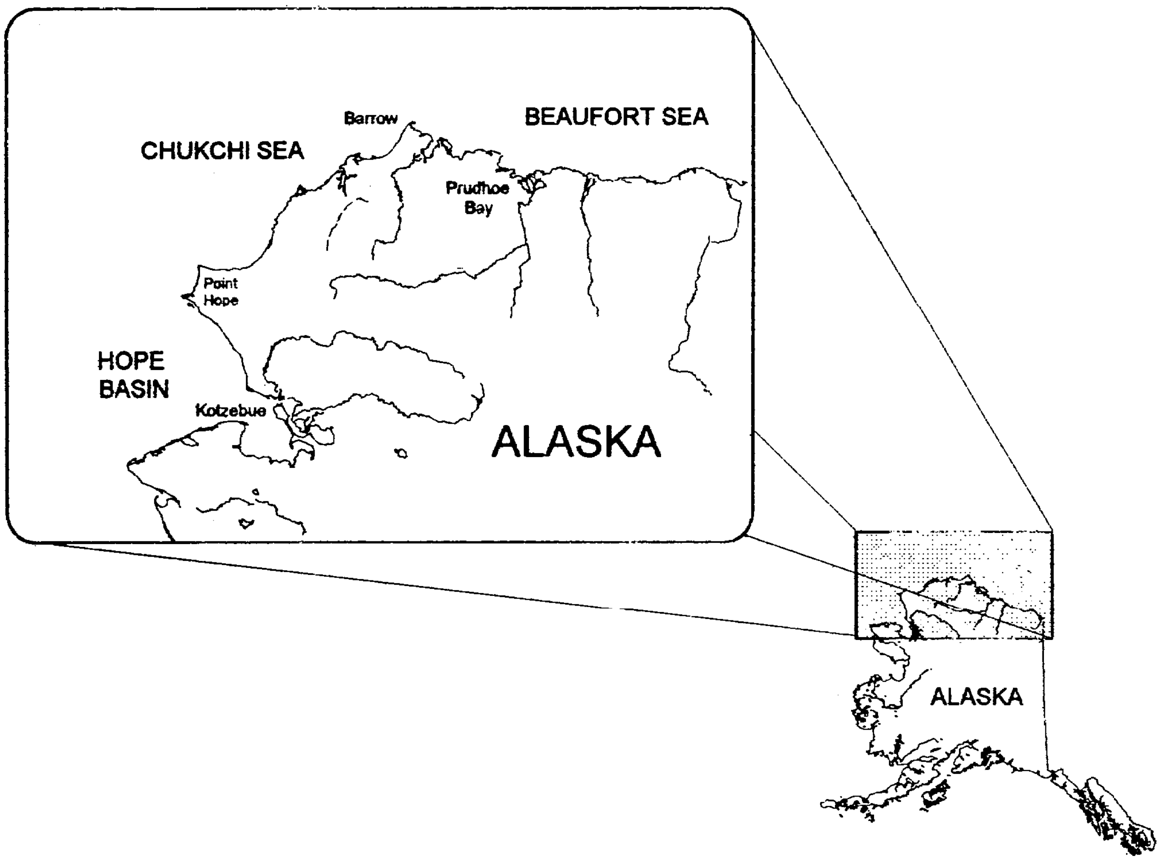
OCS Study
MMS 93-0043

Alaska OCS Region

FIFTH INFORMATION TRANSFER MEETING

Conference Proceedings



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

OCS Study MMS 93-0043

ALASKA OCS REGION
FIFTH INFORMATION TRANSFER MEETING

Conference Proceedings

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Chair: Robert Meyer, Minerals Management Service

WELCOME AND INTRODUCTION

Wednesday, January 20, 1993

INTRODUCTORY REMARKS

Joy Geiselman
ITM Coordinator
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Good morning. I am Joy Geiselman, the coordinator for this Information Transfer Meeting and an oceanographer on the Environmental Studies staff of the Minerals Management Service. I would like to welcome you and thank you all for attending this meeting. I would also like to introduce Kathy and Chuck Mitchell with MBC Applied Environmental Sciences. They are MMS' contractors for the logistics of this Information Transfer Meeting. Kathy, Chuck and I are here to be of any assistance in regard to this meeting. So please find one of us if you have any questions or problems or need any information. I just have a few brief reminders. Please feel free to ask questions of the speakers. We do ask you to use the microphones in the center of the room and also to identify yourself. This year's Information Transfer Meeting is an opportunity to comment on the information base available for future OCS oil and gas lease sales proposed in the Beaufort Sea, Chukchi Sea, and the Hope Basin. Comments can be made during the question periods of the sessions or they can be written on the form found in your packet. These forms can be turned in here at the meeting to Kathy, Chuck, to me or the Session Chairs or they can be mailed to the Minerals Management Service. We also have in your packets some feedback forms and mail list forms, if you would like to be on our mailing list.

There will be a published proceedings from this Information Transfer Meeting. If you would like one, please be sure to register for the meeting.

Now I would like to introduce Alan Powers, the Regional Director for the Minerals Management Service, Alaska OCS Region.

