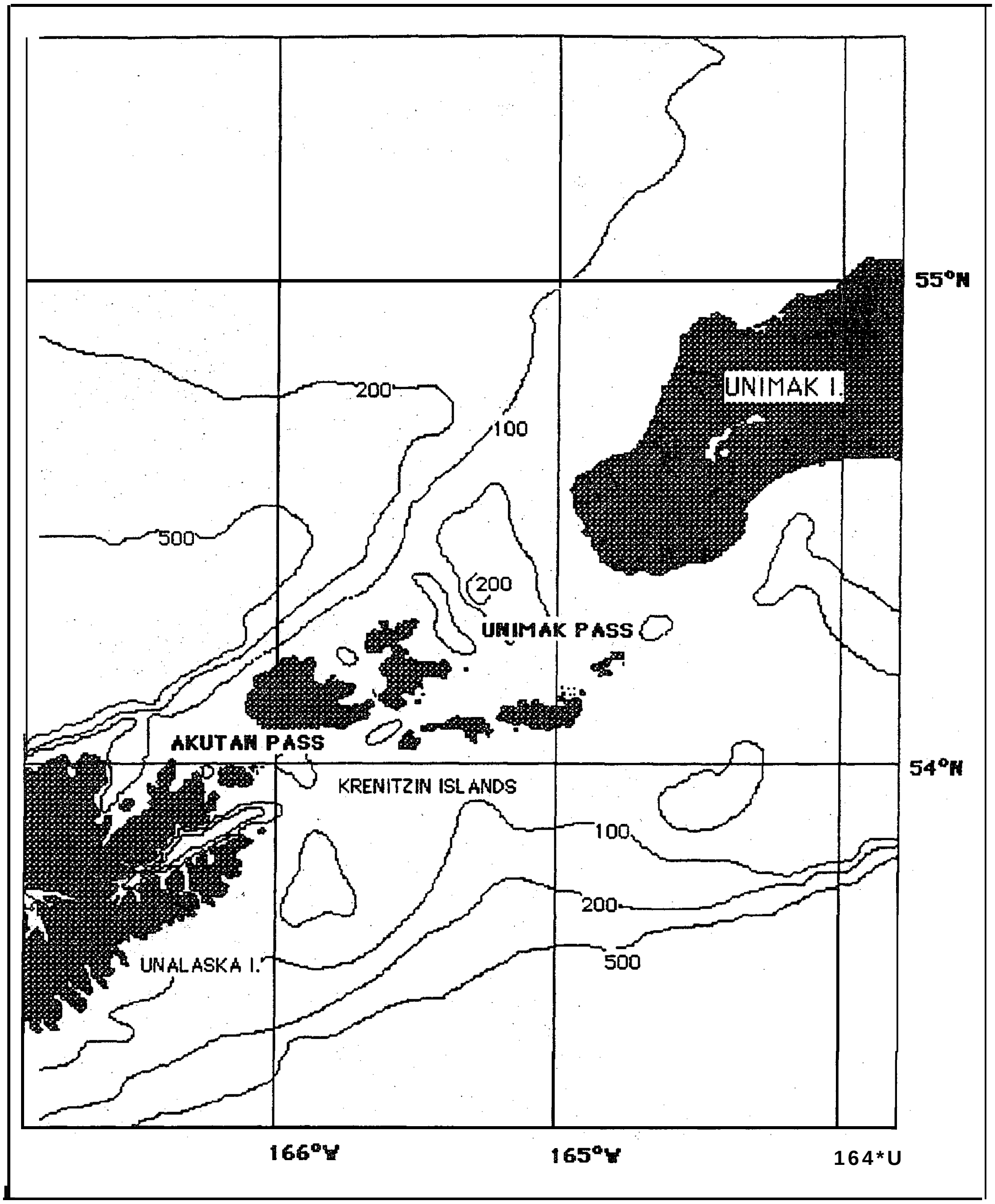

Figure 1. The Unimak Paas study area.

Species of uncertain status include several species or species group that were expected to occur, but their distribution and actual use of the pass area needed additional quantification. These include northern fur seal, whiskered auklet, and seaducks.

METHODS

Cruises

Three cruises were dedicated to this study. These cruises, all using the NOAA ship, R/V *Miller Freeman* were as follows:

MF-86-1 O 18 September to 7 October 1986 = "fail"
MF-87-02 14 February to 9 March 1987 = "winter"
MF-87-05 12 April to 14 May 1987 = "spring"

Marine Birds and Mammals

Surveys were made from the flying bridge while the ship was at full steam, Many survey lines were repeated each survey to ensure sampling of all major depth classes and (expected) oceanographic domains (e.g., Gulf of Alaska and Bering Sea sides of the Aleutians and all passes and straits within the Krenitzin Islands). Transects were 300 m wide and of 10 minute duration as is the customary protocol for conducting marine bird surveys in Alaska.

Environmental Features

Sampling to characterize oceanographic conditions and prey availability were undertaken, usually at night, along transects just censused. This sampling included bongo net samples (zooplankton), CTD casts (oceanography), and Marinovich mid-water trawls (forage fish). Most sample stations were reoccupied on each cruise,

Table 1. Densities of marine birds bv cruise.

Species	Fall	Winter	Spring
northern fulmar	9.9	5.3	5.1
sh.-tld shearwater	186.3	0.0	39.1
bl.-lggd kittiwake	42.1	2.4	1.7
murre	0.1	14.2	4.7
whiskered auklet	16.3	11.0	15.3
crested auklet	0.1	317.8	4.8
auk let	3.9	58.5	0.3
tufted puffin	9.9	0.1	0.5
Total	281.0	424.6	79.8
Area Sampled (km^2)	748.8	594.0	670.5

RESULTS

Distribution of Birds and Mammals

Fall. Most species peaked in abundance during the fall cruise (Table 1). This was particularly true of procellariids, larids, and puffins. Although many species were relatively common during this season, the total density of marine birds was not as high in fall as was observed during the winter, but fall abundance was considerably higher than during the spring cruise.

Short-tailed shear water was overwhelmingly the most numerous species, accounting for almost two-thirds of all birds seen. Next in abundance was black-legged kittiwake; this species accounted for an additional 15% of all sightings. Three additional species were common (occurring at densities $\geq$ 10 birds/km^2) - whiskered auklet, northern fulmar, and tufted puffin. In total, these five species accounted for 94% of the birds seen,

Several species, including most of the common ones, - northern fulmar, short-tailed shearwater, phalaropes, black-legged kittiwake, and tufted puffin - had an area of localized abundance in the northwest portion of Unimak Pass, off Akun Island (Figure 2).

As expected many whiskered auklets were encountered within the passes and straits of the Krenitzin Islands, especially off Akutan Pass. However, this species was aiso numerous in the Gulf of Alaska south of the islands with peak numbers occurring off passes (Figure 3).

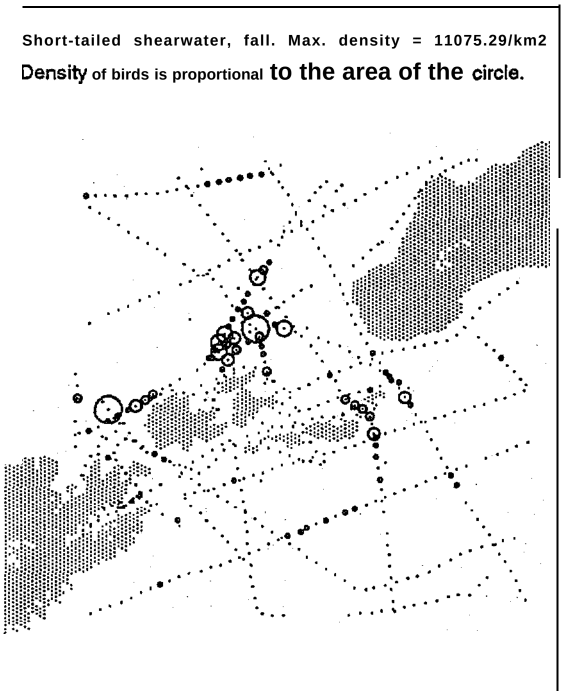

Figure 2. Distribution of short-tailed shearwaters during the fall 1986 cruise.

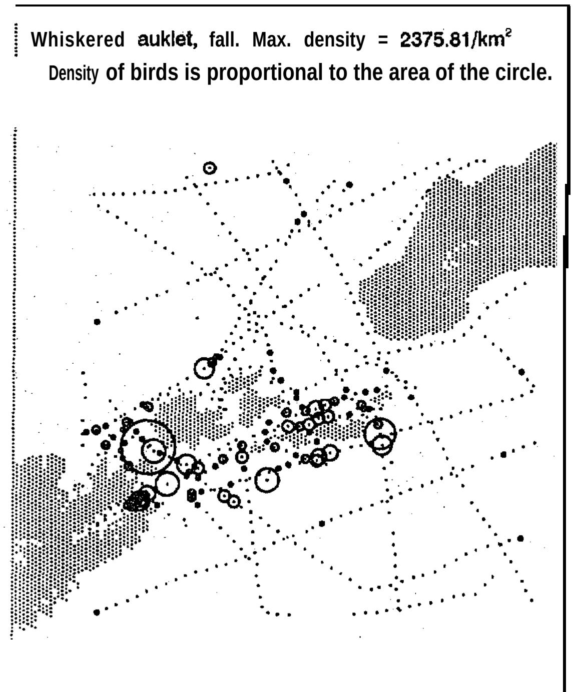

Figure 3. Distribution of whiskered auklets during the fail 1986 cruise.

Most marine mammals also were found at their peak abundances during fall (Table 2). Dall's porpoise, sea otter, and northern fur seal were most striking in this regard.

There were too few observations of marine mammals to make broad generaiizations regarding distribution. Northern fur seals were not as common as expected. They were encountered primarily in the Bering Sea to the west of Unimak Pass, Most Dali's porpoise were in the Bering Sea, peaking in abundance north of Unimak Pass, but they aiso occurred in the deeper waters of the Gulf of Alaska, Humpback whales were observed in the area of seabird concentration northeast of Akun Island.

Table 2. Densities of marine mammals by cruise.

Species	Fall	Winter	Spring
sea otter	0.029	0.007	0.009
Steller's sea lion	0.003	0.002	0.000
northern fur seal	0.039	0.000	0.000
harbor seal	0.004	0.000	0.000
killer whale	0.005	0.000	0.009
Dan's porpoise	0.139	0.074	0.051
gray whale	0.000	0.000	0.003
minke whale	0.004	0.003	0.001
fin whale	0.000	0.000	0.003
Tota 1	0.22	0.10	0.08

Winter, The highest overall density of marine birds was recorded on the winter cruise, Sightings were, however, restricted to a small set of species. At least three-quarters of all birds were crested auklet. Murres, predominantly common murre, were the second most numerous group, but they were an order of magnitude less numerous than the auklets. The only other common species was whiskered auklet. These three species accounted for approximately 97% of all marine birds present during the winter cruise.

The centers of abundance of birds occurred in two areas; north of Unimak Island and within the passes and straits of the Krenitzin Islands, Murres were numerous in both of these areas being most common in western Unimak Pass, Avatanak Strait, and off Cape Sarichef (Figure 4). Crested auklets were concentrated north of Unimak Island (between Capes Sarichef and Mordvinof) and within Akutan Pass (including Baby Pass) (Figure 5). Whiskered auklets were

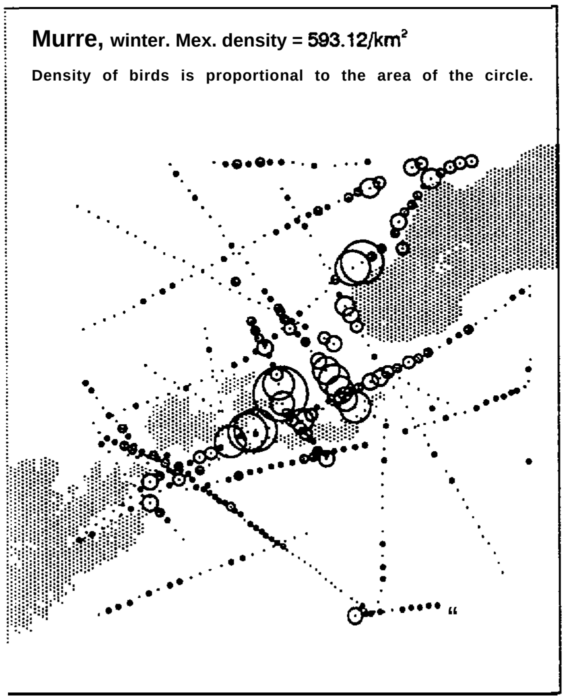

figure 4. Distribution of murres during the winter 1987 cruise.

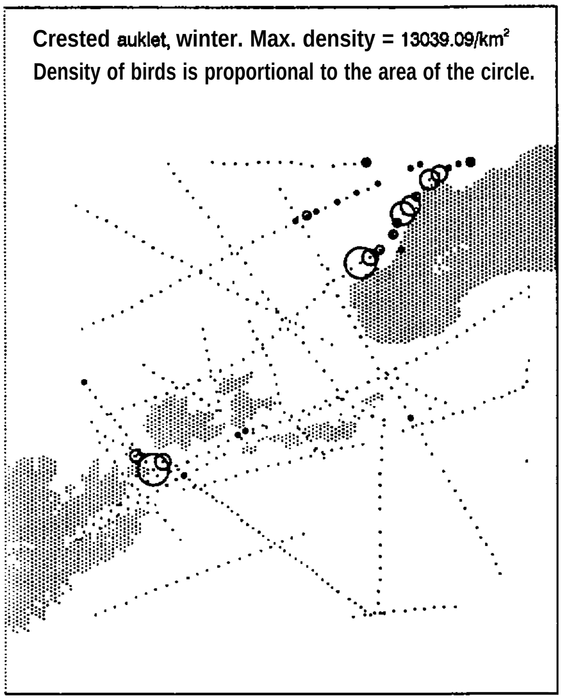

Figure 5. Distribution of crested auklets during the winter 1987 cruise.

restricted to the Krenitzin Islands, sharing the Akutan Pass area with the crested auklets but aiso in Derbin Strait (Figure 6).

Marine mammals were very infrequent during the winter cruise. The most numerous species recorded at sea was Dall's porpoise; these were largely restricted to the deepest portions of the study area in the north Pacific. The oniy species of baleen whale recorded during winter was minke whale which was found within the passes and straits of the Krenitzins.

Spring. The spring cruise had the most depauperate marine bird fauna of all our cruises. Overall densities were oniy one-fifth of those recorded during the winter cruise that ended not much more than a month earlier. This illustrates the dynamic nature of bird populations during times of migration. it was obvious that most winter birds had ieft for breeding areas and that few of the summer birds had returned. Indeed, the most numerous species during the spring cruise, short-tailed shearwater, was only recorded in appreciable numbers towards the end of the cruise.

in contrast to fall, during the spring shearwaters were most numerous in the eastern part of Unimak Pass, close to Unimak Island (Figure 7).

The oniy other common species observed during this cruise was whiskered auklet. These two species comprised 68% of all the sightings. Note that whiskered auklet was the oniy species that was common during all cruises. During spring this species was more frequent north of the Krenitzin Islands (still opposite passes) than during the other cruises (Figure 8).

Marine mammals were at their lowest abundance during this cruise but several sightings of interest were made. Gray whales were recorded, close to Unimak island as expected. Fin whales were observed within Unimak Pass. Although not during a census, a group of Baird's beaked whales was seen repeatedly in the deep water of the Bering Sea north of Dutch Harbor.

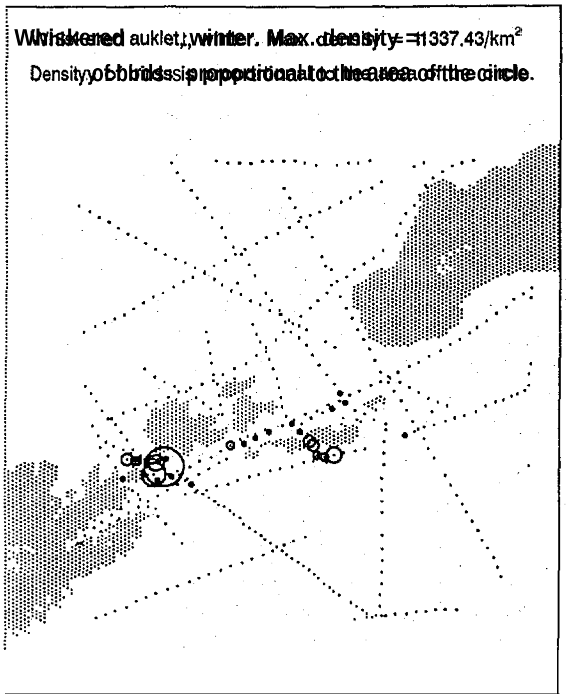

Figure 6. Distribution of whiskered auklets during the winter 1987 cruise.

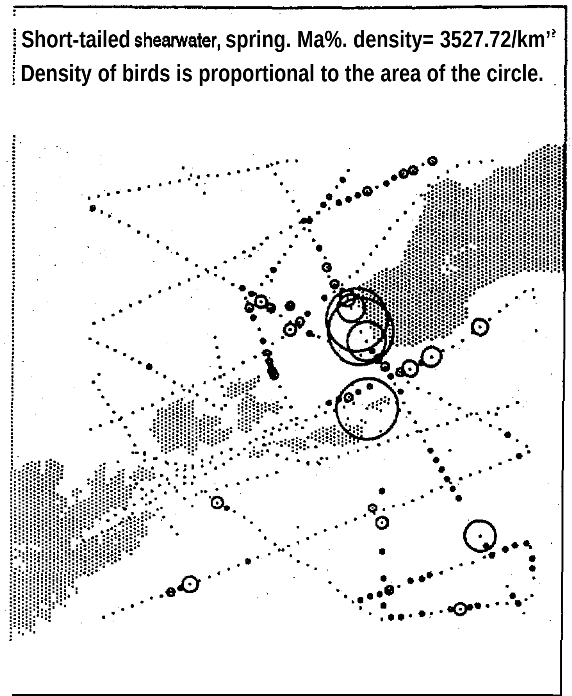

Figure 7. Distribution of short-tailed shearwaters during the spring 1967 cruise.

Oceanographic Features

Distributional analyses of water quality variables were based on shipboard CTD casts nitrate/nitrite samples taken on transects through the area, and oninspection of remote-sensing analyses of sea surface temperatures. Findings having implications for marine bird and mammal distributions in the area include the following:

1. Low-salinity Alaska coastal current water was associated in all seasons with Unimak island. The width of this water mass grew each season; it was particularly broad in the Bering Sea during spring.

2. Water quality distributional characteristics indicated that upwelling of deep Gulf of Aiaska water south of Unimak Pass and its subsequent transport through the pass was probably an uncommon occurrence. Rather, it seemed that upwelling probably occurred a few to several hundred km father west in the Aleutian chain, and that the

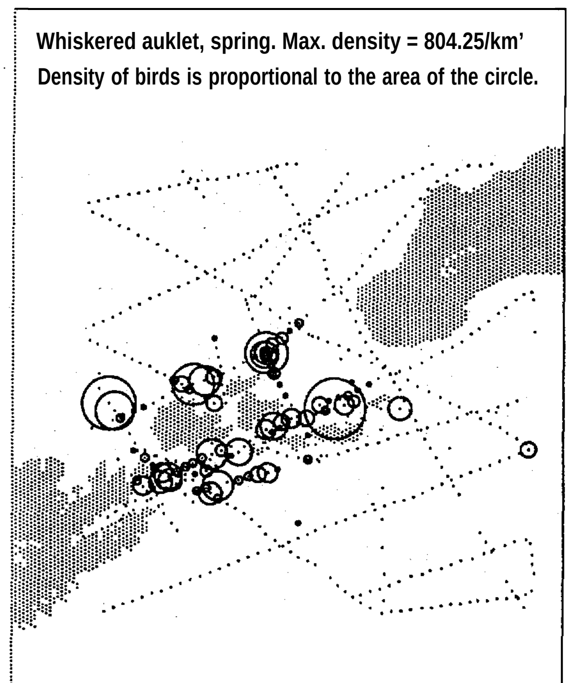

Figure 8. Distribution of whiskered auklets during the spring 1987 cruise.

upwelled water moved westward along the north side of the chain, eventually reaching the Unimak Pass area. This is consistent with recent theory by other workers.

3. Four different water masses appeared to occur in the study area as a whole, based on surface salinities and mixing regimes. These were Alaska Coastal Current water (ACW), Shelf Break Water (SBW), (north and west of the pass), Tidally-Mixed Water (TMW) (in shallow areas), and what we called Gulf of Alaska water (GAW) (widely distributed in deeper, western parts of the study area),

Two of the water masses, the GAW and the ACW were subdivided into northern and southern (Bering and Pacific) masses. In the case of the GAW, these two regions were frequently discontinuous and hence logically analyzed separately. As discussed earlier, the ACW retained its integrity as it passed through Unimak Pass. However, based on prior studies and the nitrate data we anticipated that effects of potential upwelling would be manifest on the Bering Sea component of this water mass but not the Pacific side. The narrowest portion of the Pass, off Seal Cape, was used as the boundary between northern and southern regions, Thus, most of Unimak Pass itself is in the northern portion of the ACWn.

Prey Resources

Fish. During the fall cruise very large numbers of small pollock were captured within the Krenitzin Islands. At all times of the year myctophids were present in the very deep portions of the north Pacific and Bering Sea. Otherwise forage fish were quite rare.

Invertebrates. Euphausiids and copepods, the zooplankton groups expected to dominate pelagic environments and vertebrate diets, were sampled in the water column and at the surface by nets deployed from aboard the R/V *Miller Freeman.* Estimates of vertebrate wet-weight biomass and composition by major taxa (e.g., copepods, euphausiids) were made. Major findings and their implications include the following:

1. Proportions of the total biomass that major zooplankton groups contributed varied seasonally. Gelatinous zooplankton (jellyfish) dominated spring catches northeast of Unimak Pass but were inconsequential in other seasons and places. Euphausiids formed the overwhelming majority of non-gelatinous zooplankton biomass in fall and winter and a slight majority in spring. Copepods were scarce in fall and winter but nearly equaled the abundance of euphausiids in spring.

2. During fall euphausiids were virtually absent from the ACW but were present in all other water types. They peaked in abundance in the Bering Sea, especially in the SBW. During winter euphausiid distribution changed markedly; large concentrations being found in the ACWn. By spring abundance had dropped in most areas and the highest densities were found in the ACW and TMW.

3. The marine birds food habit studies indicated that euphausiids in bird stomachs from the study area were largely oceanic species; shelf species were uncommon. This finding supports other evidence that water upwelled from off the shelf dominates the Unimak Pass area.

DISCUSSION

The following sections summarize the distribution and abundance of seabirds and their prey in relation to the water masses. Following completion of these analyses some errors were discovered in the watermass delineations. Hence, the details of these results are imprecise but the broad patterns are probably reliable.

Fall

Marked differences in abundance of marine birds were evident among water masses. The highest densities occurred in the SBW due to the extreme abundance of short-tailed shearwaters (Figure 9) and black-legged kittiwakes in waters of this type. During the fall cruise, the spatial extent of this water mass was more extensive than was observed during other cruises, occupying much of the northwest corner of the study area. Shearwaters were also abundant in the adjacent Gulf of Alaska Water north (GAWn); however, black-legged kittiwakes were abundant only in the SBW. The abundance of birds in the SBW and GAWn was paralleled by the highest densities of euphausiids, their principal prey, in these areas.

The ACW was quite depauperate in birds in both the north (ACWn) and south (ACWs) regions. Horned puffins reached their peak abundance in the south portion of the water mass; however, even here they were quite rare. These areas were also lacking in potential prey for seabirds. Oceanic areas in the Gulf of Alaska have very low densities. One species; black-footed albatross was restricted to this area.

Although absolute densities in the TMW were substantially lower than in the more structured water masses to the north, several species were largely restricted to this water mass. Most striking in the regard was whiskered auklet (Figure 10) and tufted puffin. Cormorants, murrelets, and common murre were also most frequent in the TMW. The occurrence of many of these birds in the TMW is probably due to proximity to breeding colonies in the Krenitzin Islands. Some species, especially tufted puffin were preying largely on the large numbers of young pollock abundant in this area.

In general, the ACW was little used by birds. Excepting this water mass, bird use of the Bering Sea side of the chain was high relative to the Gulf of Alaska side. Intermediate densities of a distinctive species composition occurred in the TMW.

Winter

Use of the various water masses during winter differed markedly from the use observed during the fall cruise, The highest densities occurred in the ACW. The contrast between the south and north components was striking with almost all the birds being in the northern portion. Crested auklet made up the greatest proportion of birds encountered in this water mass (Figure 11); however, many species reached their peak abundance here, Other common species in the ACWn were northern fulmar and common murre. Several species of seaducks (Figure 12) and gulls also reached peak abundance in this area, A corresponding shift in distribution of prey items was recorded with euphausiids being markedly more abundant in the ACWn than elsewhere during the winter,

The TMW apparently increased in importance to birds. Whiskered auklet were still largely confined to this water mass but even higher densities of crested auklets were using these areas. Common murres were also numerous in this water mass although densities were not as high as in the ACW. Although not common in the areas surveyed by the ship, most of our encounters with emperor geese and cormorants were in TMW.

Gulf of Alaska water had a dearth of birds. The northern portion had more than the south; however, neither area had many birds, Both tufted and horned puffins were most numerous in the GAWn, but puffins were rare everywhere during the winter.

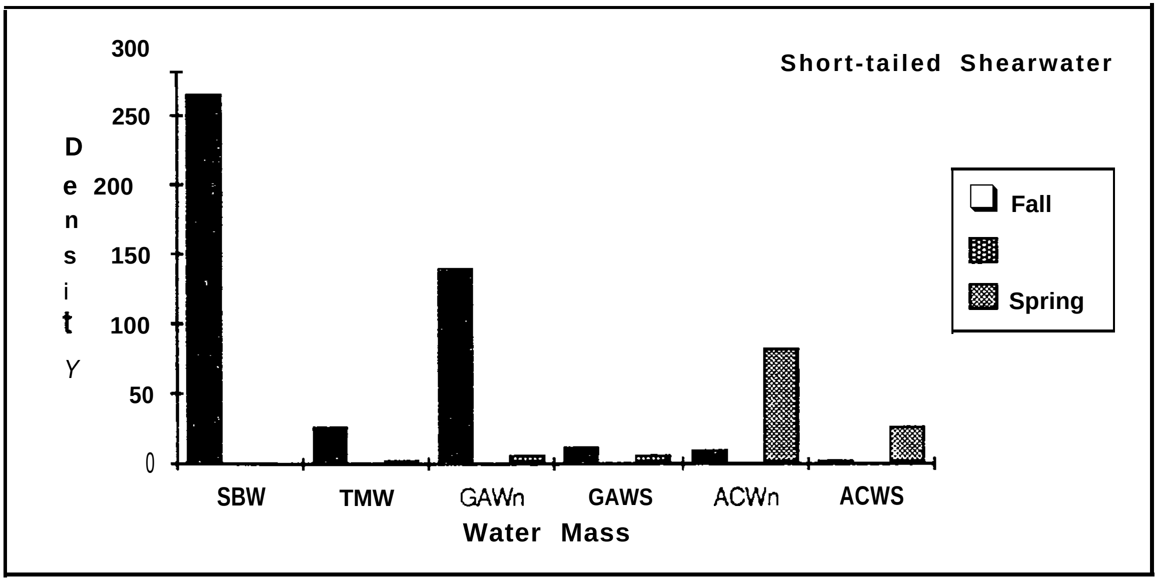

Figure 9. Abundance (birds/km^2) of short-tailed shearwater by water mass and cruise.

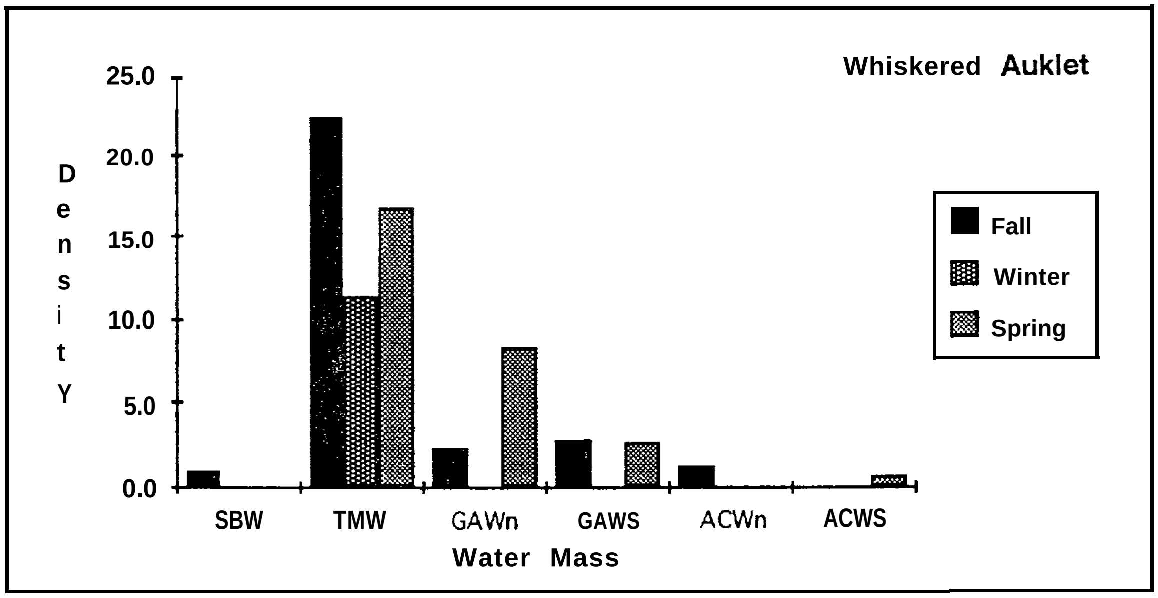

Figure 10. Abundance (birds/km^2) of whiskered auklet by water mass and cruise.

The SBW was much reduced in size during the winter compared to the fall. Water of this character was identified in two areas, one north of Unalaska Island, the other at the north extreme of the study area. A complete picture might reveal this area as being connected to the west of our study area. Moderate densities of birds, mainly auklets (presumably mostly crested auklets) were found in this water mass.

Overall, the winter results show that the Gulf of Alaska continued to have only a few birds, bird use of the western segment of the Bering Sea habitats was greatly reduced; whereas habitats in the eastern portion under the influence of the ACW were heavily used by marine birds. TMW was of greater importance to birds during the winter as compared to the fall.

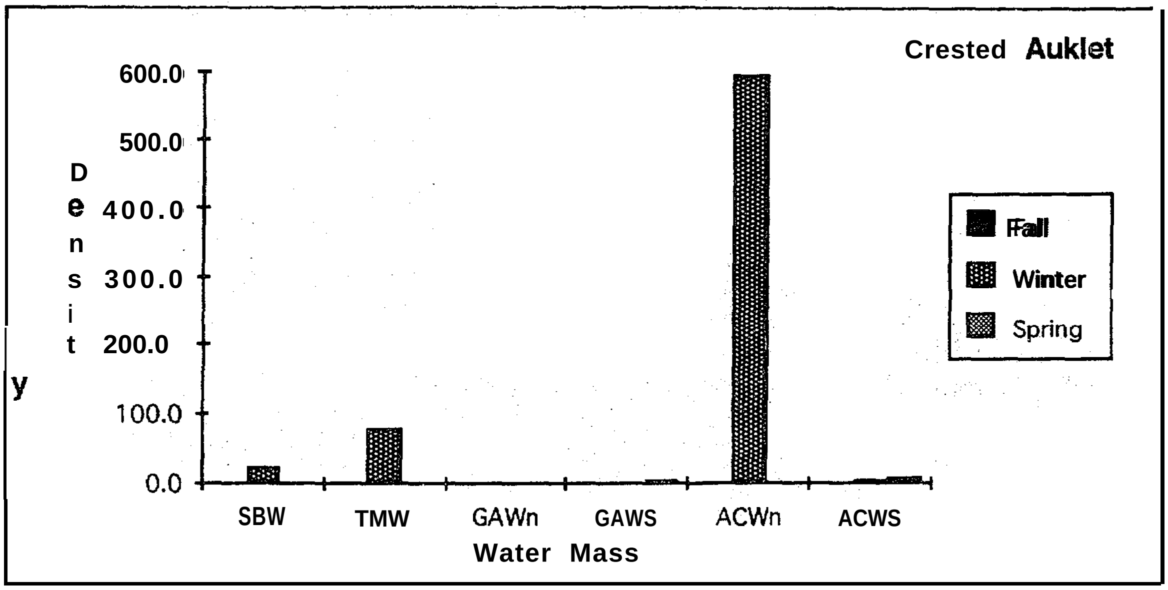

Figure 11. Abundance (birds/km²) of crested auklet by water mass and cruise.

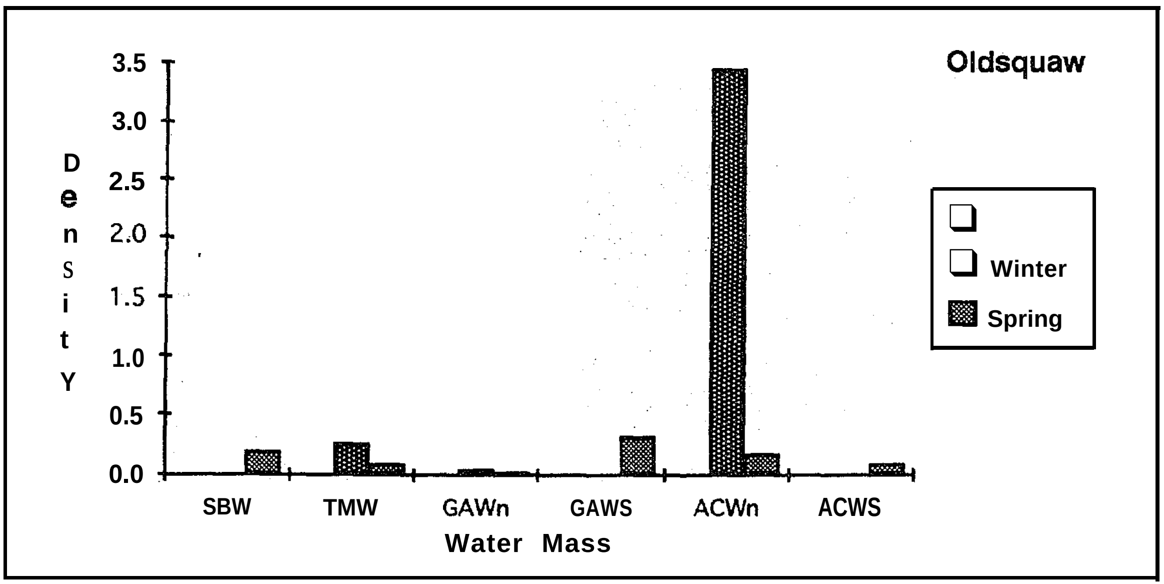

Figure 12. Abundance (birds/km²) of oldsquaw by water mass and cruise.

Spring

Use of the various water masses was much more equitable during the spring cruise than at other times of the year; although overall densities were relatively low. The highest densities of marine birds occurred in the ACW. The region continued to have the highest abundance of euphausiids, although not as high as during the winter. Although the northern portion was again the most important, the portion south of Unimak Island had more birds in the spring than were observed during any other cruise. In both areas, short-tailed shearwater predominated.

GAW had similar overall densities in both northern and southern sectors, but the species composition was rather different. In the south, where densities were highest of all cruises, common murre was the most frequent species. In the north, whiskered auklet predominated; although this species was more numerous in the TMW.

As mentioned above, the TMW continued to be the important habitat for whiskered auklet. Although several species peaked in abundance here - murrelets, pigeon guillemot, cormorants - only whiskered auklet occurred in appreciable abundance.

In marked contrast to the results of the fall cruise, the SBW was the least used of any of the area habitats during the spring cruise. No species, even of the less frequently encountered species, peaked in abundance in this habitat.

CONCLUSION

The Unimak Pass was found to support spectacular concentrations of marine birds and lesser numbers of marine mammals. Marked differences in distribution were found both temporally and spatially. Prey availability appeared to play a major role in determining bird distribution.

Virtually all the key species - shearwaters, auklets, and murres - were found to be preying predominantly on euphausiids. Some of these species frequently feed on fish in many other areas,

In the fall both prey and birds were most common north of the Krenitzin Islands in areas considered to be SBW. Spectacular concentrations occurred in the northwest corner of Unimak Pass (off Akun Island). This location may represent an area of local upwelling.

During winter, the euphausiid concentrations were further east, to the north of Unimak Island within the ACWn. The major bird concentrations, mostly crested auklets and common murres were also present in this area. The spring cruise found no major concentrations, although the ACW supported the highest densities of birds and prey.

Some species, including the whiskered auklet, did not follow the prey concentrations on a seasonal basis. This species was always associated with the Krenitzin Islands and the TMW. Euphausiids were always present in this area although they did not reach the high densities of some other areas. It may be that zooplankton availability increased during periods of high tidal flux when the birds appeared to be most active in the passes but sampling was impossible. Birds collected in the passes were found to have been successful in procuring euphausiids.

We did find that whiskered auklets venture much further from the passes than previously believed. Relatively large numbers were found at sea (5 to 10 nm) both north and south of the islands. Occurrence in these areas did appear to vary seasonally (they were most concentrated closest to land during winter) and even at sea they appear to be concentrated opposite passes.

Our results tend to support the hypothesis that very little upwelling or influx of nutrients or prey occurs due to movement through Unimak Pass or the other passes we sampled. Rather, upwelling appears to occur in the Bering Sea to the west of our study area and the nutrients (or subsequent trophic products) transported east along the north side of the eastern Aleutians and into the north Aleutian Shelf area. Local upwelling north of Akun Island during the fall was suspected.

ECONOMIC IMPACTS OF THE S.S. *GLACIER BAY* OIL SPILL

Patrick Burden
Northern Economics
2810 Cutwater Court
Anchorage, Alaska 99516

INTRODUCTION

On July 1, 1987, the S.S. *Glacier Bay was* en route to Kenai Pipeline Company facilities at Nikiski with 380,000 barrels of North Slope crude oil from the Valdez terminal of the Alyeska Pipeline Service Company. Early in the morning of July 2, 1987, another vessel was occupying the berth where the S.S, *Glacier Bay* was to unload so the S.S, *Glacier Bay* anchored off the mouth of the Kenai River. The crew felt the vessel bump once and then again as it turned with the tide. Thus began an event that was the largest spill in Alaska waters prior to the S.S. *Exxon Valdez* spill in 1989. The sport fishery in Cook Inlet was in mid-season at the time of the spill and the commercial fishing season was barely underway with the largest salmon return in history moving up the Inlet.

The S.S, Glacier *Bay* spill represented an opportunity to study the economic impacts of an oil spill event in Alaska, particularly with regard to commercial fishing impacts and the public costs of cleanup. The purpose of the study was to analyze the direct economic effects resulting from the study. There were three primary objectives to the study:

1. Document and describe the events that transpired during the oil spill, response and cleanup efforts, and compensation procedures;
2. Estimate the direct economic costs associated with each activity mentioned above; and,
3. Estimate the cost of the oil spill to other groups, emphasizing the major distributional effects on commercial fishing, recreation, subsistence, government entities, and property values,

APPROACH

The approach began with identifying the categories of information required to address the objectives outlined above. Literature searches were conducted of industry journals and newsletters, Alaska business journals and newsletters; local newspapers; federal, state, and local government agency file reports; other publicly available documents; and computer data bases. Several types of information were not addressed, or not adequately covered in the literature concerning the S.S. *Glacier Bay* oil spill. These included

1. Economic impacts on commercial fishing and processing activities, and on subsistence and personal use fisheries;
2. Economic impacts on recreation and tourism values;
3. Effect of the oil spill on property values;
4. Amounts of compensation sought and received following the oil spill; and
5. Remaining government and industry expenditures on spill response and cleanup activities,

This information was the focus of subsequent protocol development and an interview-based data collection effort.

RESULT'S

The analytical methodology developed costs for the groups affected by the spill, and benefits to the local economies of the Kenai Peninsula Borough and the Municipality of Anchorage. Table 1 summarizes the direct economic impacts for each group calculated from the available information.

Table 1. Summary of economic impacts.

Category	costs	Benefits
Petroleum Industry	$4,217,000	Insufficient data
Government	$1,359,000	$1,103,000
Commercial Fishing	$11,105,000 to $124,091,000	N/A
Sport Fishing	No measurable impacts	
Subsistence	No measurable impacts	

SUMMARY

The study commenced two years after the spill occurred, The major cleanup contractor was no longer in business, and many individuals had moved, transferred, or were otherwise unavailable, More importantly, the affected parties were involved in litigation before the study began. Many firms and individuals were advised not to provide information by their legal counsel, The vessel owners and other petroleum industry firms involved in litigation refused to provide more than publicly available information. None of the seafood firms would comment on the spill, and fishermen often provided estimates of their losses based on values that legal counsel was seeking in court. Even government agencies involved in litigation did not provide requested information.

Because of these difficulties even those economic costs and benefits shown in Table 1 are significantly understated. Endeavors to identify the economic impacts of future oil spills must begin immediately after the spill to avoid these problems,

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Patrick Burden is the principal economist for Northern Economics and has been associated with the consulting firm for the past 10 **years.** *Many of his research projects entail modeling the economic and socioeconomic effects of resource extraction and harvesting industries in Alaska. Mr. Burden received his B.S. in business administration and his M.S. in geography from Portland State University, and has completed several years of coursework in a Ph.D. program at the University of Washington.*

QUESTIONS AND DISCUSSION

Stephanie Reynolds: I was just wondering if you could tell us about the effect of the spill on fish prices?

Pat Burden: We went back and looked at historic fish prices and daily fish prices in the Inlet and what had transpired there. Fish prices did fall during the spill, Lots of fishermen and the law firm claimed that it was due to the spill and the fears of the buyers that the fish were tainted, etc. That claim by the fishermen prevailed in the court, but I am not sure that it did affect it as much as the overwhelming or very, very large return that came back into the Inlet in 1987. It was the largest return in history. Processors were overwhelmed. For the first time in history there were floating processors in Cook Inlet. We looked at those prices, We could not verify that prices fell as a result of the oil spill. I guess our opinion, after reviewing all of the data, was that it was more likely due to the very, very large return. The fact is that the processors, once they were full, didn't need to pay $1.70 for fish, they could get all the fish they could handle at $1.00, so that was the price they elected to pay. Anecdotally, talking to some processors that I know, they said that oil didn't matter that much, We just had too many fish. But 1 couldn't get them to say that on the record.

Harold Lee: My question to you is that since the spill in 1987 have you or any of the other studies in the Inlet seen a reduction in the returning salmon stock that would have come up to spawn four years later or two years later for that particular species?

Pat Burden: I'll have to give you some historic perspective on what has occurred in the Inlet. in 1987, there was an escapement of 1.6 million fish in the Kenai River which is the major sockeye producing system in the Cook Inlet. The escapement goai for the system is somewhere between 400,000 and 700,000 fish. So they more than doubled what their escapement goai was. in 1988 they had a little over one million fish escapement into the Kenai. in 1989 they had 1.5 million. in 1990 it dropped back to about 700,000, We had three years of very large escapement into the Kenai System. The sockeye in the Kenai is a five year fish. It is due back in 1992. The 1987 brood year will return this year. The forecast is for it to be a respectable return, somewhere between 5.8 and 6.2 million fish total return to the Inlet. it will probably place it about the fifth or sixth highest return in the inlet since 1960. The management and research biologists in Soldotna who are responsible for the Kenai System don't know what is occurring. What has happened is that smolt production from the lakes on the Kenai System has been dramatically reduced. They think, weii they aren't saying because it is tied up in litigation, but part of the issue might be that the large escapements reduced the productivity of the lake systems. That is still being researched, they don't know, So we may have had an impact from the over-escapements that happened.

Lynn Robbins: Why didn't you use the Freedom of Information Act?

Pat Burden: We didn't have time. it was going to take us four to five months to get the data and we oniy had three.

Lynn Robbins: What were the financial benefits to governments? You had them listed there, certain dollar figures. Could you tell us what those were?

Pat Burden: it was not total "benefits" to the government rather benefits to the local economy. By local that came out to be the Kenai Peninsula Borough and Anchorage. That was what we were asked to iook at. it was not a benefit to either of any of those sectors but rather a benefit to the local economy.

Lynn Robbins: Where did those dollars come from, settlement money?

Pat Burden: That would have been the subsequent purchases by the government from monies they were compensated. For example, the Coast Guard went out to a local spill contractor, or they rented cars from Hertz, or they purchased airpiane tickets, etc. Those were benefits in the local economy. So there were expenditures and benefits were generated.

Pamela Miller: Are there any plans to tie the economic impact study more closely with the natural resource damage assessment study? it seems to me that that is the most meaningful or logical thing to do next to get a reai good sense of the economic impact.

Pat Burden: We weren't asked to do that. We followed the scope of work that we were given by MMS. NOAA was pursuing the Natural Resource Damage Assessment process but they wouldn't give us information because they were in that process. I would assume that they will or they may have aiready done so. But i assume that they were in the process and that they wiil come out with an assessment. i have not seen it.