WELCOME

Alan D. Powers
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Good morning. I, too, would like to welcome you to the Region's Fifth Information Transfer Meeting. I suspect that this may be the Clinton Administration's first scientific meeting, but I am not absolutely sure about that, so we can't really make that claim without doing a lot of checking. This meeting is going to focus on the Arctic and it serves two purposes. First, it is an open forum for the exchange of scientific information and ideas and as Joy mentioned, it serves as the Information Base Review for three prospective lease sales in the Arctic: the Beaufort Sea, the Chukchi Sea, and the Hope Basin. These sales are tentatively scheduled for 1995, 1996, and 1997, respectively. This meeting is a public meeting and is part of our public input process, and every speaker will allow time for questions and discussions. I want to personally thank all of the speakers for their time and effort. For without their contributions, the meeting could not be held. The Outer Continental Shelf program, like many other Federal programs, has a contracting budget. Consequently, there is increasing competition for the funding of new studies. New undertakings must have solid justifications and must be shown to be superior to other funding alternatives if they are going to be financed. Fortunately, both the Beaufort and Chukchi Seas have already received considerable information-gathering attention. I don't want to leave it on a low note like that, but that is kind of a fact of life for our agency and for a lot of other Federal agencies. So now, so that the meeting can go on, I'll thank Joy and turn it over to the next speaker.

DECISION-MAKING UNDER THE AREA EVALUATION AND DECISION PROCESS

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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 consultation, information acquisition, public input, environmental analysis, decision, and review and comment procedures under the OCS Lands Act and the National Environmental Policy Act (NEPA).

Coordination with and public input from 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.

Two new steps were input in the process.

1. The Information Base Review (IBR) step which is what we are doing with this ITM. We are reviewing the information available for the EIS and want your help in that process.

2. The proposed Notice of Sale (NOS) comes out with the draft EIS instead of after the final EIS.

The major emphasis of the AEDP is the public input process. We accept input anytime — if it arrives too late for one step, it will be picked up in the next step.

Public input is formally requested at:

1. Information Base Review so we can be sure we have the latest information available to use in our process.

2. Call for Information and Nomination. Request for specific concerns with a specific area.

3. Scoping. Request to be sure the EIS covers all concerns.

4. Public Hearing. Formal hearings on the draft EIS.

THE ENVIRONMENTAL STUDIES PROGRAM: CURRENT STATUS AND RESEARCH PRIORITIES; AND UPDATE ON THE NRC/NAS REVIEW OF THE ADEQUACY OF INFORMATION AVAILABLE ON THE BEAUFORT AND CHUKCHI SEAS AND THE NAVARIN BASIN

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It only seems like a year since we held the last ITM, and I guess it is because it was held just a year ago. I want to add my welcome and appreciation to those attending, and those who are presenting papers or otherwise participating. This, the Fifth Alaska OCS, ITM will focus on studies related to the Beaufort and Chukchi Seas and to the Hope Basin. I will spend a little bit of time on the studies program, and also on the National Review Committee/National Academy of Sciences (NRC/NAS) review update. 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. Our goal is to provide MMS and the public with more up-to-date information on the research that has been performed since our last Arctic-focused ITM. Again, I would like to repeat my thanks to those participating.

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 activities (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 the extent that OCS development can potentially affect the human, marine and coastal environment.

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

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

Again, the basic purpose has not changed, even though budgets, direction and focus have changed many times over the years.

The ESP in Alaska is still experiencing change, and that may accelerate given the uncertainties of possible new program direction. Since last year's ITM, the same conditions largely apply to the Alaska program, except for a possible upturn in interest in the Arctic planning areas sparked by ARCO's Kuvlum discovery and the continuing interest in Cook Inlet. We still haven't received the benefit of the NRC/NAS review in the Chukchi, Beaufort Seas, and in the Navarin Basin. We are still largely focusing on the Arctic areas, and in a general sense we have more contemporary studies information in those areas than in others.

I can report that we are well on the way to the establishment of a significant cooperative research effort with the University of Alaska, Fairbanks, and one that we are looking forward to as a productive relationship.

The NRC/NAS review panel did submit a Congressionally requested interim report to MMS in June 1992, which was basically an update of activities to date. The panel also visited Alaska in September of this year, and focused on receiving comments about the program from the residents of Barrow in public meetings held there and also in Anchorage afterwards. They also received a briefing from MMS, and are proceeding, and should be able to deliver the final report by the September 1993 due date.

RESOURCE EVALUATION AND PETROLEUM POTENTIAL OF THE BEAUFORT AND CHUKCHI SEAS AND HOPE BASIN

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Larry Cooke has served the Federal Government as an evaluator of oil and gas resources for 20 years. His interests include resource assessment methods and offshore resource potential. He received his B.S. degree in geology from Virginia Polytechnic Institute. Mr. Cooke currently supervises the Resource and Economic Analysis Section of the Minerals Management Service.

INTRODUCTION

Minerals Management Service (MMS), an Agency of the U.S. Department of the Interior (DOI), administers the Federal offshore minerals leasing program. The MMS independently assesses the undiscovered oil and gas resource potential of the Outer Continental Shelf (OCS) to identify areas for possible leasing and exploration. The Arctic Federal offshore, which includes the Beaufort Sea, Chukchi Sea, and Hope Basin administrative planning areas, has favorable geologic attributes for the formation of oil and natural gas accumulations. Alaska, in particular the Arctic, has the highest potential for large oil accumulations in the United States. The question is whether these undiscovered accumulations could be large enough to overcome constraints related to the harsh environment and remote locations and the attendant high development and transportation costs.

RESOURCE EVALUATION PROGRAM

The DOI is required by the OCS Lands Act and Amendments to periodically assess and report to the Congress on the undiscovered oil and gas resource potential of the Federal offshore (Dellagiarino 1986). MMS, through the Resource Evaluation Program (RE), estimates both the undiscovered resources and the net economic value of specific tracts. RE addresses the following questions:

- Is there ANY undiscovered, commercially recoverable oil and gas in the evaluation area?
- If any, then how much?
- What is it worth?

An early step in the resource assessment process is to acquire all available, relevant geological and geophysical information. The information includes various surveys in drilled wells in the area (if any), and grids of common depth point (CDP) seismic data collected during offshore geophysical surveys. The seismic data is processed by computer to yield a seismic profile, resembling a slice through the rock layers underlying the seafloor. Individual profiles are interpreted and tied to existing well data, where possible. The profiles are collected in a grid. Particularly strong subsurface reflectors corresponding to prospective rock layers are traced across each profile and through the grid. Depths to the rock layer are mapped throughout the grid and contoured to yield an image of the subsurface rock layer, showing various uplifts and depressions, similar to a topographic map of the surface. Prospects are uplifts or other geologic features which can capture migrating oil and gas.

Geologic studies are initiated to assess whether key geologic attributes are present in the area. Absence of any one of these attributes means that economic accumulations of oil and gas will not be discovered. Adequate source rocks must be present to generate oil or gas in sufficient quantities to fill traps. Reservoir rocks must be available with sufficient porosity and permeability to store the hydrocarbons and allow them to flow when produced. Migration pathways must exist to permit generated hydrocarbons to flow from the source to the reservoir. A mechanism must exist to trap the oil and gas in the reservoir, and a dense seal or cap must be in place over the reservoir to prevent the hydrocarbons from migrating to the surface. If available data indicate that these geologic attributes are favorable for an area, then individual prospects are assessed by estimating ranges of values for uncertain geologic variables.

In addition to geologic variables, engineering and economic factors are assessed. Even though oil and gas accumulations may exist in an area, they may not be of sufficient size to proceed with development.

Ranges of possible values for geologic, engineering, and economic values for individual prospects are entered into an MMS drilling simulation program. The computer model simulates the possible results if a drilling program is conducted. The results are a range of possible answers with associated probabilities of occurrence.

The estimates are used:

- as a basis of analysis in socio-environmental studies and decision documents (e.g., Environmental Impact Statements);
- as a basis for oil spill risk analysis studies;
- to estimate economic benefits which could result from a lease sale; and
- as information to develop a 5-year leasing plan.

In the event that an area is offered for lease, RE determines the adequacy of bids received on individual tracts, by using market criteria and a detailed tract evaluation method. Tract evaluation provides a tract-specific risked net present value, based on estimates of resources, development and production schedules, price and costs projections, tax considerations, and geologic and economic risk factors.

The undiscovered, conditional oil (a statistical quantity obtained if it is assumed that economically recoverable oil exists in the areas) estimated by MMS, as of January, 1990, for the Arctic OCS is show in Table 1 (Cooke, 1991).

Table 1. MMS estimates of undiscovered oil for the Arctic OCS, January 1990.

Area	Average (billion barrels)	High (billion barrels)	MP
Chukchi Sea	5.96	13.10	0.23
Beaufort Sea	1.66	4.69	0.23
Hope Basin	0.50	1.44	0.01

BEAUFORT SEA POTENTIAL

The primary geologic elements of Arctic Alaska are illustrated in map view on Figure 1 (Sherwood 1993) and in cross-section on Figure 2 (Thurston and Theiss 1987). Particularly noteworthy is the regional uplift known as the Barrow Arch, along which the producing fields are located. The trough of the Arctic Alaska and Colville Basins is located south of the arch. Like onshore Alaska, the Beaufort Sea has favorable geologic attributes, including rich source