A COMPARATIVE, SUBREGIONAL ANALYSIS OF SUBSISTENCE PRACTICES IN THE BRISTOL BAY REGION OF ALASKA

Joanna Endter-Wada
College of Natural Resources
Utah State University
Logan, Utah 84321

Lynn A. Robbins
Huxley College of Environmental Studies
Western Washington University
Bellingham, Washington 98225

INTRODUCTION

The Subsistence Division of the Alaska Department of Fish and Game has had an active research program in Bristol Bay since 1980. The department has completed baseline studies for most communities in the region which document subsistence harvests and describe subsistence activities. The reports and data base from these studies was provided under contract to the Minerals Management Service (MMS). MMS contracted with us and several colleagues to analyze this data, review secondary literature, and conduct research in seven sample Bristol Bay communities. The purpose of the research is to analyze subregional variations in subsistence activities and the factors affecting those activities. Our research builds upon this work conducted by the Alaska Department of Fish and Game, Subsistence Division and relies upon other research which has attempted to analyze the complexities of Alaskan subsistence economies (Jorgensen 1990, Langdon 1986, Little and Robbins 1984, Luton 1985, Wolfe et al. 1984).

The naturally-occurring resources utilized for subsistence comprised well over eighteen fish species (mainly salmon), dozens of plants species (especially various kinds of wild berries), three major species of land mammals (caribou, moose and bear), several small land mammal species (chiefly beaver, hare, porcupine), various clam and crab species, several species of marine mammals (seals, and occasionally walrus), and several species of ducks and geese, as well as grouse, ptarmigan, an incidental number of other bird species, and bird eggs.

METHODS

Our initial task was to analyze data gathered by the Subsistence Division of the Alaska Department of Fish and Game (ADF&G) over the previous eight years. ADF&G collected detailed data on types and amounts of species harvested for most Bristol Bay communities in order to document dependence upon subsistence resources and to address regulatory questions, Two variables were fairly consistent across all communities in ADF&G's Bristol Bay data set: 1) the percentages of households harvesting various types of resources (a rough indication of involvement in subsistence activities and of the relative mix of resources harvested); and, 2) the average pounds per household hatvested (a measure of nutritional dependence upon particular foods), We used Chernoff's faces, Fourier plots, and Guttman-Lingoes multidimensional similarity structure analysis to compare communities based on these two variables.

In general, community comparisons based on percentages of households that harvest particular resources indicated three distinct subregions: the Pacific side of the Alaska Peninsula; coastal communities on the Bristol Bay side of the Alaska Peninsula; and inland or "upriver" communities. Comparisons based on the amounts of various resources harvested (pounds per household) often produced finer distinctions within those subregions. For example, in some analyses, the Bristol Bay Borough communities clustered separately from other communities on the Bristol Bay side of the Alaska Peninsula. Similarly, in some analyses, the inland communities could be broken into a Nushagak River cluster and an Iliamna Lake cluster. The clusterings are largely geographical, indicating that people generally harvest the resources available in their environment.

Based on this analysis of ADF&G data and a review of secondary literature, we selected seven communities to represent the identified subregions: Chignik Lake, Dillingham, Naknek, New Stuyahok, Nondalton, Port Heiden, and Togiak. The populations of these communities ranged from 2017 for Dillingham, the regional center, to 119 in Port Heiden, a small community on the Alaskan Peninsula. Ethnic compositions included various mixes of Eskimos, Athapaskans, Aleuts, and non-Natives. Fieldwork was conducted in these communities during August and September 1990 in which primary interview and ethnographic data was collected. Focused discussions were conducted with members of randomly selected households (212 households representing 778 total household members) and with institutional officials (98 people), and subsistence practices were observed.

This paper is based upon analysis of the household-level and ethnographic data. Cooperation and sharing networks based on geography and kinship were analyzed to illustrate the importance of subsistence activities to social structure. Models of individual and household participation in subsistence activities were constructed by regressing each of three, weighted involvement indices on a set of explanatory variables. Fourier plots and Guttman-.Lingoes multidimensional similarity structure analysis were used to compare communities based on subsistence harvesting and processing patterns, The meanings of subsistence, changes in subsistence practices, and threats to subsistence were also analyzed.

RESULTS AND DISCUSSION

Subsistence Cooperation and Sharing Networks

The data collected in this study differed from data collected in most previous Alaskan subsistence studies in that we documented connections between households that cooperate in subsistence activities and share subsistence resources. We did so by calculating the percentages of households in each community that have harvesting, processing, giving and receiving ties to households in various locations (geographic networks) and to households that are related to them in various ways (kinship networks). The geographic extent of these networks and the kinship relations on which they are based were analyzed to illustrate the importance of subsistence activities to community and regional social and cultural structures.

In terms of geography, cooperation and sharing networks are most concentrated within communities but extend to other communities throughout the Bristol Bay region, to other areas of Alaska, to the lower 48 states, and, in a few instances, to foreign countries. Households tend to engage in subsistence harvesting and processing activities with people that live in the same or nearby villages, with cooperation generally decreasing as the distance between communities increases. Harvesting networks are more extensive than processing networks, that is, people from different villages get together more often to harvest resources than to process them.

Sharing networks are more extensive and intricate than cooperation networks and exhibit a somewhat different geographic pattern. While the strongest ties for giving and receiving subsistence resources are between households within the same community, the strength of sharing ties does not decrease with distance outside communities. The next strongest receiving ties are generally between the sample communities and other communities within Bristol Bay (not necessarily neighboring ones), indicating that the subsistence needs of Bristol Bay residents are generally provided for from within the region. However, the next strongest *giving* ties are to communities outside Bristol Bay, especially in the case of non-commercial fish, big game, and plants, and to a lesser extent with small game and birds. This indicates that Bristol Bay is a net "exporter" of subsistence foods and that resources which are abundant in Bristol Bay provide for the subsistence needs of people in other areas as well.

Differences in geographic patterns for cooperation and sharing were observed across sample communities. Communities with the highest percentages of Alaskan Native inhabitants (Chignik Lake, New Stuyahok, Nondalton, and Togiak) generally exhibited the greatest intracommunity cooperation in subsistence activities and sharing of subsistence resources. Dillingham (the regional center) and Naknek (a subregional center) have more extensive inter-community harvesting and processing networks, probably due to connections maintained by people who have moved from villages to those centers. Several communities occupy important positions in terms of regional sharing networks: New Stuyahok shares resources of all kinds with other Upper Bristol Bay communities; Togiak has extensive sharing connections with the Kuskokwim region; Port Heiden has the most sharing connections with the three major subregions of Bristol Bay and serves as a crossroads between them; and, Dillingham and Naknek generally receive more subsistence resources from other communities in Bristol Bay than they give.

Differences in cooperation and sharing patterns also were observed across resource groups. People most often cooperate to harvest non-commercial fish, plants, big game, and birds. The harvesting networks for these resources extend beyond the region and, except for birds, outside of the state. Processing cooperation between households is greatest for big game and non-commercial fish, the two most important subsistence foods by bulk in Bristol Bay. Communities generally share the particular resources which they have in abundance and receive resources which they lack, need, and desire. Big game, plants, and non-commercial fish are widely shared within and between communities even though these resources are harvested by the highest percentages of households in all sample communities. This is because people share different species and share resources preserved or prepared in different ways in order to increase the overall variety in their diet. Even though piants and birds generally add a small amount of edible pounds to local diets, the high level of cooperation in their harvest and of sharing in the case of plants indicates that these resources are more important in terms of the overall subsistence economy than their mere bulk would indicate.

Our data indicate that kinship is the primary basis for cooperating in subsistence pursuits and sharing subsistence resources. Harvesting is most often conducted alone, with other household members, and with friends, affines, and siblings from different households. More harvesting is done among persons reiated matrilineally than through the male lines of descent. Most of the inter-generationai hatvesting networks are found within households while inter-household, inter-generationai networks are most often composed of affinal and extended kin. The large percentage of harvesting among friends and siblings indicates that harvesting often is done with contemporaries and is a form of recreation and social activity. It also suggests that availability, skill, and reliability, in addition to kinship, are factors determining the formation of harvesting groups. Harvesting birds, big game, plants, and non-commercial fish is more of a group activity with a wider variety of harvesting group compositions than is the case with harvesting small game, marine mammais, or marine invertebrates.

Subsistence processing is generally done alone or with other members of the same household. Inter-household processing networks are fewer and smaller than harvesting networks, Processing non-commercial fish is the activity which involves the most inter-generational kin groups and the widest variety of collateral and affinal kin.

The kinship networks for sharing subsistence resources are more extensive than the kinship networks for harvesting and processing subsistence resources. Subsistence resources are widely distributed among family and friends, and the sharing of subsistence resources connects more households than the harvesting or processing of those resources. More households give subsistence resources to parents and offspring than harvest those resources with them, which suggests that inter-household, inter-generational groups (parents, offspring, grandchildren) are more connected in the distribution and consumption of subsistence foods than in the harvesting and processing of them. Parents and grandparents tend to receive resources that are harder for eider people to process (birds, small game, big game, and marine mammals) and to give resources that they are able to continue harvesting (plants, non-commercial fish). Parents and grandparents generally receive more subsistence foods because of need, because they usually know best how to prepare subsistence foods, and because their houses tend to be gathering places which ensures the widest distribution of the food among relatives.

Factors Affecting Participation in Subsistence Activities

Data gathered on participation in subsistence activities was more detailed for the respondents (n= 212) than for other members of their households (n=778). Analyses of factors affecting participation in subsistence were conducted for all household members (n=778), for respondents (n=212), and for sampled households as a whole (n=212).

The factors analyzed using data on all household members (n=778) were gender, ethnicity, length of residency, and age. The strongest predictor of involvement in subsistence activities was length of residency. The likelihood of engaging in subsistence activities increased consistently with length of residency across all seven of the major resource categories for both harvesting and processing. This indicates that subsistence is a regional way of life influencing all residents to some degree.

In general, men are more involved in all aspects of subsistence activities (harvesting *and* processing) than women, although there are some differences across resource categories. The only resources that women harvest more than men are plants and berries, and women are much less involved than men in hunting and trapping (or harvesting birds, small game, big game, marine mammals). While females process subsistence resources much more than they harvest them, the distinctions between genders in terms of processing are slight. Women are much more likely than men to process plants and berries, but only slightly more likely to process non-commercial fish and marine invertebrates, about equally likely to process birds and marine mammals, and less likely to process small game and big game, Our ethnographic research suggests that more women are wage earners and work full-time, thus limiting their ability to engage in subsistence activities, while more men are seasonal commercial fishers, which leaves the rest of the year free to hunt, trap, and fish *and* to process what they harvest,

Significant differences based on ethnicity (coded as full Native, part-Native, or non-Native) were found for some resource categories and some subsistence activities. Natives and part-Natives are more likely to harvest and process marine mammals (restricted to Natives) and to harvest marine invertebrates than non-Natives, while full Natives are more likely to harvest and process small game and birds than either part-Natives or non-Natives. The only resource category in which non-Natives are more likely to harvest and process than either Natives or part-Natives is non-commercial fish, There are no significant differences based on ethnicity for harvesting big game, non-commercial fish, or piants and berries, the three main subsistence resource categories. in general, ethnic differences are significant for subsistence activities which are not normally undertaken for sport,

Significant differences were found for harvesting and processing by age group. Over 90% of individuals between the ages of 21 and 60 harvest or process at ieast one subsistence resource. Participation remains high (over 80%) for those over the age of 60. Youth under the age of 20 are much less likely to be involved in harvesting (60?’.), and especially in processing (35%).

Regression models were used to analyze data for respondents and sampled households. Involvement indices were created, elements of the indices were weighted according to importance for involvement in subsistence, and indices were regressed on a set of explanatory variables. The model for respondents indicated that males participate in subsistence more than females; involvement in subsistence activity increases as the years in commercial fishing increases; young adults engage in more subsistence activity (the youngest respondent was 19 years old); persons with more education have increased involvement in subsistence (not surprising since education is negatively correlated with age); and, respondents from Nondalton were more engaged in subsistence activities than residents of the other villages. The model for sampled households indicated that larger households harvest and process more resources, household involvement in commercial fishing is associated with higher subsistence involvement, and single parent households were less involved in subsistence even when controlling for household size.

Community Comparisons

Part of our task was to integrate our findings with our previous analysis of the ADF&G data in which communities were compared based upon percentages of households harvesting various subsistence resources and the average pounds per household harvested. Differences in the years of data collection, protocols, and methodologies prevented a direct comparison of data sets. Instead of comparing absolute percentages or amounts, we compared the rank ordering of communities. Overall, our data shows a similar pattern to ADF&G's in terms of amounts harvested. For percentages of households harvesting, the top and bottom ranks were usually the same with some reversals occurring in the middle ranks on some resources.

Amounts of resources harvested varied by community, with each community focusing on the resources in abundance in their locale. Harvests of subsistence foods were generally high in all communities. In comparison, however, New Stuyahok and Togiak most often rank highest, followed by Nondalton. Chignik Lake, Dillingham, and Naknek generally occupy the intermediate ranks. Port Heiden usually ranked fifth, sixth, or seventh.

Comparisons between communities based upon percentages of households harvesting were made using the same multivariate graphical techniques employed to analyze the ADF&G data (Fourier plots, Chernoff's faces, and Guttman-Lingoes' multidimensional similarity structure analyses). In general, Chignik Lake and Port Heiden have similar characteristics as do New Stuyahok and Nondalton. Dillingham and Naknek are most similar to one another, but were also close to New Stuyahok and Nondalton. Togiak is not similar to the other communities. These subregional clusterings generally fall out geographically, but clearly the nature of the communities also influences the comparisons, as evidenced by the facts that the regional "centers" cluster (Dillingham and Naknek).

Meanings of Subsistence and Perceived Threats to Subsistence Activities

Much of the data collected through the focused interviews was descriptive and not easily subjected to statistical analyses. Interviewees stressed the meaning and importance of subsistence in their lives, Meanings of subsistence are based on cultural continuity (need and preference for naturally-occurring foods, sharing, relationship with place, family traditions and recollections). The social and recreational pleasures of subsistence activities are important, as is the contribution that subsistence makes to economic security and stability and psychological well-being. Subsistence foods are widely shared at community events, religious occasions, celebrations, and gatherings of family and friends, and the consumption of subsistence foods often provides the main reason for people to get together. For some, subsistence is an expression of aboriginal rights.

The threats to subsistence resources and activities most commonly mentioned were increases in government regulations, federal take-over of resource management in the wake of the McDowell decision, resource depletion due to increased human population, increased competition from sport hunters and fishers, and oil exploration. Changes in subsistence practices overlapped threats, but many persons mentioned new devices and machines, some changes in diet and food preferences, changes in the composition of harvesting groups, and the shortened duration of hunting and fishing excursions. Most of the residents contacted for this study believe subsistence activities will persist indefinitely despite perceived threats, and discussion with school children suggested a strong desire to continue subsistence pursuits and to favor subsistence foods,

SUMMARY

This research produced several significant findings, Documentation of subsistence cooperation and sharing networks suggests that subsistence is an important foundation of regional social structure and provides intra- and inter-community integration and cohesion. To the extent that these networks are based upon kinship, subsistence also helps to maintain Native cultural traditions. More Bristol Bay residents send subsistence resources outside the region than receive subsistence resources from outside the region, indicating Bristol Bay's naturally-occurring resources provide for both local and non-local subsistence needs. Those most likely to engage in subsistence activities are long-term residents, males, younger adults, and Natives, although there are variations in this pattern across resource categories. There is a positive relationship between involvement in commercial fishing and involvement in subsistence, indicating the two activities are integrated and suggesting that changes in the commercial fisheries could impact subsistence activities. Finally, subsistence adds meaning to people's lives, people desire to maintain subsistence lifestyles, and people are concerned about various perceived threats to subsistence.

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*Joanna **Endter-Wada is** an Assistant Professor and Director of the Natural Resources and Environmental **Policy** Program **in the College** of Natural Resources at Utah State **University,** Logan, Utah. She is **also** owner of **Social** Science Research Associates, which contracted with the Minerals Management Service to conduct the Bristol Bay Subsistence Study. She has worked on other research projects in the western United States analyzing the **socio-cultural** impacts of water and energy projects.*

*Lynn A. **Robbins is** a Professor of Environmental Studies at Huxley College of Environmental Studies, Western Washington University, **Bellingham,** Washington. He has studied the socioeconomic effects of energy projects on Native Americans over the past 20 years. His most recent work is on Alaskan communities. **He is** co-principal investigator on the **Bristol** Bay Subsistence Study with Joanna **Endter-Wada.** '*

QUESTIONS AND DISCUSSION

Warren Matumeak: I haven't been in that part of the country, but it looks like the culture there is dying, In my area we are getting into these federal regulations now. We didn't have those before. I was just telling the Fish and Wildlife people the other day that you guys are putting in too many regulations now. Our culture will die. As you mentioned, food is shared among those people that don't have anyone to hunt for them. I do that. I am a subsistence hunter. I gather food in the fall and in summer time. In the fall time, I decide how much more I should need and about how much my wife will want to give away to those people who don't have anybody to hunt for them. So this type of subsistence will probably die out if there are too many regulations, Because people will want to just gather for themselves if they are so regulated. The Christmas feast and Thanksgiving feast are where we share the things that we catch and still try to leave some to last until springtime. So I just wanted to bring that up. I think I am sensing that some of those people down there are starting to get stingy too. Like, here in Anchorage, how many of you go looking for people who don't have anything? That is what my wife and I do, to make sure those people have something to eat, like fish. They may have some store-bought food, but we know that our preferred food is the animals, like caribou. You get this beef from the store and it is marbled with fat and that doesn't look too good for me. I try to tell people with cattle to let them run around so that the fat will come off and it would be like eating caribou,

Charles Degnan: Your study just highlights the differences in culture. You need to take into account the time western civilization has come into these native areas. The dependence on subsistence will never go away, The attempts on regulation by both the federal and state governments are very hostile to local natives and people who are dependent on subsistence resources. They are viewed that way. It is one of those conflict areas, it depends on which side of the fence you live on. Are you a subsistence user or are you those that rather have animals rather than people who live on animals?

REGIONAL CITIZENS' ADVISORY COUNCIL
PRINCE WILLIAM SOUND, ALASKA - OVERVIEW AND ACTIVITIES

Sheila Gottehrer
PWS-RCAC
601 West Fifth Avenue, Suite 500
Anchorage, Alaska 99501

INTRODUCTION

The Regional Citizens' Advisory Council of Prince William Sound (RCAC) was established in response to the *Exxon Valdez* oil spill. RCAC is a non-profit, independent oversight organization that gives local residents a voice in oil issues related to the pipeline terminal in Valdez and tanker traffic in Prince William Sound.

Our members are communities in Prince William Sound and the Gulf of Alaska affected by the spill, as well as native, conservation, aquiculture and tourism organizations.

The mission of the RCAC is to ensure the safe operation of the trans-Alaska pipeline terminal so that environmental impacts associated with the terminal and tanker fleet are minimized.

One of the major lessons of the *Exxon Valdez* was that oil transportation is a risky business; and the people who bear the burden of that risk must be involved at all levels of decision making. There is no substitute for local knowledge, experience and commitment. That local interest is brought to the table, alongside industry and government, through the RCAC.

While the council is charged with citizen oversight, our relationship with Alyeska is designed to be a cooperative one. We monitor, we research, and we advise.

ORGANIZATION

Our funding - about $2 million a year - comes from Alyeska and is guaranteed for as long as oil flows through the pipeline. Under the terms of our contract with Alyeska, RCAC provides regional and local input on a wide range of issues, participates in development of Alyeska's oil spill prevention and response plan, provides public education, and conducts research.

Despite the funding relationship, RCAC is independent of Alyeska. That independence was a cornerstone of the agreement.

We didn't invent the concept of citizen involvement with industry. The model came from Scotland's Sullom Voe, an oil terminal in the Shetland Islands. But it is new in this country. Under a pilot program established by the federal Oil Pollution Control Act of 1990, citizens' councils are required for Prince William Sound and Cook Inlet. The RCAC has been certified by the President as the citizens advisory group for Prince William Sound.

COMMITTEE STRUCTURE

Most of our work is done through volunteer committees, consisting of council members and other citizens with interest, experience and background in a given field. The committees work for the council, with assistance from staff provided by the council. All formal action is taken by the council as a whole, which considers recommendations from the committees.

ACTIVITIES

I would like to briefly review a few of the bigger projects we're working on this year. Christine Klein will discuss the Scientific Advisory Committee's projects.

One of our basic responsibilities is to work with Alyeska and others in the oil industry on oil spill prevention and response plans, called "contingency" plans. These are huge, heavy and fairly complex documents and our Oil Spill Prevention and Response committee (OSPR) has spent hundreds of hours working with industry and government representatives to refine and hone those plans,

The OSPR committee has been involved in development of regulations to implement the more stringent state and federal laws passed in response to the *Exxon Valdez* spill. Currently, we have a representative participating in a regulations drafting process in Washington, D.C. Those regulations will spell out the federal requirements for vessels that carry oil in U.S. waters.

Closer to home, the Terminal Operations and Environmentai Monitoring committee (TOEM) is conducting extensive research in Vaidez on several air quality issues and ballast water treatment.

The Port Operations and Vessel Traffic committee is working closely with industry and government officials to undertake a major study of disabled tanker towing.

SUMMARY

The dedication, time and commitment that so many Alaskans have brought to bear on this work has been astounding. Especially when you consider that they don't receive uniform praise for their work.

On the contrary, the council and the committees get blasted with criticism from every side:

"They don't know enough." "They know too much."

"They've sold out to the industry." "They're controlled by greenies."

These are volunteers who are willing to make mistakes. They - along with good people in industry and government - are willing to try working together to build something we can all live with. A better, safer industry in our backyards,

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Sheila K. Gottehrer is the Executive Director for the Regional Citizens' Advisory Council of Prince William Sound. She has worked with citizen empowerment as a Peace Corps Volunteer in Medellín, Colombia, as the Regions/ Representative of the Alaska State Ombudsman's Office for the Interior region, and as Director of State Boards and Commissions for former Governor Steve Cowper. She has taught children with learning and emotional problems in California and Connecticut and undergraduate and graduate students at St. Josephs College for Women in West Hartford, Connecticut. Ms. Gottehrer earned a Masters degree *in Comparative and International Education and Special Education from Teachers College, Columbia University.*

REGIONAL CITIZENS' ADVISORY COUNCIL
PRINCE WILLIAM SOUND, ALASKA - OVERVIEW AND ACTIVITIES

Christine Klein
PWS-RCAC
601 West Fifth Avenue, Suite 500
Anchorage, Alaska 99501

ACTIVITIES OVERVIEW

Three projects of the Regional Citizens' Advisory Council (RCAC) scientific advisory committee will be addressed in this presentation:

1. Annotated bibliography and current research profile
2. Environmental ecological monitoring
3. Socio-economic model

The annotated bibliography which RCAC has commissioned to be completed consists of a select current biological research profile and select annotated bibliography of work done in the Prince William Sound and northern Gulf of Alaska from 1987 to 1991. It includes published and unpublished research from fields of biology, marine biology, botany, microbiology, fisheries, biological oceanography, and marine zoology. The database has been set up in the bibliographic program Pro-cite, similar to the ones completed by Minerals Management Service (MMS) and Exxon.

This work is to be used in determining which areas of research in the region are weak or have been neglected. It will help determine what work needs to be done in the future and the possible scope of work for the RCAC ecological environmental monitoring program.

The environmental ecological monitoring project is intended as a baseline by which to identify present and potential impacts to the ecosystems of the region as a consequence of oil transportation, The monitoring program is anticipated to focus on water quality, air quality, and ecological processes which may serve as indicators of adverse impacts. This monitoring work will be utilized to assist in the development of mitigation measures. The final proposals are due February 24, 1992.

A request for proposals for a socioeconomic model of impacts is underway and these proposals are due February 1, 1992 or before noon February 3, 1992. The intent of the socioeconomic project is to develop a model to help communities assess the social and economic impacts of oil spills on people, government, and businesses. We hope to develop a baseline by which to measure the economic and social impacts resulting from oil spills, clean up, and response activities. It will enable communities to assess damage to individuals, families, and businesses, and what resources are needed to mitigate the socioeconomic and psychological impacts which result, During the *Exxon Va/dez* oil spill, increased incidents of psychiatric disorders, depression, substance abuse, and domestic violence were documented, Family and community social relationships changed, Native villages were especially hard hit by the disruption in subsistence activities. Local governments struggled with reduced revenues and increased demands for services, and private businesses were also affected as employees left for other employment opportunities.

The RCAC socioeconomic model is intended to assess the social, cultural, and economic impacts to individuals, communities, local governments, and businesses. This information will be utilized to recognize these impacts, plan for them, mitigate the damage caused by them, and measure them in the event of another spill. The council is concerned with what happens to the people living and working in Cordova, Kodiak, Valdez, and the regional villages and towns if the

commercial fishing season or other economic activities are interrupted or cancelled due to a disaster such as the *Exxon Valdez* oii spill. What are the consequences to native Alaskans if their subsistence ways are threatened or are no longer considered safe, or if sacred places are intruded upon? How can local governments and small businesses, as well as individuals, prepare for, react to, and document the economic impacts of a catastrophic spill in the region and the resulting response and cleanup operations? These are some of the concerns voiced by the RCAC members and issues that we anticipate the socioeconomic model to address.

The produced modei will be used as a tooi to assess the socioeconomic impacts from a future spill in Prince William Sound, and to prepare for it with mitigation measures ahead of time. The model wiii advance suggestions and schedules, a map for what to do, and a pian to disseminate information and document appropriate changes.

RCAC sees the need for oii spill response plans that incorporate socioeconomic mitigation measures, as well as protection of the environment. We hope that RCAC's socioeconomic project will become an important resource document to support future spill prevention and spill response plans.

Christine Klein - a lifelong native Alaskan - joined the RCAC as support to the Scientific Advisory Committee in October. She has worked as an Environmental Consulting Engineer throughout Alaska since 1981 in both industry and regulatory capacities. She has been active in cross cultural education, native language and cultural presentation, as well as, advocacy for youth and homeless. Her research and applied work is in development impacts, social change, and spill response /technology. Ms. Klein has a B.S. in Environmental Engineering from Northern Michigan and University of Alaska, Fairbanks, and an M.A. in Cultural Anthropology from the University of California.

COOK INLET REGIONAL CITIZENS' ADVISORY COUNCIL

Doug Coughenhower
Cook Inlet RCAC
4014 Lake Street, Suite 201 B
Homer, Alaska 99603

I'll try to rapidly get through an explanation of the Cook Inlet Regional Citizens' Advisory Council (RCAC). Actually, just about everything that Sheila (Gottehrer) told you, can be applied to the Cook Inlet Council with the rather major exception of the $2 million budget. That's another story, and we'll get into that in a moment.

Both Councils were created by the Oil Pollution Act of 1990 (OPA 90), so they do have that in common. They are both to be funded by the oil industry, so there's that commonality. They both have very specific kinds of duties that were assigned to them by the Oil Pollution Act which have to do with the kinds of activities, and the kinds of committees that have been formed.

I should have started off by saying those of you that expected to hear Lisa Parker, obviously, 1 am not she. And I do send her apologies. She is very busy getting ready for the annual meeting of our Council, which takes place on Saturday. I was planning to attend the MMS meeting anyway, so she asked that I fill in for her. And I'll do the best I can.

I am a member of the Council, representing the City of Homer. I am also chairman of the Environmental Monitoring Committee of the Council, one of our major committees.

While there are a lot of similarities between the Councils, perhaps if I concentrate on the differences you will get a better understanding of the two Councils.

Our geographic area of responsibility is one of the major differences. Prince William Sound Council, obviously, covers Prince William Sound. The Cook Inlet RCAC takes in all the lands and waters that are impacted by Cook Inlet. So, in effect, we cover from the City of Palmer all the way down to the Barren Islands and Kennedy Entrance. And because what happens in Cook Inlet can impact areas beyond the Inlet, we do take in and have representation from the Kodiak area.

Membership, while it's similar to that on the Prince William Sound Council, there are some differences. We have 13 members on the Cook Inlet Council, There are representatives from the cities of Homer, Seldovia, Kodiak, and Kenai. The Boroughs of Kenai and Kodiak are represented, as well as the Municipality of Anchorage. Then we have the special interest groups that are members. The Alaska State Chamber of Commerce is a member. Native organizations have a member. Recreational groups are represented on the council with one member. Aquaculture organizations are represented by one member. The fishing and environmental groups are each represented by a member on the council.

Now it's time for a little quiz. Those of you that were paying attention to Sheila's talk, you might remember that there are some overlaps. And how many of you recall what groups, what entities have members on both Councils? Anyone? Sorry, Sheila.

All right. Well, I'll help you out here. On both Councils are representatives from Homer, Seldovia, Kodiak, Kenai Peninsula, and Anchorage. So, there are some duplications. Part of the reasons for those duplications are the *Exxon Va/dez,* and where the impacts from the *Exxon Valdez* spill had an effect. So, we do have that overlapping membership.

How the Councils began is also little bit different. Sheila alluded to the fact that the Prince William Sound Council began as a committee and actually had its beginning prior to the passage of the OPA 90 legislation. I won't try to explain the details of that, but I know they did come together as a committee prior to the requirement that these Councils be formed, And then, when OPA 90 was passed, they became a Council.

Cook Inlet RCAC had its beginnings in October of 1990 when Don Gillman, Mayor of the Kenai Borough called together a group of organizations and communities to take advantage or to react to the passage of OPA 90, and to begin the formation of the Cook Inlet Regional Council. That organization, that process, has been carried on for 1 5 months now, beginning with the organizing of the council, developing of by-laws, securing of funding agreement, and establishing the committees. Much of the past 15 months, which the Cook Inlet Council has existed, has been an organization process. So we're not quite as far ahead in terms of our actual duties, although we have carried out a number of studies that I'll mention in just a moment. But we're a little bit behind the curve in terms of where the Prince William Sound Group is. As you can see, we don't have audio visuals yet, but they're coming.

Now to the funding of the Council. That's a major difference between the two groups, Prince William Sound has one organization which they must deal with in terms of funding, and that's Alyeska, as Sheila mentioned. Cook Inlet RCAC, on the other hand, has approximately 13 different industry companies, in the Inlet, which could and should participate in the funding of the Council.

When the Council created itself, we began working with the Cook Inlet Spill Prevention and Response, Inc. (CISPRI) and they came forward as an industry organization on a voluntary basis to take over the responsibility of funding that was required by OPA 90. A funding agreement was worked out. It was a long, hard effort, as Sheila indicated, in trying to hammer out a funding agreement. Unfortunately, over the past few months that funding agreement has basically fallen apart. I don't want to put all the blame on the industry, because I don't think it was entirely industry's fault. I think, perhaps, it was the wrong group representing Cook Inlet oil industry to try and fund the Citizens' Advisory Council,

I think that the CISPRI organization, which still exists but for oil prevention and response purposes, realized that maybe they weren't the right group, the right way to bring together Cook Inlet oil industry to fund the Council.

We're in kind of a holding pattern right now as far as our Council funding is concerned. We do have some interim funding provided by CISPRI for the next six months into June. We are working with industry, with our congressional delegation, and with others to try to develop a new funding mechanism for the Council. I'm confident that something will be worked out. It's required by OPA 90. I truly believe that we'll find a mechanism to continue the operation of the Council, because as Sheila indicated, the dedication, the commitment of the citizens on the Cook Inlet Council is just as great and just as concerned as they are in Prince William Sound about making this experiment, making this demonstration really work. I believe we will be able to pull that off.

1 do want to mention the committee structure that we have in Cook Inlet. We don't have quite as many committees as they do in Prince William Sound. The ones we have are the two committees that were specifically described in OPA 90 as being something that Councils must be involved in.

One of our committees, the Prevention, Response, Operations and Safety Committee (PROPS), has the responsibility of looking at contingency plans, looking at the actual operation and transportation of oil in Cook Inlet, and working with industry to make those safe and proper operations. This committee has carried out a number of studies. They've been able to conduct a spill drill evaluation of a spill drill that was carried on in Cook Inlet. They have carried out a review of safety and navigation and oil spill contingency plans in Cook Inlet, They have also provided an evaluation of the liability that exists between response action coordinators and others. A great concern is who has the liability when a spill or an emergency occurs and people respond, just exactly what kinds of liability exist there. So those are some of the activities that the PROPS Committee has been conducting. There are a number of other studies currently underway.

The Environmentai Monitoring Committee, of which i am chairman, and which has been in existence not quite as iong as the PROPS Committee, is also in the process of carrying out some studies. We've been charged by the OPA 90 to deveiop and implement a comprehensive environmentai monitoring program for Cook Inlet *vis a vis* the oil industry.

Towards that end, we currently have three contracts that were iet just before the end of the year. One is to develop a composite directory of Cook Inlet oil facility operations, including fuel tank farms, pipelines, terminals, platforms, and refineries. Just what is out there in Cook Inlet currently operating that makes up this oil production and transportation industry. There's a lot there. We as a committee, and we as a council, need to know just exactly what is there. So we're going to pull that all together in one study.

Similar to Prince William Sound, we are also putting together a bibliography of environmental literature for Cook Inlet. We hope to have that in a similar kind of computer accessible form that will give us an idea of all the environmentai studies that have been done involving Cook inlet.

The third, and what i consider to be the most important contract that we currently have out is the design of a comprehensive environmental monitoring program for Cook Inlet. Right now, we're oniy looking to design a program. We hope, after we see what the design of this program might be, that we will begin to see where we can impiement parts of the program, hopefully, parts of a good designed program will already be in place. We will be looking to see how we can supplement what already exists to do as the Act says, put a comprehensive environmental monitoring program into place in Cook Inlet.

That is a very quick synopsis of the Cook Inlet Regional Citizens' Advisory Council. A lot of similarities to the Prince William Sound, some differences. I'd iike to end with what is my personal perception or statement of the Councils. i did this iate last night, so it may or may not make any sense,

The Regional Citizens' Advisory Councils offer the people of Aiaska a unique opportunity to say to the oil industry, "Yes, you are providing products that we want. But if the production of these products is not done in a safe and responsible manner, and if the production is causing harm to the place where i work and play, then i want to know that. And more important, i expect to have a roie in correcting those problems."

Doug Coughenhower received his B.S. in Science Education and M.S. in Oceanography from Oregon State University. He is currently an Associate Professor in Fisheries at the University of Alaska at Fairbanks, Marine Advisory Program. He represents the City of Homer on the Cook Inlet Regional Citizens' Advisory Council.

QUESTiONS AND Discussion

Tom Newbury: I am curious about the relationship between the government's Regional Environmentai Technical Working Group (RTWG) and the Regional Citizens' Advisory Council? Is there a relationship? Are there people that are on both groups?

Doug Coughenhower: 1 am not sure I can answer you too specifically. You reminded me of something I forgot to mention earlier. I think this is probably true of the Prince William Sound Council. in addition to the members that I mentioned, there are also a lot of *ad hoc* members to the Council. Participation from industry, participation from all the government agencies that are involved in oversight responsibilities from the industry. Coast Guard is of course involved as *ad hoc* members on these Councils. So there is a lot of participation on the Council end of things from both industry and government. You mentioned one organization, and I am new as a member of the Cook Inlet Council, so I can't be specific if we have a direct relationship with that organization, However, it turns out there have been as a result partially of the *Exxon Valdez* spill and other things, there are a lot of organizations out there that have varying degrees of responsibility both put upon them by state decree and by other means, that are looking at the oil industry now and looking at oil operations around the state, We are attempting as a Council to interact and have talks and get together and work with all of these groups in an effort to try and avoid as much duplication as possible. I am not sure I answered you question directly. That particular group 1 am not personally familiar with, but I suspect that there are others in the 'Council that are.

TRAJECTORY MODELING AND SURFACE DRIFTER STUDIES RELEVANT TO THE *EXXON VALDEZ* OIL SPILL

Mark Reed
Applied Science Associates, Inc.
70 Dean Knauss Drive
Narragansett, Rhode Island 02882

TRAJECTORY MODELING

The Applied Science Associates, Inc. (ASA) arctic oil spill model was applied to predict the transport of oil in the vicinity of Prince William Sound and from the *Exxon Valdez* oil spill (Jayko and Spaulding 1989). Hydrodynamic data necessary as input to the model were derived from a three dimensional numerical hydrodynamic model of the Gulf of Alaska. Individual simulations of wind, density, and tidal forcing were superimposed to represent the circulation in the region. Wind data were provided by the Fleet Numerical Oceanographic Center (FNOC) weather model and from observations in the area. Figure 1 shows the model-predicted density-induced flow at the surface. Model predictions are in very good agreement with the schematic representation of the major currents in the Gulf of Alaska, as summarized by Reed and Schumacher (1985) (Figure 2). The counter clockwise mean circulation in Prince William Sound, the southwesterly Kenai current and the bifurcation of the mean current east of the Kenai Peninsula are all predicted by the model. Stochastic simulations of spill trajectories at the entrance to Prince William Sound, made several years prior to the *Exxon Valdez* spill as part of a proposed Minerals Management Service (MMS) lease sale in the Gulf of Alaska, were in very good agreement with the observed trajectories of *Exxon Valdez* oil. A deterministic simulation of the *Exxon Valdez* incident using observed winds and the model-generated hydrodynamics reproduces the general path of the spilled oil, but misses many of the details. Improved predictions will require increased hydrodynamic model grid resolution for Prince William Sound and a careful definition of the wind field to more accurately represent the complex orographically controlled wind patterns in the region.

The oil spill trajectory model was used in 1987 (Spaulding et al. 1988) to simulate releases from three spill launch points located at the entrance to Prince William Sound in the Gulf of Alaska. For each launch point, three hundred (300) 30-day trajectory simulations were performed to provide an estimate of the mean trajectory path and its associated variability. This number of trajectories was selected to assure accurate and stable statistics in representing the trajectory paths. The model time step was one hour to assure accurate resolution of the tidal currents.

Stochastic trajectories from launch points south and southwest of Montague Island are shown in Figure 3. The similarity to the behavior of the oil from the *Exxon Va/dez* (Figure 4) is strong, and can be attributed primarily to the persistence of the Alaskan coastal current, the ability of the hydrodynamic model to accurately reproduce this current, and the reliability of the FNOC model in this area.

The oil spill model was also applied to hindcast the *Exxon Valdez* spill. The hindcast trajectories (Figure 5) compare extremely well with the actual path taken by the oil spilled. The simulations were limited by the spatial and temporal scales of the available wind data and by the coarseness of the model grid used for hydrodynamics (Jayko and Spaulding 1989).

DRIFTER STUDIES

Two types of satellite-tracked surface drifters (Figure 6) were released in Prince William Sound during the latter half of April 1989 with oil spilled by the *Exxon Va/dez.* Drifters were deployed and retrieved and re-deployed as possible. Ballasting was performed by hanging weights from the bottoms of the drifters. Results suggested that these drifters, properly ballasted, would track or simulate the movement of surface slicks better under some conditions than

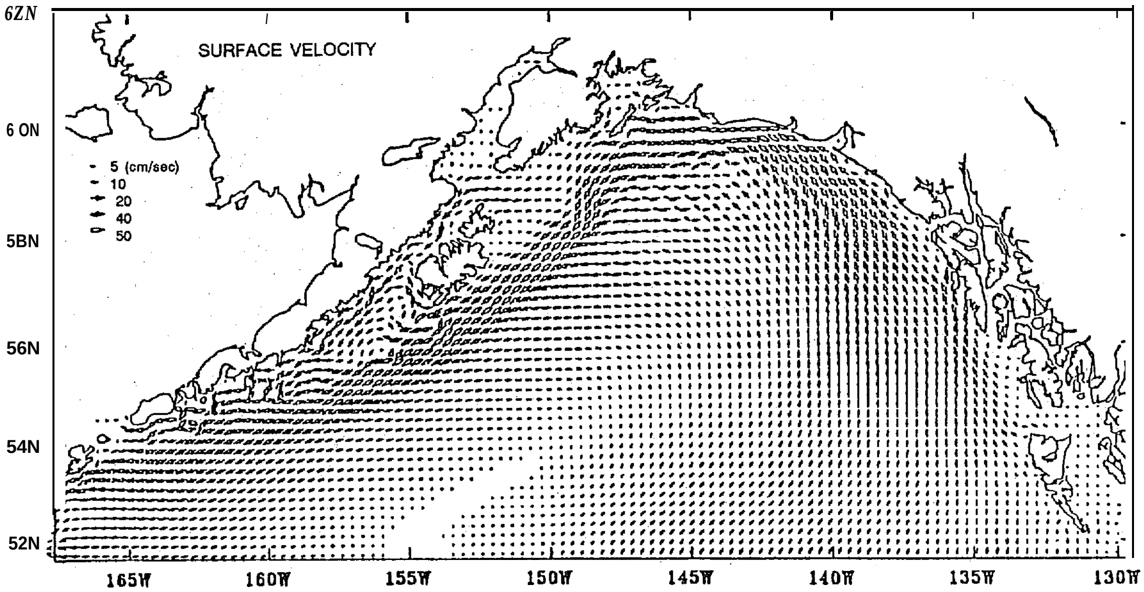

Figure 1. Hydrodynamic model-predictions of density induced flows at the surface for summer.

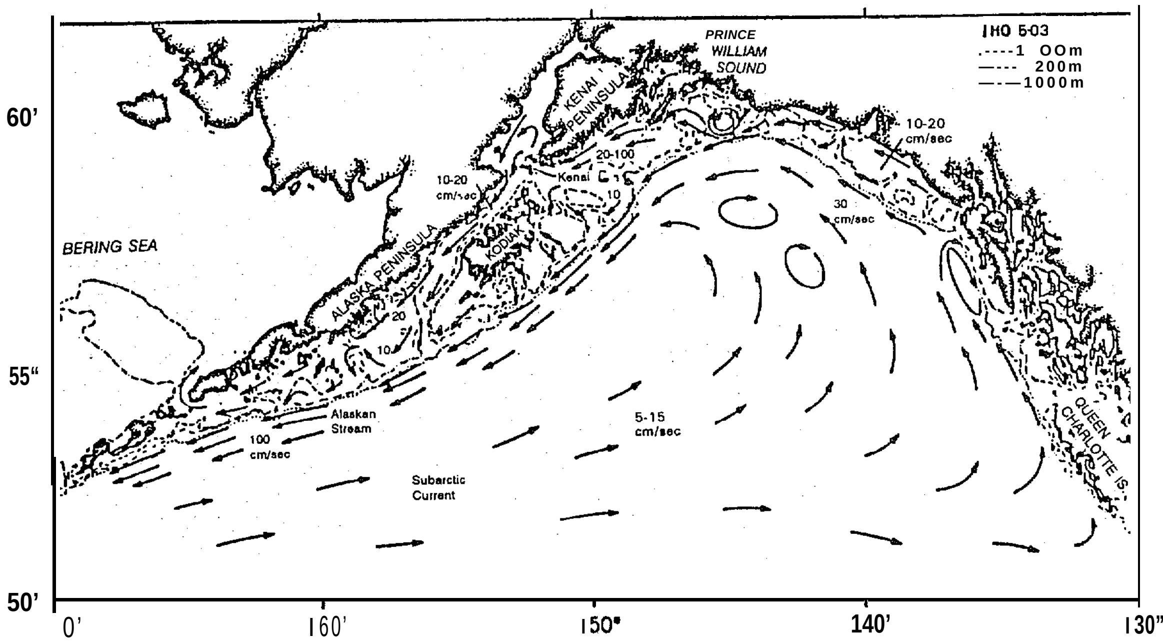

Figure 2. Schematic representation of the major currents (speeds in cm/s) for the Gulf of Alaska (Reed and Schumacher 1985).

others. Good tracking performance depended on achieving a balance between atmospheric and hydrodynamic forcing on the buoy, to match the forcing on the oil. The amount of weight added as ballast and the manner of attachment, as weii as the shape of the drifter, affected this performance. Observed slip rates of drifters relative to oil slicks ranged between 1 and 5 cm/sec. The extent that the lower slip rates could be achieved in general performance, these drifters would simulate oil slick trajectories to within 1 km/day, and should be useful in future environmentai assessment, spill contingency pianning, spill response, and trajectory model testing and evacuation.

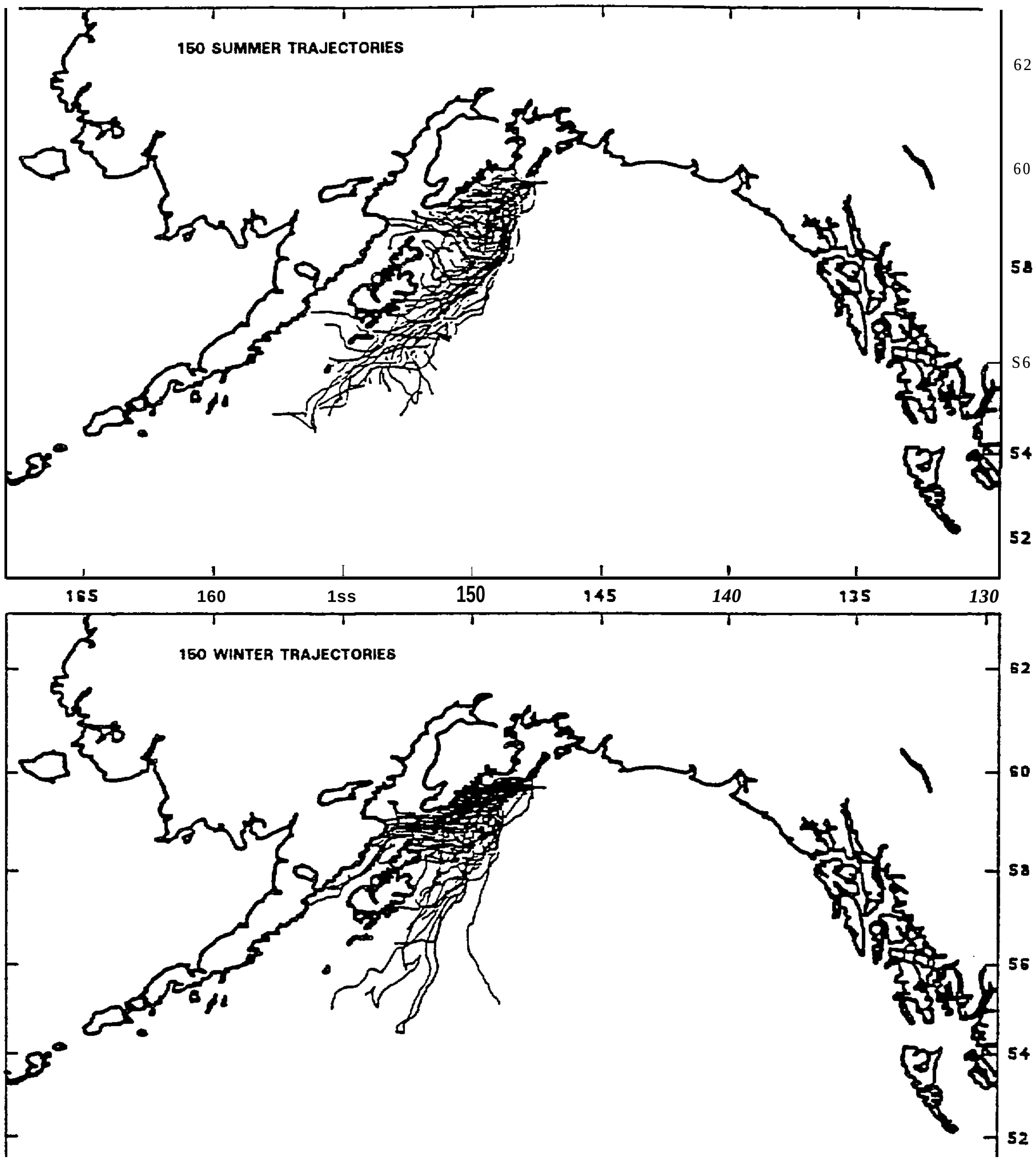

Figure 3. Oil spill trajectories for launch point LP2.

The deployments of drifters with oil in Prince William Sound showed clearly the potential usefulness of this technology. The transport of one drifter into Port Nellie Juan, for exampie, coincided with the overnight appearance of surface oil in that fjord, and clearly showed the route the oil traveied from the Sound. in generai, weather was unusually good for this time of year, and multiple daily overflights to map surface oil distributions were possible. During times when overflights were not possible, drifters would be useful for relocating oii slicks when the weather cleared.

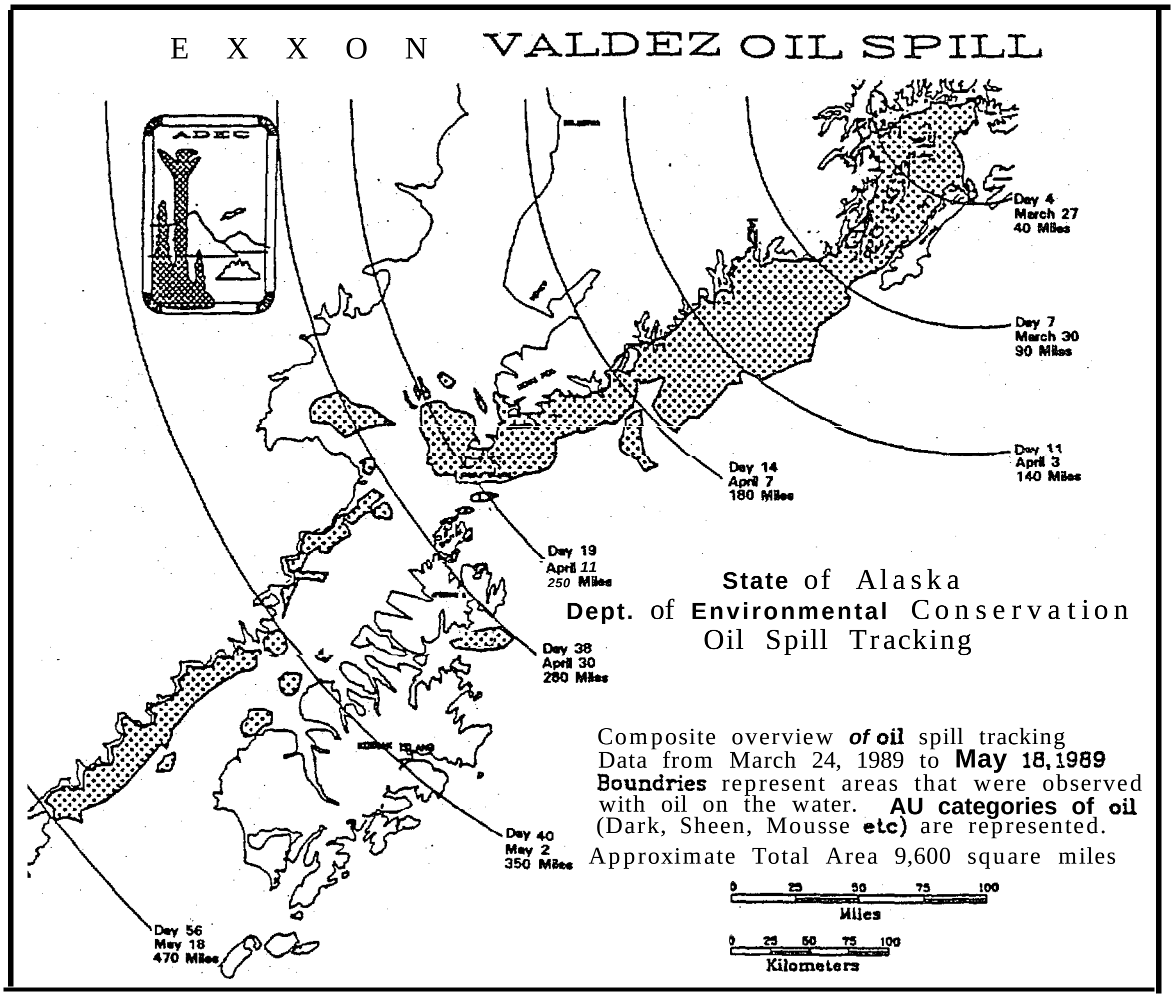

Figure 4. Composite of observations based on NOAA and Alaska Department of Environmental Conservation (ADEC) sightings of the Exxon *Valdez* oil spill distribution, 24 March -18 May 1989.

This study places some preliminary bounds on drifter ballasting, providing valuable information prior to the large experiments carried out in the summers of 1989 and 1991 in Norwegian waters.

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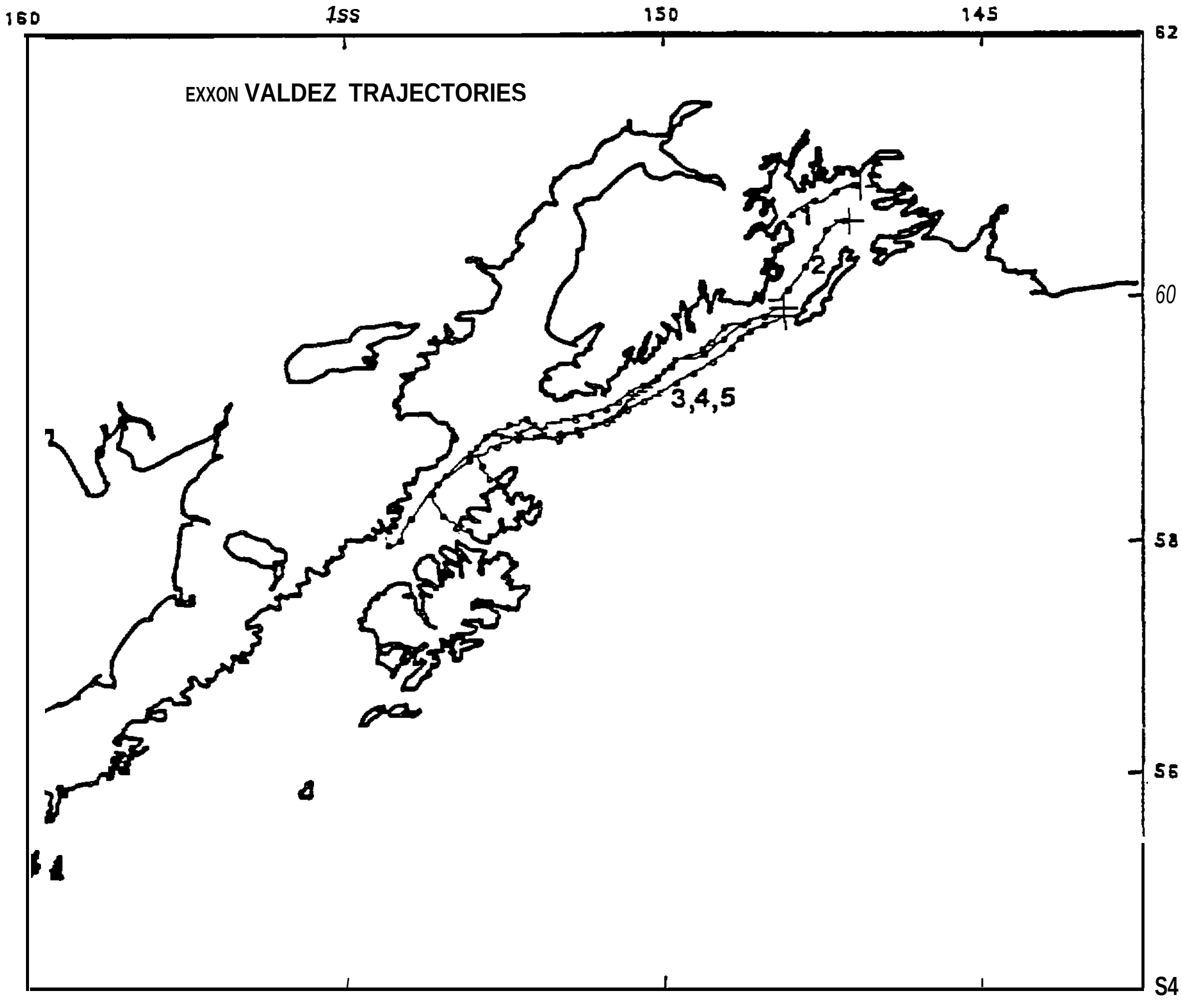

Figure 5. Hindcast trajectories of the *Exxon Valdez* oil spill.

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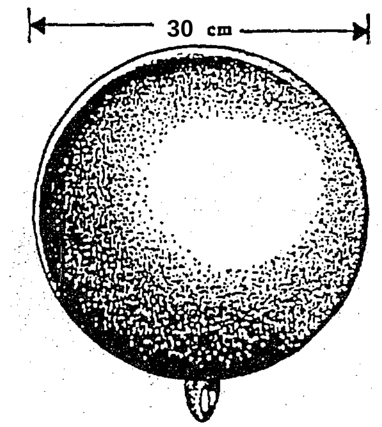
Dr. Mark Reed is senior scientist and project manager with Applied Science Associates, Inc. (ASA). Dr. Reed specializes in numerical modeling of the fates of oils and hazardous substances in aquatic environments.

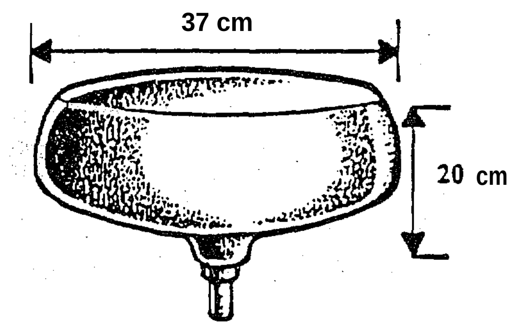
QUESTIONS AND DISCUSSION

Dick Prentki: If you had let those buoy drifters go for 25 or 30 days, do you think they would have done as well as your model for showing where the oil went?

Mark Reed: I suspect that if we let them go out in the Alaska Current, yes. Because there essentially you have got the winds and the currents agreeing with each other. It is when you have these really high shear situations, where the currents are doing one thing, essentially contrary to what the wind is doing, that you have problems. I can describe a little bit what happened in another experiment in Norway this last summer (1991). In 1989, this was in the Norwegian Sea, the whole place was wind driven. The wind forcing was very strong, it dominated the whole event. That was the first big difference between the 1989 and 1991 experiment. The second big difference was that we used in 1989 an oil that emulsified heavily, sort of the way Prudhoe Bay crude does. In this case the oil behaves much more like a solid body in drift behavior. This resulted in very good tracking over a period of about four days. In 1991, the oil that was released behaved more like a diesel. It spread quickly to a microlayer, without emulsifying appreciably. Due to high winds, the oil was rapidly entrained in the water column, and its transport was governed more by current than wind. In those situations with different types of oil and different types of forcing mechanisms for the hydrodynamics, the jury is still out. In this situation I think you could safely put drifters in to the Alaska Current and you would get a good picture of the envelope of possible trajectories.



TECHNOCEAN ARGOSPHERE



DRAPER LABS: LOW COST SURFACE DRIFTER

Figure 6. Satellite-tracked drifters deployed for this study.

EFFECTS OF THE 24 MARCH 1989 *EXXON VALDEZ* OIL SPILL, SHORELINE OILING - FATE AND EFFECTS

Eugene A. Pavia
Alaska Department of Environmental Conservation
Exxon Valdez Oil Spill Response Center
4241 B Street, Suite 304
Anchorage, Alaska 99503

INTRODUCTION

Four minutes after midnight 24 March 1989 the supertanker *T/V Exxon Valdez* spilled 10.8 million gallons of North Slope crude oil into the sub-arctic waters of Alaska's Prince William Sound (PWS). The vessel was transporting 1.3 million barrels from Valdez, Alaska to Long Beach, California.

The spill became the largest in U.S. history in the amount of oil discharged, the area affected, the continuing national and international interest, the magnitude of response effort, and agency and public involvement (Ciancaglini 1990). The monetary cost of an oil spill clean-up has increased significantly over the last 10 years and now greatly exceeds the economic value of the crude oil spilled. In 1978 the Amoco *Cadiz* spill involved 68.7 million gallons of Arabian light crude oil, the clean-up cost $115 million — the *T/V Exxon Va/dez* clean-up costs have exceeded $2.5 billion through 1991.

By late August 1989, 2490.9 km (1547.8 miles) of Alaskan coastal shoreline (ADEC shoreline) had been impacted by *Exxon Valdez* oil to varying degrees. Figure 1 presents a composite overview of oil spill tracking from 24 March through 20 June 1989. Approximately 28,500 km' of oil contamination on water existed.

The spill response had three phases: Immediate containment and recovery of oil from the water; emergency removal of oil from the shoreline; and long-term shoreline treatment to remove oil. The immediate containment and recovery phase of this spill response revealed several problems: the approved spill response plan for supertanker oil transport vessels within Prince William Sound was not followed; the available technology proved insufficient for the task; there was a severe lack of equipment immediately available to do the job; and even the best technology was shown not to perform well without effective management and logistical planning (Kelso and Kendziorek 1991).

Within the first two weeks of the 24 March spill an estimated 35% of the total spilled oil evaporated or dispersed into the water column in Prince William Sound. An additional 40% impacted the shoreline within the Sound, mostly on Smith, Eleanor, Ingot, and Knight Islands (with secondary amounts on Green and Latouche Islands).

Floating oil first exited Prince William Sound about 30 March 1989, due to the prevailing wind and ocean circulation patterns in the Sound. Throughout the month of April oil continuously spilled into the Gulf of Alaska, reaching its maximum sometime within the first week. By the second week of April (a little over two weeks into the spill), between 20 and 25% of the total oil spilled had moved into the Gulf of Alaska. Only about 10% of that oil made it beyond Gore Point, and 2% actually got as far as Shelikof Strait (Gait et al. 1991). Although the Prince William Sound system continued to feed oil into the Gulf of Alaska, the amount was greatly reduced.

Summarized data from six survey stations which are representative of the variety of coastal settings where oil contamination persisted through 1991, and will likely persist for the next few years is presented here (Pavia et al. 1991).

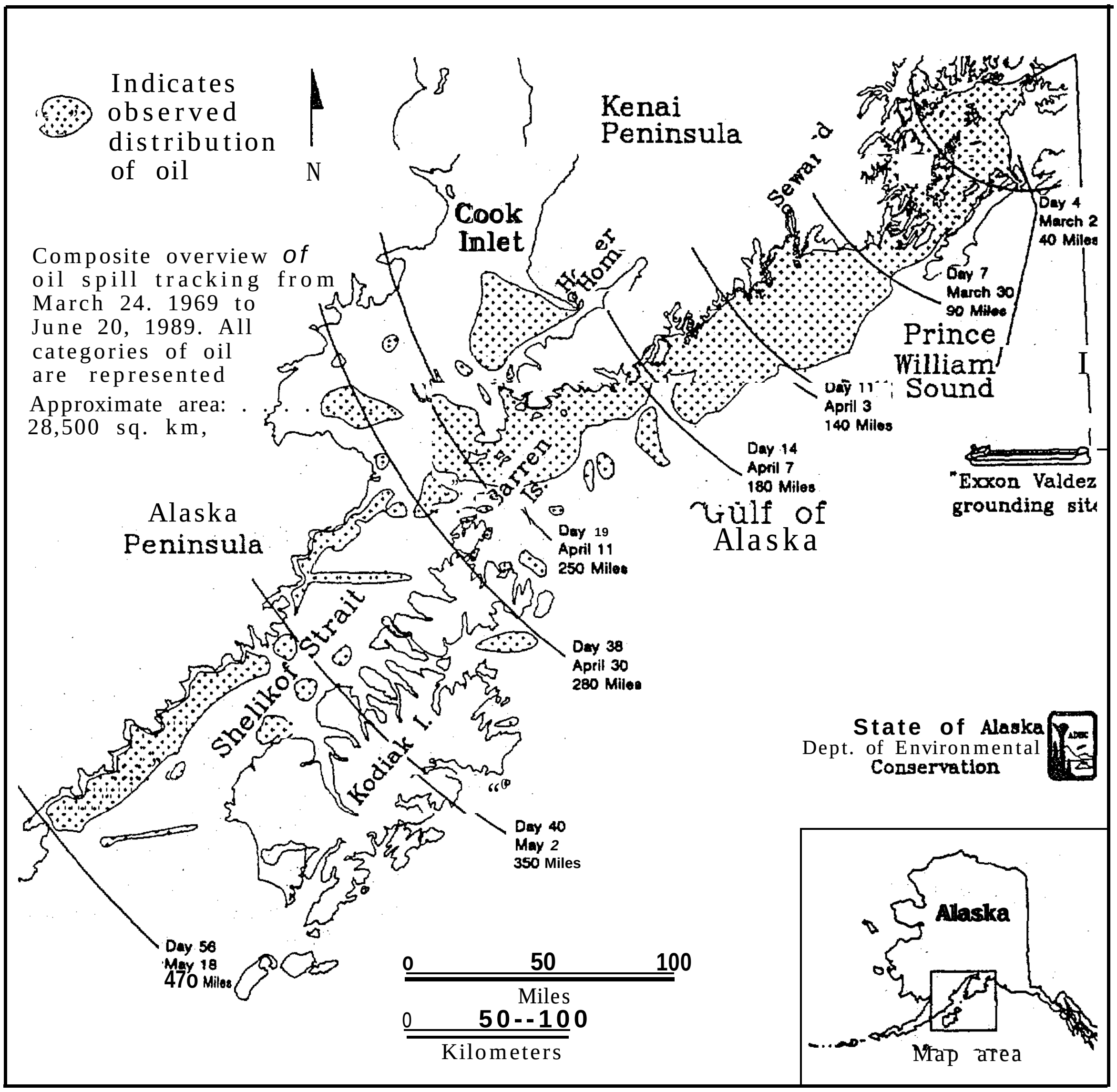


Figure 1. ADEC composite overview of oil spill tracking from 25 March through 20 June 1989.

METHODS

The scientific methods used in this shoreline assessment program were developed from methods employed in previous investigations of several other major oil spills. References include Gundlach et al. (1978) study of the *Urquiola* spill; Gundlach and Hayes (1978) study of the Amoco *Cadiz* spill; Gundlach, et al. (1981) study of the Ixtoc I blowout; and Gundlach et al. (1982) study of the *Metula* spill.

The Alaska Department of Environmental Conservation (ADEC) Shoreline Evaluation Group initiated oiling transect and geomorphologic surveys recording field data concerning stranded North Slope crude oil immediately following the 24 March 1989 *Exxon Valdez* oil spill.

The entire spill site was divided into four regions for the purpose of data collection: Prince William Sound, Kenai Peninsula, Alaska Peninsula, and Kodiak.

Site-specific oiling data were collected during approximately 2217 surveys at 1103 stations throughout the four regions between March 1989 and September 1991. Survey teams visited some stations only once during 1989, while many stations were visited several times to document temporal changes in oil impact contamination. Shoreline evaluation of many survey stations were discontinued each year as oil contamination was removed at that particular site.

The ADEC Shoreline Evaluation Group provided specific field information to the spill response effort including: the location of oil concentration along the shoreline; scientific data on subsurface contamination in the beach and natural removal rates; a basis for monitoring long-term changes in oil levels on the shore; and the effectiveness of various clean-up techniques proposed during the response effort.

Three types of surveys were conducted to document the position of oil along the shoreline and to determine the quantity of resident oil; aerial observations, ground surveys, and transect profile surveys. All surveys were conducted approximately two hours on either side of slack low tide, to provide maximum exposure of the oiled intertidal areas. Aerial surveys were by helicopter for slow, low altitude mapping of oil band widths. Ground surveys consisted of a relatively rapid assessment of a site during which shoreline oiling was described in a field notebook, photographs were taken, and oil thickness and penetration was measured. Transect profile surveys were more intensive, and involved running a topographic profile across the intertidal area using Emery's method (Emery 1961). Along the profile, observations of surface and subsurface (from pits) oiling, geomorphology, sediment type, and biological characteristics were recorded on data profile sheets, a field sketch was made, and 35 mm photographs were taken at a variety of perspectives to document the shoreline condition. All this data was entered into the ADEC Oilspill data base.

Field data from 25 April 1991 are presented for Station 004, Segment EL056 Subdivision C, Eleanor Island, Prince William Sound to demonstrate the type of data the ADEC Shoreline Evaluation Group collected.

The oil classification system evolved to reflect the changing oiling conditions observed in the field. Initially, the oiling was such that it was satisfactory to delineate a surface band width with a description of the oil attached, With time, surface oiling was less continuous, and a dominant emphasis was placed on subsurface oiling occurrence and distribution.

Comprehensive shoreline survey data, in addition to the Shoreline Evaluation Group survey data, helped direct specific clean-up operations and documented the status of oil impacted shorelines throughout the spill site. In the fall of 1989 ADEC conducted the Post-Treatment Assessment (PTA) segment survey. In the spring of 1990 a joint Exxon USA, Inc., State, and Federal survey (SSAT) was conducted. In August 1990 the ASAP survey, another post-treatment assessment, took place. In spring 1991 the MAYSAP survey was conducted. The comparison of surface oiling mileage from each survey is presented in Table 1.

RESULTS AND DISCUSSION

The fate and effects of crude oil in seawater is summarized in Figure 2 (JPT 1989). The documentation of the fate and effects of weathered, *Exxon Valdez* stranded oil from 1989 through able 1. ADEC comprehensive survey data, comparison of oil contamination mileage.

	Miles of Shoreline							
	Fall 1989	SSAT 1990	ASAP 1990	MAYSAP 1991	Fall 1989	SSAT 1990	ASAP 1990	MAYSAP 1991
		PWS				Kodiak		
Heavy	47.0	12.9	4.3	1.0	0.3	0.3	0.1	0.0
Moderate	80.0	28.5	6.3	7.0	1.2	3.2	0.1	0.1
Light	82.0	49.6	10.6	9.8	5.2	4.3	0.2	0.0
VLight	192.0	169.6	23.4	41.6	41.2	58.9	6.8	6.6
No Oil	360.0	425.0	44.2	177.0	49.2	214.0	32.4	20.8
H+M+L+VL	361.0	260.6	44.6	59.4	47.8	66.7	7.1	6.8
		Kenai				All Regions		
Heavy	6.0	1.6	0.0	0.0	53.3	14.8	4.4	1.0
Moderate	7.9	4.8	2.7	0.6	49.1	36.5	9.1	7.7
Light	15.3	9.8	3.6	0.3	102.5	63.6	14.4	10.1
VLight	51.5	52.7	12.9	10.0	284.7	281.2	43.1	58.2
No Oil		179.5	6.7	33.8	409.2	818.5	83.3	231.6
H+M+L+VL	80.7	68.9	19.2	10.9	489.5	396.1	70.9	77.1

1991 has increased the understanding of the fate and effects of oil impacted shorelines within the sub-arctic setting of Prince William Sound and the Gulf of Alaska.

The duration of oil persistence involves many different components and the relationship between components is often complex. The following list presents recognized factors that effect the fate and persistence of stranded oil from the *Exxon Valdez* oil spill (Pavia, In press).

1. Shoreline type
2. Exposure and hydrodynamic energy level
3. Initial impact (areal extent and quantity of oil)
4. Crude oil chemistry, (various distillate products weather and behave differently with time, temperature, concentration, etc.)
5. Wind and sea conditions during and following the spill
6. Tidal stage during impact(s), (multiple impacts were common)
7. Shoreline level of the water table during impact as well as after impact (affects depth of penetration, oil has a higher specific gravity than both salt and fresh water and tends to "float")
8. Individual shoreline hydrology (flushing, percolation, free exchange with seawater during tidal fluctuations, and the fresh water component from the watershed behind the beach, all affect the water table level, which changes daily and seasonally)
9. Storm activity, duration, intensity, wind direction, and fetch
10. Natural sediment distribution weathering processes;
11. Solar radiation (solar radiation affects stranded oil in a number of ways, It degrades oil, by de-watering mousse mixtures, by softening, and thinning tar and weathered petroleum residue if temperatures are warm enough to cause the oil to flow. This

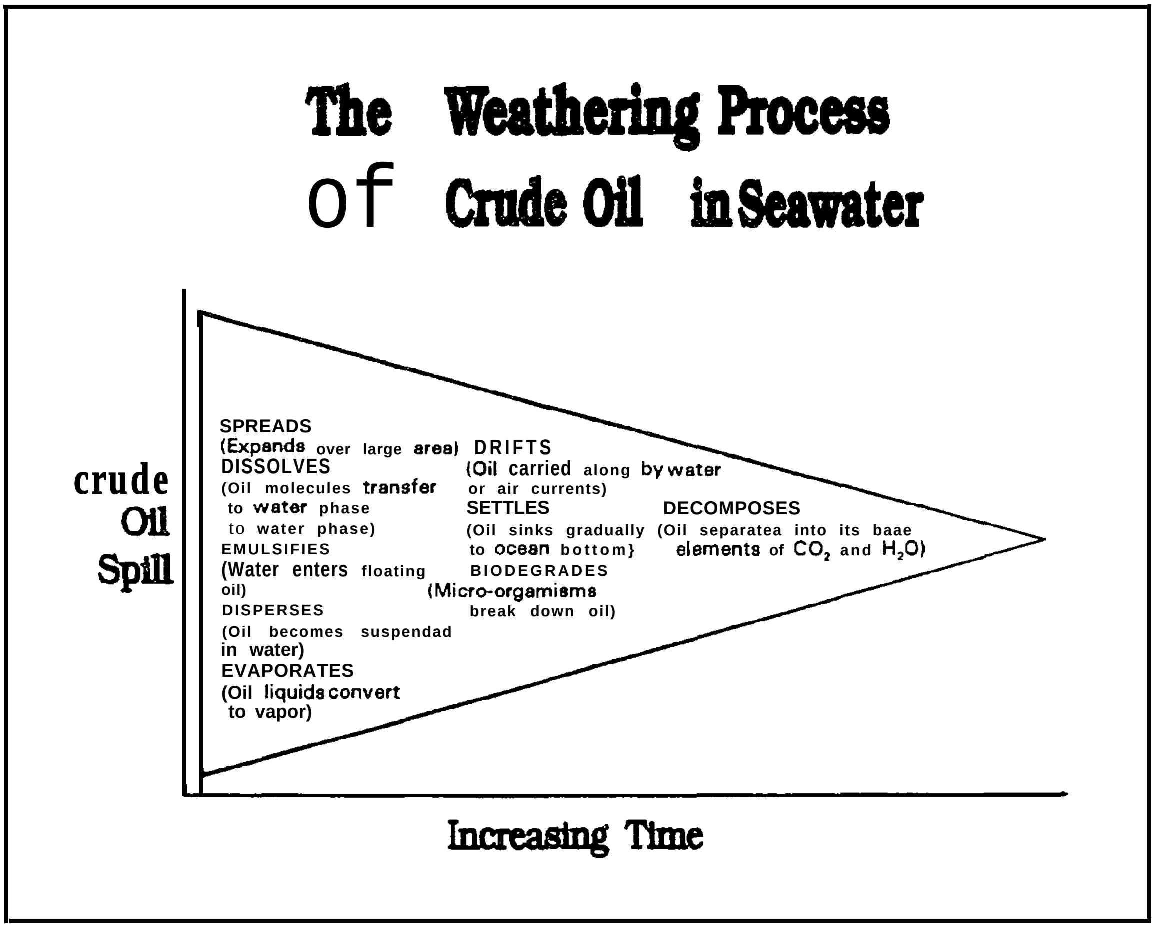


Figure 2. The weathering of crude oil in seawater (JPT 19s9).

tends to increase the effectiveness of other natural, physical processes, and probably helps natural biodegraders as well.)

12. Oleophylic microorganisms (natural occurring organisms were enhanced with the addition of fertilizers (bioremediation treatment))
13. Duration oil remained on shoreline prior to cleanup
14. Type of treatment method employed
15. Duration of each treatment method employed
16. Quality of treatment methods
17. Aptitude of treatment crew
18. Variety of treatment methods employed
19. Multiple treatments (i.e.. adequate manual or mechanical surface oil removal was mandatory prior to bioremediation application for example)

The Alaskan coastal shoreline affected by *Exxon Valdez* oil is composed of a variety of shoreline types with varying wave energy exposure. Rock outcrops, and poorly-sorted coarse-grained sediment beaches, separated by rock outcrops, dominate much of the shoreline, Only a few affected sites — mainly on the Alaska Peninsula — are composed of sand. Affected marshes and tidal flats are equally rare (Gundlach et al. 1991). The persistence of oil contamination is related to the wave energy/exposure setting. The greater the exposure to wave energy the more rigorous natural weathering processes. act to dissipate oil contamination,

Case histories are presented for six survey stations which demonstrate the variety of coastal settings where *Exxon Valdez* oil contamination persisted through September 1991, Oiling profile transects are presented for a few of the stations discussed graphically displaying the changes in the beach profile, surface oil coverage, oil thickness, and oil penetration that occurred between comparative survey dates (Figure 3) (Gundlach et al. 1990),

1. 004, Segment EL056 C, Northwest Bay, Eleanor Island, PWS: This small "pocket" beach is flanked by bedrock outcrops, The upper beach is dominated by sub-rounded pebbles and granules, while the lower beach is composed of sub-angular cobbles with occasional boulders, This site was very heavily oiled in 1989. Treatment included: hot-, warm- and cold-water washing, medium- and high-pressure washing, bioremediation fertilizer application, and berm relocation. Oil persistence through August 1991 was concentrated along the peripheries of the beach in the low and mid-intertidal zones. Liquid, black oil was documented between 8 and 46 cm at approximately a -2 ft. low tide level in two penetration pits.

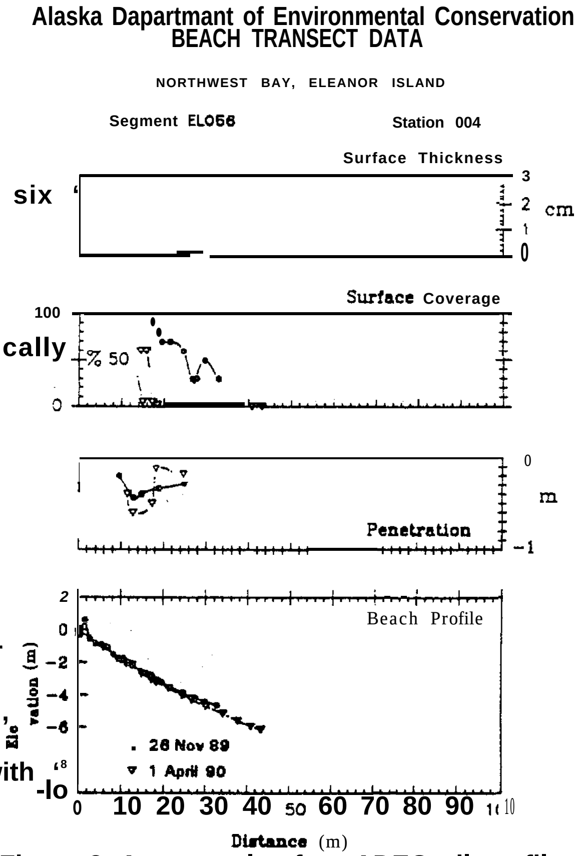


Figure 3. An example of an ADEC oil profile transect Sigmaplot graphics.

2. 036, Segment KN0405 A, Pt. Helen, Knight Island, PWS: High energy, exposed, coastal setting experienced heavy oiling in 1989, The upper beach is composed of well-sorted, rounded pebbles and cobbles, while the lower beach is dominated by rounded boulders. Considerable treatment was performed along this segment including the following: water deluge, Omni boom, hand wiping, cold, warm, and hot water washing, moderate, and high pressure washing, bioremediation fertilizer application, and storm berm relocation. Surface and subsurface oil contamination persisted through August 1991 throughout the upper and middle beach face.

3. 043, Segment IAO18 A, Sleepy Bay, Latouche Island, PWS: Moderately exposed coastal setting with a beach face dominated by poorly-sorted, sub-angular boulders and cobbles. An anadromous salmon stream is located nearby. Initial impact was very heavy at this site, Treatment consisted of hand wiping, manual removal of oiled sediments, various temperature and pressure washing, bioremediation fertilizer application, manual tilling, mechanical tilling, and sediment relocation. Surface and subsurface oil contamination persisted through August of 1991, concentrated throughout the middle beach face.

4. 090, Segment KNO136 A, Bay of Isles, Knight Island, PWS: One of the few tidal marshes within the spill site, which received significant initial oiling. Treatment was restricted to spot washing, manual tilling, and the manual removal of oiled sediments to reduce detrimental effects of clean-up operations at this sensitive setting. Surface and subsurface oil contamination persisted through August 1991, concentrated along the upper-intertidal zone. Free standing surface water continues to retain oil sheens.

5. 312, Segment TBO04 A, Tonsina Bay, Kenai Peninsula: "Grim Beach" was the most heavily impacted site within Tonsina Bay. It is a sheltered, shallow-inclined beach composed of mixed muddy sand and gravel sediments. Treatment included: manual removal of oiled sediments, warm-water deluge with high-pressure wash, tilling, and multiple bioremediation fertilizer applications. Oil persistence continued through June 1991, with oil concentrated below a dense canopy of fucal growth and mussel beds.

6. KO1 1002, Segment S1003, Perevaline Passage, Shuyak Island, Kodiak Region: The station is located in a narrow cove flanked by bedrock outcrops. The intertidal area is dominated by poorly-sorted, sub-angular boulders. Segment S1003 received the most treatment in the Kodiak Region, including; manual pickup, excavation of sediments, rock-wiping, high-pressure warm-water wash in 1989; manual sediment removal and bioremediation fertilizer application in 1990. In 1991 surface oil coverage was less than 1 percent consisting of highly weathered stain and coat (tar) on the sides of boulders and cobbles, some friable asphalt was also present. Pooled mousse was documented underlying boulders in the low intertidal zone with a thickness of 10 cm.

SUMMARY

Portions of shoreline affected by *Exxon Valdez* spilled oil retains stranded, weathered, oil remnants throughout the spill area. Much was learned about spill equipment and operations during this spill clean-up. Knowledge of what treatment did not work or was environmentally detrimental is equally if not more important than discovering what worked effectively.

Natural weathering processes reduced the quantity and distribution of surface and subsurface oil contamination from the *Exxon Valdez* oil spill. It is important to note that Exxon cleanup operations during 1989, 1990, and 1991 removed much of the gross oil contamination and significantly increased the weathering rate of spilled oil along much of the shoreline. If Exxon had done nothing about the stranded oil — especially during 1989 — significant oil impact contamination would be more extensive at this time — and likely for the next decade, based on field observations of untreated shorelines. This suggests that a contingency plan which is practical and site-specific should be implemented immediately to mitigate damage from spilled crude oil. It takes more time, money and resources to clean-up oil after it has become stranded on shore.

Some areas have retained surface and subsurface oiling to varying degrees, with time the oil has weathered and degraded, its distribution is less continuous, and less severe. Very few locations surveyed during the summer of 1991 showed gross oil contamination. Much of this oil contamination is beyond practical and available clean-up considerations. Oil remains sporadically distributed throughout the intertidal zone at those locations protected from wave-action, especially below and in-between large boulders and rock outcrops. The underside of cobbles and boulders retain oil contamination along with the sediments directly below this larger substrate — a common phenomenon expressed on numerous coarse-grained sediment beaches within the *Exxon Valdez* spill area. The sediments and oil below the surface are protected from surface weathering processes, including wave agitation, physical abrasion and solar radiation. This protection creates a setting where oil persists for extended periods of time. A conservative estimate — based on field observations — indicates that the oil in these settings will persist for 3 to 10 years.

The discussion of coarse-grained mixed-sediment beaches affected by oil spills is noticeably lacking in available literature. Data from the *Exxon Valdez* oil spill may help our understanding of this particular setting and the unique problems it presents with regard to persistence of oil contamination and the effectiveness of treatment methods employed.

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Eugene A. Pavia was formerly employed as the Project Leader for the ADEC **Exxon Valdez** *Oil Spill Response Center, Shoreline Evaluation Group from August 1989 through November of 1991. As an Environmental Specialist he performed scientific coastal geomorphology studies documenting the fate and persistence of stranded oil contamination resulting from the* **Exxon Valdez** *Oil Spill. Mr. Pavia received his B.A. in geology from The City College of New York, C. U. N. Y., and has recently returned to the University of Alaska, Fairbanks to complete his M.S. in geology, Title: Structural Evolution and lithostratigraphy of the Northeastern Okpilak Batholith Area, Northeastern Brooks Range, Arctic National Wildlife Refuge, Alaska. Current 'address: P.O. Box 83241, Fairbanks, Alaska 99708, phone: (907) 474-5313.*

QUESTIONS AND DISCUSSION

Doug Martin: I wanted to know if Dept. of Environmental Conservation did any comparisons of weatherization in beaches that were not cleaned versus beaches that were cleaned? Do you have any information to indicate how effective the cleaning was relative to natural weathering of the oil on beaches?

Eugene Pavia: Yes, it is speculative. Basically it is based on treatment records. DEC has a data base that every time we had a DEC person on the beach we were able to record specific data as to what was there, how many people were there, what they did, what they didn't do, what they did wrong. Then we have survey studies that were done in between and sometimes following those treatments. Quite often we didn't have the liberty to go before and after, though we did do some work, specifically for bioremediation work that we supported transect profiles, recording oil contamination before, during and after specific operations. We got involved a lot in berm relocation. We were able to do prior to the treatment versus after. Rates of oil degradation, etc. is difficult and complex, there are a lot of factors. In the field is where you have to do it, but you really need lab conditions to say specifically what happened when and we've lost X amount of oil concentration at this point. It is very difficult to say.

AT SEA AND SHORELINE CLEANUP - WHAT WAS USED AND WHAT WAS LEARNED

Dennis M. Maguire, Cdr.
U.S. Coast Guard
601 W. 5th Avenue, Suite 410
Anchorage, Alaska 99501

The response to the *Exxon Valdez* oil spill (EVOS) employed many types of cleanup technologies. As the response went on and the oil spread, the cleanup effort transitioned from offshore containment and removal to shoreline cleanup. These two groups, offshore and onshore, are used in this paper to broadly categorize the technologies. The offshore response did not account for large amounts of recovered oil relative to the size of the spill. However, in the offshore arena, new technologies were tested and non-oil spill cleanup equipment adapted to cleanup uses.

In a sensitive, rugged and remote environment such as Prince William Sound, the cost and difficulties in removing oil from the shoreline are much higher than from water, These costs are defined not only in direct oil removal costs, but in the damage from the oil and from the oil removal efforts to natural resources. We know now that four years' cleanup efforts by man and nature may not remove all of the oil. In a few relatively small areas, oil remains in buried sediments, armored beaches, and sheltered areas. The old adage that the purpose of oil spill response is to keep the oil off of the beach was never more true than during the EVOS. With estimates of bird losses between 260,000 and 580,000, sea otters at 3500 to 5500, and harbor seals at 200, we must do better (Gertler 1992). By learning from the technology used on the EVOS, we can better clean up future spills.

During the first days of the oil spill, we learned that control has to be centralized into one operational command. Decisions must be made quickly. Sometimes all one has is minimal information. The "no decision, study it" philosophy will not keep oil off the beach. The Federal on Scene Coordinator (FOSC) must exercise knowledge, ability and authority to quickly make binding decisions. Not all of the decisions will be correct, but the battle will certainly be lost if nothing is done. Oil spreads rapidly, and too many technologies have brief windows of opportunity for use to allow procrastination. Not all of the oil can be prevented from reaching shore. Technologies such as dispersants and *in situ* burning of oil have negative side effects (Figure 1). Environmental tradeoffs must be assessed quickly. The battle is one of mitigation, but the damages outlined in the paragraph above make these efforts worthwhile.

IN SITU BURNING OF OIL ON WATER

The two key technologies which had the greatest potential for impacting the amount of oil reaching shore were the aerial application of dispersants by heavy aircraft and the *in situ* burning of oil. Limited supplies and transportation, and lack of trained personnel and regulatory approvals interfered with the full utilization of each.

In situ burning has the potential for eliminating large quantities of oil very quickly. *In situ* burning consumed 350 to 700 barrels (15,000 to 30,000 gallons) or 0.1 to 0.3% of the spill in 1 hour and 15 minutes. The test burn was conducted on the night of March 25 and was 98 to 99% efficient in removing oil from the surface of the water. Only a 10 ft x 10 ft, 300 gallon taffy-like mass remained (Allen 1991 a,b,c). Smoke was reported at the village of Tatitlek about 10 miles northeast of the burn, and regulatory permission for additional burns was withdrawn, The whole issue of smoke at Tatitlek remains in question because the wind was out of the west-northwest.

There is speculation by some experts that, since the unconfined slick was 4 to 8 mm in thickness, once the slick had drifted well away from the *Exxon Valdez*, it could have been ignited and a large percentage burned. After the storm of March 26, the oil became too emulsified to sustain combustion and all opportunity to successfully bum the oil was lost.

Exxon Valdez Oil Spill
Treatment of Oil On Water

Treatment Method	Advantages	Disadvantages
Dispersant Application	Rapid response time Reduces shoreline impacts, No waste products generaled. Low cost per volume ol product treated.	Effectiveness contested. Potential lethal and sub-letha effects to aquatic organisms. Negative public Image re garding use 01 "toxic" chemicals to treat an oil spill.
Diversion / Deflective Booming	Concentrates 011 al collection points for optimizing use ol skimming equipment. Can be used in conditions where current or sea state would restrict the use of protective booming.	Effectiveness is a function 01 current direction (a curren reversal can change a diversion configuration into a col lection Or concentration configuration). Requires anchor ing and must be tended to maintain effectiveness.
in-Silu Burning	Rapid removal of lighter weight (higher toxicity) hydrocar-bons. Reduces total volume of oil remaining in environment. Does not generate waste products.	Requires fire retardant boom and well trained personnel Generates smoke plume containing large quantities of soo and combustion byproducts.
Protective Booming	Readily available in large quantities (various manufacturers) Can be rapidly deployed from a variety of plaltorms. Most common use ol 011 boom Use requires minimum of training.	Not effective in high wind, wave or current conditions Larger models require mechanical assistance for deploy ment and recovery. Requires lending 10 maintain boom integrily.
Sorbent Boom	Can be deployed m combination with diversion / deflection booming or as part of a protection booming strategy. Once anchored, requires minimal tending. Available in large quantities and is easily transported.	Ineffective on heavy or weathered oils (lend 10 coat surface ol boom). Must be removed / replaced once oiled. Gen-erates high volume o! waste per quantity ol oil collected.

Figure 1. Various methods and advantages/disadvantages for treatment of oil on water.

The burning of oil contained by ice or other non-combustible barriers has been used for oil spill response. During a response to a diesel spill which occurred on an ice road in Canada's Northwest Territory, there was no containment or recovery equipment available. The oil was naturally contained by the snow. A burn was conducted in several steps. As the fire went out, the oil was herded by wind and the fire re-ignited. Essentially the spill was cleaned up by one person and a lighter.

DISPERSANTS

Dispersants were the most controversial technique used during the initial response. Strong public and state opposition was encountered. Although a pre-approval plan was in effect for Prince William Sound, the location of the spilled oil dictated that Regional Response Team (RRT) approval be obtained prior to test spraying or use, Approval for continued application was made conditional upon positive results from tests.

Dispersants mitigate damages from a spill by preventing or reducing the amount of oil reaching the shoreline. Aerially applied dispersants break the oil slick into fine droplets which are dispersed both horizontally and vertically in the water by ocean turbulence. The droplets are then subject to natural processes such as biodegradation. . In shallow waters with low flushing, it is possible for toxic concentrations of dispersed oil to accumulate. Tests in open waters have shown that toxic levels do not persist long enough to cause serious damage.

The results of dispersant use were controversial and inconclusive. Calm seas, an overly thick slick, limited supplies, and difficulties obtaining regulatory approvals reduced effectiveness. A 300-gallon helicopter bucket of dispersants was tested on the afternoon of March 24, 1989 and was determined to be unsuccessful. The first C-130 application was conducted March 25 at 6:00 p.m. during "extremely calm seas." Low light and sun angle did not provide for a valid visual assessment, On March 26, the first DC-6 run had problems with nozzles. Exxon video tapes (reviewed by the FOSC) of the second C-130 run (wind 20 kn, seas to 4 ft), indicated an "improvement in performance," and it was "considered a success." Continued application was approved by the FOSC for March 27, 1989 (USCG). High wind prevented the morning flight and moved the oil out of the approved area. An afternoon application was approved, but the aircraft sprayed an unauthorized area without Coast Guard or state observation.