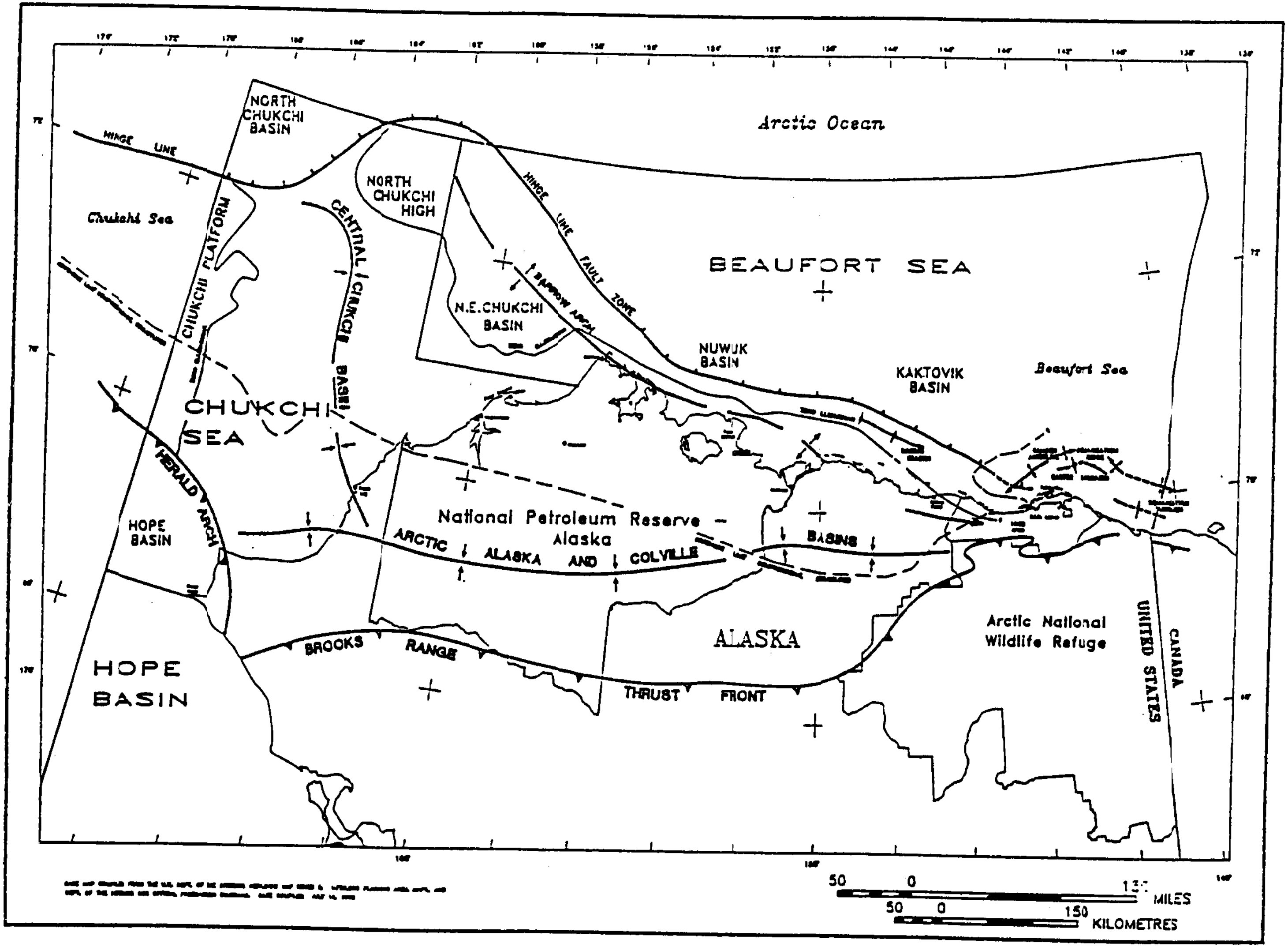

Figure 1. Geologic elements of Arctic Alaska.

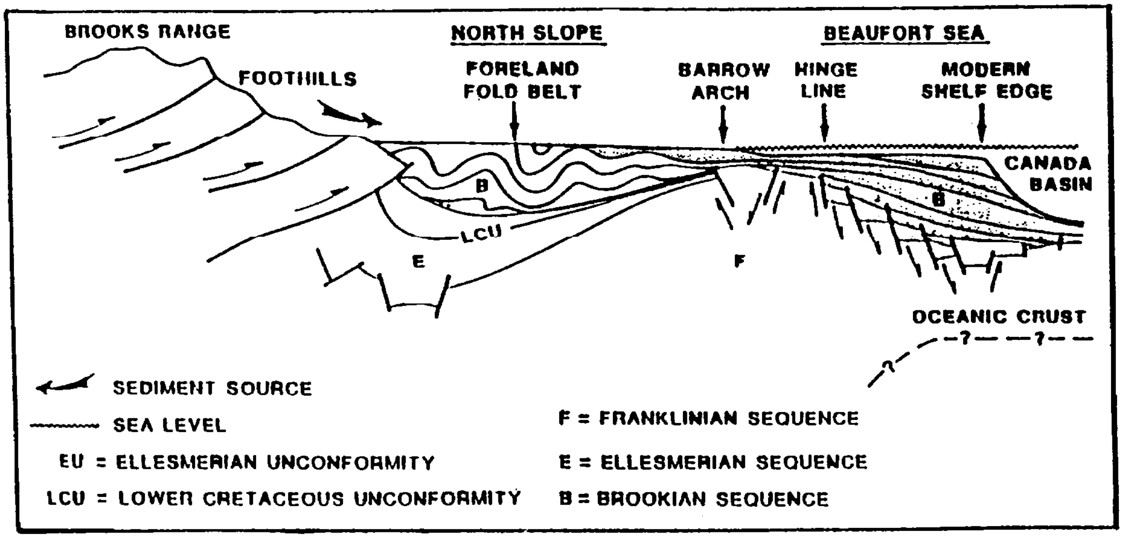

Figure 2. Beaufort Sea cross-section.

rocks, excellent reservoirs, various traps, migration paths, and seals. Existing production is from an older rock sequence which contains excellent sources and reservoirs. Since 1946, over 30 oil and gas discoveries have occurred onshore and in the state offshore waters.

As shown in Figure 2, the older sequence ("E") thins onto the Barrow Arch. Future exploration targets for the Federal OCS are primarily in a younger sequence ("B") north of the Barrow Arch. This younger sequence is thick, but potential reservoirs are often thin and localized, with moderate to good porosity.

The Beaufort Sea has had five lease sales and 25 exploratory wells, including the most recent ARCO discovery at the Kuvlum prospect. Over 1 billion barrels of oil (BBO) have been discovered but not produced in Arctic Alaska (onshore and state waters). In spite of the favorable geologic characteristics, a combination of low prices, high development and transportation costs, and more favorable operating and regulatory conditions overseas has prevented the development of what would be considered giant discoveries anywhere else in the U.S. The overriding question in Arctic Alaska is whether accumulations will be of sufficient size to warrant development and production. Economic viability of Federal OCS prospects is enhanced by their proximity to the Trans-Alaska Pipeline System (TAPS).

CHUKCHI SEA

Two Federal lease sales have occurred in the Chukchi Sea Planning Area. The area contains proven North Slope reservoirs, source rocks, and seals. Trap and migration factors are favorable. Numerous prospects have been identified and mapped. The area is geologically complex, highly faulted, and has been explored by only four wells. Economics and the harsh environment have constrained exploration. Although the geologic elements are favorable, lack of transportation infrastructure would restrict economic viability of discoveries to fields in the supergiant (greater than 1 BBO) category.

HOPE BASIN

Hope Basin has not had a previous Federal lease sale and is untested by exploratory drilling. The Herald Arch separates the Chukchi Sea and the Hope Basin (Figure 1). Two onshore wells show excellent reservoir properties. However, the area has complex faulting, smaller prospect sizes, and young sediments which may not have been adequately buried to generate oil. If anything, the development and economic constraints described for the Chukchi Sea would be even more severe for Hope Basin.

SUMMARY AND CONCLUSIONS

With the economic and engineering challenges of working in the Arctic, why even consider the area for development? When compared with other oil producing nations of the world, the U.S. has fallen to the "middle of the pack" in terms of proven oil reserves, having less than one-tenth of the reserves of Saudi Arabia. The Arctic inevitably must be considered for development, because it contains such a rich share of the nation's increasingly meager hydrocarbon endowment. A 1987 DOI assessment of undiscovered resources shows one-third of the remaining United States oil potential to be in onshore and offshore Alaska (Mast et al. 1989).

Low oil and gas prices, high development and transportation costs owing to logistics and the harsh environment, and more favorable operating and regulatory conditions overseas impede Arctic exploration. The Beaufort Sea has the highest near term potential, having proven accumulations and access to onshore transportation facilities. Chukchi has high oil potential, but development potential is more questionable. Finally, Hope Basin is the least likely to overcome economic constraints, given its location and the low oil potential.

With favorable geologic factors, the Arctic has the highest U.S. potential for large oil accumulations. Technology, economics, and the stability of foreign sources will determine the viability of future Arctic discoveries.

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QUESTIONS AND DISCUSSION

TOM NEWBURY: Was the Kuvlum discovery right along the Barrow Arch?

LARRY COOKE: It is on the other side of the Arch. This is the coast line, the Arctic National Wildlife Reserve down here, and Kuvlum would be located in a position like this. So it is on the far side of the Arch.

JERRY IMM: How many discoveries have actually been made in the Beaufort, on the OCS?

LARRY COOKE: Six that are producible.

BRUCE MATE: I have a question that might seem a little glib but I am sure it is complex. If I were a market investor right now, I would see that lease sales might go at a more favorable price right now because of the world conditions and the more favorable offshore markets for oil. But if I were an oil company thinking about the long term investment before I could reap a benefit, obviously the other sources of oil are cheaper. How do you go about bringing that basis for judgement in your economic assessment of whether a bid is valued enough to let a lease now from the stewardship side of your responsibility? I know it is a very difficult question, I've asked something really hard, but could you give us just a kernel of how you perceive the near term or the far term when the present economics are so strongly dictating a different direction?

LARRY COOKE: It is a very good question. He is asking how do you judge a bid with the current economics? Is it better to go and lease something now or to wait? Is that essentially what you are saying? And it is a good question. It really gets more into policy. Do we wait until a future time? Right now we are basically going at a very slow pace in the Arctic. If you look at bids, with the current prices, with the high up front costs, with the long lead times necessary for development, that is going to drastically lower the value of those resources. So you are right. That means that they are valued less today than if you had some vision that prices would be high and stay fairly high. In fact that is what we have seen in the past when prices were high and projections were that they would stay high. That is when we saw a lot of development in the Arctic. Now development has backed off. There is sort of a low level. In the last two sales in the Arctic, in the Chukchi and Beaufort, we had very low interest. So I think it is sort of taking care of itself. If prices were projected to be higher, then I think you would see the activity increase.

BRUCE MATE: I guess I'll pursue it just moment longer, seeing this is also considered a public input session. It strikes me that the things that dictate the determination of whether a bid is adequate or not are dictated by the long development time it will take to get oil out. But the things that affect the price of oil can be as quick as a change in the Persian Gulf next week or next month. It is a very difficult situation you face trying to balance these values, of present value and future value. In public documents I have seen, there is not a good description of how you come to grips with that near term and long term value in a changing world. I would love to see something like that in a format that was digestible by lay public.

LARRY COOKE: The only way that we can do it at this point it to use statistical methods that allow you to look at a low cost scenario versus a high cost scenario. And the methods that we do use in the tract evaluation allow you to input variables for things like oil price and have it change. Running the model a number of times, coming out with a wide variety of results. Ultimately, you are basing the decision on an average value that comes out of that. Those are the tools that we have right now, that is what we are using. It is complex. In fact, when we had the Gulf War the price spiked up for a short period of time and then fell back down.

LEASING HISTORY, EXPLORATION, AND PRODUCTION ACTIVITIES IN THE BEAUFORT AND CHUKCHI SEAS AND HOPE BASIN

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Jeffrey Walker is a supervisory petroleum engineer with the Minerals Management Service (MMS). Over the last 15 years, Mr. Walker has been involved with administering 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.

INTRODUCTION

There have been seven Outer Continental Shelf (OCS) and six State of Alaska lease sales in the Beaufort and Chukchi Seas. No offshore sales have been held for Hope Basin. A total of 75 exploratory wells have been drilled; 30 on the OCS, and 45 on state submerged lands. On the OCS, there have been several discoveries, but none are currently economic to produce. A major OCS discovery was announced by ARCO Alaska, Inc. (ARCO), for it's Kuvlum well drilled 55 miles northeast of Prudhoe Bay in the summer of 1992. Currently, the only offshore production is from the Endicott Field from state submerged land near Prudhoe Bay. Exploratory drilling is continuing on existing leases and is expected to continue in the near future. The Minerals Management Service and the state plan additional lease sales in the Beaufort and Chukchi Seas and Hope Basin.