Tests conducted on April 2 and April 10, 1989 showed little effect on the water in oil emulsions (mousse) that remained.

OIL SPILL CONTAINMENT BOOM

During the initial response, boom was used to collect free floating oil or to direct oil into skimmers. it was used to protect resources such as low energy beaches and fish hatcheries by either excluding oil or diverting it away from the resource. Boom was also used to prevent the migration of oil and collect it as it was washed off beaches.

Boom is most effective when used in calm seas and iow currents. No boom can contain oil when placed perpendicular to oil in more than about a 3/4 to 1 kn current. Boom can be used to deflect oil in currents greater than that, but the oil must ultimately be deflected into a low current environment or into a skimmer for recovery. As seas build and winds increase, construction, flotation, and wave following ability determine the effectiveness of a boom.

Harbor Boom

Harbor boom is generally considered to be boom of about 18" to 24" in overall height[1]. Most harbor boom loses effectiveness in three foot seas. Even "offshore boom" can lose effectiveness in relatively modest seas.

Self-Inflating Boom

Self-inflating boom is lighter and requires less storage space, allowing rapid deployment of more boom. it is more expensive and easily damaged. We learned that if it is depioyed, it must be monitored to guard against flooding because it was frequently observed with flooded compartments. During long term deployments, replacement with conventional boom should be considered.

Offshore or Open Water Boom

Boom was towed at low speed in a "U" configuration between two vessels. Speed has to be kept to iess than one kn so oii would not entrain at the apex of the "U," Towing vessels had to be closely matched in size and speed or one would overpower the other, Also, many vessels couldn't go slowly enough without using their clutch. Oil filled boom was tied off in a circle or "teardrop." A skimmer would then be brought in to recover the oil. Open water boom was used to recover oil in conjunction with a skimmer either in the stationary or mobile mode. The skimmer was placed at the apex of a "V boom deployment.

No matter what type of boom was used, unless it was regularly tended and maintained, boom failure was certain. Mooring systems would break, boom would break or debris would become hung up on the boom and submerge it. Inflatable boom would flood. Different types of boom and end connectors created problems in joining sections. Cold water and anchor points on the bottom of some boom created problems in anchoring.

Lack of training resulted in much of the damage to boom. Exxon estimates over 50% of the damage to the larger boom resulted from improper recovery. Boom was improperly lifted

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[1] There do not appear to be common standards for a particular size boom. Some manufactures may tail an 18 in. boom (18 in. overall height) a 6 x 12 in., meaning a 6 in. diameter float and a 12 in. skirt. Another 18 in. boom might be 8 in. x 10 in.

or pulled, Ruggedness and durability of the boom proved to be essential for ccessful deployment by the available work force (Exxon 1990).

CONTAINING OIL AND SHEEN FROM BEACH WASHING OPERATIONS

A series of two or three rows of boom around the cleanup operation were r uired to control escaping oil and sheen. The inside, or primary boom, was anchored on the be h above the high tide line <u>outside</u> of the runoff stream. It was usually backed with sorbe oom or consisted of two rows of boom separated by sorbent boom. A secondary boom ed with sorbent boom, was placed at least 15 yards outside of and around the primary m and anchored above the high tide line. It either encircled the cleanup barge or was attached to bits near the stern. This space allowed time and distance for oil entrained in the wash w which had passed beneath the primary boom to surface. A third absorbent boom was plac ehind the secondary boom, usually behind the cleanup barge, Sometimes it extended well side of the recovery operation.

Depending on beach configuration, duration of cleanup operation and degree of oiling, three rows of porn porn (snare) boom were placed horizontally across the beach face: one row at the high-tide line, one at the low-tide or water line and one half way between the other two, This trapped and absorbed oil being washed down the beach, reducing emulsification and skimming, Another method was to run a porn por boom right at the water's edge. This method would contain most of the solid oil, although sheen might escape. When high pressure washing produced emulsified oil which sank and passed under the primary boom, loose porn pores were placed on the oil/water mix within the secondary containment area. This was the most efficient way to recover that type of oil.

"Outside of the five-inch primary sausage boom, porn porn boom is used to form a triangle with a 15-ft base above the high-tide line, extending to an apex below the low-water line. The triangle is then filled with loose porn pores. This system will trap and absorb oil that escapes from the primary containment boom at the water line as it is shifted on the beach by changing tide" (Veto 1989).

During the high volume high pressure washes of small areas, such as those from an Omni barge, the use of three parallel rows of porn porn (snare) boom across the beach was impractical, Some oil would pass under the primary boom. Deploying porn porn (snare) boom and/or loose porn pores within the containment area worked best to recover the oil and eliminate sheening.

SHEEN RECOVERY

For open water sheen, sorbent boom was towed behind a fishing boat in a "U." A circular or zigzag track worked best. Sorbent boom was placed loose within the "U" to increase sorptive area. Closer to shore and inside containment areas, sorbent boom was towed in a "U" configuration by one or two skiffs. During extended towing, the sorbent boom absorbed four to eight times its weight in water, decreasing its ability to absorb oil,

Sheens contain little oil but require considerable effort and equipment. With recoverable oil available and scarce resources, sheen recovery may not be the most effective use of those resources.

SKIMMING

The lack of oil storage capacity lowered the effectiveness of open water skimming. After the storm, the increased viscosity of the oil significantly decreased the "pumpability" of the oil.

Screw auger type skimmers and their pumps and air conveyors (Super Sucker, Vat-All and King Vat) were about the only things that could handle the viscous mousse.

Navy Marco Skimmers

These skimmers recovered oil well. As the oil thickened, the sorbent filter belt material was removed and recovery accomplished using the underlying stainless steel belt. The limited oil storage aboard the skimmers and the inability of the skimmers' pumps to offload the mousse reduced their effectiveness.

Paddle Belt Skimmers

Paddle belt skimmers were used early in the spill to recover free oil. Later, they were used during beach cleanups to recover contained oil from the washing operations. The French Egmolap was reported by Exxon to be "very effective in heavy mousse and debris, recovering as much as 18,000 gal/hr." The Canadian Coast Guard paddle belt skimmer "was easily clogged by viscous oil." "It (Egmolap) will clean up a full maxi-containment area in 45 to 60 minutes. This skimmer was the most popular and far and away the most requested skimmer used in the Prince William Sound oil spill" (VECO 1989). The Egmolap is part of a self propelled barge-skimmer system of French manufacture. Its use required a wavier under the Jones Act which prohibits coastwise trade by non-U.S. built vessels. Waivers may not be forthcoming on future spills.

Oleophilic Disc and Oleophilic Rope (Rope Mop) Skimmers

They were less effective on heavy oil in water emulsions. They were particularly ineffective on emulsions formed from hot water beach washing.

Rope mop skimmers were slow but effective on small quantities of oil. The recovery rate was dependent on ambient temperature and worked best above 60°F. They required more effort than other skimmers to set up, and required frequent adjustment to maintain recovery efficiency.

Dredges

Hopper dredges were effective in recovering heavy oil, emulsion and debris from containment areas without clogging. Their best use was recovering oil collected by towing boom between two vessels which was then tied off to form a "teardrop." The draghead was turned upside down with the suction side up and placed under the boom and the oil sucked into the ship (VECO 1989). Problems included their deep draft and difficulties in cleaning the onboard oil storage areas. Dredges recovered a lot of water with the oil, but had large onboard storage capacity and the ability to decant water.

THE ONSHORE RESPONSE - SHORELINE TREATMENT

The *Exxon Valdez* shoreline cleanup was the largest and most costly of any U.S. spill; 3245 miles were surveyed for oil impact and 2662 miles were treated. At it's maximum, the *Exxon Valdez* oil spill response work force rose to 12,000 people with six floating task forces. Huge Maxi barges, Omni barges with hydraulic arms, and floating camps housing hundreds of workers worked the oiled beaches. Bioremediation (nutrient augmentation) was used extensively, The Coast Guard, NOAA, state agencies, land managers and Exxon developed a Technical Advisory Group (TAG) to insure that the most appropriate technology was used on each individual shoreline segment. Figure 2 lists the various treatment methods and advantages/disadvantages for shoreline cleanup,

Exxon Valdez Oil Spill
Shoreline Cleanup

Treatment Method	Advantages	Disadvantages
Serm Relocation	Uses natural processes to mechanically clean sediments. Does not generate waste products requirint transportation and disposal.	Effectiveness varies with energy level of beach. Reties on storm events. Released oil is smt recoverable.
Bioremediation	Low impact. Minimum of personnel.3 equipment. Cues not generate waste material.	Effectiveness contested. Slow process, results not readily observed.
Burning	Minimizes waste transportation and disposal.	Effectiveness limited to small areas. Residual scarring. Mechanical assistance required.
Chemical Beach Cleaners	Loosens oil coatings. Lowers temperature requirements for warm waler wash that follows Minimize-a treatment time and contact time for biological community.	Potential lethal or sub-lethal effects to biological comunities in immediate area.
Cold Water Deluge	Uses water at ambient temperatures. Minimizes treatment effects on biological communities.	Requires extensive eqipment support (vessels, pumps etc.). Effective only on relatively fresh oil. lima consun ing really and labor intensive. Generates high volume waste oil.
Hot Water Injection	Mobilizes significant quantify of subsurface oil in immediate area 01 Injection probe,	Effective in small area around probe. Mobilizes 011 but may not facilit ale recovery of mobilized oil. Pmba insertion difficult
Hot Water Washing (> 100 degrees)	Mobilizes moderately weathered oil. Rapid cleaning of oiled beach malarial. Aids in recovery of stranded ol.	High mortality to intertidal biological communities. Potential for transportation of oiled lie beach sediment: to lower intertidal and sub-tidal part of beach. Requires extensive logistical support. Delays biological recovery process.
Manual Removal	Low technology method. Can be applied to a variety of shoreline types and oiling conditions.	Labor intensive. Generates large amounts of waste per unit of treated shoreline.
Mechanical (Removal)	Removes all oil and contaminated sediment if limits are welt defined and site is relatively small	Disrupts wildlife. Generates large volume of waste material rapidly.
Mechanical (Tilling)	Mobilizes significant volume of subsurface oil. Generates small quantity of waste material.	Disrupts wildlife. High cost par unit of shoreline.
No Treatment	Simplicity. No action is required.	Effectiveness is a function 01 chance (i.e. level 01 tide, direction of wind, waves, etc.).
Sed me	Effectively removes all oil from treated material.	High cost par unit of beach. Unproven. Potential for severe environmental impacts to treated site.
Vegetation Cutting/Removal	Law technology method. Minimum training required. Can be applied 10 a variety 01 shoreline types and condition.	Generates large amount 01 lightly oiled waste. High pm bability of cutting clean vegetation with oiled vegetation.

Figure 2. Various treatment methods and advantages/disadvantages for shoreline cleanup.

Flood and Float - Cold Water Deluge

Cold water deluge involved pumping massive quantities of seawater onto a beach, filling the pore spaces and floating the oil down the beach into the water for recovery, A large flexible suction hose was converted into a "sprinkler hose" by drilling big holes in it. It was placed along the upper beach face and hooked to high capacity pumps, providing a deluge. It was very effective early in the spill when the oil was still fresh and mobile.

Water Washing

Cold water for washing was supplied by centrifugal wash pumps, Water heated to 140"F was supplied by high capacity heaters on landing craft, Maxi and Omni barges. Hot and cold washing and commercial pressure washers were used independently or with the deluge. As the oil weathered, higher temperatures were required. Concerns are being raised that the hot water may have damaged the intertidal organisms more than the oil would have. Damage could have been reduced had the hot washing been conducted during times when tidal water covered the sensitive lower intertidal zone.

In order to conduct water washing on the scale required, equipment had to be built to fit on a vessel. The concepts were formulated during the first few weeks and presented in a draft

Type of Equipment Developed*	Shoreline Cleanup Technique Utilized					
	Washing/ Flooding With Water "Deluge"	**Washing, Cold Water (Ambient)** Low Pressure	**Washing, Cold Water (Ambient)** High Pressure	**Washing, Warm Water, Moderate** to High Pressure	**Washing, Hot** Waler, High Prssure Hydro-Blasting	**Booming & Recovery (Skim/Sorb)**
Landing Craft Vessel (LCV) "Cold-mini" Large volume cold water pumping Commercial pressure washers (hot to cold) 2 to 8 washers total 20-80 GPM @140°F "Standard" 40 LCV (Approx L=40 W=15 Up to 7s landing craft used	PRIMARY USE Cold water "Deluge"	USED	PRIMARY USE		PRIMARY USE	
Landing Craft Vessel (LCV) "Hot-mini" Large volume hot water (250 GPM @ 140°F) "Standard" 40 LCV (Approx L=40 W-IS	HAD CAPABILITY Could flood w/ cold & hot wash or flood hot & wash cold	HAD CAPABIL ITY	HAD CAPABILITY	PRIMARY USE		
Maxi-barge Beach cleanup support Manlift-could mount fire monitors 20-30 ton crane-could lift man-basket/monitors Hot water (135 GPM @ 140°F) Large volume cold water Tug supported barge Nominal L=1 30' to 180 W= 34' to 54 Shop storage for parts sorbents skimmers hose etc crew shelter office & head	PRIMARY USE	USED	PRIMARY uSE	PRIMARY USE		PRIMARY USE crane to lift boom boats etc
Omni-barge Very high volume hot water (750 GPM @ 140°F) (110' Omni boom could reach out to wash shore; Nominal L=115 t W=40' self-propelled barge Flexifloat con struction one or two outdriv -	HAD CAPABILITY C-old flood w/ hot or cold water	HAD CAPABILITY	HAD CAPABILITY	PRIMARY USE		

" Equipment did not exist prior to spill Bare hulls and Flexifloats were gathered from around the country

Figure 3. ***Exxon Valdez* oil spill special equipment ana usages.**

cleanup plan by Exxon on April 15, 1989. The plan was revised on April 24. By early June, most of the plan had been implemented. This equipment is described in Figure 3.

Bioremediation (Nutrient Augmentation)

The purpose of nutrient augmentation is to provide the missing components in the existing oil eating bacteria's diet to increase the biodegradation rate of surface and sub-surface oil. The addition of non-indigenous bacteria was not used. Bioremediation was used on boulder, cobble and gravel beaches, usually following working of the sediments. After 1989 tests, two fertilizers were chosen for continued use. Customblen is a granular fertilizer applied by hand or broadcast spreaders. Inipol EAP 22 is a liquid fertilizer which is believed to enhance the degradation of surface oil. Due to its 53°F pour point, a landing craft was fitted with heated tanks and insulated lines for transferring the Inipol.

Inipol contains chemicals which require Level D protective clothing. Federal OSHA removed the respiratory protection requirements after 1989. The required monitoring did not detect hazardous concentrations. The effectiveness of bioremediation has been subject to continued controversy. Concerns were raised by Native groups regarding potential toxic effects on subsistence foods. The National Park Service prohibited bioremediation on their lands in 1989 and allowed only Customblen in 1990 and 1991,

Surficial Burning and Debris Burning

A small hand-held weed burner was used to bum oil off moderately to heavily oiled logs without disposing of the entire log. The technique was used where the removal of the logs was

not desirable and to prevent contamination of wildlife. It was also appropriate for aesthetic reasons in recreational areas, It was not to be used where adjacent habitats or organisms could be adversely impacted, In a few instances whole logs were burned after approval by the USCG, Exxon, Alaska Department of Environmental Conservation and the upland land manager, Gaining necessary approvals to burn proved to be the most difficult problem with burning.

Manual and Mechanical Removal

Mechanical removal utilized Caterpillar tractors, trac-hoes, etc. Manual removal removed surface oil with hand tools and labor. Manual removal imposes lower impact and provides precise cleanup, Manual removal is also slow and labor intensive. Whether mechanical or manual removal was utilized, the potential existed for disturbing archaeological sites, shore animals and birds,

Natural Cleanup - Recovery

Natural recovery removes oil with no additional impact and is the least intrusive cleanup method. "Oil left alone is eventually removed from water surfaces and shoreline by a variety of natural means, including evaporation, photo-oxidation, solution, physical dispersion, sedimentation on particulate matter, and biological degradation, Although these natural processes may be slow, possibly taking as long as several years, they are generally conceded to be environmental acceptable, and in some cases may be preferable to using active countermeasures" (NRC).

TECHNOLOGIES INVESTIGATED BUT NOT USED

Chemical Beach Cleaners

Chemical beach cleaners were tested but not used. Several field tests were conducted with a number of chemical beach cleaners including Exxon's newly developed Corexit 9580 (Corexit 9580 M2 in the development stage), Field tests were conducted to evaluate Corexit 9580's performance relative to other selected products and further tests were conducted on Corexit 9580. Ultimately, concerns that too much oil was being dispersed, the fear of adding another chemical and concern by Native groups and subsistence users caused its use to be rejected.

Rock Washer

A large-scale rock washer (sediment washer) was designed, construction started and a smaller scale prototype tested, A Net Environmentai Benefit Analysis (NEBA) of the rock washer was conducted concurrent with its development, The NEBA indicated more environmentai harm than good would result from removing, washing and repiacing sediments than result from methodologies already in use, Therefore, the FOSC disapproved use of the rock washer.

Hot Water injection

Hot water injection was tried but not used. Probes are used to inject heated water into the sediment, reducing the viscosity of the buried oil. in the rocky beaches, it proved to be effective oniy in a small area around the probe. it did not facilitate the recovery of the mobilized oil. Probe insertion was difficult and the results were sporadic in mixed sediments.

DETERMINING THE MOST APPROPRIATE CLEANUP TECHNOLOGY

Throughout the *Valdez* response, attention was paid to determining which technology would produce the greatest environmental benefit with the lowest side effects. The methodology formalized during the evaluation of the rock washer, the NEBA established a goal which remained for the duration of the cleanup.

During the early days after the *Exxon Valdez* oil spill, an Inter-Agency Shoreline Cleanup Committee (ISCC) was formed in Valdez, chaired by NOAA and consisting of agency and local interest representatives, (Similar groups were organized in other areas.) Exxon shoreline surveys or SCAT (Shoreline Cleanup Assessment Team) reports for each beach segment, with recommended cleanup procedures, were reviewed by the ISCC and recommendations made to the FOSC. The FOSC then approved, disapproved or modified the plan. For each individual beach segment, the FOSC and the State of Alaska insured the cleanup was conducted according to plan.

During the second and third years of the shoreline cleanup, a TAG, consisting of the State of Alaska, Coast Guard, NOAA and Exxon representatives, reviewed those beach segments for which consensus could not be reached. Their recommendations were forwarded to the FOSC who made his decision based on the technical recommendations from TAG along with any other input which he felt appropriate.

Controversy will always exist over what could have been done to limit the damage of the *Exxon Valdez* spill. The shoreline cleanup allowed time for information to be obtained and careful decisions to be made. Unfortunately, the initial response to the *Exxon Valdez* or any spill cannot be conducted by committee. Lessons learned following analysis of the response are reflected in the Oil Pollution Act of 1990. *Exxon Valdez* not only improved technology, but resulted in a better understanding of the management of spill response.

From all the information presented above, the following are some of the lessons learned:

1, It is easier and more cost effective to remove oil from the water than the shoreline (at least in Alaska).

2. It is essential in spill mitigation and effective cleanup to have people in positions of authority who are willing to exercise that authority using the best available information at that time. Decisiveness and compromise are the tools needed to resolve pressing issues.

3. There will always be critics. Don't count on a lot of support for your final decisions. No matter what you opt to use, someone will insist it was environmentally detrimental, useless or too expensive.

4. Finally, prevention is the optimal cleanup technology.

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Commander Maguire is the Deputy Federal on Scene Coordinator for the Exxon Valdez oil spill. Related to this oil spill, he served as the Deputy Chief of Staff in 1990 and Supervisor of the incident Command Post, Kodiak on 1989. Cdr. Maguire is actively involved in shaping the management of oil spill response within the U.S. Coast Guard. He received his B.S. in marine and electrical engineering from the Massachusetts Maritime Academy, his MBA from Southeastern University, and his M.A. in marine affairs from the University of Washington.

EMERGENCY CARE AND REHABILITATION OF OILED SEA OTTERS: A NEW HANDBOOK FOR SEA OTTER OIL SPILL CONTINGENCY PLANNING

Randall W. Davis
International Wildlife Research
2661 Concord Circle
League City, Texas 77573

Terrie M. Williams
International Wildlife Research
322 Aoloa Street, #805
Kailua, Hawaii 96734

INTRODUCTION

The March 1989 Valdez accident was the first documented oil spill to involve large numbers of sea otters, Similarly, the response was the largest effort ever to rescue and rehabilitate oiled sea otters (Williams and Davis 1990; Davis and Styers 1991; Davis and Williams 1991 a,b; Williams et al. 1991). The Sea Otter Rehabilitation Centers at Valdez and Seward treated 357 otters, of which 197 were eventually returned to the wild and 37 were placed in seaquariums. Otters that died in the rehabilitation centers were necropsied and tissues taken for histopathology and toxicology.

The Sea Otter Rehabilitation Program demonstrated that large numbers of oiled sea otters could be successfully rehabilitated following an oil spill. The experience contributed enormously to the wildlife rehabilitation community's understanding of what is needed to successfully rescue and treat sea otters after an oil spill. The large data base generated by this effort has been under analysis for the past two years, and is the basis for a new handbook on the care and rehabilitation of oiled sea otters and other fur-bearing marine mammals. Publication of the book is planned for late 1992.

NEED AND PURPOSE FOR THE BOOK

Sea otters are perhaps the most vulnerable of all marine mammals to the detrimental effects of oil spills. This results from their dependence on fur for thermal insulation in the cold marine environment. Exposure to oil eliminates the air layer trapped within the fur and reduces the thermal insulation of the pelt by 70% (Williams et al. 1988). Without this insulation, the otter has a very limited ability to increase metabolism and the intake of food energy to counteract the increased heat loss (Davis et al. 1988). As a result, a heavily oiled sea otter must leave the water (where it cannot feed), or it will be come hypothermic. Whether it remains in the water or hauls out on land, an oiled otter will eventually die.

Sea otters are also vulnerable to petroleum hydrocarbon toxicosis during an oil spill, This results primarily from their behavior of resting and eating on the surface of the water where oil is concentrated during a spill. Sea otters may inhale volatile petroleum hydrocarbons and absorb heavier fractions through their skin. The ingestion of oil may result when otters lick their fur during grooming and when they bring their food to the surface to eat.

Heavily oiled sea otters must be captured and treated quickly if they are to survive. This book will provide the most up-to-date information on the rescue and rehabilitation of oiled otters, It will include chapters on the design of rehabilitation facilities, management and personnel, capture and transport, triage, cleaning, clinical care, pathology, nutriiion, and the husbandry of adult, juvenile and pregnant sea otters. This book will contain contributions from over 25 authors, most of whom worked at the rehabilitation centers or have expertise in marine mammalogy and veterinary medicine. Their affiliations include universities, veterinary clinics, seaquariums, the California Department of Fish and Game, and the US. Fish and Wildlife Service. Financial support for data analysis, manuscript preparation, editing, and professional review has been provided by the Minerals Management Service (MMS) and Exxon Company USA,

OVERVIEW OF EACH CHAPTER

Chapter 1. Facilities for Oiled Sea Otters
1. Design of primary rehabilitation facilities The flow-through system for treating oiled otters.
2. Mobile stabilization trailers for remote sites.

Chapter 2. Management and Personnel for Rehabilitation Centers
1. Incident Command System approach to response
2. Management structure and key personnel
3. Personnel requirements

Chapter 3. Training Volunteers in the Rehabilitation Centers
1. The need for volunteers
2.. Safety
3. Hygiene
4. Quarantine: The importance of disease control

Chapter 4. Capture and Transport
1. Training
2. Capture vessels and equipment
3. Capture techniques
4. Handling captive otters
5. Transporting captive otters

Chapter 5. Physical and Chemical Restraint
1. Techniques of physical restraint
2. Drugs, dosages and contraindications for chemical restraint

Chapter 6. Triage: Assessment of Oil Exposure
1. Triage and clinical evaluation of oiled otters
2. Assessing the degree of oil exposure
3. Medical disorders of oiled otters

Chapter 7. Cleaning and Restoration of the Fur
1. The thermal properties of sea otter fur
2. Cleaning methods
3. Restoring the water repellency of the fur
4. New research

Chapter 8. Pathology of Oiled Sea Otters
1. Necropsy and tissue collection procedures
2. Mortality and postmortem observations of oiled otters
3. Histopathology
4. Toxicology
5. Clinical pathology

Chapter 9. Emergency Care and Clinical Treatment
1. Stabilization of oiled sea otters
2. Emergency treatment
3. Long term care
4. Promising new treatments for treating oil toxicity
5. Alleviating stress in captive otters

Chapter 10. Blood Chemistry and Hematology

Chapter 11. Husbandry and Nutrition
1. Pens and pool design
2. Nutrition and food preparation
3. Sanitation and disease prevention

4. Handling and transport
5. Frequent health problems encountered by husbandry staff

Chapter 12. Care of Pregnant Sea Otters

Chapter 13. Care of Sea Otter Pups
1. Transportation of the rehabilitation centers
2. Triage and stabilization
3. Cleaning and restoring oiled pup fur
4. Clinical treatment
5. Feeding and husbandry

Chapter 14. Release of Rehabilitated Sea Otters

Chapter 15. Considerations for other Fur-bearing Marine Mammals
1. Fur seals
2. Hair seals and sea lions
3. Polar bears

Chapter 16. Synthesis of the Rehabilitation Process: Critical Path Decision Making

CONCLUSIONS

The Sea Otter Rehabilitation Program following the Valdez oil spill provided valuable opportunities and much needed data to improve the clinical care and rehabilitation of oiled sea otters and other fur-bearing marine mammals. With support from the MMS and Exxon Company USA, these data have been analyzed and will form the basis for a new handbook on the care and rehabilitation oiled sea otters. This practical guide will provide information on rehabilitation facilities, management, capture, transport, triage, cleaning, clinical care, pathology, toxicology, nutrition, and the husbandry of adult, juvenile and pregnant sea otters. With contributions from over 25 authors, this book will provide the most up-to-date information on sea otter oil spill contingency planning and response.

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Dr. Randall Davis is chairman of the department of marine biology at Texas A&M University and co-director of /international Wildlife Research. 'He was senior director of the sea otter rehabilitation program during the Exxon Valdez spill. He has studied the effects of oil on marine mammals and methods of mitigating those effects for over **15 years.**

EFFECTS OF THE *EXXON VALDEZ* OIL SPILL ON BIRDS AND MARINE MAMMALS

Paul E. Gertler
Office of the Oil Spill
U.S. Fish and Wildlife Service
1011 East Tudor Road
Anchorage, Alaska 99503

INTRODUCTION

On March 24, 1989, the M/V *Exxon Valdez* ran aground on Bligh Reef in Prince William Sound, Alaska. Approximately 11 million gallons of crude oil spilled into the Sound and eventually moved up to 600 miles, contaminating shorelines in Prince William Sound, along the Kenai Peninsula, the Kodiak Archipelago, and the Alaska Peninsula. This occurred just prior to the most biologically active season of the year in southcentral Alaska. During the two month period after the spill, seaward migrations of salmon fry, major migrations of birds, and the primary reproduction period for most species of birds, mammals, fish, and marine invertebrates took place. The organisms involved in these critical periods of their life cycles encountered the most concentrated, volatile, and potentially damaging forms of the spill oil. This paper discusses the studies conducted by federal and state Trustee agencies (Trustees) to assess injuries to migratory birds and marine mammals caused by the largest oil spill in North American history. It also discusses preliminary results of these studies.

The comprehensive suite of studies conducted by the Trustees, termed the Natural Resource Damage Assessment (NRDA) program, was intended to document oil spill related injuries to natural resources to support the Trustees claim for damages from the responsible parties, in this case, Exxon Corporation and Exxon Shipping Company (Exxon). The Trustees anticipated that it might be necessary to enter into litigation against Exxon and took necessary measures to ensure that the federal and state governments were in the best position to succeed in litigation. This required that all data and results from the NRDA studies be treated as confidential and litigation sensitive and not be made public. The NRDA studies were also to provide the information on natural resource injury needed to plan and implement measure to restore these resources.

Even though the Federal District Court in Anchorage, Alaska, accepted the criminal plea agreement and civil consent decree negotiated between the state and federal governments on October 8, 1991, full release of NRDA results is not yet authorized due to pending litigation. Nonetheless, the federal Trustee released to the public the Summary *of Effects of the Exxon Valdez Oil Spill on Natural Resources and Archaeological Resources* in March 1991. That report provided a comprehensive assessment of the federal Trustees understanding of injuries to natural resources. The Trustees are currently preparing an update summary of effects.

This paper provides a general summary of results from studies conducted by scientists in Trustee agencies as well as scientists contracted by the Trustees. The author was responsible for coordinating studies conducted by the Department of the Interior and did not conduct any of the research discussed here. The scientists responsible for conducting the studies will publish their results, or otherwise provide their results to the public, once the Trustees determine that NRDA information can be released. Only information currently in the public domain is presented here.

RESULTS AND DISCUSSION

Injuries to Migratory Birds

Among the most conspicuous effects of the *Exxon Valdez* oil spill was the death of large numbers of birds. The Trustees designed a set of studies to assess both the acute impact during the spill and the long-term impacts. In order to determine whether study results were directly attributable to impacts of the oil spill, and not the result of natural variation or other cause, where possible, studies were designed to compare data gathered after the spill with data gathered prior to the spill. When this was not possible, studies were designed to compare oiled areas or populations with areas or populations not impacted by the spill. All migratory bird studies were the responsibility of the Department of the Interior.

The first focus of an injury assessment is to determine how many birds were killed. Following the spill, approximately 36,000 dead birds were retrieved from the spill area and deposited in wildlife morgues. Because it was known that these carcasses represented only a small proportion of the total bird mortality, a study was implemented in 1990 to develop a more accurate estimate of the total mortality. This study modelled the fate of219 birds collected, oiled, and fitted with radio transmitters that were released into Prince William Sound and the northern Gulf of Alaska. Utilizing multiple data bases on weather conditions following the spill,. cleanup efforts, and movement of oil, this study accounted for the variables that would limit the number of birds found killed by the spill. These variables include birds that sank, floated out to sea, were scavenged, were trapped and hidden in masses of oil and were not visible, were buried under sand and gravel by wave actions, decomposed, or beached in areas where they were not found. Also taken into consideration were the known cases of carcasses found but not turned into the wildlife morgues. Preliminary analyses accounting for these variables estimate that the total number of birds killed ranges from 260,000 to 580,000 with a best estimate that between 350,000 and 390,000 birds died during and immediately after the. spill. Prior to this study, experts estimated, based on limited data, that the *Exxon Valdez* oil spill killed between 100,000 and 300,000 birds.

Boat-based surveys were conducted in Prince William Sound, beginning in 1989 and continuing through 1991, to determine: 1) distribution and abundance of waterbirds; 2) to test the hypothesis that relative abundance of waterbirds, using new and comparable historical data, were not significantly lower in oiled as compared to unoiled areas; and 3) to estimate long- and short-term trends in population determined to be reduced by the oil spill. Transects were selected to enable data to be compared with surveys conducted prior to the spill. Preliminary results indicate that certain species or groups of species declined comparing post- and pre-spill surveys. These birds included harlequin ducks, black oystercatchers, pigeon guillemots, and *Brachyramphus* (marbled and Kittlitz's) murrelets.

Seabird colony surveys were initiated in 1989 and continued through 1991 to determine if numbers of selected colonial seabird species decreased as compared to pre-spill surveys and surveys of unoiled colonies. Murres were the most heavily impacted species, with about 22,000 carcasses being retrieved following the spill. Preliminary results of colony surveys indicate that approximately 120,000 to 140,000 breeding adult murres in the major surveyed colonies were killed by the spill. Extrapolating these results to other known murre colonies impacted by the spill, but not specifically studied, the mortality of adult breeding murres is estimated at 172,000 to 198,000, and including non-breeding and wintering murres, total murre mortality is estimated to be about 300,000. The large mortality of murres is not unexpected since the oil reached areas outside Prince William Sound at the same time that adult murres were congregating on the water near colonies in anticipation of the nesting season.

Although not an initial objective of the study when it was initiated in 1989, the impact of this 60% to 70% loss of breeding murres from impacted colonies on breeding behavior and success became a major objective of the study in 1990 and 1991. Murres nest in dense colonies and rely upon high density, synchronized breeding to repel predation from gulls, eagles, and other avian predators. The decreased density of breeding birds, late initiation of breeding, and disrupted breeding synchrony in affected colonies caused complete reproductive failure during

1989 and 1990, and a lost production of at least 215,000 chicks. Murre colonies not impacted by the spill showed none of these impacts and had normal reproduction.

The large number of carcasses on the beaches raised concerns about potential impacts on scavenging species such as bald eagles. Studies were initiated to determine if bald eagle population decreases had occurred as a result of the spill, to monitor reproductive success, and to investigate potential sublethal effects. Although only 144 dead bald eagles were found following the spill, it is estimated that several times that number of bald eagles were killed. Tracking of radio-tagged eagles found that eagles that died subsequent to the spill generally moved back into the forest and did not die on the beach front where they would be more likely found. During 1989, bald eagle reproductive failure was significantly greater (85%) for nests on moderately or heavily oiled beaches as compared to 55% on unoiled or lightly oiled beaches. Reproduction rebounded to more normal levels in 1990.

A study was initiated to assess sea duck exposure to and injury from oil. This study focussed on those species that utilized the intertidal and shallow subtidal zones, areas most heavily contaminated by oil. Harlequin ducks, Barrow's and common goldeneyes, and black, surf, and white-winged scoters were studied. Harlequins feed in the shallow intertidal zone, while the goldeneyes and scoters feed in the deeper intertidal and shallow subtidal zones respectively. Harlequins are also the only one of these species that nest in the spill area, All of these species feed on invertebrates such as mussels and continue to be exposed to remaining petroleum hydrocarbons through their food. Harlequins were most impacted by the spill, with about 33% of birds collected in the winter of 1989-1990 in the spill area showing poor body condition and about 40% with petroleum hydrocarbon contamination of tissues. Preliminary results indicate that harlequins may have failed to reproduce in the spill-impacted area of Prince William Sound in 1990.

Studies on other waterbirds that utilize the intertidal zone such as black oystercatchers and pigeon guillemots, found that these species were also impacted by the spill. Reduced black oystercatcher breeding success was documented in oiled areas. Pigeon guillemots are susceptible to continued exposure to petroleum hydrocarbons because they predominantly use the intertidal rocks and waters within 200 meters of shore. Between 1500 and 3000 pigeon guillemots are estimated to have been killed by the spill.

It was not possible to study all bird species that may have been impacted by the spill and, therefore, the extent of injury to certain species, including loons, cormorants, and gulls will probably never be fully known. Studies did not document injury to certain bird species such as Peale's peregrine falcon or songbirds.

Injuries to Marine Mammals

Concern by the Trustees that marine mammals might be vulnerable to oii on the surface led them to initiate studies on humpback whales, Steller sea lions, harbor seals, sea otters, and killer whales in 1989. The humpback whale study was not able to document any injury and was discontinued after the 1990 field season. Because of on-going pre-spill population declines it was not possible to distinguish pre- and post-spill effects clearly and the study was completed in 1990. Studies on humpback whales and killer whales were the responsibility of the National Oceanic and Atmospheric Administration (NOAA), those on harbor seals and Steller sea lions were conducted cooperatively by the Alaska Department of Fish and Game and NOAA, and those on sea otters were the responsibility of the Department of the interior.

The impact of the *Exxon Valdez* oil spill on sea otters was likely the most visible and most highly publicized effect of the spill on wildlife. Massive efforts were deployed to capture and rehabilitate oiled iive sea otters. These animals were particularly vulnerable to the spill because when their fur is contaminated by oil, it loses its insulating capabilities, causing hypothermia and death. Sea otters also died as a result of ingestion and pulmonary complications associated with exposure to oil. Sea otter studies included surveys of wild populations, analysis of tissues for petroleum hydrocarbons and indications of reduced health, radio tracking of instrumented animals, and estimating total mortality.

As with bird carcasses, the total of 1011 sea otter carcasses retrieved in the spill area represented only a portion of the total number of sea otters killed by the spill. Preliminary results of models designed to estimate total mortality indicate that between 3500 and 5500 sea otters were killed by the spill. The continued occurrence of a high proportion of prime-age animals among carcasses retrieved in 1990, and preliminary indications that weanling mortality rates were higher in the oiled area of Prince William Sound in the spring of 1991, are indicators of continuing injury to sea otters.

Although only 19 harbor seal carcasses were retrieved following the spill, aerial surveys estimate that about 200 seals were killed by the spill. Harbor seal populations were known to have been deciining prior to the spill, However, the population declines from 1988 to 1990 showed a significantly greater decline at oiled (35%) than at unoiled (13~0) sites. Severe debilitating lesions were found on the thalamus of the brain of one heavily oiled seal in Herring Bay 36 days after the spill and similar, though milder, lesions were found in five seals collected three or four months after the spill. Oiled harbor seals behaved abnormality in 1989, being lethargic and unwary.

Boat based killer whale studies documented that seven whales were missing from the 36 whale AB pod seven days after the spill and an additional six whales were missing from this pod in 1990. Several of the missing whales were females that left behind calves. This abandonment is unprecedented and the whales are presumed dead. Nine members of the AT pod were missing in 1990. Explanations for the possible cause of death of these missing whales are being explored.

SUMMARY

The state and federal Trustee agencies conducted a set of Natural Resource Damage Assessment studies to document injuries caused by the *Exxon Valdez* oil spill. Studies on birds estimated that between 260,000 and 580,000 with a best estimate that between 350,000 and 390,000 birds were killed by the spill. Murres were most severely impacted, with 60% to 70% mortality of adult breeding birds from impacted colonies and complete reproductive failure in 1989 and 1990. Several hundred bald eagles were killed and reproductive success was significantly reduced in oiled areas in 1989. Sea ducks, especially harlequin ducks, showed physiological effects of the spill and signs of reproductive impact. Studies on marine mammals found that sea otters and harbor seals were injured by the spill. An estimated 3,500 to 5,500 sea otters were killed by the spill and the proportionally high number of prime age carcasses that were found during 1990 indicate that seal otters continue to be impacted. An estimated 200 harbor seal were killed by the spill, Killer whales were documented as missing from two pods in Prince William Sound,

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Paul E. Gertler has worked for the U.S. Fish and Wildlife Service for the past 12 years, most recently as their coordinator of response, natural resource damage assessment, and restoration planning for the Exxon Valdez oil spill. He chaired the Trustee Agencies Management Team from November 1990, until the settlement of the federal and state governments' case against Exxon in October 1991. Previously, Mr. Gertler has worked in Fairbanks, Alaska, Cabo Rojo, Puerto Rico, and Washington, D. C. on a variety of wildlife resource issues, and as a Smithsonian-Peace Corps volunteer in Colombia, South America. He received B.S. degrees in biology and Anthropology from the University of Colorado and his M.S. in Wildlife Biology from Colorado State University.

QUESTIONS AND DISCUSSION

Kristin Stahl-Johnson: One of the species of whales that you did not mention was the gray whale. In the Kodiak Archipelago, specifically Tugidak Island and other areas, there were up to 25 dead whales found on the beach during the summer of 1989, We have never heard anything about those and it wasn't mentioned in the discussion. So I was wondering are we going to hear about them in the future or where are we at with those 25 whales?

Paul Gertler: Let me see if I can try to answer that. Gray whales were not a subject of specific study for natural resource damage assessment. I am aware of the whales that you are talking about. I also believe that National Marine Fisheries Service, that is part of NOAA, indeed did send some biologists out there to take a look at those carcasses to try and determine cause of death. I am unaware of any information indicating that the death of those whales was related in any way to the oil spill. I would recommend that you contact National Marine Fisheries Service to determine whether or not they could provide you with more specific information.

Craig Mishler: I work primarily in Kodiak and I was wondering if you had done regional mortality figures for the Kodiak area as opposed to the Sound? Most of your data, I take it, comes from the Sound or are you doing aggregates for the whole oil spill area?

Paul Gertler: Primarily, when I am talking about mortalities for any particular resource I am talking about aggregate numbers that are for the spill area comprehensively. Indeed for birds, the majority of the mortality occurred outside of Prince William Sound in the northern Gulf of Alaska where the murre colonies, a major colonial nesting bird, are located.

Craig Mishler: But you don't have Kodiak area statistics?

Paul Gertler: No, unfortunately it is extremely difficult to be able to determine specifically where mortality might have occurred. There are some cases where you might be able to do that, but in many cases because the birds that are killed are frequently moving with the oil mass you know where they end up, but you might not know where they were killed. So it is extremely difficult to assess that geographically. I feel fortunate that we appear to be getting a reasonable grasp on the total mortalities.

Pamela Miller: I was interested in the marbled murrelet. I understand that the impacts on the marbled murrelet population was very significant as a result of the spill. Given the recent finding by the Fish and Wildlife Service that the marbled murrelet population in Alaska not be listed despite quite a bit of, at least, anecdotal information that the population is declining throughout its range in Alaska and the fact that it did take a big hit in the spill, I wondered how you justified finding that the Alaska population should be not listed, and when are the data on the marbled murrelet population impacts going to be released? As a member of the public in reviewing a finding that the marbled murrelet population should not be listed, it is very frustrating not having the data available to make an assessment of whether your judgement was correct or not,

Paul Gertler: I am not responsible for the process of listing of the marbled murrelet and determing the information that goes into that. I am very cognizant of the frustrations on the part of many people in the public wanting to know what has happened as a result of the *Exxon Valdez* oil spill. Hopefully in the not too distant future that information will be made available to you, Policy decisions on listing of an endangered species are certainly outside of my area of authority.

Unidentified Questioner: I missed the numbers on that.

Paul Gertler: I can certainly get you numbers on that. The best that you can do on marbled murrelets is if you can find a copy of the March 1991 report released by the federal Trustees on injuries, it would have the number of carcasses that were retrieved following the spill.

Kristin Stahl-Johnson: 1 would just like to follow up on your answer. I have an objection that gray whales weren't included in the resource damage assessment and the fact that on Tugidak Island we had well over 12 or more whales found on one island where there is normally only one or two. If we haven't been able to analyze the informaiton that says that the oil spill had no impact on those whales. The numbers were far in excess of what was normally seen and the explanation" was that we just had more ice out there. But we haven't seen any data to prove that. The fact that the gray whales are in our area and they weren't part of the damage" assessment work is surprising to me.

Paul Gertler: I register your concern, thank you.

Suzanne Winder: I have two concerns. First of all I am concerned about the spectacle and Steller's eider that U.S. Fish and Wildlife has just recently considered threatened. I am wondering if the by-products of this oil spill or the recent oil spill in Cook Inlet are going to affect that population? They do overwinter in Cook Inlet, Another thing, people in Homer are concerned about a major die-off of seabirds in the Kachemak Bay and Lower Cook Inlet. I am wondering if you people are addressing that?

Paul Gertler: Steller's and spectacle eiders were not significantly injured by the *Exxon Valdez* oil spill, As far as potential implications for future management decisions, I am really not prepared to answer that.

Carrie Holma: I have brought a number of copies of the summary of natural resource damages. There are some on the front table. If anyone wants additional information you can contact me at (907) 278-8008.

IMPACT OF *EXXON VALDEZ* OILING AND SHORELINE TREATMENTS ON INTERTIDAL COMMUNITIES - TWO YEARS LATER

Jonathan Houghton, Dennis Lees[1], and Alan Mearns[2]
Pentec Environmental, Inc.
120 W. Dayton
Edmonds, Washington 98020

INTRODUCTION

A substantial amount of the crude oil that spilled from the tanker *Exxon Valdez* on March 24, 1989, was deposited on beaches in Prince William Sound. Major beach cleanup activities began in May and continued throughout the summer of 1989 (Harrison 1991). Several hundred kilometers of shoreline were treated in the sound in 1989 using various hydraulic wash and bioremediation (fertilization) techniques; additional mechanical cleanup and bioremediation occurred during the summers of 1990 and 1991. Significant concerns have been raised regarding the potential effects on intertidal habitats and biota of shoreline treatments, especially those using hot-water, high-pressure washes.

The overall objectives of this study have been: 1) to evaluate recovery of important intertidal habitats and resources from the effects of oiling and shoreline treatment and 2) to assess the influence of hot-water treatments on the nature and rate of recovery. A companion study has investigated effects on subtidal eelgrass beds (Houghton et al. 1991a).

The study plan established for 1990 and 1991 was designed, in part, to document persistence of effects of 1989 hot-water washes, if they remained evident, over the broader area where hot-water treatments had been applied. Thus, the intermediate-term (25- to 27-month) effects of the oil spill and subsequent shoreline treatment activities on intertidal community structure were examined in 1991 by resampling stations occupied in 1990. Primary variables isolated in the sampling design were habitat type, tidal elevation, degree of oiling, and use of hot-water, high-pressure shoreline treatments.

This design assumed that the site (habitat) groupings were similar enough to permit robust comparisons that identify major shifts in species dominance within the biological assemblages. We believe that the results to date, despite the limited replication of sites within each station category, accurately suggest the nature of initial impacts and describe the direction of recovery. Validation of the 1990-1991 results will occur within the sequence of longer term monitoring and trend analyses. Access to 1989 data gathered by the authors at many of the same sites (with Exxon funding) would greatly aid in these interpretations and, in several cases, allow direct pre-treatment comparison.

STUDY DESIGN AND APPROACH

Quantitative field surveys were conducted in Prince William Sound twice in 1990 and twice in 1991 to document environmental conditions in several types of habitats subjected to a variety of disturbances during 1989. Stratified-random sampling was used to assess epibiota and infauna at 31 intertidal sites representing several habitats and degrees of disturbance in selected oiled and unoiled locations in the sound (Figure 1). At each site, two or three stations were established to represent intertidal elevations (zones) of biological interest. This sample design allowed monitoring of long-term trends in recovery at sites of known oiling and treatment history. Because of the level of replicated sampling at each station, the sample design is also well suited

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[1] Ogden Environmental and Energy Services Company, Inc.

[2] National Oceanic and Atmospheric Administration

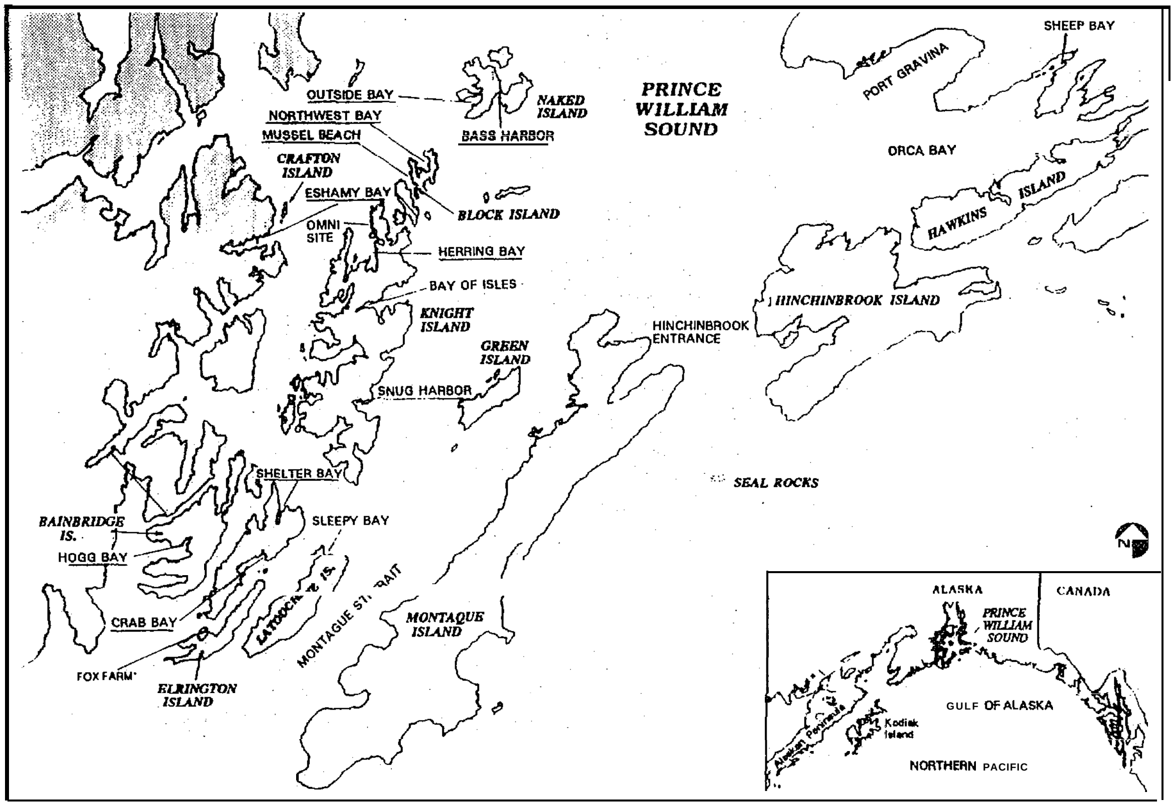

Figure 1. Prince William Sound study area and sampling location.

for comparison, at specific points in time, between pairs of stations with similar habitat but different oiling and/or treatment histories.

Habitats of interest were productive rocky and mixed sand/gravel/cobble ("mixed-soft") beaches common in protected embayments. Studies sponsored by Exxon in 1989 in Prince William Sound (reported in Houghton et al. 1991 b) demonstrated that major intertidal assemblage dominants (both plants and animals) had survived 3 to 4 months in heavily oiled habitats. Significant reductions (50 to 100% losses) occurred in all of these dominant species, however, immediately following hot-water, high-pressure washing (Figure 2). Because of these identified adverse impacts, effects of this type of treatment on intertidal ecology were a major focus of the present research effort.

Within each habitat type we sampled multiple beaches that had been unoiled (controls or Category 1 sites), oiled but not treated with hot-water washes (Category 2), and oiled with hot-water-wash treatment (Category 3). Information on initial oiling and on shoreline treatments applied at our study sites was derived from state and Exxon records and through contacts with on-site personnel. Samples were also collected for analyses of tissue hydrocarbon levels and sediment hydrocarbon concentrations.

This sample design allows for monitoring of long-term trends in recovery at sites of known oiling and treatment history. It is also well suited (by the level of replicated sampling at each station) for comparisons, at specific points in time, between pairs of stations with similar habitat but different oiling and/or treatment histories. Because the number of stations that could be sampled in each habitat/oiling/treatment category was limited, this design is less well suited to statistical inference regarding the generalized impacts of oiling and treatment over all stations

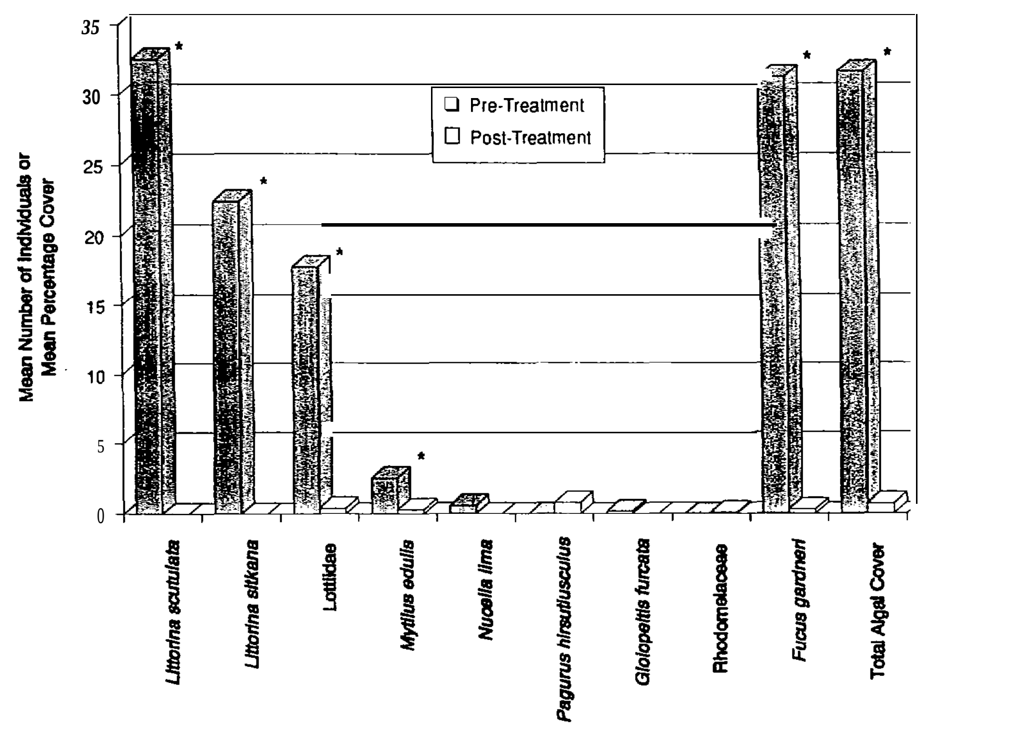

Figure 2. Comparison of dominant epibiota before and after treatment by Omni-Barge at Herring Bay, July 1989 (* = $p<0.1$).

with similar histories. Nevertheless the degree of difference in some variables among site categories in both sampling years was sufficient to show statistically significant differences and to draw some general conclusions regarding initial impacts and directions of recovery.

RESULTS AND DISCUSSION

Sediment Hydrocarbons

In 1990, sediment concentrations of polycyclic aromatic hydrocarbons (PAHs) were significantly lower at unoiled control stations than at all oiled stations, but there was no significant difference in mean PAH between treated and untreated stations (Houghton et al. 1991a). On average, sediment PAH concentrations were higher at upper elevations at untreated sites and higher at lower elevations at treated sites. This pattern suggests that treatment moved some hydrocarbons from the upper beach downslope, but the pattern was not statistically significant.

Distribution patterns of polycyclic aromatic hydrocarbons (PAHs) in sediments in 1991 were similar to those observed in 1990. PAH concentrations in sediments were substantially lower in 1991 than in 1990. Overall concentrations declined by about 60% at Category 2 sites and 45% at Category 3 sites. Ten-fold declines were observed at three of four elevations in Category 2 but at only one of four elevations in Category 3. Reduced concentrations of naphthalenes and fluorenes in 1991 were another reflection of the weathering process.

Tissue Hydrocarbons

Tissue PAH concentrations in two grazing species (littorine snails, *Littorina* spp., and the blue mussel, *Mytilus* cf. *edulis*) in 1990 showed significant positive relationships with site history (higher at untreated than at controls, higher at treated than at untreated), while two predatory species (a drill, *Nucella lamellosa,* and the sun star, *Pycnopodia helianthodes*) did not (Houghton et al. 1991a). Since PAH levels in predators were lower than in the primary consumers, we concluded that no biomagnification was occurring in components of the food web examined as of the time of sampling; thus, sampling these latter two species was discontinued in 1991.

PAH analyses in 1991 focused on determining whether high concentrations of PAH in mollusc tissues at some sites were due to continued exposure to hydrocarbons or to residual hydrocarbons in the tissues from exposure during previous years. These-analyses produced three important findings.

PAH concentration in tissues of mussels and littleneck clams transplanted from reference sites to areas of high residual sediment contamination increased over the summer by an order of magnitude or more to levels of contamination as high as, or higher than, those in resident (local) animals.

Levels of tissue PAHs in mussels (transplants and local animals) at Smith Island (3.7 to 20.4 ppm dry), considered one of the more highly contaminated sites remaining in the sound because of the heavy residual deposits of subsurface oil, were similar to the levels of PAHs in mussels from near Seward (6.2 ppm dry). The Seward sample was collected in late April, a period of relative inactivity for watercraft, in an area unaffected by the spill along a stretch of vacant shoreline at least *0.5* miles from town.

Levels of contamination observed in resident mussel tissues at Smith Island in July and September 1991 were more than an order of magnitude lower that those observed at the site in July 1990. The composition of PAHs in mussel tissues was quite similar to that seen in 1990 but reflected weathering in the source hydrocarbons. Phenanthrenes and dibenzothiophenes were dominant; naphthobenzothiophenes and fluorenes were of intermediate importance; and naphthalenes, pyrenes, and chrysenes were of low importance.

The most likely sources of long-term contamination of mussel tissue in the sound are the reservoirs of subsurface oil at many sites. Large reductions in PAHs in mussel tissues from Smith Island suggest that leaching rates from such subsurface deposits of oil have declined dramatically since July 1990, however. This observation is important in consideration of the advisability of continued shoreline treatment activities, particularly in view of the fact that, by 1991, the tissue contamination at Smith Island had declined to a level similar to that observed in animals from near Seward.

Epibiota on Rocky Habitats

In our 1990 and 1991 sampling, a high degree of variability was seen among biota at sites subjected to varying degrees of treatment. Many of the important longer-lived dominants remained intact at some treated sites in 1990, but at other areas, apparently those that had been cleaned more rigorously, these species did not survive. In 1991, colonization of these areas was evident on most shorelines, particularly on rocky substrates.

One rocky site in Northwest Bay (Figure 1), which was stripped bare by treatments in 1989 and remained essentially bare in 1990, showed little colonization through September 1991. Films of blue-green algae (Cyanophyta) and possibly other algae that developed early in 1990 and 1991 were grazed or eroded away; mostly bare rock was left. Even early successional

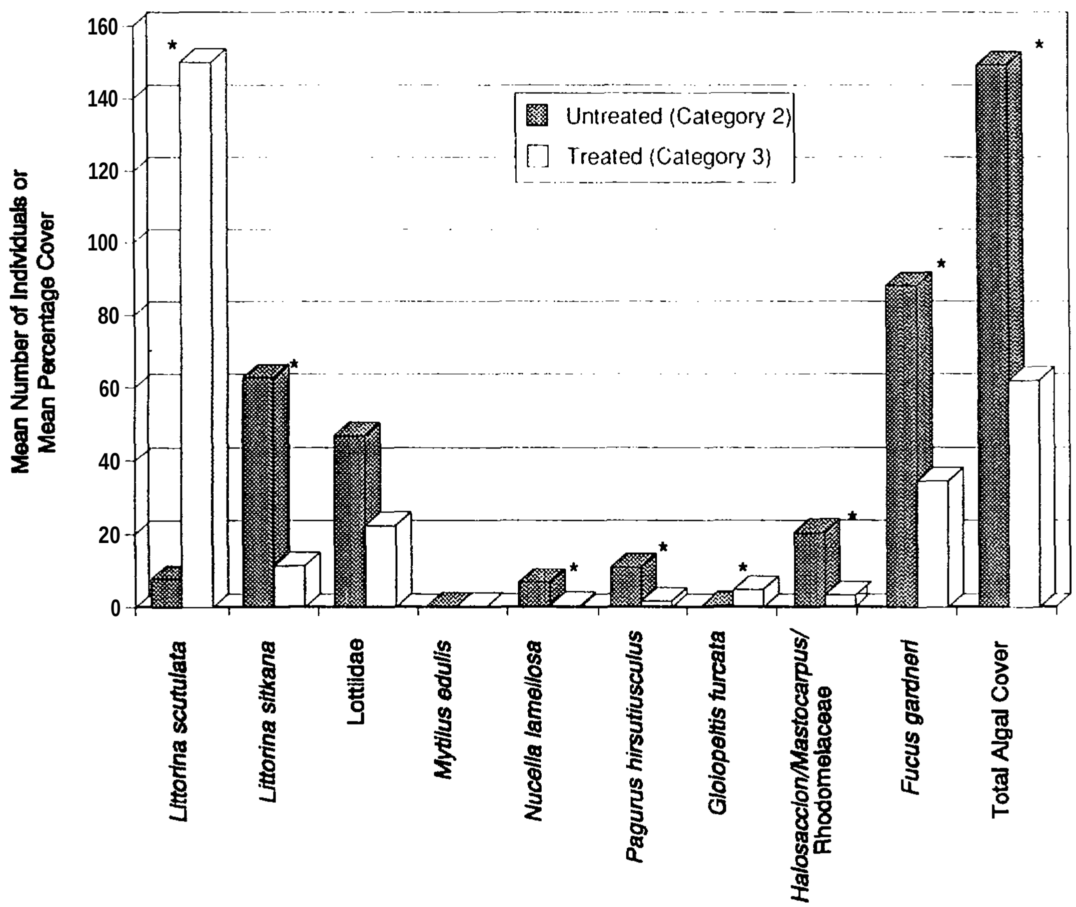

Figure 3. Abundance of dominant epibiota at adjacent middle rocky Category 2 and Category 3 stations sampled at Northwest Bay West Arm, July 1991 (* = $p<0.1$).

colonization by rockweed sporelings, *Fucus gardneri*, or the barnacle *Semibalanus balanoides*, such as was seen elsewhere in great abundance, occurred only sporadically and in isolated patches. Clearly, the epibiota at this site will take many more years to recover to pre-spill and pre-treatment conditions.

In 1990, we noted many areas along the straight, steeply sloping rocky shorelines of Northwest Bay where biota was visibly reduced as described above. Sharp vertical boundaries often separated these areas from adjacent rocky areas that exhibited abundant associated biota and a normal cover of rockweed, barnacles, and mussels (Figure 3, Category 2 station). Because it can be reasonably assumed that 1989 oiling was continuous over these reaches, and because there was no apparent natural reason for the vertical boundaries, we conclude that the differences reflect differing degrees or severity of treatment. The fact that little or no oil was visible in 1990 or 1991 on either side of these vertical boundaries indicates that less severe treatments were as successful at removing oil as the more severe.

Dense stands of young rockweed, which had been evident only as inconspicuous sporeling mats in these heavily treated areas in 1990, were growing well in 1991 and gave the superficial appearance of a "normal" shoreline. A more detailed examination at our Northwest Bay

West Arm rocky sites, however, revealed that the community associated with the more heavily treated areas as yet bears little semblance to that on Category 1 (unoiled) or 2 (oiled but not hot-water washed) shores. Longer lived, more stable components of the upper rockweed zone (rockweed; several red algae, Rhodophyta; hermit crabs, *Pagurus hirsutiusculus*; a limpet, *Lottia pelts;* and drills, *Nucella lamellosa*), were significantly more abundant on the Category 2 site (Figure 3). On the adjacent Category 3 site, opportunistic species (*Littorina scutulata*) as well as a species typical of the uppermost intertidal zone (*Endocladia muricata*) were significantly more abundant (Figure 3).'

Rockweed on the Category 3 site comprised predominantly 2-year old plants that were not reproductively mature as well as a small percentage of sporelings. In contrast, the Category 2 site included an equal percentage of sporelings, along with an even mix of several year classes of older and reproductively mature plants. Several taxa associated with the mature rockweed community were significantly more abundant at this site. Finally, total algal cover and animal diversity were significantly higher on the Category 2 site,

Thus, oiled rocky areas that were not subjected to severe cleanup activity have recovered to the point where they are generally indistinguishable from unoiled sites, while more heavily treated sites remain in early stages of recovery, Qualitative examinations of other shorelines around the northern portions of the Knight Island group in July 1991 revealed many areas where similar early successional assemblages were present where hot-water treatments were used in 1989. The broader ecological implications of resetting the successional stage over larger areas of shoreline are not clear. Trends in the initial impact and recovery of three key taxa (rockweed, limpets, and drills) at all middle elevation rocky stations sampled (Figure 4) illustrate that oiled but untreated (Category 2) stations are well on their way to recovery by mid-1 991 while populations at hot-water washed (Category 3) stations remain significantly depressed.

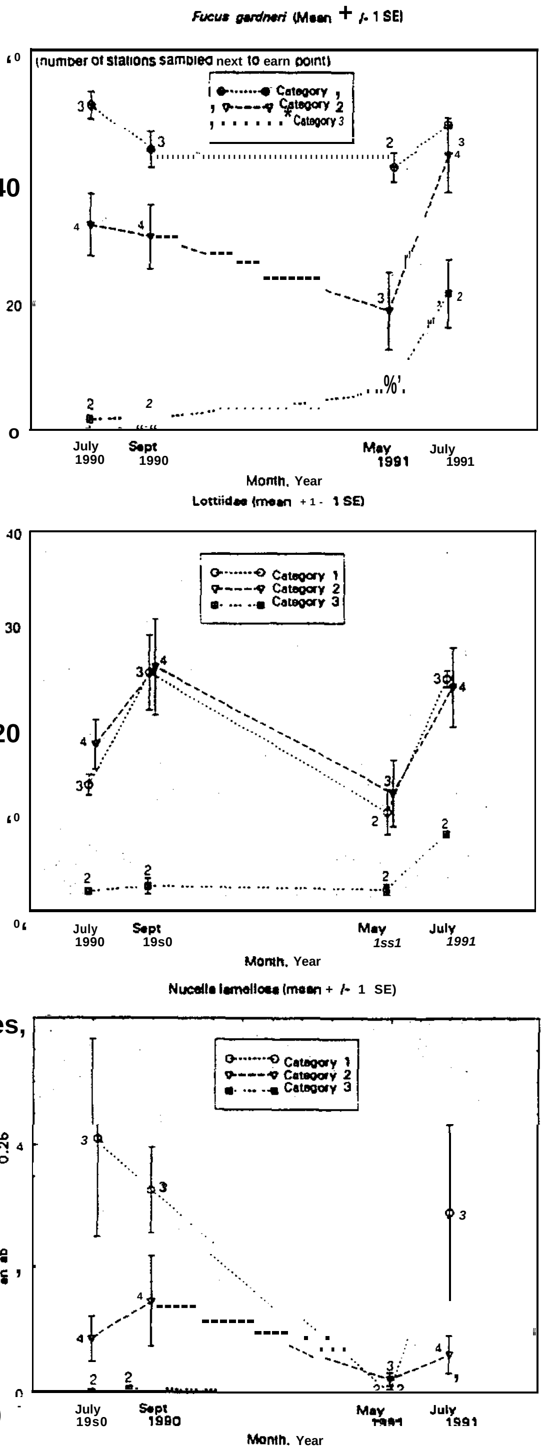

Figure 1. Mean abundance of rockweed, limpets, and drills at middle elevation rocky stations 199o -1991.

Infauna on Mixed-soft Beaches

Protected sand and gravel beaches were severely affected by hydraulic treatments that greatly attered beach morphology. Finer sands and gravels were flushed from upper intertidal elevations and often buried the lower beach in several centimeters of sediment. In this process, many infaunal organisms and a high percentage of the silts and organic materials in the sediments were dislodged and transported from the site.

In 1991 and 1990, infauna appeared only moderately affected by the spill on Category 2 (oiled but untreated) beaches with few apparent differences between Category 1 (unoiled) and two stations. The infauna on Category 3 (oiled and hot-water washed) beaches was fundamentally altered in comparison with both other classes of beaches, however. Most major taxa (gastropod, bivalves, polychaetes, some crustaceans) had significantly lower abundances on Category 3 beaches than on Category 1 beaches in both years ($p < 0.1$ in randonization t-test; Figure 5).

In 1991, several dominant taxa were most abundant at the lower intertidal station at the heavily oiled Category 2 site at Block Island. This area continued to show extremely high sediment oiling yet had higher densities of the deposit feeding bivalve *Macoma* spp., harpacticoid copepods, nematodes, and oligochaetes than any site group. These taxa may be capable of exploiting hydrocarbon-degrading bacteria in these oily sediments.

The Block Island site also had the highest density of the hardshelled clam *Protothaca staminea* (6.4 per 0.009-m^2 sample) despite indications that residual hydrocarbon concentrations were sufficient to cause reduced survival of clams transplanted to this site. In both 1990 and 1991, the Category 3 sites had the lowest overall density of hardshelled clams. The three Category 3 stations had virtually no *Protothaca*. No butter clams, *Saxidomus giganteus*, were taken in cores at Category 3 sites in 1990.

Analysis of 1990 and 1991 infauna data confirmed that the effects of shoreline treatments related more to physical disturbance (burial, displacement, reductions in fines and organic content) than to oiling. The 1991 data also confirmed earlier projections (Houghton et al. 1991a) that recovery of infauna on hot-water-washed beaches will take many years; the two hardshelled clam species likely will take well more than 10 more years for recovery to pre-spill densities and age structure.

SUMMARY

The existing body of data suggests that hot-water hydraulic treatment displaced some deposited oil from upper to lower intertidal elevations; reduced abundances of dominant epiflora, epifauna, and infauna including important hardshelled clams, and delayed or depressed infaunal and molluscan recruitment. These conclusions are consistent with observations reported in 1989 studies before and after hot-water treatments at two experimental sites.

At least partial recovery of most variables measured was apparent by mid-summer 1991; few differences remained between unoiled stations and stations that were oiled but not treated with hot-water washes. Some recovery was also evident by 1991 in most variables at sites that were hot-water washed, but recovery at hot-water washed stations significantly lags behind that at oiled but untreated stations. This leads one to question whether the treatments applied achieved the desired objective of oil spill response stated by Lindstedt-Siva (1991): to minimize the net ecological impacts.

The hypotheses tested thus far, together with additional measurements of biological recovery, will be more rigorously examined in future years.

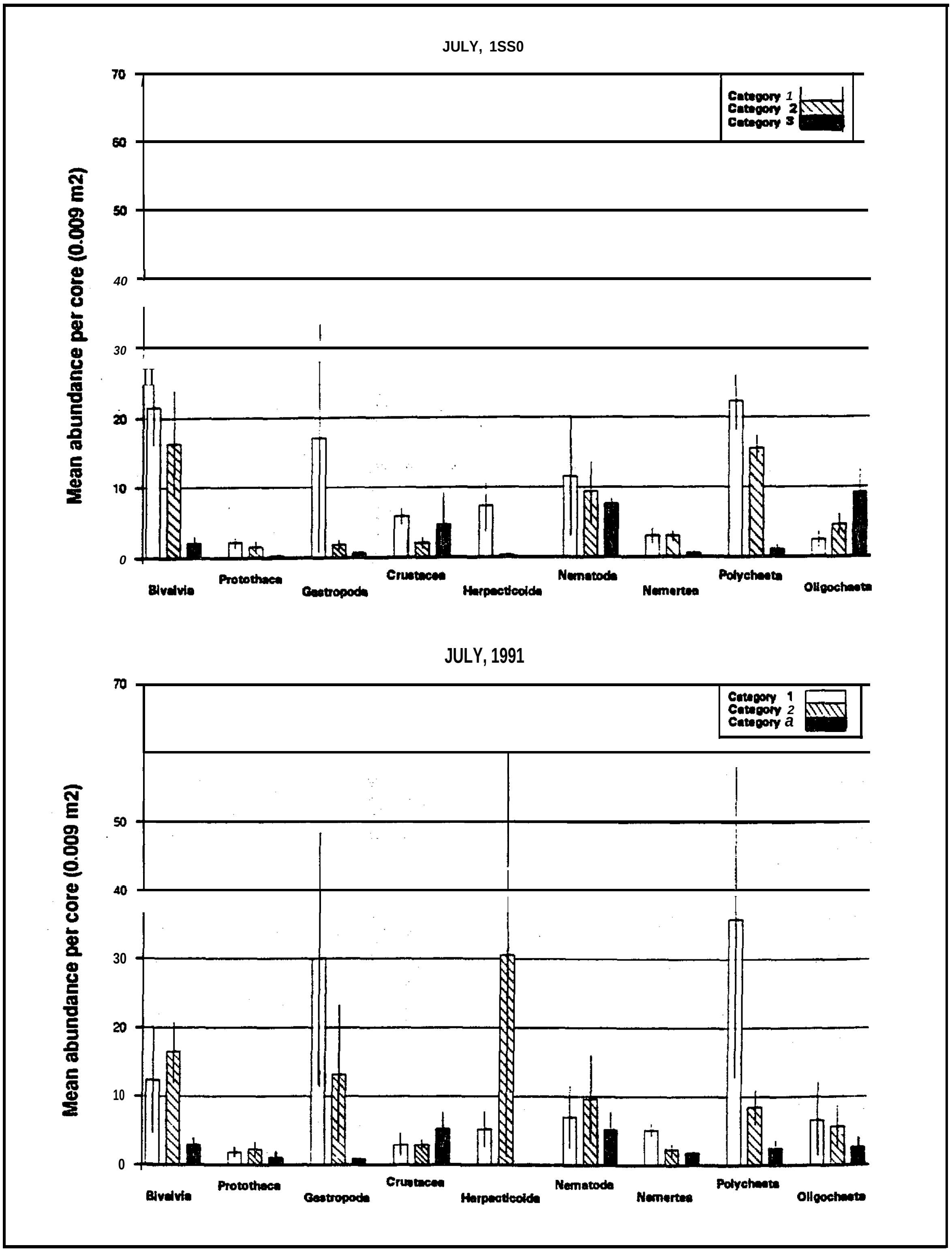

Figure 5. Infaunal abundance from lower intertidal stations, July 1990 and July 1991 (± 1 SE).

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Dr. Jonathan Houghton has **been active** *in intertidal and nearshore research along the various* **coastlines** *of Alaska since* **1976** *including considerable work on the biological effects of OSC oil and gas development and a four-year study of the intertidal ecology of Lower Cook Inlet. lie was a founding Principal in Pentec Environmental, Inc., (Edmonds, Washington). In* **1989,** *he monitored the effects of the Exxon Valdez oil spill and various beach treatment approaches on intertidal ecology of Prince William Sound (for Exxon). Since 1990 he has been a Co-Principal Investigator in a study for NOAA of long-term biological recovery of nearshore communities from the spill. Dr. Houghton received his bachelor's degree from Harvard College* **in** *1964 and his Ph.D. from the University of Washington, College of Fisheries in 1973.*

QUESTIONS AND DISCUSSION

Dick Prentki: Has anyone been measuring polycyclic aromatic hydrocarbons (PAHs) in the biota in the intertidal areas?

Jonathan Houghton: Yes. I didn't mention that. That is another thing that we did do and have done in 1990 and 1991. What we found were noticeable accumulations of PAHs particularly in mussels. The target species there were mussels, littorines, *Nucella*. In 1990 we also did starfish, *Pycnopodia*. *Nucella* and the starfish are both predators and the littorines and mussels are grazers. We are also doing the *Protothaca* which is a grazer. We actually showed, in looking at the two trophic levels, no biomagnification of hydrocarbons. In fact we couldn't distinguish, statistically, levels of hydrocarbons in starfish or *Nucella* between oiled and unoiled sites so we quit sampling those in 1991.

Dick Prentki: You didn't sample them at all in 1991?

Jonathan Houghton: Not for hydrocarbons.

Dick Prentki: In the Baffin Island Oil Spill Project experiment they had some increases through years two and three.

Jonathan Houghton: It is something actually that we pick up may again in a subsequent year.

Dick Prentki: One other quick question for you, I was told in the summer of 1989 not to worry about the water temperature on the beaches. Because even though it was 140°F coming out of the barges, by the time it got out of the nozzle it was down to supposedly 70°F. Do you know of any measurements on that?

Jonathan Houghton: Yes. But 1 am not sure that I can talk about them. But it was hotter than 70°F.

Ray Emerson: In the conclusion to say that there was no effectiveness with the treatment, do we know that the comparative difference between those beaches, untreated and treated, had about the same level of oil impact?

Jonathan Houghton: Were they oiled equally to start with? Well, in many cases, there is uncertainty with respect to that. There were a lot of things that could have been done better if we were designing this experiment before "Capt. Joe" left the Pipeline [Tavern]. What really was needed was a much more controlled effort to leave heavily oiled sites untreated for scientific purposes. But there was not a lot of popular outcry in favor of that. So as a result, we, in many cases, were forced to look for sites of opportunity like the one I showed with the vertical line, That was probably the closest we came to saying something had happened here, The oiling was the same but the treatment was highly varied from one side to the other. There were a lot of places where you could see that kind of vertical line and you knew that either the Omni barge or the Maxi barge had sat there for a couple of days and hadn't got their next site assignment yet,

Ray Emerson: The vertical line, you mean where there was a strip taken out? Wouldn't that be the intense oil sector and they would have just put the cleaning process to that particular spot?

Jonathan Houghton: Well, I doubt it. It is a little awkward for me to talk about because I don't know how much I can talk about what I saw in 1989. But there is no reason to believe that the oiling was any different on either side of that. Typically one those rock faces like that within a quiet bay, particularly Northwest Bay which was full of oil for months, it was evenly distributed.

Ray Emerson: Was the overall intent of the more rigorous cleaning methods to hit those areas that were most heavily hit by oil? To direct the clean up approach to those spots?

Jonathan Houghton: Well, certainly in the ideal sense that would be it. But there was an awful lot of variability depending on schedules, tides, individual crew bosses, and people running the hoses, tremendous variability in treatment effort and that is a complicating factor. And that is why we've replicated our sites: so that we have three or four sites within this condition or presumed condition, because we know that there is a lot of variability in those things.

Ray Emerson: Then you would still say that treatment is not a good idea?

Jonathan Houghton: Well, in certain circumstances I would say that it is not a good idea to treat it quite as severely as it was there, from the standpoint of intertidal biota. Did I qualify that enough?

Stephanie Reynolds: Just for whatever it is worth, in regard to that question, which is an excellent one in terms, of methodology, I worked in Cordova and the spill response office there complained bitterly that Exxon had its own time table such that there would be these lines. And in this case it is a verification of what you have been saying. In that it wasn't that they treated the most oiled areas rather they would treat until they spent a certain amount of weeks there and then they had to move on, Such that a time frame was constructed prior to entering the sites.

Jonathan Houghton: There was a lot of arbitrariness as to how heavily a site got treated.

CHANGES IN SUBSISTENCE USES OF FISH AND WILDLIFE RESOURCES IN 15 ALASKA NATIVE VILLAGES FOLLOWING THE EXXON VALDEZ OIL SPILL

James A. Fall
Division of Subsistence
Alaska Department of Fish and Game
333 Raspberry Road
Anchorage, Alaska 99518

INTRODUCTION

The *Exxon Valdez* oil spill of March 1989 fouled the waters and beaches used for subsistence hunting, fishing, and gathering by 15 predominantly Alaska Native villages. These are Chenega Bay and Tatitlek in Prince William Sound; English Bay and Port Graham in lower Cook Inlet; Akhiok, Karluk, Larsen Bay, Old Harbor, Ouzinkie, and Port Lions in the Kodiak island Borough; and Chignik Bay, Chignik Lagoon, Chignik Lake, Ivanof Bay, and Perryville on the Alaska Peninsula. This paper provides an overview of some of the findings of research conducted by the Division of Subsistence of the Alaska Department of Fish and Game concerning subsistence harvests and uses in these communities before and after the oil spill.

METHODS

The primary source of data on subsistence harvests in the 15 study communities is systematic household surveys administered by division personnel, for the most part in respondents' homes. One goal of these surveys is to collect detailed, quantified harvest data for a specific study year from each household. The results are summarized and reported at the community level, Before the spill, the division had conducted at least one round of harvest surveys in each of the 15 villages. These findings are reported in the division's technical paper series (Stanek 1985, Stratton and Chisum 1986, Morris 1987, Schroeder et al. 1987, Stratton 1990, Stanek, in prep, a) and in the division's Community Profile Database (Fall 1990, Paige et al. 1991).

After the spill, the division began a multi-component oil spill response program. Among other things, this included the systematic collection of subsistence harvest and use data that would be comparable to that available for pre-spill years. Accordingly, the division designed a survey instrument which was modeled after those used in earlier studies. Interviews took place from January to April 1990. The goal was to interview representatives of all of the year-round households in the 12 smaller communities, and a 50% random sample in the larger villages of Old Harbor, Ouzinkie, and Port Lions. As shown in Table 1, in total, 403 households were interviewed, 88.2% of the project goal. Analysis of these data was supported in part by a cooperative agreement with the U.S. Minerals Management Service (MMS).

In April and May 1991, the division conducted a second round of post-spill interviews in seven of the villages: Chenega Bay, Tatitlek, English Bay, Port Graham, Ouzinkie, Larsen Bay, and Karluk. This research was supported in part by the U.S. Fish and Wildlife Service and the MMS. Our goal was to interview every household in each community. In total, 221 of 263 households were surveyed, an achievement rate of 84.0%.

Some of the findings of this research are discussed below. For more information the reader should consult one of the summary reports now in preparation for the technical paper series (Fall 1991, Fall et al., in prep.; Mishler and Cohen, in prep.; Stanek, in prep. b; Stratton et al., in prep.). The data presented from the 1991 study should be considered preliminary,

Table 1. Sample sizes, division of subsistence household surveys, 1990 and 1991.

	Number of Households 1990			Number of Households 1991		
Community	Target	Completed	Percent	Target	Completed	Percent
Chenega Bay	21	18	85.7%	21	18	85.7%
Tatitlek	28	22	78.6%	28	17	60.7%
English Bay	41	33	80.5%	41	35	85.4%
Port Graham	61	48	78.7%	55	46	83.6%
Akhiok	13	10	76.9%	0		
Karluk	17	14	82.4%	19	17	89.5%
Larsen Bay	39	34	87.2%	40	35	87.5%
Old Harbor	46	48	104.3%	0		
Ouzinkie	35	35	100.077	59	53	89.8%
Port Lions	36	36	100.0%	0		
Chignik Bay	39	35	89.7%	0		
Chignik Lagoon	15	15	100.0%	0		
Chignik Lake	28	21	75.0%	0		
Ivanof Bay	7	7	100.0%	0		
Perryville	31	27	87.1%	0		
TOTAL	457	403	88.2%	263	221	84.0%

PATTERNS OF SUBSISTENCE USE BEFORE THE SPILL

Division research has documented the continuing significance of subsistence hunting, fishing, and gathering to the economies and ways of life of the communities of Prince William Sound, Lower Cook Inlet, Kodiak Island, and the Alaska Peninsula. Table 2 summarizes some information about subsistence uses in the 15 study communities in 1980s. In general, the findings showed that a very large number of subsistence foods was used in each of these areas, including salmon and other fish, marine invertebrates, land mammals, marine mammals, birds and eggs, and wild plants. Subsistence harvests, as measured in useable pounds per person per year, have ranged from about 200 pounds per person to about 600 pounds per person annually. These are substantial harvests, considering that the average family in the western United States purchases about 222 pounds of meat, fish, and poultry per person each year (Wolfe and Walker 1987). In addition, subsistence activities have profound social and cultural meanings in these villages. For example, harvest and processing groups are organized around kinship relations, and extensive sharing of subsistence foods is commonplace.

SUBSISTENCE USES AFTER THE *EXXON VALDEZ* OIL SPILL

This section will focus on three aspects of subsistence uses and describe some of the changes that have been documented since the spill. These are harvest quantities as measured in pounds useable weight per person per year, the range of resources used for subsistence purposes, and levels of participation in the use of wild foods, Other characteristics of subsistence uses that were investigated included changes in harvest areas, methods of harvest, and sharing of wild foods.

Table 2. Some characteristics of subsistence uses in the study communities before the Exxon *Valdez* oil spill.

				Percent of Households that				
Community	Year	Per Capita Harvest	Mean Number of Resources Used Per HH	Used Resources	Attempted a Harvest	Harvested Resources	Received Resources	Gave Away Resources
Chenega Bay	1985	374 lbs	18.0	100	100	100	94	88
Tatitlek	1988	644 lbs	22.6	100	100	100	100	95
English Bay	1987	289 lbs	25.0	97	94	94	94	94
Port Graham	1987	227 lbs	21.5	100	100	100	98	82
Akhiok	1982	520 lbs	15.5	100	MA	100	86	76
Karluk	1982	863 lbs	19.1	100	MA	90	100	90
Larsen Bay	1982	404 lbs	16.3	100	MA	94	97	8a
Old Harbor	1982	491 lbs	15.4	100	MA	100	82	78
Ouzinkie	1982	369 lbs	17.7	100	NA	97	91	84
Port Lions	1982	280 lbs	13.5	100	MA	95	84	76
Chignik Bay	1984	188 lbs	12.5	100	84	84	95	79
Chignik Lagoon	1984	220 lbs	10.4	100	88	88	82	71
Chignik Lake	1984	279 lbs	16.2	100	100	100	96	83
1 vanof Bay	1984	456 lbs	18.5	100	100	100	100	83
Perryville	1984	391 lbs	21.2	100	100	100	100	100

Sources: Stratton and Chisum 1986; Morris 1987; Schroeder et al. 1987; Stratton 1990; Paige et al. 1991; Stanek, in prep.

As shown in Table 3 and Figure 1, subsistence harvests in 10 of the 15 communities declined markedly in the first year after the spill compared to most pre-spill study years and pre-spill averages. For example, harvest levels in Chenega Bay and Tatitlek both dropped by about 60% and those of English Bay and Port Graham declined by about 50%. There was a range of decline in subsistence harvests in the Kodiak villages, from a high of a 77% reduction at Ouzinkie to a low of a 12% reduction at Akhiok. In contrast, subsistence harvests in the five Alaska Peninsula villages in the year after the spill were about the same or higher than the single pre-spill year for which data are available.

Preliminary data on total subsistence harvest levels for the second year after the spill are shown in Figure 2, For five villages (English Bay, Port Graham, Ouzinkie, Larsen Bay, and Karluk) these harvests increased over the first post-spill year. For three of these communities (Port Graham, Larsen Bay, and Karluk) subsistence harvests in April 1990 through March 1991 matched at least one pm-spill year. However, in three villages (English Bay, Ouzinkie, and Karluk) harvests remained below pm-spill averages. On the other hand, subsistence harvests in the Prince William Sound villages of Tatitlek and Chenega Bay showed no overall increase over the year before, and remained starkly below pre-spill levels of harvest.

The range of resources used for subsistence purposes in the villages of Prince William Sound, Lower Cook Inlet, and the Kodiak Island Borough also decreased in the first year after the spill. For most communities, this range increased in the second post-spill year, but did not return to pre-spill norms. Figure 3 provides an example from Tatitlek. On average, households

Table 3. Comparison of subsistence harvests of the study communities before and after the Exxon *Valdez* oil spill.

Community	Year One	Year Two	First Post-Oil Spill Year[a]	Post-Spill Change: Compared to Most recent Previous year	Post-Spill Change: Compared to Average of all Previous years
Chenega Bay	308.8	374.2	148.1	- 60.4%	- 56.6%
Tatitlek	351.7	643.5	214.8	- 66.6%	- 56.8%
English Bay	288.8	b	140.6	- 51.3%	b
Port Graham	227.2	b	121.6	- 46.5%	b
Akhiok	519.5	162.3	297.7	+ 83.4%	- 12.7%.
Karluk	863.0	385.2	250.5	- 35. 0%	- 59. W
Larsen Bay	403.5	209.0	209.9	+ 0.1%	- 31.5%
Old Harbor	491.1	422.2	271.7	- 35.6%	- 40.5%
Ouzinkie	369.1	402.8	88.8	- 78.0%	- 77.0%
Port Lions	279.8	333.1	146.4	- 56.0%	- 52.2%
Chignik Bay	187.9	b	208.6	+ 11.1%	b
Chignik Lagoon	220.2	b	211.4	- 3.7%	b
Chignik Lake	279.0	b	447.6	+ 60.1%	b
Ivanof Bay	455.6	b	489.8	+ 8.4%	b
Perryville	391.2	b	394.2	+ 1.0%	b

[a]For Prince William Sound and Kodiak communities, two pre-spill measurements are available. Pre-spill study years are as follows: Tatitlek, 1987 to 1988 and 1988 to 1989; Chenega Bay, 1984 to 1985 and 1985 to 1986; English Bay and Port Graham, 1987; Kodiak Island Borough, 1982 to 1983 and 1986; Alaska Peninsula, 1984. The "spill year" is 1989 for all communities but Chenega Bay and Tatitlek, for which it is April 1989 - March 1990. Source: Paige et al. 1991.

[b]Only one previous measurement.

in this village used 20 different kinds of wild foods in a 12 month study period in April 1987 through March 1988, and 23 kinds in April 1988 through March 1989. In-contrast, the average was only 12 kinds used during the first year after the spill. The range of subsistence resources used during the second post-spill year at Tatitlek rose slightly to 14, but remained well below either of the pm-spill years. The mean number of kinds of resources harvested per household, received per household, and given away per household in Tatitlek showed a similar pattern. This can be compared with the findings for Port Graham (Figure 4). There, as in Tatitlek, the range of resources used dropped almost by haif in 1989; however, this average showed a more notable increase in April 1990 through March 1991, to 17,4 kinds, than in the Prince William Sound village.

Finally, the research has found that participation in the use of certain resource categories declined in the first year after the spill, and has, with some exceptions, bounced back up in the second year, Figure 5 provides an example for Chenega Bay. The percentage of sampled household which used fish other than salmon, marine invertebrates, marine mammals, and birds was much lower in the 12 months after the spill than in the April 1985 through March 1986 study year. In the second post-spill year, the percentage of households in Chenega Bay using other

Fall — Changes in Subsistence uses of Fish and Wildlife Resources in 15 Alaska Native Villages following the *Exxon Valdez* Oil Spill

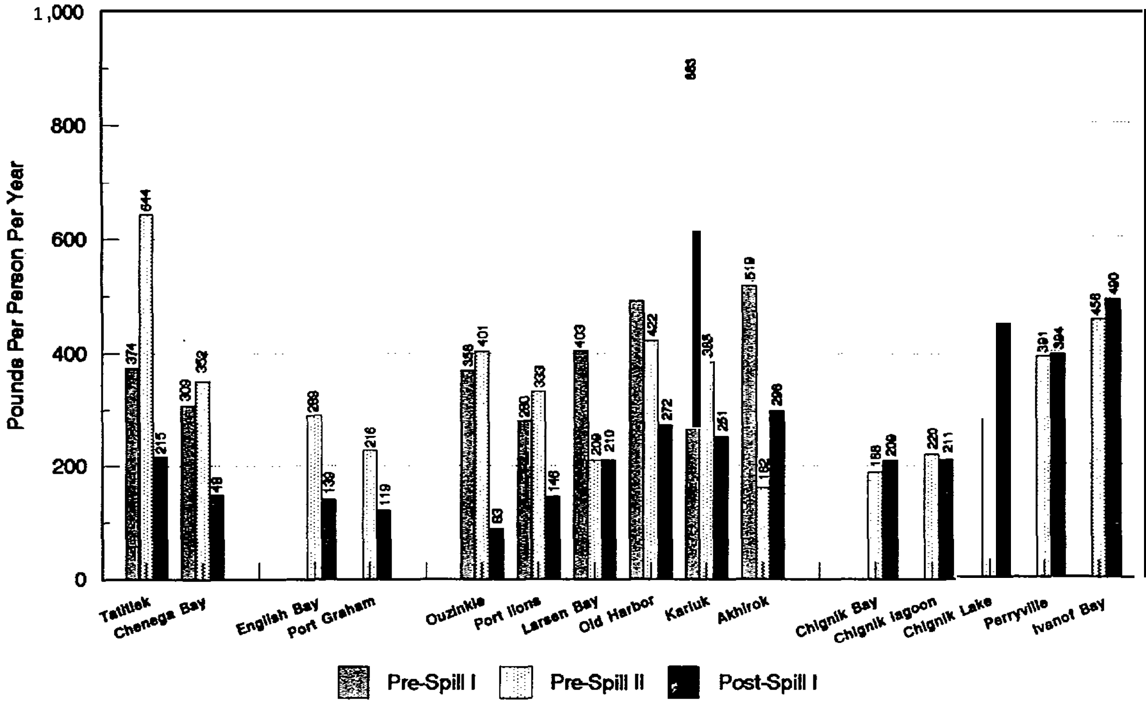
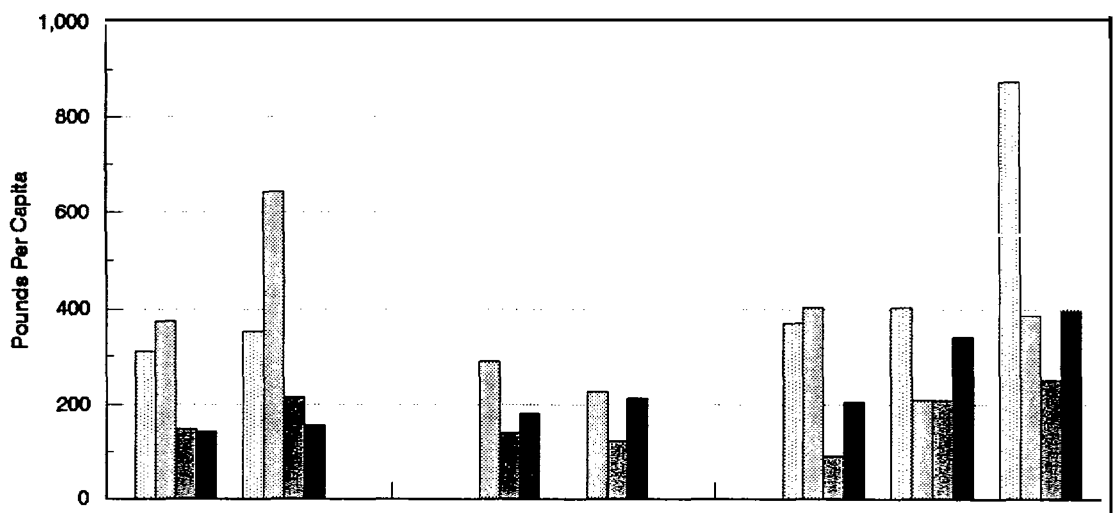


Figure 1. Per capita subsistence harvests, study communities, pre-spill and first post-spill years.