LEASING HISTORY

The first Federal OCS lease sale in the Arctic was Beaufort Sea Sale BF held in 1979. Four additional OCS lease sales have been held in the Beaufort Sea; Sales 71, 87, 97 and 124. In the Chukchi Sea, two OCS lease sales have been conducted; Sales 109 and 126. There have been no OCS sales held in the Hope Basin.

The State of Alaska has held six lease sales for the Beaufort Sea submerged lands. There have been no state sales in the Chukchi Sea or Hope Basin.

Three OCS lease sales are scheduled for the Beaufort and Chukchi Seas and the Hope Basin under the current 5-year OCS leasing program; Beaufort Sea Sale 144 is scheduled for 1995, Chukchi Sea Sale 148 scheduled for 1996, and Hope Basin Sale 159 is scheduled for 1997.

The State of Alaska has four sales scheduled for the Beaufort Sea, Sales 81 (1995), 83 (1995), 86 (1996) and 89 (1997). One sale is scheduled for the Chukchi Sea; Sale 82 (1995). The state has no sale scheduled for the Hope Basin.

EXPLORATION

Thirty exploratory wells have been drilled on the OCS; 25 in the Beaufort Sea and 5 in the Chukchi Sea. Forty-five wells have been drilled on state submerged lands in the Beaufort Sea. In the Beaufort Sea, drilling on the OCS has ranged from east of Kaktovik to Dease Inlet. Drilling on state submerged lands has concentrated in the central Beaufort, closer to the Prudhoe Bay area.

Seven discoveries have been announced on the OCS. None of these discoveries are currently economic to develop. Two discoveries, North Star and Sandpiper, both located to the northwest of Prudhoe Bay, are currently undergoing additional engineering and economic analyses for their development potential. The recent Kuvlum discovery announced by ARCO could be the first commercial discovery on the OCS, pending results of additional drilling. The Kuvlum discovery well was drilled by ARCO in the eastern Beaufort Sea during the 1992 open water season. The well tested at 3,400 barrels of oil per day. The Kuvlum discovery could facilitate development of other marginal fields in the area.

Seven exploratory wells have been proposed for state lands during the 1993-94 winter season. Offshore wells are Exxon Company, U.S.A.'s Thetis Island well, ARCO's Jones Island well, Amerada Hess Corporation's Northstar No. 3 well, and Conoco, Inc.'s, Badami well. Onshore, ARCO has proposed three wells in the Kuukpik unit. For the OCS, no permits have been submitted, but additional drilling at the Kuvlum location by ARCO is anticipated during the 1993 open water season.

DEVELOPMENT

The only offshore development in the Arctic is currently the Endicott Field located to the northeast of Prudhoe Bay. Plans are continuing for development of the Niakuk and Point McIntyre Fields.

SUMMARY

Recent discoveries, onshore and offshore, have maintained industry interest in conducting exploratory drilling activities in the Arctic. The Federal and state governments are planning future lease sales to make offshore lands available for additional exploration. The Kuvlum discovery in 1992 could be the first commercial discovery on the OCS and could facilitate development of other discoveries in the area.

QUESTIONS AND DISCUSSION

WALTER RUSSELL: I noticed that Mr. Cooke had mentioned that there were two wells drilled in the Hope Basin and I was wondering if Mr. Walker had any information on the Hope Basin.

JEFF WALKER: I do not, they were onshore wells...

LARRY COOKE: Two wells were drilled onshore, which indicated potential for reservoir rocks. These wells are in the Selawik Basin, southeast of Hope Basin. Extrapolation of this information indicates potential for reservoir, but source rocks remain a question.

INTERNATIONAL ARCTIC MONITORING AND ASSESSMENT PROGRAM

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Elizabeth Leighton is a U.S. Foreign Service Officer who is currently on a temporary assignment with the University of Alaska Fairbanks. Her areas of expertise are international Arctic affairs and U.S. Arctic Policy. Ms. Leighton came to Alaska from an assignment with the Division of Polar Affairs in the Bureau of Oceans and International Environmental and Scientific Affairs at the Department of State where she was responsible for the development and implementation of U.S. Arctic and Antarctic policy. Ms. Leighton attended Mount Holyoke College in Massachusetts, graduating cum laude in 1983 with a B.A. in politics.

In June 1991, the eight Arctic nations[1] adopted the Arctic Environmental Protection Strategy (AEPS). The Arctic Monitoring and Assessment Program (AMAP) forms the keystone of that Strategy. AMAP is a circumpolar monitoring program designed to monitor and assess, on a continuing basis, threats to the Arctic environment. The AEPS established AMAP "so that monitoring results may be used to anticipate adverse changes to the ecosystem and to prevent, minimize and mitigate these adverse effects." This knowledge will form the basis of future cooperative action to protect the Arctic environment.

BACKGROUND

It is important to understand the context in which AMAP was proposed and developed. AMAP is one of a growing number of circumpolar cooperative programs. Heightened awareness of environmental problems, increased autonomy of indigenous peoples, and last but not least, the end of the Cold War, have changed the Arctic from a region of confrontation to one of cooperation. This new political openness has brought us to the threshold of unforeseen opportunity.