	Chenega Bay	Tatitlek		English Bay	Port Graham		Ouzinkie	Larsen Bay	Karluk
Pre-spill year one	30s.9	2s20					259.1	403.5	863.0
Pre-spill year two	374.2	644.0		266.0	227.0		402.8	20%0	225.3
Spill Year	148.0	215.0		141.0	1220		64.8	206.9	25o.5
Post-spill year one	143.1	1552		181.1	213.5		204.9	240.4	3952

Figure 2. Per capita harvests, study communities, pre-spill and both post-spill years.

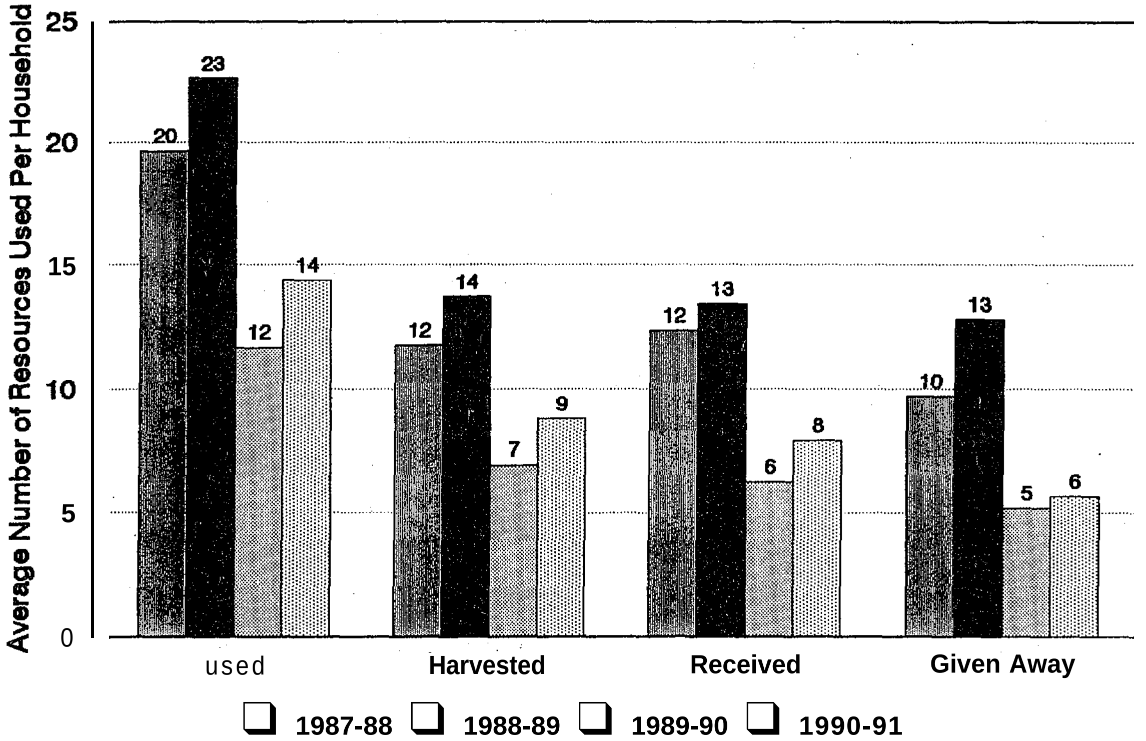


Figure 3. Average number of resources used, harvested, received, and given away. Tatitle, 1987 to 1988, 1988 to 1989, 1989 to 1990, and 1990 to 1991.

fish and marine mammals matched the pre-spill level, while the percentage using marine invertebrates and birds, while up from the year before, remained relatively low,

The household surveys in both post-spill years asked each respondent if they believed their subsistence uses had increased, decreased, or remained about the same compared to other recent years. If they indicated a difference between years, they were asked for a reason for the change. For the year after the spill, about 84% of the households in the Prince William Sound and Lower Cook Inlet villages said their subsistence uses had declined for reasons associated with the *Exxon Valdez oil* spill, as did 40% of the Kodiak Island Borough respondents, and 23% of the Alaska Peninsula households. More specifically, concerns about contamination of subsistence foods by the spilled oil were the major reason cited for reduced subsistence uses. Overall, 66% of the Prince William Sound households, 63% of the Lower Cook Inlet households, 23% of the Kodiak Island Borough households, and 14% of the Alaska Peninsula households reported that this concern had led to a reduction in their overall subsistence harvests in the year after the spill, This issue remained a major concern during the second post-spill year as well, especially in Prince William Sound and Lower Cook Inlet. (For discussions of programs designed to address the issue of hydrocarbon contamination of subsistence foods, see ADF&G 1990, Fall 1991, Walker and Field 1991) Respondents have also noted declines in the population size of some resources, such as marine mammals, some birds, and some marine invertebrates.

SUMMARY

In summary, extensive research by the Division of Subsistence demonstrates the significance of subsistence uses of fish and wildlife in all the villages whose harvest areas lie within the area affected by the *Exxon Valdez* oil spill. This research has also shown that, in the first year after the spill, subsistence harvest quantities, the range of subsistence foods used, and participation in the use of subsistence foods declined sharply in the villages of Prince William

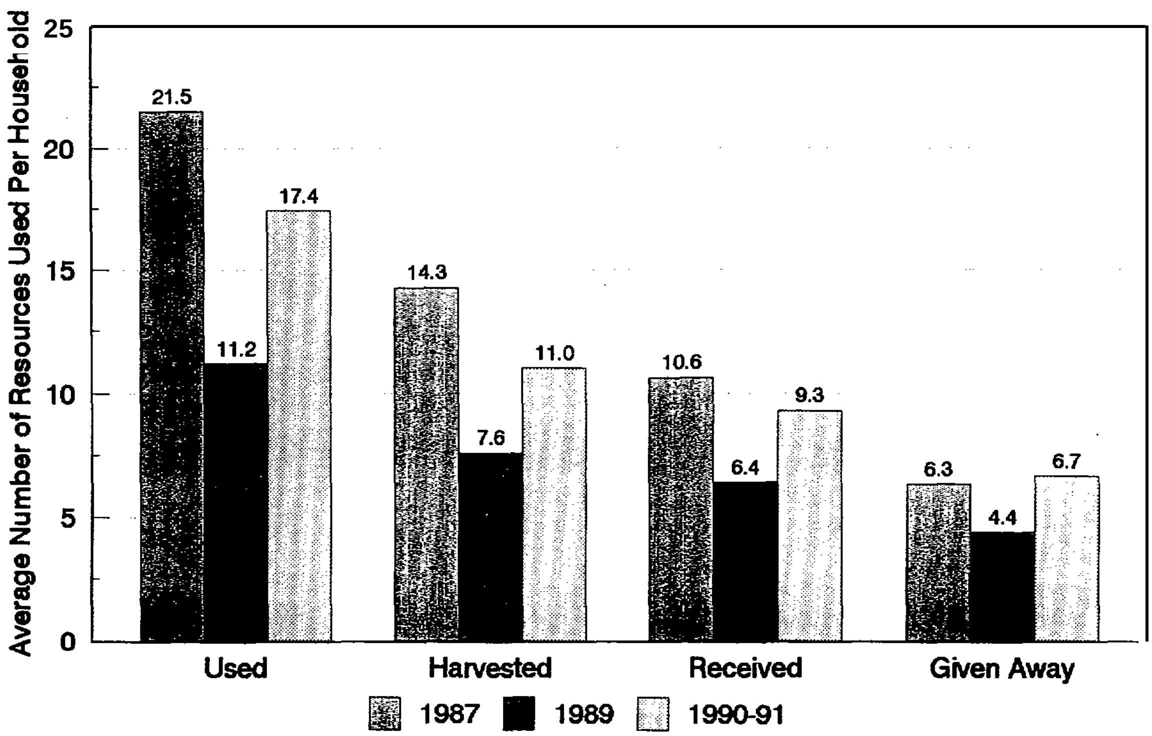


Figure 4. Average number of resources used, harvested, received, and given away. Port Graham, 1987, 1989, and 1990 to 1991.

Sound, Lower Cook Inlet, and the Kodiak Island Borough. During the second year, subsistence hatvests were up for all but Chenega Bay and Tatitlek, but generally remained below pre-spill averages. Concerns about possible oil contamination of subsistence foods were a primary cause of reduced subsistence uses during the first post-spill year, and continued to affect the subsistence uses of many families, especially in Chenega Bay, Tatitlek, English Bay, and Port Graham, during the second post-spill year as well,

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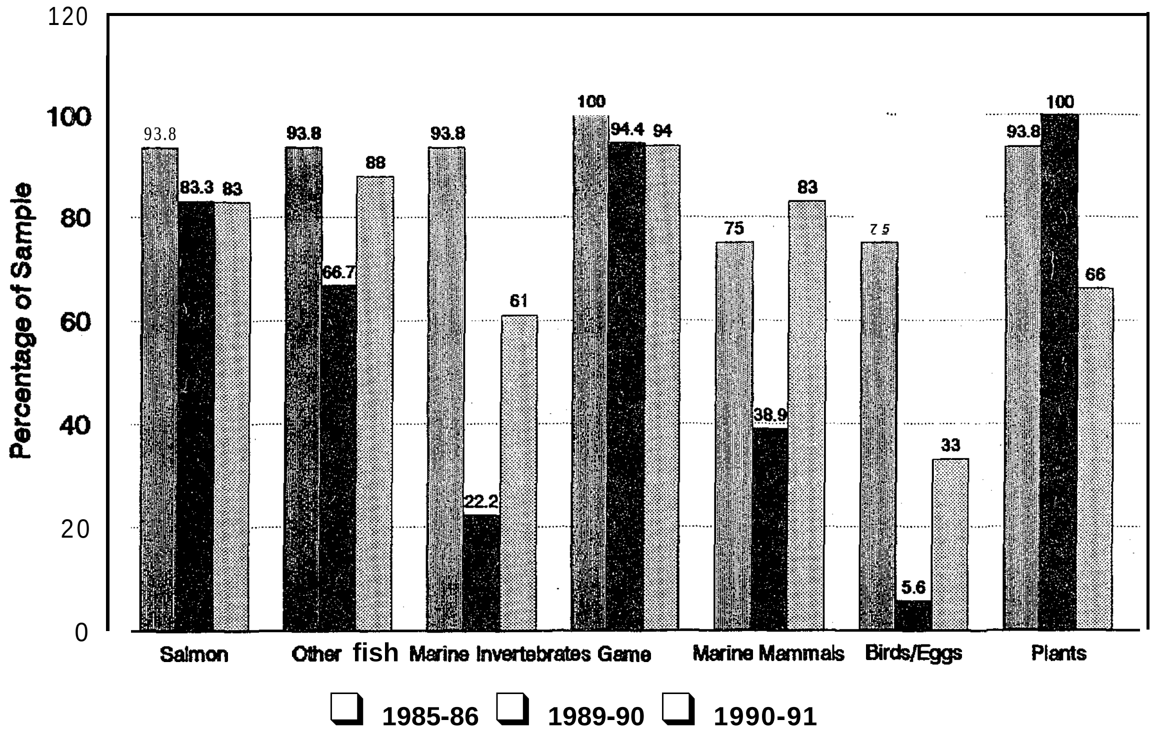

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Dr. James Fail has worked for the Division of Subsistence of the Alaska Department of Fish and Game since 1981 and present/y serves as a regional program manager in Anchorage. As such, he is responsible for the development of the Subsistence Division's program of applied social science research in southcentral and southwest Alaska. Dr. Fall received his B.A. from the University of Pennsylvania, his M.A. and Ph.D. in anthropology from the University of Wisconsin - Madison.

QUESTIONS AND DISCUSSION

Ray Emerson: I am not a social scientist so I probably shouldn't be here but... since I am already here. When you take a survey like this, how can you somehow gauge the objectivity of your respondents with respect to potential remuneration? I didn't say that, but possibly that could occur?

Jim Fall: Sure that is a legitimate question that I have been asked many times and I will be asked many times again. The primary way we can do that is consistency over responses, over resource categories, and between communities. I think what we are seeing is very interesting relationships between geographic location of communities, degree of exposure to the spill in terms of oil spill employment, degree of oiling of traditional use areas, and so forth. The fact that we see about the same level of reduction in Tatitlek and Chenega Bay, both about 60% pre- and post-spill, about the same level of reduction in English Bay and Port Graham at about 50%, really encourages me about our results. There is a great deal of internal consistency there. We can also compare our post-spill results with pm-spill results. We are seeing a great deal of continuity in the kinds of responses that we are getting, which encourages me. Which is not to say that there isn't that motivation for people. I think the consistency of our findings suggest that people are reporting their pre- and post-spill levels of subsistence harvests to the best of their ability.

Charles Degnan: How about the quality of the subsistence harvest? What impact did the oil spill have on the harvested species?

Jim Fall: For one thing, we know in the year after the spill, a lot of people just didn't go out and harvest. So what we found in a place like Chenega Bay was that people didn't harvest a lot of resources and discard them because they thought the quality was low. That did happen to

some extent, But it was basically that they were convinced that the resources were unsafe or they were too uncertain about the safety that they didn't harvest. Now there were incidence in every community, more actually in the Alaska Peninsula and some Kodiak places than elsewhere, where people did harvest resources which were suspect and which they discarded, In addition, there was the cooperative program that we conducted to look at the safety of subsistence foods. The first findings from that program were available in August and September of 1989. Of course the spring and summer subsistence harvest opportunities were already gone by the time that first set of information got to communities. The basic advice that was given to people then, and which has continued to be pretty consistent since, is that in terms of hydrocarbon contamination, finfish are okay. We didn't find any levels of PAHs in the salmon or halibut or other fish that we tested that would indicate a safety issue with those. Most of the marine invertebrates that were tested were safe too. But there were elevated levels found in samples of mussels and some other shellfish that were taken from beaches that were obviously contaminated with oil, People were advised not to use shellfish from such beaches.

Dick Prentki: In your response to Ray Emerson you mentioned that employment on the spill may have had some effect on these numbers, could you expand on that?

Jim Fall: When we asked people if they thought that their resource harvest had declined in the year after the spill by their own assessment as to why did it decline, the top reason overall that people mentioned was "1 was concerned about the quality of the resources, about contamination." Another reason that people often cited, sometimes in conjunction with the first one, was that they had been working on spill clean up for three, four, or five months and they missed their opportunities to harvest subsistence foods because that summer their number one priority way to clean up their traditional territories. Now quite a few of those people that cited that as a reason also mentioned contamination of subsistence foods. So the reasons aren't independent by any means.

OILED MAYORS SOCIAL IMPACT ASSESSMENT

John Petterson
Impact Assessment, Inc.
2160 Avenida de la Playa, Suite A
La Jolla, California 92037

INTRODUCTION

The human effects of the *Exxon Valdez* oil spill resulted from both the oil spill event and Exxon's privatized cleanup effort. The oil spill event directly damaged natural resources that have economic importance and sociocultural meaning for the affected communities. While response activities to an event usually integrate communities, the privatized cleanup efforts of Exxon and its contractors fragmented communities, changed local economies, and generated social conflicts. These response impacts occurred despite the reported expenditure of more than $2 billion for cleanup operations. The presentation summarizes the conclusions of this study effort, analyzing the differences between event and response-related impacts, focusing on the reasons why the cleanup disrupted the socioeconomic functioning of the affected communities. The implications for preventing or mitigating socioeconomic impacts from both event and response sources are developed.

The objective this presentation, in keeping with the information transfer objective of the ITM, is to familiarize the participants with work carried out by Impact Assessment, Inc. (IAI) in the wake of the *Exxon Valdez* oil spill in March 1989. The presentation will briefly summarize: 1) IAI's independent study effort conducted immediately following the accident; 2) the selection of IAI to carry out the "Oiled Mayors'" social, economic, and psychological impact assessment of the *Exxon Valdez* oil spill; 3) the products of these initial study efforts; and 4) subsequent presentations, articles, and other related consequences of our original study effort,

Initial Study

IAI initiated its study of the social, economic, and psychological impacts of the oil spill within one week of the event. i and John Russell, also of IAI, conducted field data collection for approximateiy three and a half weeks following the accident. Information was collected in the communities of Valdez, Tatitlek, Cordova, Seward, and Kodiak. This initial appraisal established a range of immediate socioeconomic and sociopsychological impacts, including variations in the organizational response of affected communities to the oil spill, cancellation of tourist reservations, impacts of anticipated lost income to fishermen, fish processors, and related businesses, entrepreneurism by local residents capitalizing on the spill, family disruption, individual psychological distress, overburdening of local governments in response to the spill and a host of other impacts. It is our feeling that without this actual participation in the initial events, decision-making processes, and response efforts, we would not have been abie to understand the causal factors that gave rise to many of the unforeseen results of the event. A preliminary report of the results of this effort were presented at a session arranged by the MMS Social and Economic Studies Program in late April 1989.

Oiled Mayors Study

The IAI proposal to conduct a study entitled *"Social, Economic, and Psychological Impact Assessment of the Exxon Valdez Oil Spill"* was funded by the Oiled Mayors subcommittee of the Alaska Conference of Mayors in November 1989. The first report of this study entitled *Fiscal Impact of the Exxon Valdez Oil Spill* (100 p.) was completed in February 1990. The second report, entitled *Public and Private Sector Economic Impacts of the Exxon Valdez Oil Spill* (180 p.) was completed in June 1990, and the third report entitled *Social and Psychological Impacts of* the *Exxon Valdez Oil Spill (311* p.), was completed in August 1990. The final report, *Social, Economic, and Psychological Impact Assessment of the Exxon Valdez Oil Spill* (173 p.), was completed in November 1990, Copies of these reports have been distributed in all of the affected communities, to local libraries, and to over 100 researchers and others throughout the U. S.. Copies were made available for duplication at the meetings.

Presentations

The results of this study have be summarized in the following presentations: 1) Alaska Conference of Legislators (full session devoted to results of the IAI study, November 1990); 2) Governor's Oil Spill Conference (Lafayette, Louisiana 1991); 3) American Anthropological Association meetings in Chicago (1990), in a full session devoted to IAI results; 4) presentation at the International Association for Impact Assessment, Champaign-Urbana (1 991); and 5) two presentations at the most recent American Anthropological Association meetings in Cincinnati (1991).

Publications

The following publications have been accepted for publication: *Ethnic Differences in Stress, Coping and Depressive Symptoms after the Exxon Valdez Oil Spill in* Journal of Nervous and Mental Disease; and *Social, Cultural, and Psychological Impacts of the Exxon Valdez Oil Spill in* Human Organization. An article entitled *Community Patterns of Psychiatric Disorders* is currently under review for publication in the American Journal of Psychiatry.

Findings and Conclusions

The objective of the presentation is to provide an overview of information about social and psychological impacts in communities affected by the *Exxon Valdez* oil spill and cleanup. This presentation develops the idea that social and cultural environments affect the nature, course, and outcome of a disaster event such as the *Exxon Valdez* oil spill and cleanup, It is argued that inattention to local conditions and regional cultures resulted in preventable social and psychological impacts from the *Exxon Valdez* oil spill. The paper is based on a multi-method study of the economic, social, and psychological impacts of the spill and cleanup. The study was initiated by the "Oiled Mayors" with grant monies from the Alaska Department of Community and Regional Affairs. The study was conducted in 22 communities of Prince William Sound, Kodiak Island, the Kenai Peninsula, and the Chignik region of the Southern Alaska Peninsula. The presentation is based on information derived from: 1) a mail survey regarding private sector economic impacts sent to 7031 businesses; 2) a household survey of 596 individuals in 12 "affected" and 2 "control" communities; 3) four years of financial data from local governments regarding pm-spill and spill-related expenditures and revenues; 4) interviews with community leaders; 5) interviews with municipal department heads; and 6) citizens. It also includes information derived from: 1) interviews with providers of psychosocial services in more than 20 affected communities and organizations; 2) examination of compiled statistics regarding the provision of psychosocial and emergency services to the affected communities during 1989 and previous years; and 3) compiled statistics regarding the effect of the spill on community services, including mental health and other psychosocial services.

Conceptual Framework

This Oiled Mayors Study was guided by a straightforward conceptual framework. This framework emphasizes that the socioeconomic conditions in human communities interact with the biological characteristics and natural resources of an ecosystem. If these interactions are disturbed, then ecological or socioeconomic consequences may result. Socioeconomic impacts are mediated by sociocultural conditions. That is, the specific characteristics of the event (material spilled, volume, etc.) affects particular features of an ecosystem (biological species in the area, coastal characteristics, etc.). Socioeconomic conditions of communities that use or interact with the affected features of the ecosystem will then determine the type, degree, and duration of socioeconomic impacts. Consequently, to understand economic and social well-being implications of an ecosystem disturbance, it is necessary to understand community socioeconomic conditions and how these interact with ecosystem characteristics. The emphasis is thus on the nature of socioeconomic conditions that need to be monitored and modeled to project and prepare for impacts. In the remainder of this paper I discuss how this framework is applied to implement the modeling of sociocultural and psychological impacts from the Exxon Valdez event.

Importantly, the implementation of this framework for modeling these impacts emphasizes the "community level" of analysis. The importance of community level impacts is indicated in numerous studies about similar events such as Chernobyl, Bhopal, Times Beach, and Love Canal. These studies show that the "availability" of the resources of a community to its members can inhibit or buffer the psychosocial effects of disasters. From these works, as well as research about natural and man-made disasters (Edelstein 1988, Drabek 1986), it can be inferred that the more community level functioning is disrupted, altered or destroyed, the greater the likelihood that social and psychological impacts will occur. Consequently, it is important to examine community level impacts to understand the social processes and structures that influence adaptation to the demands presented by the oil spill and cleanup.

An important part of modeling the impacts of a major ecological disaster are the sociocultural as well as the ecosystem parameters of a disaster event. The interaction of these two domains affects the demands placed on individuals and communities, the actual process of impact occurrence, and the nature of response efforts. No two disasters are ever the same. Each event has unique elements that influence the emergence of social and psychological impacts. Among the most obvious of these are properties of the sociocultural environment of the disaster as well as the characteristics of the event itself. Current scientific literature also suggests that an important source of variation in impacts and outcomes is attributable to differences in causation: natural and man-made disasters result in different types and degrees of impacts (Berren et al. 1989), with social and psychological impacts being more severe and lasting for longer periods of time in man-made disasters (Baum 1987), Consequently, it is important to briefly review some of the unique sociocultural properties of the region in which the spill occurred as well as characteristics of the event itself that contribute to the event as a stressor affecting individuals, households, local economies, and communities.

Properties of the Affected Regions

There are at least 5 characteristics of the affected regions that are important for understanding the social and psychological consequences of the oil spill and cleanup. These characteristics are: 1) different cultural backgrounds and histories; 2) differences in socioeconomic composition; 3) involvement with or dependence upon the use of marine resources; 4) exposure to previous disasters, particularly the 1964 earthquake and tsunami; and 5) the attribution of "pristine" to the environment of Prince William Sound. Each of these characteristics and their relevance for understanding social and psychological impacts is briefly discussed in the following pages.

Differences In Culture. The *Exxon Valdez* oil spill covered a wide geographical area that ranged from upper Prince William Sound to southern Kodiak Island and west to the Alaska Peninsula area of Chignik Bay. This geographical area encompasses thousands of square miles of ocean and land, although only parts of this immense area were oiled. Some of these areas are actual community beaches or shoreline, other areas are used by community residents for fishing or other activities.

Within this wide-ranging area reside a number of distinct cultural groups of Native and non-Native origin. The Native ethnic groups represented in the affected areas include Aleuts, Alutiiqs, and Koniags. However, there are two basic commonalities among the Native groups which contrast with non-Natives. They share unique cultural history as indigenous Alaskans in terms of their acculturation to Western society. In addition, subsistence practices crystallize many of the cultural values of Natives which don't apply to non-Natives.

There are at least two areas where culture is an important consideration for understanding impacts from the *Exxon Valdez* oil spill: 1) explanations of cause, effect, duration of effects, effective remedies, and the meaning of the event are likely to influence the types of impacts experienced and the character of response efforts; and, 2) the cultural history of the Native communities places them at risk for social and psychological impacts. In regards to the first issue, there is a developing literature about the effects of culture on the definitions of risk and the experience of disaster (Sutlive et al. 1986, Douglas and Wildavsky 1982). From this literature we can infer that in Native communities the event maybe defined and appraised such that impacts and response efforts are different in Native and non-Native communities. For example, Native communities generally tend to emphasize impacts to subsistence resources and concerns about health effects from consuming potentially contaminated wild foods. This emphasis is rooted in cultural values, beliefs, and practices. In regards to the second issue, since early contact with Russian fur traders, the cultural history of Native communities is one of intensive pressures for sociocultural change. Such changes, and, especially, the rate at which change occurs, consume extensive social and psychological resources. Diversion of these resources to respond to an event such as the *Exxon Valdez* accident thus place these communities at risk because community support systems can be disrupted or. The results can be either partial or extensive sociocultural disruption that has consequences for the psychosocial health of entire communities (Shkilnyk 1985). Cultural difference is thus important for understanding which impacts individuals and communities perceive as important. Although the point may seem obvious, it is a distinguishing characteristic of how the oil spill and cleanup affects the social environment of communities.

Differences in Socioeconomic Character' Among the affected communities there are socioeconomic differences. For example, there are differences in the cultural homogeneity or heterogeneity of the populations, political and governmental organization, the structure of economies, and residence patterns. Socioeconomic characteristics are important because they emphasize structural and organizational differences that can affect the impacts experienced as weli as response capabilities (Omohundro 1982). This point needs to be made explicit since it could be incorrectly assumed that all communities are affected in the same way. However, differences in socioeconomic characteristics produce differences in impacts and response capabilities. For example, neither Cordova nor Valdez is part of an organized Borough whereas Seward, Kodiak and some other affected communities do belong to Boroughs. The Borough structure offers assets that are not available to communities without such resources, thus response efforts of communities not included in Boroughs are different than those which are. Similarly, Cordova and Kodiak experienced economic impacts directly related to the presence of commercial fishing in each local economy. However, the composition of fishing is not the same in these communities and therefore the impacts experienced are dissimilar Cordova's economy is based almost exclusively on salmon fishing. While salmon fishing is important for Kodiak, other species of fish diversify the industry making it less sensitive to the effects of salmon season closures. Thus, variation in socioeconomic structure and organization are important variables to consider when examining impacts and responses. Socioeconomic variation suggests that one cannot assume uniform consequences from the oil spill and cleanup.

involvement with Marine Resources. Damage to the marine environment can impact the lifestyles, values and social processes of the affected communities. To some degree, most of the communities in the affected regions are involved with the use of the ocean and its assets through commercial fishing, harvesting wild foods for personal consumption, or recreation. These marine resources thus have varying degrees of social, economic, and cultural significance. For example, as we noted above, the basis of the Cordova and Kodiak economies is commercial fishing. To lesser degrees Seward and Valdez also depend upon commercial fishing as an economic base, but the significance of commercial fishing in these latter economies is substantially different from Cordova or Kodiak. Furthermore, the lifestyle and quality of life of residents in these as well as other affected communities is tied to the ocean and its resources. In Native communities marine life provides important foods that are valued and preferred over "western" foods. Furthermore, the social process of taking, processing, and distributing these foods has cultural significance beyond the importance of the food consumed. That is, the use of marine resources as "subsistence" foods embodies cultural traditions and values that are central elements of cultural identity. Damage to these resources and to the ability of individual to harvest these resources thus results in potential disruption of cultural and social processes that have economic, social, and psychological significance. The degree of psychological and social impact in a community will depend, to some extent, on its reliance on marine resources.

Exposure to Previous Disasters. It is with some irony that many residents of the affected communities comment that the 1964 earthquake occurred on Good Friday, the same day as the *Exxon Valdez* ran aground on Bligh Reef in 1989. Valdez, Kodiak, Seward and many other communities in and near Prince William Sound were damaged or destroyed by either the earthquake or the tsunami that followed. Many residents of communities severely damaged or destroyed by the 1964 disaster now reside in communities affected by the oil spill (e.g., Tatitlek, Chenega Bay, English Bay, Old Harbor). This experience with the earthquake potentially affects the experience of the oil spill and cleanup impacts because, among other things, the earthquake established a historical precedent that catastrophic events can disrupt lives, cause deaths, and destroy communities. The oil spill may be perceived as threatening to individuals and communities because it is in some way compared to the 1964 disaster. The 1964 earthquake differentially affected Native and non-Native communities because, it is theorized, their history or acculturation makes them less able to cope, Consequently, Native communities were left more vulnerable to the effects of a disaster such as the *Exxon Valdez*. Individual and community coping responses were overwhelmed when the oil spill occurred. Attention to a community's previous exposure to the 1964 earthquake emphasizes variation and differences. That is, some communities may have brought forward positive adaptative experiences whereas others, especially Native communities, may experience an added risk by these events. Attention to the specific relationship of a community to the 1964 earthquake is thus considered in the analysis of the impacts and response efforts resulting from the oil spill.

"Pristine" Nature of Prince William Sound. Alaskans praise their state as a wonderment of nature in which Prince William Sound is a "pristine" jewel in a crown of environmental riches. There is almost a reverence for the beauty and "unspoiled" character of the Sound that is expressed by those who live there and those who also use it for a multitude of purposes (e.g., O'Meara 1989, Frost 1990). In fact, there are those who would argue that both Native and non-Native Alaskans especially value the abundant wildlife, majestic mountains, verdant forests, clear waters, and other such natural riches of the state. The natural "purity" attributed to these resources is experienced as an enrichment of individual lives that is less common in the lower forty-eight. Indeed, it can be argued that the pristine character of these natural riches marks a boundary that distinguishes Alaska and Alaskans as different, from other places where pollution, smog, and toxic contamination are issues of common concern. It is not that these issues do not exist in Alaska, but "pristine" places such as Prince William Sound stand for the essence of the Alaskan experience of unspoiled wilderness. While all Alaskans do not share in such valuations of the environment, among those who do, damage to the "pristine" quality of these resources is significant. The spill spoiled something that people define as pure and irreplaceable; something fundamental to who people are and what they value. Thus, the attribution of "pristine" to the area in which the oil spill occurred is a property which can influence how people define and understand the consequences of the spill and cleanup effort.

Other Factors Affecting Impact Distribution. There are also particular characteristics of the event itself that influence the expression of and response to social and psychological impacts. Among these are the following: 1) classification of the event; 2) scope of the event; 3) the duration of the event; 4) uncertainty about its effects; 5) different degrees and types of exposure to the effects of the spill; 6) nature of the cleanup. The presentation briefly identified the role of each of these issues in the ultimate distribution of impacts throughout the region.

CONCLUSIONS

A major lesson of the *Exxon Valdez* event is that the human and ecological environments of Prince William Sound and the Gulf of Alaska are inextricably linked: A problem for one is a problem for the other. Thus, future contingency planning for an event such as the *Exxon Valdez* spill must take into consideration not only how the environment will be affected but also how the people who live in and depend on that environment for economic and sociocultural reasons will be affected. This requires monitoring a baseline of information about the sociocultural conditions in these communities. We need to be able to predict how these baseline conditions will change as human and natural ecosystems interact in response to ecological damages from another spill. The technical capabilities exist to achieve this type of analysis and monitoring. It only takes will and foresight to make sure that we are prepared for the human as well as the ecosystem impacts from a future event.

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Dr. John Petterson, President of Impact Assessment, Inc., has served as PI on over a dozen *MMS socioeconomic (TRs #75A, 75B, 92-93, 103, 126-128, 732, and 139-142) and other* *studies conducted in Alaska since the late 1970s (NSF, NPFMC, USFWS, etc.). He also served as PI on the State of Washington's socioeconomic impact assessment of the proposed high-level nuclear waste repository at Hanford site, Washington, and is currently the PI on* **the** *State of Nevada's socioeconomic impact assessment of the proposed high-level nuclear waste repository at Yucca Mountain, Nevada. Dr. Petterson also served as PI on recent studies of the La* ***Haven,*** *Genoa, Its/y oil spill for the Italian government, the American Trader oil spill for Newport, California, the Dunsmuir train derailment near Shasta, California with the California Department of Health Service, the Duffy Street train derailment in San Bernadine, and followup studies of the nuclear accident in Goiania, Brazil (USDOE). He also served as Principal Investigator on the IAI study conducted – between March 1989 and December 1990 – under the auspices of the Alaska Conference of Mayors, "Oiled Mayor's" Subcommittee, entitled "Social, Economic, and Psychological Impact Assessment* **of** *the Exxon Valdez Oil Spill."*

QUESTIONS AND DISCUSSION

Ray Emerson: Well, now I know why I am not a social scientist, but we won't get into that. One of the issues, though, with subsistence, the cultural framework, is the issue of reciprocity. If there isn't as much to share, it that one of the major factors of concern with you? Or does it go like this: in hard times you have less to share, but it is appreciated more?

John Petterson: Well, I would probably say that is closer to correct, But the response is if you are unemployed is the meaning of Christmas more important to you and would you give and share at Christmas time? What it meant to the people of these native villages that got shipped fish from the Southeast to compensate for the lack of subsistence food, it is like having a .,.

Ray Emerson: Well that is a separate issue. I am thinking of, let's say, within the village those people that still do some harvesting of subsistence resources are more limited now in the resources that they can harvest and that they can obviously share with their kinfolk. But for what they do have now is there more value place on that in a socio-cultural sense?

John Petterson: We worked with Jim Fall and his staff to divide up the world when we went out to the field. We knew they were doing the quantitative, how much do you collect, what kinds of species. We asked those social and cultural questions. So we've got those kinds of data established and those are reflected in the social and psychological volume. I don't know if that answers your question.

Ray Emerson: Well does that cancel out, does that compensate, in the human sense of the word, if somebody brings something you know is in short supply is that even appreciated more than when there is a time of abundant sharing?

John Petterson: You are forcing me to generalize, but I would say I don't think it is the food that is important which might violate somebody's perceptions...

Don Callaway: Let me reply to that briefly. I think one speculation was that the trauma of the oil spill would bring people closer together. Unfortunately, it is very difficult, as you may guess, Ray, to parcel out a number of different effects that cause changes in people's psychological well being. I think what John's study did show was that there was an increase in significant levels of anxiety, post traumatic stress, and depression in these communities. But these communities were inundated by bureaucrats, they were inundated by researchers. Many of the decisions, in terms of any number of social and cultural behaviors were taken out of their hands, So whereas what the well being of sharing resources in scarce times had played into all these other outside forces and influences, 1 think it would be extremely difficult to parcel out. I think the basic finding was that in a number of these communities, based on these measures, there were

psychological stresses due to the spill and significantly different than that would occur in the control communities of Angoon and Petersburg.

Ray Emerson: . ..focus on the reciprocity...

Don Callaway: it is really difficult to parcel out.

Pat Burden: John, I would like to ask a quick question, In looking at the table of contents of your fiscal impact and your business sector reports, it looks like you obtained an enormous amount of data. Could you identify how you did it, what were the key points that enabled you to do that?

John Petterson: Enabled us to collect the data? Being sponsored by the Oiled Mayors and having absolute open access to the communities really helped a lot, We had to fight to get around the attorneys, to be allowed to get in there. They finally agreed not to inhibit us, physically prohibit us from going in to communities. I-low they were going to do that I never knew, but the threat was enough to undermine some things. That was important, As far as getting the data, 1 didn't get to taik about the data. We had 596 household surveys that took one to three hours each that had 600 questions each. This is an interesting question, getting somebody to sit down, selecting them. The question of methodology is critical. How do you get a sample that you can depend on that is going to stand up through any duress. How do you select those individuals within the household to represent it. Not the head of household but just household surveys, because we are asking ail kinds of questions. There is an astronomical amount of information in there that we can work on for several years,

Carrie Holma: I just wanted to offer the information that copies of the reports are available at the Oil Spill Public Information Center.

THE SOCIAL AND ECONOMIC CHARACTERISTICS OF KENAI, ALASKA AND SOME OF THE EFFECTS OF THE *EXXON VALDEZ* OIL SPILL

Lynn A. Robbins
Huxley College of Environmental Studies
Western Washington University
Bellingham, Washington 98225

Kenai, Alaska - a community of about 7,000 people - was sampled on two occasions as part of the Alaska Outer Continental Shelf Social Indicators Study (AOSIS). The first random sample of households was conducted in August, 1989, and it consisted of 92 questionnaire interviewees and the second was completed in March and April, 1991, and it comprised 65 randomly-selected adults. Kenai was one of several communities selected for study of the social and economic effects of the *Exxon Valdez* oil spill. It was chosen because it represented a community that seemed to have been marginally affected by the spill, in contrast to most of the other selected communities which were directly affected, Questionnaires on essential social and economic characteristics and effects of the *Exxon Valdez* oil spill were administered to these persons. About two-thirds of each of these samples were selected at random for intensive protocol discussions on key variables on quality of life, cultural values, social networks, sharing patterns, mobility, income, occupation, use of community facilities, marriage patterns, and other important social and economic characteristics. The focused interviews also elicited observations on the effects of the oil spill. Sampling was designed to repeat a portion of the 1989 randomly-selected persons in the 1991 as well as to include a portion of persons who were not in the 1989 sample. In this way about half of the sample was tracked for social and economic changes and the fresh sample broadened our knowledge of the community and the effects of the spill.

The *Exxon Valdez* oil spill, and the subsequent efforts by the Exxon and Veto corporations to remove oil, drew an estimated 300 persons from Kenai to Prince William Sound. Some of these migrants vacated lower-paying jobs in Kenai, those which paid about $5 to $7 per hour, and for this reason many small businesses were left short-handed. Independent repairpersons, mechanics, equipment operators, fish processors, and others quit their Kenai employment to search for the high-paying spill cleanup work which paid well over $1500 per week. Others who sought work were unemployed persons who would not have otherwise gained employment during the summer period. Some business owners and managers had to work extra hours to fill in for employees who absented the community. Fish-processing plants were also short-handed either because their customary workers stayed away from the Cook Inlet thinking it was seriously contaminated with oil or to work on the spill cleanup. Processors, not wanting to lose steady suppliers, purchased the fish brought to them, but because some of them were labor short, a certain quantity of fish could not be processed. Crimes declined in frequency in 1989 because many habitual trouble-makers also went to get jobs on the cleanup.

The summer sockeye run was huge, with about 5 million fish harvested under Alaska Department of Fish and Game (ADF&G) management. The driftnet commercial fishing season was closed by ADF&G because oily remnants of the spill were found in the central channel of the Lower Cook Inlet, the section of the Inlet where driftnet fishers make their harvests. Although these fishers were eventually compensated for a lost season by Exxon, and though most of the 600 or more fishers were pleased with the sums they received, there was a period of great anxiety and uncertainly during which the fishers did not know if the season would be opened and whether they would receive some kind of settlement from Exxon. The United Cook Inlet Driftnetters Association (UNCIDA) was pleased, for the most part, with Exxon's timing and levels of compensation, as were fish processors who acknowledged prompt and just compensation soon after meetings between the processors' attorneys and Exxon representatives. The setnet fishers who work along the shores of the Inlet were allowed to harvest, and they brought in record hauls and record incomes. This anomalous circumstance created some bitterness and controversy between driinet and setnet fishers, some of whom were in the same family and friendship networks. There were some hard feelings between driftnet fishers, their friends and families, and those who worked on the spill cleanup. The fishers believed their misfortune was callously used to others' advantage. There was also-anger against fossil fuel industry employees and their families, the impression being that these persons were part of a monolithic entrepreneurial presence that had no feelings for people and nature. Businesses that ordinarily supply the driftnet fishers with equipment, loans, and who sell properties to them, suffered from lack of business. In all, there was a feeling of despair and futility among many driftnet fishers, and for the population at large in the city a sense of the inevitability of oil contamination of Cook Inlet was common. This attiiude stemmed, in part, from experience, For example, in 1987 the vessel *Glacier Bay* spilled between 33,000 and over 100,000 gallons of oil at the mouth of the Kenai River during the driftnet commercial fishing season, and many fishers were still processing claims from that accident. (In December 1991, applicants received compensation from the companies involved in that spill.)

The City of Kenai filed for and received compensation for loss of about $45,000 at its loading dock where some business had been lost during closure of driftnet fishing. Kenai city officials estimated that the city's economy received an infusion of about $2.5 million from monies spent by cleanup workers who returned to the community. This increased consumer spending earned the city about $300,000 in taxes. Furthermore, unlike many small businesses, the city and other institutions, private and public, whose employees earned well and received generous fringe benefits, did not lose employees to the cleanup work.

The tourist season in 1989 was vety busy, as many sight-seers, having seen ads on television jointly paid by the State of Alaska and Exxon explaining that most of the state was untouched by the spill, came to enjoy the Kenai Peninsula and to sport fish for sockeye which were in abundance. Some sport fisher guides rushed information to their steady customers informing them that the spill had not harmed the Inlet fisheries. These businesses, after an initial scare, thrived in 1989. (They have not done as well since, because the 1990 and 1991 king salmon and sockeye salmon seasons for sport and commercial fishers were in the low end of their cycles.)

The Laborers Union local office placed members at cleanup jobs, but activity was relatively slow because hiring was carried out in Anchorage. The union local in Kenai received some, but not many, new members as a result of employment at the spill. In the 1990 cleanup season only about 100 persons were employed and this number did not affect union membership in a substantial way.

Kenai, its sister-city Soldotna 11 miles away, and Nikiski, have many families dependent on oil and gas extraction and processing at the Cook Inlet energy industries. These sources of employment pay considerable wages and taxes (the Kenai Peninsula Borough received about 25% of its income from the energy industries in the Inlet), and the 13 off-shore drilling platforms, many of which pm-date major national environmental laws, are a permanent part of peninsular life and are pointed to with considerable pride by many residents. The Kenai Peninsula College, located between Kenai and Soldotna, features an academic program in oil and gas extraction and processing. For this reason, there are many North Slope employees who have permanent homes in Kenai, and many of the leaders in Kenai promote further oil and gas exploration, as one would expect. The Chamber of Commerce sent letters to Chambers throughout the United States urging them to put pressure on Congress to approve industry plans to drill for oil in sections of the Arctic National Wildlife Refuge (ANWR). Oil from Valdez comes to the Inlet for processing as well, and this is a source of concern about environmental protection for many persons, including some of the oil and gas employees, many of whom are also commercial fishers. Thus the community is a blend of (among other economic activities) fossil fuel extraction and processing and fish harvesting and processing. This mix fosters, in general, tolerance and accommodation between these two essential economic activities. This attitude is reflected in the official stand made by UCIDA endorsing oil exploration in ANWR.

The following generalizations are based on the results of the survey of 65 households conducted in 1991:

1. Fifty-two percent of the residents live in nuclear family household.
2. Average household income is about $40,000.
3. Average household size is slightly under 3 persons.
4. Three percent of the city's population are Native Americans.
5. Sixty-six percent of the adults are married.
6. Fifty percent of adults have between 9 and 12 grades of schools and about 50% have one or more years of college.
7. Sixty-six percent of the adults in the sample (ages 17 to 79) were employed, 38% had worked two weeks or more outside of the city during 1990.
8. Five percent of the households contacted had lost property as a result of the *Exxon Valdez* oil spill; 8% said they lost money as a result of the spill.
9. Ten percent of the households lost jobs to the spill, some more than one job.
10, There were 1.6 persons harmed financially by the spill for each person who gained income.
11. Twelve percent of the households lost income because of the spill and 7% gained income.
12. Ten percent of the households had gained jobs as a result of the spill, half of which were on the cleanup; the others were in various support services.
13. Fifty-four percent of the respondents said their households were better off in 1991 than in 1986 (5-year comparison); (in 1989 nearly 50% said the same). About 25% of the households in the 1989 and 1991 samples reported worse economic circumstances than 5 years previous to the interviews.
14. About 50% of the adults contacted had attended one or more public meetings in the week prior to interviews.
15. Sixty-five percent of the adults had lived in Kenai 11 or more years.
16. Eighty-four percent of the adults were born outside of Alaska.
17. Ninty percent of the adults were satisfied or very satisfied with their social ties in the community.
18. Ninty percent were satisfied or very satisfied with their standard of living, and 75% were satisfied or very satisfied with their income.
19. Fifty percent of the adults did not believe further searches for oil in and near the Cook Inlet would adversely affect the numbers of fish and game in the area.
20. Sixty-three percent believed, however, that oil and gas exploration would have a net adverse effect on the land and water.
21. Sixty percent were pleased with the condition of the land and water; about 40% were not (they pushed for cleanup of toxic materials deposited by energy industries, among other things),
22. Fifty-five percent of the adults said Exxon, and the federal and state governments were to blame for the *Exxon Valdez* oil spill. Twenty percent believed that Captain Hazelwood alone was at fault.
23. Seventy-five percent of the adults had eaten naturally-occurring foods (mainly salmon) in the 12-month period before they were interviewed.
24. Sixty percent of the adults had close kin in Kenai.
25. Sixty percent of the adults give money, food, or free labor to kin and friends in Kenai, and in other communities.

The oil spill resulted in passage of the Federal Oil Pollution Control Act of 1990. This is the subject of several presentations at this meeting. The Act profoundly altered institutions in the Kenai Peninsula which play a role in environmental quality, and it created wholly new organizations, The Cook Inlet Regional Citizens Advisory Council (CIRCAC) was established under the Act to work with the industry group, the Cook Inlet Spill Response, Inc., (CISPRI). The

details and workings of these organizations are not presented in this paper and need not be repeated here since they overlap talks summarized in this volume.

Lynn A. Robbins is a Professor of Environmental Studies at Huxley College of Environments/ Studies, **Western** *Washington University, Bellingham, Washington. He has studied the socioeconomic effects of energy projects on Native Americans over the past* **twenty** *years. His most recent work is on Alaskan communities. He is co-principal investigator on the* **Bristol** *Bay Subsistence Study with Joanna Endter-Wada.*

SOCIAL, ECONOMIC, AND SUBSISTENCE EFFECTS OF THE EXXON *VALDEZ* OIL SPILL ON THE KODIAK REGION

Joanna Endter-Wada
College of Natural Resources
Utah State University
Logan, Utah 84321

INTRODUCTION

The Kodiak Region was included in the original schedules of the Social Indicators Research Project and field work was conducted there in 1988 and early in 1989, prior to the *Exxon Valdez* oil spill. Additional research focusing on spill-related impacts was conducted subsequent to the spill in September 1989 and again in February 1991. This paper is based upon data from interviews conducted with members of sample households and institutional officials, first-hand ethnographic observations, and local media accounts of events.

The oil slick that driied southwest from Prince William Sound began washing up on Kodiak beaches on April 17, 1989, within three weeks after the oil tanker *Exxon Valdez* struck Bligh Reef and spilled nearly 11 million gallons of crude oil. Much of the oil that drifted out of Prince William Sound passed through the Shelikof Strait between Kodiak and the Alaska Peninsula, which has rich fishing grounds frequented by members of the Kodiak fishing fleet,

Several themes run through Kodiak Island's experience with the *Exxon Valdez* oil spill. First, the oil spill exacerbated existing pressures on and tensions in the Kodiak fishing industry. Americanization of the Alaskan fishing fleet, a rapidly evolving international seafood market, and changes in resource stocks had made the Kodiak fishing industry more diversified, competitive, and capitalized. Kodiak fishers were being forced to take greater personal and economic risks in an already high-risk occupation, The industry changes had increased traditional divisions among fishers based on gear type, fishery, size, and geographic area and had created an underlying tension between those for whom fishing had become a highly capitalized business venture and those who continued to perceive fishing as a lifestyle.

A second theme was that Exxon's response and actions resulted in some of the most serious impacts from the oil spill. Exxon's control over the oil spill cleanup and the way it treated the residents of impacted communities added to local frustrations and inhibited community involvement and cooperation in responding to the spill, Much of Exxon's response was determined by monetary and liability considerations and this itself became a significant oil spill impact.

Third, Kodiak was impacted by two major natural disasters in the past, the eruption of Mt. Katmai in 1912 and the Great Alaskan Earthquake in 1964. Stories and memories of these disasters, of the community's cohesive response, and of the reconstruction which followed remain alive. The *Exxon Valdez* oil spill was not the same. Its impacts and the need to respond to those impacts were continuous and closure was not forthcoming. Exxon's action inhibited community mobilization similar to that which took place after the previous natural disasters. Furthermore, the oil spill was a man-made disaster that people believe could have been avoided, which resulted in deep anger that was not easily dissipated.

Institutional Responses and Impacts

Local government was the first to respond to the oil spill in the Kodiak region. Kodiak benefitted from having plans already in place for an Emergency Service Council to deal with disasters, which had been instituted after the 1964 Earthquake. The Emergency Services Council was activated before oil reached the island and initially directed community efforts and mobilization to respond to the spill. The Emergency Services Council remained key players in the oil spill response throughout the summer. They kept Kodiak residents informed and heid public oil spill meetings daily at first and later three times a week. Kodiak was the only impacted community that held on-going public meetings.

Federal agencies and Exxon did not respond until days after oil had reached Kodiak. When they did respond, Exxon and the Coast Guard took over control of the clean-up operations and local governmental entities were put in a reactive position. Exxon directed the clean-up effort by controlling the purse strings. Clean-up expenditures had to be justified to Exxon's representatives, who decided which costs the corporation would assume.

Burdens Placed Upon Local Government. Kodiak island Borough communities suffered financial impacts. Time and money was spent responding to the spill, some public employees left their jobs, tax revenues and interest income was lost, and the costs of providing community and social services increased.

Disruption of Existing Programs. During the spring and summer of 1989, Kodiak communities had to substitute oil spill response for community infrastructure and construction projects. Such projects have been crucial for Kodiak City's competition in the rapidly evolving seafood trade of Southwestern Alaska, Facilities and services provided to Kodiak villages already had been deciining for several years as regional fish processing became concentrated in Kodiak City and as village populations declined. The oil spill increased the disruptions that the economies of these villages were already experiencing. Programs of state and federal agencies located in Kodiak, which aided the local fishing and recreation industries, were also disrupted.

Strain on Local Officials. The oil spill placed a tremendous strain on Kodiak's public officials. Dealing with the oil spill required a great deal of time and energy over an extended period of time. While Exxon and state representatives were rotated in and out of Kodiak, local officials never had a break from the pressures of dealing with the oil spill. The public meetings which Kodiak officials chaired throughout the summer became a forum for releasing anger and expressing grief. Kodiak residents were united on the need to do something, but they were frustrated with not being able to do much. Having little or no control over Exxon or over the involved state and federal agencies, their anger was vented on local officials. Part of the strain on local public officials was due to differences of opinion within the community on how to deal with Exxon. Community residents were angry with Exxon, but because Exxon was in charge of the spill clean-up, local officials had to find a way to work with them. Several of these local officials were accused of being traitors and themselves became the object of community criticism.

Difficulties In Dealing with Exxon, A major difficulty local governments had dealing with Exxon was defining the problem, both the geographic extent of the oil spill and the nature of the impacts. At first, Exxon tried to limit its sphere of responsibility through denying problems in areas outside of Prince William Sound. Once the oil spill spread, Exxon was forced to admit the obvious impacts. Kodiak government officials continually had to combat Exxon's denial and misinformation about the extent of spill impacts in their area and even had to fight to get Exxon to pay for the oil-spill related costs which the company recognized. Exxon only recognized immediate environmentai and direct economic impacts but would not recognize social or potential long-term impacts from the oil spill, Exxon also fought with the state and local communities over definitions of what constituted a clean beach. Beginning in late July, Exxon started scaling back Kodiak cleanup operations in preparation for a mid-September departure date and these definitional battles were important for justifying reduced cleanup efforts.

Local communities had trouble obtaining uniform and fair treatment. All along, Exxon attempted to deal with communities on an individual basis and there were significant differences in how each impacted community was treated. One reason for the disparity was that as the cleanup efforts expanded, Exxon became more concerned about cleanup costs and media attention and shifted to a "litigation posture." Local people fought Exxon's attempts to divide them. Kodiak officials assumed the lead in the formation and operation of the "Oiled Mayors," while the Kodiak Island Borough and the Kodiak Area Native Association attempted to coordinate dealings between Exxon and Kodiak villages.

Kodiak officials also had difficulty when Exxon attempted to circumvent environmental and community regulations or procedures. Exxon fought for and obtained a state permit to operate an offshore floating incinerator which would burn spill waste near the community of Porl Lions, but did not hold public hearings, Kodiak public officials were able to get the permit voided by using the argument that they had not been allowed to prepare a consistency determination as required by their Coastal Management Plan. In addition, Exxon's revised cleanup plan called for bypassing environmental laws to burn or bury the sludge recovered in cleaning up the oil spill. In other instances, Exxon failed to obtain local permits for various aspects of its operations. One Kodiak official reported that Exxon and VECO representatives acted as if they were above the law, and it had been a nightmare dealing with them.

Economic Impacts

The economic impacts of the *Exxon Valdez* oil spill on the Kodiak region were unequally distributed. Some people experienced financial losses while for others the spill was a short-term boom. There were several reasons for the discrepancies. First, not all of the fisheries were closed. Second, by the time cleanup got underway in Kodiak, Exxon was already trying to minimize its costs and thus limited the number of vessels it chartered and people it hired to work on the spill. Third, several groups of people "fell through the cracks" and were not eligible for claims despite the fact that they had been impacted.

In terms of the fisheries, initially larger boats were hired by Exxon, but these were generally owned by fishers who had more diversified operations and had less to lose from the closing of the salmon and herring fisheries. Salmon and herring fishers had to prepare to fish in case there were openings in order to be eligible for compensation and were unable to go on charter until those fisheries were closed. It took longer for some groups of fishers to negotiate cleanup work with Exxon, particularly the salmon purse seiners, which constitute the bulk of the Kodiak fleet. Many of the smaller boats were left without charters, without a fishing season, and without certainty about compensation from Exxon. Tensions over who received Exxon vessel charters eventually led to a lottery system among seiners for choosing boats to work on oil spill cleanup.

Fishers were and still are concerned about long-term impacts of the spill on the fishing industry. When fishers lose a season, they hope to make up for it the next year, but the oil spill threatened numerous future seasons. Uncertainty exists about the biological effects of the spill on the resource base. Kodiak fishers also are concerned about the future reputation of Alaskan seafood and about maintaining market share in an ever increasingly competitive environment. The oil spill put them in a double bind: attempts to prove that Alaskan seafood was unaffected in order to protect their markets played into Exxon's hands in the litigation arena.

The tourist industry, which Kodiak had been building up for several years, was directly impacted by the oil spill. Many people canceled summer reservations with local lodges and guide services. For people still wanting to visit Kodiak, there were few hotel rooms, rental cars, or charter planes and vessels available, most of which had been reserved for the cleanup effort. In addition, the service industry was disrupted by high wages being paid for oil spill cleanup.

Most of Kodiak's economy is tied to the fishing and tourist industries. The overall negative impact to the economy was masked by the infusion of cash from oil spill cleanup. Spill cleanup brought a boom type atmosphere to the community and there were some signs of economic stability and growth: new construction, a strong real estate market, aggressive lending by local bankers for consumer and "toy" items, and inflation.

Social, Cultural, and Psychological impacts

Community Conflict. One of the most serious problems that people in the Kodiak region faced as a result of the oil spill was community factionalism caused by the way in which Exxon controlled the cleanup operations and dealt differently with various segments of the population. Kodiak residents started mobilizing on their own before the oil slick hit the archipelago. After Exxon took over the cleanup operations, it inhibited community efforts to respond to the spill by limiting the number of vessels it chartered and the number of people it hired and by discouraging volunteers due to safety and liability considerations. Exxon refused to consider a bounty program, which would have paid anyone for cleanup work based upon amounts of waste turned in. Anger, which for some people could have been dissipated by working to ameliorate the situation, was intensified.

Vessel chartering and hiring inequities resulted in jealousies and resentments between Kodiak residents and appears to have increased and exacerbated existing economic differentiation. People reported that some friendships had been severed and animosity developed between some people which would never go away,

One reason obtaining cleanup work was so acrimonious was because of the increased competition within the fisheries in recent years. Those who lost the fishing season and did not obtain cleanup work were angered to see others make big money, buy new boats, and get in a better position to compete in the fisheries in the future, Another reason for the tension was that the cleanup work violated local people's sense of fairness. Fishers generally believe the way to get ahead is through hard work, taking risks, and developing one's skills, but these were not the criteria used to get cleanup jobs.

Subsistence. The toxic effect of oil on subsistence foods was of particular concern to Alaskan Natives and village residents. People were not prohibited from obtaining subsistence foods but skepticism about the safety of doing so reduced subsistence activities significantly. Compensation for subsistence was difficult to claim and not forthcoming. Exxon flew in some canned salmon, which people appreciated, but which was a poor substitute for foods people would rather have procured themselves.

Alaskan Natives expressed several concerns over the loss of subsistence. Subsistence offered security in the villages where commercial fishing operations generally were small-scale and not diversified and where there were few jobs. Natives feared and resented returning to the dependency of the Bureau of Indian Affairs days. They also were concerned that the inability to engage in subsistence activities, even for a few seasons, would impair the transmission of subsistence skills to younger generations,

The significance of subsistence losses was minimized. As one interviewee put it, "The process, not just the product, is important." Subsistence activities strengthen cultural identity, self-esteem, family and community ties, and cooperation. They aiso provide spiritual sustenance and enjoyment for Native people, Oil spill work did not provide the same level of satisfaction. instead, it fostered competition for high paying jobs and exacerbated petty jealousies and rivalries among villagers.

Disruptions to Customary Habits and Patterns of Behavior. The oil spill disrupted the existing patterns of interaction among fishers. There was suddenly a "new game, new rules, and new players." instead of the normal competitive fishing game, people had to compete in a new realm where they did not understand the rules. The common occupational status that many residents shared as fishers, which cut across the divisions based on gear and size, was no longer a binding community force in Kodiak.

The corporate culture of Exxon clashed with the culture of Kodiak's fishing community. Exxon's formal, inflexible corporate hierarchy was not successful at dealing with a small rural community of independent business people. The two groups have very different ways of doing business.

Spring and summer are important times for members of fishing communities and their normal rhythms were disrupted, Interviewees stressed that life was not normal. People were unsettled and uncertain, One person remarked, "Some things you cannot put in a claim for because money won't buy missed moments and the serenity of uninterrupted lives."

Emotional Impacts and Stress-Related Disorders. People experienced feelings of futility as the magnitude of the spill became known. In the words of one fisher, "We are a community used to dealing with the worst nature can throw at us. We perform the nation's most dangerous occupation in the world's worst weather. But we feel fearful and inadequate in the face of the advancing oil from the Exxon spill." Their own skills were of no use in controlling it. Residents experienced stress associated with the long-term nature of the impact from the spill. They feared losing their independence and becoming dependent. People wanted to work instead of drawing claims money. They felt stress and uncertainty related to their futures.

Confronting Environmental Degradation and Death. The *Exxon Valdez* oil spill had a tremendous impact on people who are used to living by the sea and who assign all sorts of intrinsic values to their environment. Interviewees often talked about experiencing the losses; the weight of the death they were surrounded with was obvious. People missed hearing the familiar sound of birds and seeing fish and sea mammals in the bay. Many local residents, and the community as a whole, went through a grieving process that involved denial, anger, depression, and, finally, wanting to do something about the oil spill.

Some residents expressed despair and fatigue as areas that were already cleaned were hit again with mousse, 'It's like taking ground again and again in a battle," remarked one interviewee. Others likened it to a guerrilla war where puffs of smoke come up and then disappear, only to reappear somewhere else. Indeed, the oil spill headquarters were like command posts.

Stress in Dealing with Exxon. Kodiak residents' initial stress and frustration in dealing with Exxon stemmed from the fact that Exxon was responsible for the oil spill, did not have adequate clean-up technology or contingency plans in place, and was inexcusably slow in responding to the spill and formulating a plan to deal with it. As clean-up operations proceeded, locals criticized Exxon for slow payments, for not paying boats under contract as agreed, for unkept promises to the villages, for lack of communication and information, and for frequent turnover of representatives in the area. People were particularly angry with Exxon's mishandling of the cleanup and with the fact that as the oil increased, Exxon's presence did not. Exxon's original promises of cleaning up all of the oil and making everyone "Whole" were never kept,

Other problems in dealing with Exxon included the complications and frustrations of the claims process, the arrogance with which Exxon management treated local people, the battle local people had with Exxon over how the spill was portrayed in the media, the control Exxon exerted over the clean-up operations, and the thwarting of local initiatives to respond to the spill.

Violation of Community Values. Kodiak residents' experience with the oil spill vioiated community values. Residents of Kodiak, many of whom are small, independent fishers and business people, place tremendous value on hard work and individualism. Fishers believe that the way to work oneself up in the fishery is through hard work. The oil spill response efforts violated that value. Peopie who had connections, or peopie who were not considered very employable within the fishing industry, were the ones who often obtainedspill-related work. After severai fisheries were closed, idleness was a problem for many fishers.

Inherent in the worid view of fishers is the belief that they have a certain amount of control over their own destiny and that fishers ail have a somewhat equal chance against the sea or nature. Government interference and foreign competition is often blamed for the existing inequalities, The *Exxon Valdez* oil spill resulted in fishers experiencing a ioss of control over their destiny. in generai, the Kodiak communities wanted and fought for more local control over the decisions being made,

SUMMARY

There were disparities in the impacts of the *Exxon Valdez* oil spill on the Kodiak Region both within communities and between communities. These disparities exacerbated existing community divisions, some of which were based upon the transformation of the fishing industry in recent years, The oil spill caused changes in the social processes that structured and patterned Kodiak life. Exxon's handling of the oil spill response itself caused significant impacts to Kodiak communities.

Joanna Endter-Wada is an Assistant Professor and Director of the new Natural Resources and Environmental Policy Program in the College of Natural Resources at Utah State University, Logan, Utah. She conducted research in the Kodiak region prior to the Exxon Valdez oil spill and subsequently in August 1989 as part of the Social indicators Project. She would like to acknowledge Rachel Mason from the Department of Anthropology, University of Virginia, for her research efforts both in 1989 and in 1991 as part of this project. Joanna Endter-Wada has conducted research in other parts of the western United States analyzing the socio-cultural impacts of water and energy projects.

QUESTIONS AND Discussion

Craig Mishler: Just a comment, it is interesting that Exxon is no longer part of the dialogue here today.

THE SOCIAL EFFECTS OF THE SPILL OF THE *EXXON VALDEZ* ON VALDEZ, ALASKA

Edward Robbins
Graduate School of Design
Harvard University
Cambridge, Massachusetts 02138

To understand Valdez and its reaction to the spill of the *Exxon Valdez*, we need to look even if only briefly, at the history, economy and sociology of the community.

HISTORY

The present situation in Valdez may be best understood in light of three major interventions in its recent history. All these interventions, two of which were major disasters, had critical impacts on the economy, social constitution and form of Valdez. The three interventions; 1) the earthquake of March 27, 1964, 2) the building of the oil pipeline, and 3) the oil spill of March 27, 1989 all had a role in changing the very nature of Valdez. Ironically, the two disasters, i.e., the earthquake and the spill, had as economically a positive impact on Valdez in many ways as did the pipeline.

In each disaster the population of Valdez was radically affected for both briefer and longer periods. A 1964 Civil Defense list of residents and their location just after the quake reveals that less than 25% of the local adult population with their children remained in Valdez as it was being rebuilt. Many who had lived in Valdez, did not return, while a number of those who helped build the new town remained. During the height of the pipeline construction days and the spill cleanup, the population of Valdez more than doubled to about 8000 to 10,000. As with the quake, a number of individuals who came during the boom remained afterward.

The boom and bust nature of Valdez has been particularly important in the years since the building of the pipeline. Evidence from gross bar receipts at one of the major bars in town with the spill year as a base gives a sense of the up and down nature of Valdez's economy over the last two decades and its reliance on major events controlled from the outside. (Table 1).

'able 1. Bar review, 1974 to 1 990.

Bar Revenues: 1974-1990
1989 Base Year=l .00

1974	.32	1982	.51
1975	1.20	1983	.41
1976	1.40	1984	.55
1977	1.45	1985	.45
1978	.80	1986	.35
1979	.19	1987	.36
1980	.30	1988	.37
1981	.63	1989	1.00
		1990	.69

In sum, the history of Valdez incomplete as it is, reveals a town subject to boom and stagnation resulting from major interventions over which the community has had little or no control, The spill itself brought, although unevenly distributed through the population, a windfall to the community in the form of monies earned through the cleanup itself and the riew jobs that were created in response to the spill.

ECONOMY

A brief overview of Valdez's economic make-up' reveals a complex mix of structural interdependencies and socio-economic tensions and conflicts. Four aspects of the economy underlie the mix of interdependencies and conflicts: 1) the complex economic structure related to the transport of oil, 2) the social and economic divisions between those associated with high paying economic sectors most notably oil and

' Data for the economic analysis area based on those found in *The City of Valdez Comprehensive Plan*, by Derbyshire Associates, 1991 and from interviews with various city officials.

government and those in other low-paying sectors of the economy like tourism, 3) the divisions between winter and summer economic pursuits and full-time and transient residents and workers and 4) the division between outside and local economic actors. All four of these factors manifest themselves in a number of complex and important ways in relation to local attitudes and understandings regarding the economy, the society and culture of Valdez.

Looking at these four economic areas we find that :

1) Valdez is clearly dependent on oil and its transport through the activities of Alyeska and associated companies for its economic well-being and for the infrastructural and administrative amenities that Valdez can afford to provide its citizens,

2) The transport of oil and the oil-economy is effectively beyond the reach of local control and is, unless oil companies decide to increase their exploration of the North Slope, economically unstable over the long-term presenting as it does a non-renewable resource base and threat of a declining source of both individual incomes and tax support for the city (the latter threat may be in the process of coming a reality).

3) If oil transport does remain at its present or expanded scale in Valdez, it presents a potential threat both real and imagined in the form of potential ecological damage and disaster like the spill of 1989 to other potentially more stable and more locally controllable economic activities". — albeit within the framework of a world market — like fishing, fish processing and tourism.

4) While Valdez offers a large number of very high-paying jobs it offers an equal number of quite low-paying jobs. This division in incomes and living standards presents a number of important social problems and social tensions to the town and a series, over the long-term, of serious problems for city government vis-a-vis such issues as housing, infrastructural supports and the social well-being of Valdez.

5) The split between the 3000 to 4000 permanent residents and the 1000 to 2000 extra transient residents of summer, as well as the split between industries based on year-round employment versus those based on transient employment do create rifts and tensions in the town, Over the long-term, infrastructural issues that were exaggerated during the spill year of 1989 have remained and will continue to do so given the boom and bust quality of the economy; e.g., a new boom could develop if the gas pipeline is built or Arctic National Wildlife Refuge (ANWR) goes ahead bringing new economic and social pressures to bear on Valdez.

In a 1989 survey done by Derbyshire Associates of Anchorage for the City of Valdez, a population figure based on the City of Valdez Financial Report of 3686 was estimated for the City of Valdez with a mean annual employment rate of about 1861. With a resident per-capita income of $19,937, a figure above both national and state averages, Valdez is clearly a relatively affluent town. This affluence though is mitigated to some degree by the nature of employment in Valdez and the split between high paying and low paying jobs and the split between stable and seasonal employment.

When aggregated we can see that Valdez's economy has three critical areas of employment. They are: 1) Public Sector funded activities which accounts for roughly 35% of those employed in Valdez when direct government, education and health are aggregated, 2) transport of which Alyeska's activities through the pipeline terminal and associated industries makes up about 87% of the total or 20% of the employment share in Valdez, and 3) tourism and commercial fishing which comprise roughly 15% of the total employment share but which is for the most part seasonal. All other businesses and economic pursuits are clearly dependent on these three sectors for their survival. While sectors 1 and 2 are well paying other sectors of the economy vary considerably as to their renumeration.

Revenue share by sectors also makes it clear just how much oil dominates Valdez and just how dependent Valdez is on forces which reside outside its own economic and political domain of influence. Oil transport made up about 28% of all revenues in Valdez with government and education making up about 14% and 11 % respectively in 1988. Given that the assessed value of oil property is ten times that of non-oil property and that the proper&y tax is a critical component of the town's revenues, given that a large number of the most highly assessed properties belong to oil company employees and given that a considerable number of students in the schools come from families employed by Alyeska, Valdez's dependence on oil is quite clear.

The dependence on oil transport and on decisions made outside the community is even greater than the numbers illustrate. Oil revenues to Valdez are based not on local valuation of Alyeska's holdings but on an agreement worked out between the pipeline owners and the State of Alaska called TAPS, This agreement sets up a mechanism whereby the pipeline is depreciated over time. As a result, the town of Valdez will, over the next ten years or so, see the taxable assessed value of oil property fall from $1,139,761,160 in 1990 to $413,672,000 in the year 2003. The ratio of oil property value assessed for taxation to non-oil property assessed for taxation will fall from roughly 12 to 1 to less than 4 to 1, If net expenditures subject to property tax fall roughly 40%, the rise in millage on property will still have to rise over 50% even assuming only a 2% rise in overall expenditures per year. New projects which might renew the Valdez tax base will be based on decisions made in Washington regarding ANWR, and by oil and gas companies located in the lower forty-eight. (Table 2).

Table 2. Economic contribution by sector*.

Economic Contribution to Valdez By Sector 1988*			
Sector	Revenue	Value-Added	Income
Transport	32. l%**	40.3%**	21 .2%
Education/Heal th	10.5%	12.6%	20.8%
Government	14.3%	16.2%	26.?%
Manufacturing	13.1%	6.3%	2.8%
Hotel/Restaurant/ Bar	4.0%	3.3%	3.3%
Trade	12.2%	5.0%	6.8%
Personal Services	2.4%	2.7%	4.4%
Construct ion	1.6%	1.6%	2.0%
Utilities	4.1%	4.0%	4.4%
Finance	2.8%	4.1%	4.6%
Fishing	2.9%	3.9%	2.8%

*Based on figures from Oarbyshire et al.
**Oil is 87% of the total of transport sector

The dependence on oil also creates a clear division 'within the economy between high-end and low-end income sectors. Individuals holding oil, government and education/health sector jobs while making up roughly 55% of all jobs in Valdez earn 66% of the total income share for residents. Those holding jobs in the manufacturing, hotel/restaurant/bar and trade sectors while comprising 31 % of all the jobs in Valdez share in only 13% of the total income earned in Valdez. When one adds to that the fact that a significant portion of manufacturing income is earned by transient summer workers, the divisions in earning capacity for people who live in town the year round becomes even more glaring. Two other areas of employment, although only a small percentage of the total, add to the already clear division in the community between high-end and low-end incomes. Fishing and finance while employing only 3% of the total, comprise a little over 7% of the total income share in Valdez. Surprisingly, with the exception of finance and fishing, government reveals the biggest positive differential between employment share and income share.

What we see in Valdez is an affluent community whose affluence is dependent on oil transport and which must deal with clear economic divisions between the various sectors that make up the economy. While these conclusions are not surprising for a community the size of Valdez with the kind of economic history and profile that characterizes it, they should be kept in mind as we move to a description and analysis of the social, attitudinal and cultural realities of Valdez, e.g., attitudes toward both oil workers and government employees at times is based on their incomes compared to others in the town.

EFFECTS OF SPILL ON THE ECONOMY

The effects of the spill economically, while generally positive for Valdez, were not the same for all sectors of the economy, If we look at some critical sectors we can see different effects.

Transport

For transport the effect has been generally positive. As a result of new safety measures taken by Alyeska, there are at least 200 or so 'new jobs in Valdez all associated with spill prevention or cleanup in such areas as Ship Escort Response Vehicle Service (SERVS) and other spill and safety activities associated with loading the oil into the boats.

However while this has brought new jobs to Valdez they are not ail filled by Valdez residents. A significant number of the new employees employed by SERVS are from Louisiana on contract to Alyeska. Crews and boats come to Valdez for a specified contract period and return to their home base in Louisiana when their term is completed, While other jobs that resulted from the spill are held by residents of Vaidez, a number of these jobs have in the year since the spill been cut back. According to a number of informants, at least 16 employees working on the safe loading tankers were dismissed during the period of research in February and March, 1991. So, while most interviewed felt the spill had added significantly to the local economy,' there was a suspicion by others that the additional jobs associated with safety would either go the way of such jobs in the past, i.e, as no major accidents occurred they would be eliminated or would be contracted out to individuals not resident in Valdez.

Fishing

During the spill, fishermen piayed an active role in the cleanup. Fishermen along with some tour-boat operators in Valdez were among the first out to the spill. Most worked at spill cleanup from the beginning, and although many worked initially without thinking of compensation, most earned significant income in the process.

Only two of the fishermen resident in Valdez did not participate in the spill cleanup, Of the two, one did not by choice and the boat of the other was, at least in Exxon's estimation not up to the task of the cleanup. Both fishermen argue that they lost considerable income because of the shortened season (one boat was a tender and the other a small fishing vessel).

Those who participated in the cleanup earned as much if not more than their annual earnings from fishing. Ironically, although the season was shorter than usual, it resulted in record catches and revenues. If any of those involved in commercial fishing were adversely affected by the spill it was those who ran tenders and who iost income, according to informants, because of the shortened season. As many fishermen both fished and worked the cleanup, profits for the summer of 1989 were for the most part high.

If the spill did not directly affect the profits of most fishermen for 1989 in a negative way, the spill and cleanup did have important and some would claim potentially adverse effects on the industry. For one, the excess profits earned by many during the spill led a number of fishermen to add to their fleet and to buy new boats with the latest in fishing technology. These new boats and expanded fleets gave those who were able to benefit from the spill a competitive edge over those who were not, All those who participated in the cleanup benefited by such participation but they benefited unevenly as contracts were negotiated individually. Depending on when one got involved in the cleanup and the politics of the spill at the moment, contracts varied considerably.

The spill, according to a number of informants, may destabilize the industry over time in a number of ways and create new tensions among fisherman both within Valdez itself and on the Sound in general. The greater number of boats, many of these with a greater capacity and more efficient technology for catching fish will severely affect distribution of the catch as well as the availability of resources. The likely effect this will have on fishermen who do not have large, fast well-equipped boats and on the price of fish is uncertain. What is clear is that increased tensions resulting from the uneven benefits of the spill have created greater social conflict in the industry.

Further destabilization may yet occur as the industry shakes out from the impacts of the spill. A number who brought new boats were neither full-time nor necessarily experienced fishermen, Some of these may have miscalculated the overall cost-benefit equation involved in fishing. Some bought boats on the assumption that the spill cleanup would continue in 1990 as it did in 1989 and calculated costs on the basis of that assumption. Others may not have held back funds to pay their federal taxes from their cleanup income and purchased boats with money owed to the federal government. As a result a number may find themselves in financial trouble over the next few years as tax obligations are assessed and come due.

All of these issues give a sense of instability to the fishing industry as people wait to see how the effects of the spill ecologically, economically and socially work themselves out. Whether accurate or not the perceptions of instability are widespread. Add to these perceptions fears about the current state of world prices for salmon and the overall effects of oil transport on the ecology of Prince William Sound (PWS) and salmon over time, and the fishing industry in Valdez has been noticeably affected by the spill in particular, and the oil industry in general. Of note is that almost all the informants argued that whatever perceptions and fears they have now did not exist before the spill. Furthermore, the economic impacts of the spill certainly changed the technical and economic make-up of the industry. Just what those changes will bring is still open to question and a source of concern for most fishermen.

Fish Processing

Of all the economic activities in Valdez, the processing industry was as affected as much as any economic pursuit in Valdez by the oil spill of 1989. Not only was the season shortened by the spill, it was also extremely difficult to keep employees, especially experienced employees, from joining the spill clean up work force given the much higher wages paid by VECO for the cleanup jobs. While understandable to those who managed the processing plants, it made their work that much more difficult and economically costly during the spill year. Furthermore there is some fear about the long-term effects on the world-wide perception of Alaska's fish stock and the effects this might have on the salmon market. According to one respondent close to the industry, there is some evidence that sales of Alaska salmon were down in Europe and the United States owing to fears about polluted fish. Whether true or not, these fears add instability to what is an inherently unstable industry.

Tourism

The spill had critical effects on the tourist industry as well as the food industry. Clearly, given the rise in population during the cleanup, hotels and restaurants made an economickilling completely full as they were throughout the cleanup period. But the cleanup put great stress on the reputation of Valdez as a reliable place to visit as well as on the management of these services.

The influx of workers during the cleanup and the Exxon's need for space for its employees to live throughout the cleanup period led to the cancellation of almost all reservations made for tourists in the summer of 1989. In the case of one hotel, Exxon effectively booked all the rooms for the entire peak summer months of the cleanup making rooms unavailable to tourists or anyone but Exxon personnel.

While the hotels clearly profited from such arrangements what effects this will have on Valdez's reputation among tourists and tour operators has yet to be seen, Given that the spill also may have turned people away from visiting the Sound, the added complication wrought by cancellations adds to an already uncertain future for tourism in Valdez. However, at the same time, Exxon has underwriien a considerable public relations campaign to overcome the adverse publicity generated by the spill, and the spill itself has brought Valdez such extraordinary name recognition that the adverse effects of the spill may be overcome by the positive effects of the public relations campaign. Indeed, according to informants, there is evidence that the spill has generated a whole new type of tourist in Valdez; i.e., those who come to see the spill and its effects,

The evidence about tourism is not yet in. Some informants argue that it is down while others say that it has really not been affected. Figures from the largest hotel in Valdez, the Westmark, suggest a slight dip in overall revenues after the spill but not enough to conclusively state that tourism is down. In 1988 during the month of July revenues at the Westmark were $264,000. In 1989, the summer of the spill they were $273,000 while in 1990 they were $255,000. The roughly 7% drop in revenues is not considered by the hotel management to be significant looking as they are to a growth year the summer of 1991. However the fall in revenues must be looked at in light of a 7% rise in Alaskan tourism overall for the year 1990.[2]

Overall tourism must be looked at in light of the general economic picture in the US. and the extent to which visitors to Valdez are U.S. citizens or foreign nationals,

The spill had other effects on the tourist industry as well. The turnover of employees during the cleanup, most of whom worked the higher paying cleanup at one time or another was "drastic" according to one hotel manager. This led to a great amount of stress among those who managed food and lodging services during this period. However all has stabilized in the year following the spill and the sector is back to normalcy,

The longer term effects on tourism in Valdez aie threefold, First is the potential shift of tour operators to tour strategies that would not involve a stop in Valdez. Second, is the long term threat of another ecological disaster despoiling the Sound further. Third is the general U.S. economy,

The spill had profound effects on the charter boat industry. For one, tourism was down the summer of 1989 because of the hotel cancellations, the bad publicity and the fact that much of PWS was off limits to tour boats during the cleanup, A number of the boat operators were

[2] Figure from the Valdez Charter Boat Association,

able to make up the loss of income by working the spill and in fact earned more from that than they conceivably could from their normal charters.

While overall the cleanup was profitable to boat owners, the effects on tourism remain to be seen, The 1990 season for individuals operating glacier tours was down although Alaska tourism in general was up. Calls for tours were up over 1990. How the industry will shake out is still uncertain. As one tour boat operator observed "1 can no longer advertise a pristine sound nor a pristine boat after the spill."

The spill also has changed the boat charter industry. During the spill the wages and salaries of those who worked the boats rose considerably. These new wage rates, while not remaining at spill summer levels, have remained above what they were before the spill raising the costs of operating a charter boat. For example, for a job that paid $6 an hour before the spill, operators now pay $10 an hour. These new costs plus, as in the case of commercial fishing, the numbers of new boats that have come on the scene because of cleanup profits have led to some uncertainty about whether the industry can sustain this new expansion profitably.

Other Sectors

Other sectors were either not affected economically, e.g., the public sector, or are too small for a general review here. Housing did fluctuate a bit during the spill and housing was lost by some permanent residents as a few landlords tried to gouge transients. Overall though for most residents the effects of the spill at least economically were at best a boon and at worst mixed. For some the spill did create real economic hardship.

SOCIAL ATTITUDES AND UNDERSTANDINGS

What follows here is a very brief outline of what is a rich and complex subject.

As oil is the literal and metaphorical stuff which fuels that prosperity, it forms the central factor around which attitudes, affects and sensibilities are structured. The spill and its aftermath have brought into bold relief the strengths of Valdez as a community and its weaknesses.

Social Relations, Social Divisions and the Spill

The social divisions and conflicts that people felt were manifest in Valdez during the spill, *mutatis mutandis*[3], replicate the more general and constant social and economic relations that existed in Valdez prior to the spill and still exist today. That is because social relations, in Valdez, structurally and informally are defined by the reasons that people come to Valdez to live. If we look at our interview sample in the majority of cases there is one reason why most reside in Valdez, i.e., the job, Even unemployed and underemployed remain in Valdez because of hopes of a better job.

In Valdez, people can be divided into those who are "doing well" and those who are "making do." The 40% or so of our sample have household incomes of considerably over $60,000. About 26% of the sample below $30,000 which given the cost of living in Valdez represents relative impoverishment.

There are divisions based on longevity of residence with the critical division being that between those who resided in Valdez before the earthquake and those who did not. The former it is argued almost monopolize most of the small businesses in town,

[3]The necessary changes having been made.

Oil is central to the occupational structure of the community and the predominance of two major institutions, Alyeska and government. There is a divide between those who work for those institutions, who are also generally the highest paid members of the community and others in the community. This divide expresses itself not only economically but also in how one positions oneself in the community and the roles and attitudes one holds about life there. Alyeska employees have a special place whether they want it or not given the community's dependence on oil; they are representatives of the institution that defines, at least for now, the very reality of Valdez.

While the social relations and divisions defined directly by the oil economy loom like a benign spectra over the community, there are other important and in some ways equally critical social relationships and divisions that mitigate, and refocus the social realities defined by oil. Distance and division in Valdez are not only defined by one's work but by the backgrounds that people bring there. The community is divided by educational status and by associations with special roles or institutions like government. Social interests are often defined by one's occupation or economic pursuits rather than income alone; e.g., commercial fishermen, and tour boat operators see a community which both supports and is in some ways anathematic to their lifestyles. Business people feel unappreciated by the rest of the community and by Alyeska.

The greatest tension is between "Haves" and "Have-Nets" often expressed as a division between insiders and outsiders, These tensions are a function of competition for resources and for opportunities. Other tensions, e.g., between the various sectors of the economy were not, during my period of observation as strongly voiced.

Development, the Environment and Social Conflict

While almost everyone is resident in Valdez for some economic gain, Valdez is divided between those who are pro-growth and those who are not, It is important to note that everyone with whom I spoke in Valdez is in favor of maintaining a clean, balanced, bountiful and healthy environment. Differences surfaced about what a good and healthy environment should be, what may or may not harm the environment and what can be done to assure its continued well-being.

The disagreements over economic development, while often heated, are limited in their reach. All respondents agree that on measure oil has been a benefit to the community. There are disagreements about the desirability of the growth of that industry.

The Spill: Divisions and Conflicts

Spill tensions respondents felt were never of the order of other communities like Cordova. For one, Valdez for the most part is not dependent on the Sound. Equally, most residents who wanted to were able to earn considerable income from the spill cleanup. Moreover, the town itself was never threatened by the spill.

Centering the spill 'cleanup operations in Valdez generated a number of problems and tensions which led to divisions within the community and even open conflict, however short-lived.

For one, the insider-outsider division, always a part of the social reality of Valdez, was exacerbated by the intrusion of so many outsiders 'into the community. Residents felt alienated and angered by the incursion of outsiders from Exxon and VECO who took over the spill cleanup as soon as they arrived. "Bossy", "incompetent", "corrupt", and "inefficient" are just some of the terms applied to the executives from both Exxon and VECO who were felt to be manipulative and incompetent. More material tensions and conflict arose over the allocation of contracts and jobs by Exxon and VECO. There are still bitter memories about who benefitted and who didn't and concern about how this might distort the local economy.

Problems of Stress

While the pipeline created great stress in Valdez, it was planned for and expected. The speed with which events changed during the spill cleanup, the fact that the spill happened without any warning or, indeed, any expectation that such a disaster would ever happen and the unwelcome nature of the spill and the changes it brought, all made the spill a very different experience from the pipeline.

The spill seems to have inflicted on people a sense of insecurity, instability and powerlessness. Few trust their institutions be they government or the oil companies.

These insecurities are only now, a year and more after the spill, making themselves felt in depression, family violence and such. Police statistics show a rise in family violence in 1990 over previous years,”

The Spill: Perceptions and Understandings

When respondents spoke of both the positive and negative effects of the spill on the community, they usually dealt with three important areas: 1) the attitudes of people in Valdez toward the oil companies, 2) the social life of the community, and 3) the economy of Valdez and the ecology of the Sound.

People are divided, sometimes bitterly but mostly quietly, about the just how much the oil companies can be trusted, just how much the Sound had been damaged and to what the degree the social life of the town can ever be the same. Most people fall between the extremes believing that the oil companies while not villains should be watched, that there needs to be a greater vigilance about the ecology and especially its effects on the health of the community and that the greed, economic shifts, turnover of population and stresses that the spill produced have altered the community but not significantly and that the new safety measures while important will only be maintained through citizen watchfulness.

Whatever one's belief, the spill has produced a new form of discourse in the community about the role of oil, how much citizens should be involved with the running of the oil economy, how watchful they should be about the ecology of the Sound and other such issues.

Moreover, it has brought into the light just how much citizens should be involved with and committed to, both over the short-term and long-term, Valdez. There is a strong division over whether the boom created by the spill has put off long-term thinking about Valdez's overall economic and social well-being over the future years.

How people saw the spill's effects was a function of previous attitudes, the economic location one found oneself in which defined what opportunities for gain or loss were available, the experiences of the spill itself, and the strategies one used to deal with the spill and the activities associated with it. While there is a great amount of agreement about much of the spill and its effects on Valdez, the complexities which underlie what is generally agreed on make the agreements less than meets the eye and more open to the variety of interpretations which underlay the generality.

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[4] For a discussion of spill related stress in Valdez see Donald et al. 1990

Overall, there is still a sense that there is debate about just what kind of community Valdez is, how it should be developed, how each individual feels he or she should seethe town, and whether the town itself has a future beyond oil and for each of its citizens independent of the job they hold; e.g., retirement. Moreover, are people first citizens of a community employees of a company remains a real if unstated debate.

For many there is a real conflict between the community and Alyeska and an internal conflict about where their individual loyalties iie. The institutional reality of Valdez, the fact that it is a company town while also being independent of the company, creates complexities and problems which makes commitment to the community a politically and socially loaded act. The divisions about commitment that one hears from respondents, often with contradictory messages from the same respondent, is a function of each individuals perceptions and experiences as each tries to define a place for themselves in Valdez. The debate about commitment and the ambivalence it appears to produce in the town in general and in so many individuals suggests that Valdez is still a community seeking to define itself and still seeking to discover what it wants to be in light of social and economic history and economic structure today.

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Edward Robbins is an anthropologist currently a Lecturer in Urban Design in the Graduate School of Design at Harvard University, and a Guest Lecturer in the program on housing and development at Oxford Polytechnic. He has worked and published on the social organization of a mining town in Canada, the social consequences of the development and design of refugee camps and **settlements** *for the UNHCR having done research in the Sudan, Somalia, Mexico, and Belize, and the social implications of the low-cost housing program in Sri Lanka. Most recently, he a/so completed* **"Drawing and the Making of Architecture"** *and research in Valdez, Alaska on the social effect of the spill.*

QUESTIONS AND Discussion:

Unidentified Questioner: How did the people feel their city government reacted to the crisis? Did they feei it was effective or was it just a tool of special interest?

Edward Robbins: People varied. The permitting process is an example; some people felt that the city government was unfair, that they favored Exxon. Some people felt that they weren't served. A lot of people felt the city government did as well as could be expected. But interestingly, most people would probably have given Exxon the highest rating for responding to the spill, the state government, second, and the federal government, last. But that aiso goes along with the fact that most people toid me they didn't trust government. It doesn't mean to say that they thought Exxon did a good job. For the city government, it was over the permitting process that i heard the most complaints from individuals who felt they didn't get a chance to build. Most people felt that the city did a good job given the incredible influx of people. Remember in Vaidez, and it is important to remember this, they almost had a typhoid epidemic because so many people came so fast. So many people were living on the streets that the sewers and the streets couldn't handle the detritis that was being produce by the influx, But there isn't a great anger toward the city, except for people who had to build with permits,

SOCIAL, ECONOMIC, AND SUBSISTENCE EFFECTS OF THE *EXXON VALDEZ* OIL SPILL - CORDOVA

Stephanie Reynolds
School of Social Sciences
University of California
Irvine, California 92717

This presentation briefly summarizes impacts of the 1989 *Exxon Valdez oil* spill on the commercial fishing village of Cordova, located in southeastern Prince William Sound. Eyak Village, incorporated by the City of Cordova in 1972 (BLM 1979), is included.

METHODS

Qualitative ethnographic data were collected between February 11 and March 13, 1991, as an extension of the Alaska Outer Continental Shelf Social Indicators Study. This report is based on ethnographic and protocol interviews with: 1) 24 Key Informants, drawn by random selection without replacement from winter residents; 2) 44 institutional interviews; and 3) Native "cultural experts."

RESULTS AND DISCUSSION

For Cordovans in 1991, the 1989 oil spill was still an unfolding disaster. Spill-related problems, fears, and conflicts were widespread. Respondents who profited from the cleanup reported moral conflicts and anguish over the plight of those who suffered financially. Cordovans hold spiritual as well as commodity values of nature, and many refused to equate money to spill damages.