ARCTIC ENVIRONMENTAL PROTECTION STRATEGY

The AEPS is one of the fruits of these political and social changes in the Arctic. The Strategy is a call to action and a plan for cooperation among the eight Arctic nations in protection of the Arctic environment. The Strategy states, "the Arctic countries are committed to international cooperation to ensure the protection of the Arctic environment and its sustainable and equitable development, while protecting the cultures of indigenous peoples."

The Rovaniemi Process represents the first time the Arctic nations have joined together to work on common concerns. In addition to the "Arctic eight," indigenous peoples groups, non-Arctic countries and international organizations have been involved in the Strategy's development. The Strategy notes that "pollution problems of today do not respect national boundaries" and that the vulnerability of the Arctic to pollution "requires that action be taken now, or degradation may become irreversible."

In addition to AMAP, the AEPS includes two other areas for immediate action: 1) Emergency Prevention, Preparedness and Response; and 2) Conservation of Arctic Flora and Fauna. These initiatives work with AMAP concerning any monitoring needs.

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[1]Canada, Denmark (Greenland), Finland, Iceland, Norway, Russia, Sweden, and the United States.

EMERGENCY RESPONSE

This initiative deals with environmental emergencies stemming from marine and land-based activities. Task force meetings have led to two main actions. First, Norway has agreed to review the possibility of taking action within the International Maritime Organization in order to designate the Arctic area as a Special Area under MARPOL 73/78. This designation would obtain international recognition of the particularly sensitive character of ice-covered parts of the Arctic. Second, the U.S. and Canada agreed to coordinate the preparation of a risk assessment of activities that pose a potential threat of significant accidental pollution.

CONSERVATION OF ARCTIC FLORA AND FAUNA

The U.S. will host the second meeting on the Conservation of Arctic Flora and Fauna in Fairbanks, Alaska in May 1993. This initiative calls for the exchange of information and data, and cooperation on research and management of Arctic flora, fauna and their habitats. The 1992-1993 action plan commits countries to the preparation of:

- a protected area map of the Arctic
- lists of rare, vulnerable and endangered species for the Arctic
- circumpolar format for recording seabird colony data
- a conservation strategy for murres
- integration of traditional knowledge in conservation management.

The U.S. Fish and Wildlife Service (USFWS) is the lead agency for this effort. USFWS is consulting with Federal and state agencies and non-governmental groups regarding the agenda for the 1993 meeting.

ARCTIC MONITORING AND ASSESSMENT PROGRAM

The AMAP group has held several meetings since 1991, and established a task force to create and implement the program. The Norwegian Government supports a small secretariat, which ensures steady progress on preparation of the AMAP plan. The Canadian Government supports a half-time position to the secretariat. The AMAP Task Force consists of the eight Arctic countries. Observers and liaison groups associated with the AEPS also attend the task force meetings.

The goals of AMAP are the development of a comprehensive monitoring program which will lead to a definitive assessment of the state of the Arctic. AMAP was charged to focus on six pollutant categories: heavy metals, persistent organics, radionuclides, acids, oil, and noise. The highest priority is given to the first three. Climate change and ozone depletion are recognized as serious threats to the Arctic and links and cooperation with global programs already working on these issues are encouraged.

The monitoring plan outlines the "how and what" to monitor. It includes the following components: atmospheric, terrestrial, freshwater, marine, and human health. The plan encourages standardization of methodology along international parameters. The Inuit Circumpolar Conference is preparing a proposal on the incorporation of indigenous knowledge and concerns in the AMAP program.

AMAP is expected to provide information for detecting emerging problems, their possible causes and the potential risk to the Arctic ecosystems including indigenous peoples. It will also recommend actions required to reduce risks to Arctic ecosystems.

The long-range timetable of the first phase of AMAP is as follows:

December 1992	AMATF Meeting - Program Adopted
1993-1995	Field Monitoring
1994	Assessment of Data
1996	Status Reports on the Arctic Environment

U.S. AMAP PROGRAM

AMAP is designed to build upon existing monitoring programs. The U.S. is now in the process of completing its national implementation plan. This effort is led by a working group of the Interagency Arctic Research Policy Committee, chaired by the Environmental Protection Agency and National Oceanic and Atmospheric Administration. This group plans to conduct a survey of agencies to identify what U.S. monitoring programs can contribute to AMAP, how to coordinate these programs within the AMAP framework, and how gaps can be filled in the U.S. implementation of AMAP.

AMAP is one of the few international environmental programs in the Arctic with serious commitment from its members. The other Arctic countries are investing significant resources of staff and funding towards the implementation of the program. In recognition of Russia's severe budget situation, the AMAP Task Force has identified assistance to Russia for its implementation of AMAP as a major area of concern.

CONCLUSION

The U.S. needs to make a serious commitment to AMAP. The success of the U.S. participation depends on agencies like MMS. What resources are government agencies willing to spend on this international effort? Are they willing to redirect funds from agency-specific programs to cooperative, interagency efforts? Can programs be adjusted to fit AMAP goals and objectives?

At the U.S. Arctic Policy Conference in Fairbanks in August, 1992, Buff Bohlen, Assistant Secretary of State of Oceans and Environmental Affairs, commented, "Today, the Arctic is open to the rest of the world as never before. Today, because of this openness, the Arctic challenges us as never before."

He further stated, "We must now devise an Arctic Policy which will safeguard our national security, not just in military terms, but by protecting the global human environment; not through confrontation and suspicion, but by cooperative efforts among all Arctic nations and peoples."