Spill cleanup and damage claims processes were dominated by adversarial relations with Exxon, which proved traumatic. Respondents felt without recourse, as "Exxon was calling all the shots." Many Cordovans believe that the federal government primarily serves the oil industry, to their detriment. Cordovans view state agencies in a more positive light, but believe that they cannot control big oil interests. Also, respondents doubt whether Exxon settlements paid to the state and federal governments will be used to compensate their losses.

Cordovans predicted a disaster such as the *Exxon Valdez* oil spill when they sued the Department of the Interior to stop the pipeline terminal in Valdez in the early 1970s; respondents are angry that their fears were ignored. After the 1989 oil spill, Cordovans assumed major risks entailed by Exxon's spill cleanup: equipment risks, health risks, and legal liabilities associated with the status of independent contractor.

CITY GOVERNMENT IMPACTS

Residents described life during the spill cleanup as 'living in a war zone" or 'concentration camp," under "marshall law." Exxon and its agent VECO took over offices and "occupied" their town, according to Cordovans. The city experienced lost bond opportunities, employee losses and burnout, breakdowns in normal government operations, housing shortages, lost raw fish taxes, and extraordinary litigation expenses. One pro-Exxon city council member brought suit against other council members and the city, reportedly as an outgrowth of spill-related political conflicts. This suit had cost Cordova $500,000 by the time of this research,

Cordova as Spill Cleanup Contractor

Cordova served in the spill response as an involuntary, non-profit, independent contractor for Exxon. The city was constrained to provide services and facilities for Exxon's spill cleanup, City officials had to make expenditures and await reimbursements, thereby capitalizing the cleanup. Unpaid city leaders were not reimbursed for their time, and paid city officials did not receive remuneration for the extra workload entailed by the spill response.

PRIVATE SECTOR ECONOMIC IMPACTS OF THE OIL SPILL (NON-FISHING)

The spill affected Cordovan businesses unevenly, as Exxon reportedly substituted spill cleanup costs for spill damage payments. Businesses not involved in the cleanup were hurt disproportionately. Economic impacts of the oil spill in the private sector include bankruptcies, foreclosures, lost credit lines, economic losses due to disruptions of normal business patterns, business closures, and lost business and property values. The cleanup resulted in shortages of labor, childcare, housing, and commodities. Exxon did not comply with requests for wage subsidies, low interest loans to cover cash flow problems, or consideration of lost bank loans, business values, or propetty values. Widespread criticism centered around a chaotic and continually modified claims process. Business owners complained that this process was carried out at Exxon's discretion, with no objective agency overseeing the process. Many claimed that Exxon representatives lied to them.

Conflicts within the business community arose during negotiations with Exxon, creating hostilities that persisted in 1991. While Exxon carried on cordial relations with the Cordova Chamber of Commerce, donating $20,000, some business owners believed that their interests were not being represented. These business owners formed the Cordova Business Owners Association, and attempted unsuccessfully to negotiate with Exxon on their own. This conflict had political ramifications (in the suit mentioned above),

Conflicts between VECO and Local Businesses

Virtually all business owners complained that VECO "stole our employees." Exxon's cleanup contractor reportedly delayed payment for goods and services, exacerbating cash flow problems already created by the cancellation of fisheries,

IMPACTS TO THE FISHING COMMUNITY

Fishing forms the bulwark of Cordova's economy (see for instance Stratton 1989, Payne 1983, City of Cordova 1990, and City of Cordova 1988). Cordovans fear that the spill's long-term effects could cause the collapse of their fishing industry. Residents believe that their town will cease to exist if this happens.

The Oil Spill Cleanup

Exxon and Alyeska reportedly blocked immediate response efforts of Cordovans, organized through the Cordova District Fishermen United (CDFU). Especially galling for respondents was the rationale for refusing to let Cordovan fishermen prevent the early spread of oil: the oil companies reportedly did not want to incur the liability of using "amateurs."

Fishermen Become Oil Cleanup Contractors. After initially refusing to allow Cordovan fishermen to boom off the leaking *Valdez*, Exxon created a hiring policy that defined these fishermen as independent contractors. This designation entailed a substantial transfer of legal liabilities to the fishermen who became Exxon's spill response team. Many complained of ensuing confusion and resentment over tax and other liabilities. Exxon, consistent with treating fishermen as independent spill contractors, reportedly took no responsibility for boats that broke down during cleanup operations, even though these were more stressful to equipment than normal fishing.

Conflicts Over Cleanup Money. Great animosity was generated by the moral stigma attached to working for Exxon, Cleanup workers were called "Exxon whores," who accepted "blood money" and became "spillionaires." Some refused to work for Exxon on moral grounds.

Conflicts over Contracts. Animosity among persons who were willing to contract their boats for the spill cleanup focussed on the form of contracts and how contracts were obtained, The CDFU published objective criteria for selecting boats for cleanup contracts, but in the chaotic spill aftermath these criteria could not always be implemented. Exxon reportedly made no effort to apply a uniform contract policy, Many believe that Exxon used large cleanup contracts as a form of bribe, to quiet discontent among the more vocal fishermen. Exxon reportedly subtracted this money from subsequent claims payments. In this perception, Exxon was bribing fishermen with their own money,

Health Hazards. Spill cleanup workers experienced adverse health effects, and many objected to Exxon's short and cursory training sessions. Deficits in health and safety training continued to trouble Cordovans in 1991, as Alyeska Pipeline Service Co. declined to provide safety training for its oil spill response program in 1991, According to an Alyeska spokesman, the omission of safety training was mandated by company lawyers, to avoid liability for any damage done to sites by response teams (Cordova Times February 21, 1991, p. A 5).

The Cleanup Does More Harm than Good. Not the least of Cordovans' frustrations over the spill cleanup was that it may have done their environment more harm than good. Cordovans had to pursue cleanup activities that might be damaging their environment, to mitigate economic losses caused by the spilled oil.

Conflicts Over Fish Claims

Based on pre-season forecasts predicting a record commercial salmon harvest in 1989 (CFS May 7, 1989), fishermen and business owners had geared up for a record year in Cordova's commercial fishery. After the oil spill the herring, shrimp, and sablefish seasons were closed. Periodic closures of salmon fisheries occurred. Exxon announced their "voluntary settlement of claims" for salmon permit holders in June 1989. Fishermen objected to problematic features. In calculating settlements for fishermen, Exxon combined low harvest figures (based on past catches) with low fish prices (based on the spill year, which had a high harvest and weak market). The necessity to fish in order to file a claim was a major concern, due to fears of contamination and market damage, Market effects of harvesting older fish, due to frequent closures, reportedly contributed to the bankruptcy of the Copper River Fishermen's Cooperative, a fish processing cooperative formed by Cordovan fishermen.

Respondents described a claims process that diverged from Exxon's publicized policies. Some fishermen reportedly worked on the spill cleanup and also got good fishing claims settlements, while others who worked on the cleanup could not fish and so did not receive claims. Some were compensated for equipment upgrades while others were not. Some fishermen signed releases in order to receive money while others only signed receipts. Some claims settlements were reportedly much more generous than others.

Many fishermen are still pursuing settlements that Exxon partially paid through claims "advances." Cleanup workers could not apply for advances (CFS August 15, 1989, p.1), and only those who fished in 1989 could file (CFS September 1, 1989, p.1). Many recounted that Exxon refused to process claims any further once these "advances" were paid. Respondents were then referred to the Trans-Alaska Pipeline Authorization Act (TAPAA).

In winter 1991, many Cordovans were agonizing over filing their TAPAA claims, due on March 24, 1991. Complaints included that the fund would not contain enough money for all damages, processing of claims might take years, subjects could not determine true damages by the deadline, claims would be difficult to alter later, and individuals felt overwhelmed at the prospect of carrying out necessary litigation on their own. A reported blackout of scientific information due to pending litigation was a further irritant.

The Hatcheries: Prince William Sound Aquiculture Corporation

Prince William Sound Aquiculture Corporation (PWSAC) is a private nonprofit corporation established by Cordovan fishermen, which operates salmon hatcheries in Prince William Sound. The 1989 *Exxon Valdez* spill caused considerable turmoil and disorganization for PWSAC, by creating financial complexities, operational reorganization, and extra employee responsibilities (PWSAC 1990 Annual Report, p. 4, p.9). The corporation incurred substantial costs to protect its hatcheries from the oil, and normal business operations were disrupted. Exxon reimbursed most extra costs. However, a weak salmon market with radical drops in prices, bankruptcies of small processors, and reluctance of other processors to buy the corporation's harvests, all continue to trouble the corporation,

Cleaned Beaches

Cordovans complained in 1991 that Exxon did not clean up its spilled oil, "and that state and federal agencies did not control Exxon's cleanup efforts. There appeared to be lack of consensus within and between federal and state agencies, as to what constituted a "cleaned" beach (CFS August 10, 1990, p.1). Cordovans, particularly Natives, hold stricter standards than Exxon and federal and state agencies as to what constitutes an uncontaminated area,

SPILL IMPACTS ON ALASKAN NATIVES IN CORDOVA

Exxon reportedly claimed that Eyak Village was not "impacted" by the 1989 oil spill, and refused to provide food and services that it provided for Natives elsewhere. Eyak leaders complained to the media and to legislators, Impacts include social disruptions, higher prices, shortages of rental spaces, economic difficulties for the Chugach fish processor based in Cordova, and disruption of government operations. Chugach Alaska Corporation, Eyak Corporation, and Eyak Village sued Exxon.

Cultural impacts particular to Natives, such as looting of burial and historical sites, were emphasized. The most intense concerns relate to subsistence foods and practices. Natives were and still are unable to obtain many subsistence foods. They were and still are afraid to eat subsistence foods that they do obtain, They worry about future adverse health effects from subsistence foods that they have eaten since the 1989 oil spill. They worry about continuing damage to their environment and way of life.

Exxon reportedly ignored a circle of sharing, where Native foods are shared between villages, in assessing spill impacts. Because other areas of the Sound were oiled, Cordova Natives were not able to get the subsistence foods that they needed, Subsistence practices, including sharing, are integral to a way of life that connects Natives with their past and with each other, both in a spiritual sense and in terms of extending kin ties. Respondents describe their cultural identity as inclusive of the earth, wildlife, cultural practices, and people. The oil spill reportedly continues to threaten Native "life."

SUMMARY

Both Natives and non-Natives experienced devastating social, economic and political effects of the oil spill, which are still ongoing. Both groups report that their continued existence

in Cordova has been threatened. Bases for this fear vary between the two cultures, in that an Eyak spiritual philosophy of nature stipulates pragmatic concerns regarding persistence.

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Dr. Stephanie Reynolds is a lecturer in the Program in Comparative Culture, School of Social Sciences, at the University of California, Irvine. Her research interest include cultural and economic impacts of energy development on natives and non-natives in Alaska and rural Utah. She has studied processes of social change and performed field research in native North America, Oceania, and the U.S. - Mexico border region. She received her Ph.D. in comparative culture from the University of California, Irvine.

APPENDIX A

MINERALS MANAGEMENT SERVICE
FOURTH INFORMATION TRANSFER MEETING

AGENDA

<u>TUESDAY, JANUARY 28, 1992</u>

WELCOME AND INTRODUCTIONS

8:30 AM **Welcome -** *Robert J. Brock, Regional Supervisor, Leasing and Environment, MMS*

8:35 AM **Decision Making Under the Area Evaluation and Decision Process**
Robert J. Brock, Regional Supervisor, Leasing and Environment, MMS

8:45 AM **The Environmental Studies Program: Current Status and Research Priorities**
Jerry /mm, Chief, Environmental Studies Section, MMS

8:55 AM **Summary of Leasing History, Exploration, and Production Activities in the Gulf of Alaska, Lower Cook Inlet, and Bering Sea**
Jeff Walker, Field Operations, MMS

OCS **OPERATIONAL ISSUES AND REQUIREMENTS -** *Chair.' Jeff Walker, Field Operations,* **MMS**

9:10 AM **Oil-Spill Response Preparedness**
Tom Murrell, Field Operations, MMS

9:25 AM **MMS Operational and Regulatory Program and Requirements**
Jim Regg, Field Operations, MMS

9:45 AM **NPDES Regulatory Impacts on Offshore Oil and Gas Activities**
Brad Mahanes, Environmental Protection Agency

10:15-10:30 AM BREAK

10:30 AM **Air Quality Requirements and Jurisdictional Issues**
Dave Bray, Region 10, Environmental Protection Agency

11:00 AM **Protection of Marine Mammals (Endangered Species Act, Marine Mammal Protection Act, Incidental Take)**
John Bridges, U.S. Fish and Wildlife Service
Ron Morris, National Marine Fisheries Service

11:20 AM **Oil/Fisheries Group, Inc.**
Peter Hanley, BP Exploration

11:45-1:00 PM LUNCH

POLLUTANT TRANSPORT - *Chair: Dick Prentki, Environmental Studies, MMS Session*

1:00 PM **Circulation Studies in Shelikof Strait, Cook Inlet, and the Gulf of Alaska**
Tom Weingartner, University of Alaska, Fairbanks

1:30 PM **Oil Spill Trajectory Models in the Gulf of Alaska/Lower Cook inlet-Shelikof Strait/Bering Sea**
Terri Paluszkiewicz, Branch of Environmental Modeling, MMS
CANCELLED Ms. Paluszkiewicz unable to attend.

2:00 PM **Circulation and Fluxes Near the Continental Slope of the Eastern Bering Sea**
Jim Schumacher, Pacific Marine Environmental Laboratory, NOAA

2:30 PM **Demonstration/Application of the Coastal Zone Oil Spill (COZOIL) Model Using the Alaskan Handbook**
Mark Reed, Applied Science Associates, Inc.

3:00-3:15 PM BREAK

3:15 PM **Potential Synthetic Aperture Radar (SAR) Applications for the Gulf of Alaska/Lower Cook Inlet Shelikof Strait/Bering Sea**
William *Stringer, University of Alaska, Fairbanks*

MARINE MAMMALS - *Chair: Steve Treaty, Environmental Studies, MMS*

3:45 PM **Overview of Effects of Oil on Marine Mammals**
David St. Aubin, University of Guelph

4:15 PM **Status of Gulf of Alaska and Bering Sea Pinnipeds and Cetaceans**
Tom Lough/in, National Marine Fisheries Service

4:35 PM **Status of Walrus, Sea Otter, and Polar Bear in the Gulf of Alaska/Lower Cook inlet-Shelikof Strait/Bering Sea**
Jon Nickles, U.S. Fish and Wildlife Service

4:55 PM **Aerial Surveys of Belukha Whales, Cook Inlet CANCELLED: Mr. Morris unable to attend,**
Ron Morris, National Marine Fisheries Service

NOTE: Talk by Marine Mammal Commission was cancelled, speaker unable to attend.

5:00 PM ADJOURN

WEDNESDAY, JANUARY 29, 1992

MARINE MAMMALS (CONTINUED) - *Chair: Steve Landino, Environmental Assessment, MMS*

8:30 AM **Sidescan Sonar Assessment of Gray Whale and Walrus Feeding in the Bering and Chukchi Seas**
Hans Nelson, U.S. Geological Survey, Menlo Park

9:10 AM **Update on Archival of Tissues from Gulf of Alaska/Bering Sea Marine Mammal Specimens**
Paul Becker, National Oceanic and Atmospheric Administration

9:30 AM **Satellite Telemetry of Northern Fur Seals and Steller Sea Lions in Alaska**
Tom Loughlin, National Marine Mammal Laboratory, NMFS

10:00-10:15 AM BREAK

FISH - *Chair: Robert Meyer, Environments/ Studies, MMS*

10:15 AM **Status of Groundfish Stocks off the Coast of Alaska**
Jim Balsiger, Alaska Fisheries Science Center, NMFS

10:45 AM **Petroleum Effects on Herring Eggs and Larvae/Status of Studies on Forage Fish in the Port Moller Area**
Michael McGurk, Triton Environmental, Ltd.

11:15 AM **Response of Migrating Adult Pink Salmon to a Simulated Oil Spill**
Doug Martin, Pentech Environmental, Inc.

11:45-1:30 PM **LUNCH**

SEABIRDS - *Chair: Joel Hubbard, Environmental Assessment, MMS*

1:30 PM **Puffins as Samplers of Juvenile Pollock and Other Forage Fish in the Gulf of Alaska**
Scott *Hatch, U.S. Fish and Wildlife Service*

1:55 PM **Adult Survival of Black-legged Kittiwakes on Middleton island (Gulf of Alaska)**
Scott *Hatch, U.S. Fish and Wildlife Service*

2:20 PM **Mapping Pelagic Seabird Distribution in Alaska**
John Piatt, U.S. Fish **and Wildlife** *Service*

2:45 PM **Migration Habitats of Geese in Upper Cook Inlet**
Jerry Hupp, U.S. Fish and Wildlife Service

3:05-3:20 PM BREAK

3:20 PM **Interannual and Intercolony Variation in Bering and Chukchi Sea Seabird Colonies**
Vivian Mendenhall, U.S. Fish and Wildlife Service

3:45 PM **Alaskan Seabird Colonies: Two Computer Databases**
Vivian Mendenhall, U.S. Fish and Wildlife Service

4:10 PM **Late Winter and Early Spring Seabird Populations in the Bering Sea**
George Divoky, **University** *of* **Alaska**

ECOSYSTEMS - *Chair: Joel Hubbard, Environmental Assessment, MMS*

4:35 PM **Unimak Pass Ecological Characterization**
Declan Troy, Troy Ecological Research Associates

5:00 PM ADJOURN

THURSDAY, JANUARY 30, 1992

SOCIAL AND ECONOMIC STUDIES - *Chair: Karen Gibson, Environmental Studies, MMS*

8:30 AM **Economic Impacts of S.S.** *Glacier Bay* **Oil Spill**
Pat Burden, Northern Economics

8:50 AM **A Comparative Subregional Analysis of Subsistence Practices in the Bristol Bay Region**
Joanna Endter- Wada, Utah State University
Lynn Robbins, Huxley College, Western Washington University

OIL-SPILL RESEARCH/RESPONSE GROUPS AND PLANS - *Chair: Karen Gibson, Environmental Studies, MMS*

9:20 AM **Prince William Sound Regional Citizens' Advisory Council- Overview and Activities**
Sheila Gottehrer, Prince William Sound RCAC
Christine Klein, Prince William Sound RCAC

9:40 AM **Cook Inlet Regional Citizens' Advisory Council - What is an RCAC?**
Doug Coughenhower, Cook /n/et RCAC

NOTE: Talk by CISPRI cancelled, speaker unable to attend.

10:00-10:15 **AM BREAK**

EFFECTS OF THE EXXON *VALDEZ* OIL SPILL - Publicly-Available Information -
Chair: Joy Geiselman, Environmental Studies, MMS

10:15 AM **Trajectory Model and Sea Surface Drifter Studies During the *Exxon Valdez* Oil Spill**
Mark Reed, Applied Science Associates, Inc.

10:35 AM **Shoreline Oiling - Fates and Effects**
Eugene Pavia, Dept. of Environmental Conservation

10:55 AM **At-sea and Shoreline Cleanup - What Was Used and What Was Learned**
Dennis Maguire, U.S. Coast Guard

11:25 AM **Emergency Care and Rehabilitation of Oiled Sea Otters: A Handbook for Sea Otter Oil Spill Contingency Planning**
Randall Davis, Texas A & M University

11:45 AM **Effects on Mammals and Birds**
Paul Gertler, U.S. Fish arid Wildlife Service

12:05-1:30 PM **LUNCH - NOTE: At 12:05 PM, Keith Bayha of USFWS will show a 22 min. video on "Sea Otters in Alaska"**

1:30 PM **Impact of Oiling and Shoreline Treatments on Intertidal Communities - Two Years Later**
Jon Houghton, Pentech Environmental, Inc.

Social, Economic and Subsistence Effects - *Chair, Don Callaway, Environmental Studies, MMS*

1:50 PM • **Changes in Subsistence Uses of Fish and Wildlife Resources in 15 Alaska Native Villages following the** *Exxon Valdez* **Oil Spill**
Jim Fall, Alaska Dept. of Fish and Game

2:10 PM • **Oiled Mayors Social Impact Assessment**
John Petterson, Impact Assessment, Inc.

Social Indicators Research:

2:40 PM • **Kenai Peninsula**
Lynn Robbins, Huxley College, Western Washington University

3:00-3:15 PM BREAK

3:15 PM • **Kodiak**
Joanna Endter- Wada, Utah State University

3:35 PM • **Valdez**
Ed Robbins, Harvard University

3:55 PM • **Cordova**
Stephanie Reynolds, University of California, Irvine

4:15 ADJOURN

APPENDIX B

MINERALS MANAGEMENT SERVICE
FOURTH INFORMATION TRANSFER MEETING
JANUARY 28 TO JANUARY 30, 1992
ANCHORAGE, ALASKA

ATTENDEE LIST

* = Speaker

Judy Alderson
National Park Service
2525 Gambell Street
Anchorage, AK 995o3
(907) 257-2635

Serg Astra
Bureau of Indian Affairs
P.O. Box 25520
Juneau, AK 99802-5520
(907) 586-7618

David St. Aubin •
Dept. of Pathology
University of Guelph
Guelph, Ontario NIG 2W1
CANADA
(51 9) 823-8800

Michael Baffrey
Minerals Management Service
Leasing and Environment
949 E. 36th Avenue, Room 603
Anchorage, AK 99508-4302

Jim Balsiger *
National Marine
Fisheries Service
BIN Cl 57oo F/AKC
7600 Sand Point Way, NE
Seattle, WA 98115
(206) 526-4186

W.E. Barber
School of Fisheries & Ocean Sciences
University of Alaska - Fairbanks
Fairbanks, AK 99775
(907) 474-7177

Keith Bayha
U.S. Fish & Wildlife Service
1011 E. Tudor Road
Anchorage, AK 995o3
(907) 786-3537

Richard Beasley
Alaska Dept. of Natural Resources/Oil & Gas
P.O. Box 107034
Anchorage, AK 99510
(907) 762-2567

Paul Becker *
NOAA
Grace Hall, Suite 300
4230 University Drive
Anchorage, AK 99508
(907) 271-3033

John Beitia
U nocal
P.O. Box 196247
Anchorage, AK 99516
(907) 263-7682

Dan Benfield
Fish and Wildlife Biologist
U.S. Fish and Wildlife Service
1011 East Tudor Road
Anchorage, Alaska 99503

Sally Bibb
LGL Alaska Research Assoc.
4175 Tudor Center Drive
Suite 101
Anchorage, AK 99508

Emily Binnian
U.S. Geological Survey/EROS
4230 University Drive
Anchorage, AK 99508-4664
(907) 786-7020

Nevette Bowen
Alaska Conservation Foundation
430 W. 7th Suite 210
Anchorage, AK 99501
(907) 276-1917

Dave Bray *
Environmental Protection Agency
Region 10
1200 6th Avenue, MS-AT-062
Seattle, WA 98101
(206) 553-4253

Max C. Brewer
U.S. Geological Survey
4200 University Drive
Anchorage, AK 99508
(907) 786-7429

John Bridges *
U.S. Fish & Wildlife Service
4230 University Drive, Suite 310
Anchorage, AK 99508
(907) 561-2343

Ron Britton
U.S. Fish & Wildlife Service
1011 E. Tudor Road
Anchorage, AK 995o3
(907) 786-3483

Robert Brock *
Regional Supervisor
Leasing and Environment
Minerals Management Service
949 E. 36th Avenue, Room 603
Anchorage, AK 99508

Paul D. Brooks
U.S. Geological Survey
4230 University Drive
Anchorage, AK 99508
(907) 786-7000

Thomas Bucceri
State of Alaska
Division of Oil & Gas
P.O. Box 107034
Anchorage, AK 99510

Alice Burlington
UNOCAL
909 W. 9th Street
Anchorage, AK
(907) 263-7837

Alvin Burch
Alaska Draggers Assn.
Box 991
Kodiak, AK 99615
(907) 486-3910

Pat Burden *
Northern Economics
2810 Cutwater Court
Anchorage, AK 99516
(907) 345-5600

Don Calkins
Alaska Department of Fish and Game
333 Raspberry Road
Anchorage, AK 99518
(907) 267-2403

Kevin D. Callahan
Bogle & Gates
1031 W. 4th Suite 600
Anchorage, AK 99501
(907) 276-4557

Don Callaway
Minerals Management Service
Leasing and Environment
949 E. 36th Ave.
Anchorage, AK 99508-4302

Terry Carpenter
Corps of Engineers
P.O. Box 898
Anchorage, AK 99506

Anton Chaplin
Unocal
P.O. Box 196247
Anchorage, AK 99519-6247
(907) 263-7613

Tim Cochrane
National Park Service
2525 Gambell Street, RM 107
Anchorage, AK 99503
(907) 257-2526

Don Costanzo
Alaska Clean Seas
12350 Industry Way
Anchorage, AK 99519
(907) 345-3143

Doug Coughenower
4014 Lake Street, Suite 201 B
Homer, AK 99603
(907) 235-5643

Cleve Cowles
Minerals Management Service
Leasing and Environment
949 E, 36th Avenue, Rm. 603
Anchorage, AK 99508-4302

Michael Crane
NODC/NOAA
707 A Street
Anchorage, AK 99501
(907) 271-4063

Clara Crosby
Alaska Dept. of Environmental Conservation
4241 B Street, Suite 304
Anchorage, AK 99503
(907) 563-1126

Sal V. Cuccarese
Environment and Natural Resources institute/UAA
707 A Street
Anchorage, AK 99501
(907) 257-2718

Dr. Randall Davis *
Dept. of Marine Biology
Texas A&M University
P.O. Box 1675
Galveston, TX 77553
(409) 740-4527

Ken Dean
Geophysical Institute
University of Alaska, Fairbanks
Fairbanks, AK 99775-0800
(907) 474-7364

Susan Dearn
MBC Applied Environmental Sciences
947 Newhall Street
Costa Mesa, CA 92627
(714) 646-1601

Chuck Degan
P.O. Box 10
Unalakleet, AK 99684

George Divoky *
UAF-Inst. of Arctic Biology
10535 Interlake Ave., N
Seattle, WA 98133
(206) 364-2896

Brian Donaldson
Primary Care of Alaska, Inc.
P.O. Box 230446
Anchorage, AK 99523
(907) 522-1044

Rob Dragnich
Exxon Company, USA
P.O." Box 196601
Anchorage, AK 99519-6601

Paul Dubsky
Minerals Management Service
949 E. 36th Ave.
Anchorage, AK 99508

Lawrence Dugan
U.S. Fish & Wildlife Service
605 W, 4th Avenue, Room G-62
Anchorage, AK 99501
(907) 271-2888

Fred Dyson
Masterwork Charters
12239 Lugene Ln.
Eagle River, AK 99577
(907) 694-3744

Ray Emerson
Minerals Management Service
Leasing and Environment
949 E. 36th Avenue, Rm. 603
Anchorage, AK 99508-4302

Patrick Endres
Alaska Dept. of Environmental Conservation
4241 B Street, Suite 304
Anchorage, AK 99503
(907) 563-1126

Joanna Endter-Wada *
Utah St. University
Social Science Research Assoc.
P.O. Box 319
Millville, UT 64326
(601) 750-2487

David Erikson
Dames & Moore
5600 B Street
Anchorage, AK 99518
(907) 562-3366

Laurie Fairchild
US Fish and Wildlife Services
605 W. 4th Avenue, Rm. G62
Anchorage, AK 99501
(907) 271-2781

Jim Fall *
Alaska Dept. of Fish and Game
333 Raspberry Road
Anchorage, AK 99518-1599
(907) 267-2359

Vivian Forrester
State of Alaska
Division of Oil & Gas
P.O. Box 107034
Anchorage, AK 99510

Linda L. Freed
Kodiak Island Borough
710 Mill Bay Road
Kodiak, AK 99615
(907) 486-9360

Michael Galginaitis
Impact Assessment Inc.
911 West 8th Avenue, Suite 402
Anchorage, AK 99501
(907) 272-6811

Lee Ann Gardner
ENSR
750 W. 2nd St., #100
Anchorage, AK 99501
(907) 276-4302

Chris Gates
Prince William Sound
Regional Citizen's Advisory Council
601 W. 5th Avenue, Suite 500
Anchorage, AK 99501
(907) 277-7222

Joy Geiselman
Minerals Management Service
Leasing and Environment
949 E. 36th Avenue, Rm. 603
Anchorage, AK 99506-4302
(907) 271-6596

Paul Gertler *
U.S. Fish and Wildlife Service
1011 E. Tudor Road
Anchorage, AK 99503
(907) 786-3579

Karen Gibson
Minerals Management Service
Leasing and Environment
949 E. 36th Avenue, Rm. 603
Anchorage, AK 99508-4302
(907) 271-6613

Shelia Gottehrer *
Prince William Sound
Regional Citizens'
Advisory Council
601 West Fifth Avenue, Suite 500
Anchorage, Alaska 99501-2254
(907) 277-7222

Bill Grether
ARCO Alaska, Inc.
P.O. Box 100360
Anchorage, AK 99510
(907) 265-6459

Ed Grossman
U.S. Fish & Wildlife Service
Juneau Ecological Services
P.O. Box 021287
Juneau, AK 99802
(907) 586-7240

Paul Gronholdt
RTWG
P.O. Box 288
Sand Point, AK 99601
(907) 383-4081

Dan Hamson
National Park Service
2525 Gambell Street Room 107
Anchorage, AK 99503
(907) 257-2526

Peter Hanley
BP Exploration
P.O. Box 196612
Anchorage, AK 99519
(907) 561-5111

Don Hansen
Minerals Management Service
Leasing and Environment
949 E. 36th Avenue, Room 603
Anchorage, AK 99508-4302

Jeanne Hanson
National Marine Fisheries Service
222 W. 7th Avenue, #43
Anchorage, AK 99513
(907) 271-5006

Louise Hanson
ARCO Alaska
700 G. St. NSK Box 53
Anchorage, AK
(907) 659-7309

Patrick Harmon
Masterwork
9421 Stewart Cir.
Eagle River, AK 99577
(907) 696-0299

Scott Hatch *
U.S. Fish & Wildlife Service
1011 E. Tudor Road
Anchorage, AK 99503
(907) 786-3529

Steve Heimel
AK Public Radio Network
810 E. 9th Ave.
Anchorage, AK
(907) 277-2776

Carrie Holba
Oil Spill Information Center
645 G Street
Anchorage, AK 99501
(907) 278-8008

Tim Holder
Minerals Management Service
Leasing and Environment
949 E. 36th Avenue, Room 603
Anchorage, AK 99508-4302

Anne Holmquist
Chevron Oilfield
Research Company
P.O. Box 446
La Habra, CA 90633-0446
(21 3) 694-7454

Jon Houghton *
Pentech Environmental, Inc.
120 W. Dayton, Suite A7
Edmonds, WA 98020
(206) 775-4682

Joel Hubbard
Minerals Management Service
Leasing and Environment
949 E. 36th Avenue, Room 603
Anchorage, AK 99508-4302

Jerry Hupp *
U.S. Fish & Wildlife Service
1011 E. Tudor Road
Anchorage, AK 99503
(907) 786-3529

Jerry Imm *
Chief, Environmental Studies Section
Minerals Management Service
949 E. 36th Avenue, Room 603
Anchorage, Alaska 99506

Gail Irvine
National Park Service
2525 Gambell Street, Room 107
Anchorage, AK 99503
(907) 257-2526

Laurie Jarvela
Minerals Management Service
949 E. 36th Ave.
Anchorage, AK 99508

Carol Jorgensen
Arctic Marine Research Commission
1001 E. Benson
Anchorage, AK 99508
(907) 276-5400

Harry N. Young, Jr.
U.S. Coast Guard
601 W. 5th Avenue
Anchorage, AK 99501
(907) 263-1765

Susanne Kalxdorff
U.S. Fish & Wildlife Service
1011 E. Tudor Road
Anchorage, AK 99516
(907) 786-3458

Janet Kennedy
Kirrnetic Laboratories, Inc.
403 W. 8th Avenue
Anchorage, AK 99501
(907) 276-6178

Dale Kenney
Minerals Management Service
Leasing and Environment
949 E. 36th Avenue, Rm. 603
Anchorage, AK 99508-4302

Christine Klein *
Prince William Sound
Regional Citizens' Advisory Council
601 West Fifth Avenue, Suite 500
Anchorage, Alaska 99501-2254
(907) 277-7222

Tom Laley
ENSR Consulting & Engineering
700 W. 2nd Avenue, Suite 100
Anchorage, AK 99501
(907) 276-4302

Steve Landino
Minerals Management Service
Leasing and Environment
949 E. 36th Avenue, Room 603
Anchorage, AK 99508-4302

Gabrielle LaRoche
Office of the Governor
Div. of Governmental Coordination
P.O. Box 110030
Juneau, AK 99811-0030
(907) 465-3562

Harold Lee
Lee's Consulting Service
3540 Fordham Drive
Anchorage, AK 99508

Jon Lewis
AK Dept. Fish & Game
333 Raspberry Road
Anchorage, AK 99518-1599

Tom Loughlin *
National Marine Fisheries Service
7600 sand Point Way, NE
Seattle, WA 98115
(206) 526-4040

Cindy Lowry
Greenpeace
P.O. 60X 104432
Anchorage, AK 99510

Paul Lowry
Minerals Management Service
Leasing and Environment
949 E. 36th Avenue, Room 803
Anchorage, AK 99508-4302

Jane Lund
1670 Eastridge Drive, #102
Anchorage, AK 99501
(907) 277-0320

Andria Lust
Alaska Wildlife Response Center
6132 Neilson Way
Anchorage, AK 99518
(907) 862-1026

Dennis Maguire *
Federal On-Scene Coordinator
U.S. Coast Guard
601 W. 5th St., Suite 410
Anchorage, Alaska 99501
(907) 263-1701 or 1776

Brad Mahanes *
U.S. Environmental Protection Agency
401 M Street, S.W.
Washington, D.C. 20460
(202) 260-1056

Barbara Mahoney
National Marine Fisheries Service
222 West 7th Avenue #43
Anchorage, AK 99513

Dennis Marks
U.S. Fish & Wildlife Service
Dept. MBM
1011 E. Tudor Road
Anchorage, AK 99503
(907) 786-3453

Doug Martin *
Pentech Environmental, Inc.
120 W. Dayton, Suite A7
Edmonds, WA 98020
(206) 775-4682

Warren Matumeak
Arctic Slope Regional Corp.
P.O. Box 129
Barrow, AK 99723
(907) 852-8633

David E. McGillivary
U.S. Fish & Wildlife Service
605 W. 4th Avenue Room G-62
Anchorage, AK 99501
(907) 271-2888

Dr. Michael D. McGurk *
Triton Environmental
Consultants, Ltd.
13511 Commerce Park Way,
Suite 120
Richmond, BC
V6V 2L1 CANADA
(604) 279-2093

Paul McLaughlin
National Park Service
2525 Gambell Street
Anchorage, AK 99503
(907) 257-2562

Jim Meitener
Tesoro Alaska - Kenai
P.O.Box 3369
Kenai, AK 99611

Vivian Mendenhall•
U.S. Fish & Wildlife Service
1011 E. Tudor Road
Anchorage, AK 99503
(907) 786-3517

Bob Meyer
Minerals Management Service
Leasing and Environment
949 E. 36th Avenue, Rm. 603
Anchorage, AK 99508-4302

S. Douglas Miller
National Wildlife Federation
Alaska Natural Resource Center
75o West Second Avenue,
Suite 200
Anchorage, AK 99501-2168

James Miller
Science Applications
International Corp.
911 W. 8th Avenue, Suite 401
Anchorage, AK 99501
(907) 272-7242

Pamela Miller
Greenpeace
P.O. Box 104432
Anchorage, AK 99510

Rita Miraglia
Alaska Dept. of Fish & Game
Subsistence Division
333 Raspberry Road
Anchorage, AK 99518
(907) 267-2358

Craig Mishler
Alaska Dept. of Fish & Game
333 Raspberry Road
Anchorage, AK 99518
(907) 267-2357

Kathryn L. Mitchell
MBC Applied Environmental
Sciences
947 Newhall Street
Costa Mesa, CA 92627
(714) 646-1601

Charles T. Mitchell
MBC Applied Environmental
Sciences
947 Newhall Street
Costa Mesa, CA 92627
(71 4) 646-1601

Kyle Monkelien
Minerals Management Service
Leasing and Environment
949 E. 36th Avenue, Room 603
Anchorage, AK 99508-4302

Ron Morris *
National Marine Fisheries
Service
222 W. 7th Avenue, #43
Anchorage, AK 99513
(907) 271-5006

John Morsell
Northern Ecological Service
17130 Tideview Dr.
Anchorage, AK 99516
(907) 345-4944

Margaret Murdock
Harding Lawson Associates
601 E. 57th Place
Anchorage, AK 99518
(907) 563-8102

Tom Murrell *
Field Operations
Minerals Management Service
949 E. 36th Avenue, Room 603
Anchorage, Alaska 99508

Barbara Nather
Minerals Management Service
Leasing and Environment
949 E. 36th Avenue, Room 603
Anchorage, AK 99506-4302

Jon Nauman
Minerals Management Service
949 E. 36th Ave.
Anchorage, AK 99508
(907) 271-6181

Hans Nelson *
U.S. Geological Survey
345 Middlefield Road
Menlo Park, CA 94025
(41 5) 354-3057

Tom Newbury
Minerals Management Service
Leasing and Environment
949 E. 36th Avenue, Rm. 603
Anchorage, AK 99508-4302

Jon Nickles *
U.S. Fish & Wildlife Service
4230 University Drive, Suite 310
Anchorage, AK 99508
(907) 271-2394

Bill Park
Marine Spill Response Corp.
(MSRC)
190 W. Dayton, Suite 103
Edmonds, WA 98020
(206) 774-6772

Jill Parker
U.S. Fish & Wildlife Service
Office of Oil Spill
1011 E. Tudor Road
Anchorage, AK 99503
(907) 786-3591

Lisa Parker *
Cook Inlet Regional Citizens
Advisory Council
11355 Frontage Road, Suite 228
Kenai, Alaska 99611
(907) 263-7222

Eugene Pavia *
Dept. of Environmental
Conservation
P.O.Box 83241
Fairbanks, Alaska 99708
(907) 479-2792

Bradley Penn
Marathon Oil Company
P.O. Box 190166
Anchorage, AK 99516-0168
(907) 564-6428

Lyle D. Perrigo
Alaska Region
U.S. Arctic Research Commission
707 A Street
Anchorage, AK 99501
(907) 257-2738

George Petnikoff
City of St, Paul
Pouch One
St. Paul Island, AK 99660
(907) 546-2331

John Petterson *
Impact Assessment, Inc.
2160 Avenida de la Playa, #A
La Jolla, CA 92037
(619) 459-0142

Anna Phillip
Alaska Indigenous Council for the Environment
P.O. Box 100454
Anchorage, AK 99510
(907) 279-2511

John Piatt *
U.S. Fish & Wildlife Service
1011 E. Tudor Road
Anchorage, AK 99503
(907) 786-3549

Joni Piercy
Alaska Dept. Environmental Conservation
8321 Pioneer Drive
Anchorage, AK 99504
(907) 338-4993

Ruth Poff
Minerals Management Service
Leasing and Environment
949 E. 36th Avenue, Room 603
Anchorage, AK 99508-4302

Dick Prentki
Minerals Management Service
Leasing and Environment
949 E. 36th Avenue, Rm. 603
Anchorage, AK 99508-4302

Richard L. Ranger
ARCO Alaska, Inc.
P.O. Box 100360
Anchorage, AK 99510-0360
(907) 263-4318

Mark Reed *
Applied Science Associates, Inc.
70 Dean Knauss Dr.
Narragansett, RI 02882-1143
(401) 789-6224

Jim Regg *
Field Operations
Minerals Management Service
949 E. 36th Avenue, Room
6^X^P; Robbins *
Graduate School of Design
Harvard University
8 Norfolk Terrace
Wellesley, MA 02181
(617) 495-6092

Dick Roberts
Minerals Management Service
Leasing and Environment
949 E. 36th Avenue, Room 603
Anchorage, AK 99508-4302

Donna Robertson
U.S. Fish & Wildlife Service
1011 E. Tudor Road
Anchorage, AK 99503
(907) 786-3432

Paul Rookok
P.O. Box 135
Savoonga, AK 99769

Paul Rusanowski
Office of the Governor
Governmental Coordination
P.O. Box 110030
Juneau, AK 99811-0030
(907) 465-3562

David Sale
Alaska Dept. of Environmental Conservation
4241 B Street, Suite 304
Anchorage, AK 99503
(907) 563-1126

Gerald A. Sanger
Chugach National Forest
201 E. 9th Ave., #206
Anchorage, AK 99501
(907) 271-2560

Susan M. Saupe
Institute of Marine Science
University of Alaska
123 O'Neill Bldg. UAF
Fairbanks, AK 99775
(907) 474-7384

John Schindler
Minerals Management Service
Leasing and Environment
949 E. 36th Avenue, Rm. 603
Anchorage, AK 99508-4302

David Schmidt
Dames & Moore
5600 B Street
Anchorage, AK 99518
(907) 562-3366

Jim Schumacher *
PMEL/NOAA
7600 Sand Point Way, NE
Seattle, WA 98115
(206) 526-6197

Dara J. Seagars
US. Fish & Wildlife Service
Marine Mammals Management
4230 University Drive, Suite 310
Anchorage, AK 99508
(907) 271-2379

Doug Segar
Environmental and Natural Resources institute/UAA
707 A Street
Anchorage, AK 995o1
(907) 279-4523

Nadeen Siddiqui
Alaska Dept. of Environmental Conservation
4241 B Street, Suite 304
Anchorage, AK 99503
(907) 563-1126

Bill Simeone
Stephen R. Braund & Associates
308 G Street, Suite 323
Anchorage, AK 99510
(907) 276-8222

Claudia Slater
AK Dept. Fish & Game
- Habitat Div.
333 Raspberry Road
Anchorage, AK 99518-1599

Dorothy Smith
Greenpeace
P.O. Box 104432
Anchorage, AK 99510
(907) 277-8234

Louise Smith
Alaska Biological Research
P.O. Box 81934
Fairbanks, AK 99708
(907) 455-6777

Caryn Smith
Minerals Management Service
Leasing and Environment
949 E. 36th Avenue, Rm. 603
Anchorage, AK 99508-4302

Louise Smith
Alaska Biological Research
P.O. Box 81934
Fairbanks, AK 99708
(907) 455-6777

Kristin Stahl-Johnson
RCAC
P.O. Box 2661
Kodiak, AK 99615
(907) 486-4684

Ronald Stanek
AK Dept. of Fish and Game
333 Raspberry Road
Anchorage, AK 99518
(907) 267-2362

Sam Stoker
4920 Anderson Road
Fairbanks, AK 99707
(907) 479-5744

Dan Strickland
RCAC
601 West Fifth Avenue, Suite 500
Anchorage, AK 99501-2254
(907) 277-7222

William Stringer *
Geophysical Institute
University of Alaska
611 E. Elvy Bldg.
Fairbanks, AK 99775
(907) 474-7455

Len Suiter
Kuparuk Spill Response Team
P. O. Box 196105
Anchorage, Alaska 99519-6105
(907) 659-7472

Nancy Swanton
Minerals Management Service
Leasing and Environment
949 E. 36th Avenue, Room 603
Anchorage, AK 99508-4302

Chris Swenson
AK Dept. Fish & Game
333 Raspberry Road
Anchorage, AK 99518-1599

Henry Tomingas
Ocean Explorers
P.O. Box 111321
Anchorage, AK 99511
(907) 345-6126

Don C. Tomlin
U.S. Bureau of Indian Affairs
1675 C Street
Anchorage, AK 99501-5198
(907) 271-4124

Cynthia Toohey
Crow Creek Mine
2642 Forest Park Dr.
Anchorage, AK 99517
(907) 278-6060

Evert Tornfelt
Minerals Management Service
Leasing and Environment
949 E. 36th Avenue, Room 603
Anchorage, AK 99508-4302

Steve Treaty
Minerals Management Service
Leasing and Environment
949 E. 36th Avenue, Rm. 603
Anchorage, AK 99508-4302

Dick Tremaine
LGL Alaska Research Associates
4175 Tudor Centre Drive
Anchorage, AK 99508
(907) 562-3339

DeClan Troy *
Troy Ecological Research Assoc
2322 E. 16th Ave.
Anchorage, AK 99508
(907) 276-3436

Bill VanDyke
Alaska Div. of Oil & Gas
P.O. Box 107034
Anchorage, AK 99510

Nancy S. Wainwright
Attorney-at-Law
13030 Back Road
Anchorage, AK 99515

Jeff Walker *
Field Operations
Minerals Management Service
949 E. 36th Avenue, Room
Anchorage, AK 99508

Tom Weingartner *
Institute of Marine Sciences
University of Alaska
Fairbanks, Alaska 99775-1080
(907) 474-7993

Gary Wheeler
U.S. Fish & Wildlife Service
605 W. 4th Avenue, Rm G-62
Anchorage, AK 99501
(907) 271-2888

Bill Whiteside
Great APE
Box 202142
Anchorage, AK 99520

Robert J. Wienhold
Minerals Management Service
949 E. 36th Ave.
Anchorage, AK 99508
(907) 271-6665

Suzanne Winder
Public Awareness Committee
for the Environment
100 Trading Bay, Suite 4
Kenai, AK 99611
(907) 283-7170

David Withrow
NOAA - National Marine
Mammal Lab
7600 Sand Point Way, Bldg. 4
Seattle, WA 98115
(206) 526-4019

Larry Wright
National Park Service
2525 Gambell St.
Anchorage, AK
(907) 257-2649

Jon Zuck
Bering Sea Fishermen's
Association
725 Christensen Drive
Anchorage, AK 99501
(907) 279-6519