The intensified international concern for the environment is changing the way we view the Arctic. U.S. Arctic Policy and the Federal agencies working in the Arctic need to reflect this new view of the North and embrace the international opportunities, like AMAP, which will lead to a comprehensive, ecosystem approach to Arctic environmental protection.

QUESTIONS AND DISCUSSION

JERRY IMM: In the priorities for the AMAP were organochlorines, radionuclides, and heavy metals. And then you mentioned oil and gas and noise. I went to the meeting in Oslo in 1990 and they discounted noise and oil and gas. Are they still being considered now or are we going to focus on just those three?

ELIZABETH LEIGHTON: They are going to give the greatest priority to those three. Acidification has come in a bit in terms of atmosphere, but oil and noise are going to be dealt with at a later date. It was really because of budget constraints, also just in terms of getting the program off the ground, that they would focus on those three priorities first.

BRUCE MATE: My congratulations to the whole panel; these are really excellent presentations to start with. I am going to ask something of you, Elizabeth, that is similar to what I asked Larry Cooke. I am sympathetic to the long lead times required for leasing, but our institutions respond in very short scale time frames. For instance, the leasing process I look at is now selling "stocks" cheap with big future potential. At tremendous cost possibly, but you put them on hold, if you are in that investment mode and you have resources to do it. From an environmental standpoint, you are looking for commitments from countries and agencies whose response to environmental studies is very short term at present. If there is a change in the world market price of oil, it affects the leasing program and it affects the studies program. Yet the basic environmental data you need to have a successful leasing program in the Arctic does not change. It does require international cooperation. Do you see a plan from the State Department, within your agency, of influencing the other Federal agencies, whose budgets go up and down, balancing short term response situations to those longer term needs. Do you see a way of doing that?

ELIZABETH LEIGHTON: I would argue that it is possible to shake loose from the short term or the knee jerk reaction to problems, as we have seen to some extent with the Global Change Program. Agencies were able to convince the Office of Management and Budget and their funding people that they needed a long term commitment in order to do global change studies. It has been a year by year struggle. But they have been able to get multi-year funding. I think the same case can be made for Arctic monitoring, Arctic pollution issues. There is a real awareness in Washington now that Arctic pollution is, largely because of the radioactivity issue, a serious problem which needs a lot of investment. The recognition is there. I think agencies need to argue for these multi-year programs. If they work together instead of saying, we have our own monitoring program in the Beaufort and we want funding for that, but rather work together as an interagency group and they might get a larger sum of money. It may be possible to get some funds out of the State Department, or EPA may be able to get larger amounts of money. But I agree that it is hard to get the multi-year funding. Perhaps if the agencies pool together their resources and afford priority to something like AMAP that could happen. We have a new Under Secretary that has been named at the State Department for Global Issues. Perhaps that signifies more attention at the State Department to these environmental problems.

RAY EMERSON: Kind of along that same line, is your program then trying then to interface with, let's say, NOAA's Status and Trends program as well as EPA's Environmental Monitoring and Assessment Program (EMAP)?

ELIZABETH LEIGHTON: Yes, they are. Paul Ringold with EPA, in their Office of Research and Development and Ed Meyers of NOAA are working together with other representatives of Federal agencies in Washington to undertake a comprehensive survey of what monitoring we are doing in the Arctic and try to see how these programs would fit into the AMAP program. So EPA is aware of the linkage with EMAP and they are trying to make sure that the parameters and methodologies are similar.

CLEVE COWLES: Considering the scale of some of the problems, for example, in the Soviet Union, considering that 1996 will be an implementation phase of the State Department's integrated program, and in light of your comments on the fact that other agencies' programs could be influenced, what do you envision the structure of the public input to the implementation of this circumpolar monitoring? Will it be handled under a NEPA-type framework?

ELIZABETH LEIGHTON: The government has not prepared a NEPA-type response to this. But I should say first that the program itself isn't a State Department program. It is a U.S. national response to an international effort. So it involves the entire administration, all of the Federal agencies working in the Arctic and is represented by the Interagency Arctic Policy Group and the Research Policy Committee. In terms of public input, there are a couple of avenues. At the most recent AMAP meeting, there were representatives of indigenous peoples groups and also the Environmental Defense Fund had someone on the U.S. delegation. The State Department is also in the process of setting up a public advisory committee on arctic policy issues. That could be another avenue for public input. Other than that there hasn't been a specific effort to have a public briefing on arctic monitoring programs. Perhaps that is something we can consider now that it is further along in its development. We would welcome your suggestions on that.

ORSON SMITH: What are your views on recent efforts by the State of Alaska to initiate commercial shipping of Alaskan goods to Europe via the Arctic Ocean with Russian icebreakers?

ELIZABETH LEIGHTON: I am familiar with that, though I don't have the official State Department view on it. I have forwarded the material back to them in terms of Law of the Sea implications and sovereignty issues for passage of ships. I don't know if in the long term seeking a special area designation for the Arctic Ocean in terms of restrictions on shipping practices may have some implications. But I know that the State of Alaska is working in coordination with the Fridtjof Nansen Institute in Norway which is conducting not only economic studies but also environmental studies of the impacts of the shipping routes. That is all that I can tell you now. The State Department hasn't taken an official view, yea or nay, if this route is an international shipping right or not.

CHUCK DEGNAN: The problem in small communities in the Arctic or sub-Arctic, given the opportunity for public input through the public input process, is that the people do feel left out because of their small numbers and thus not being paid attention to very closely. And these may be the people that may be impacted the most, in their lifestyles, their customs. How do you propose to improve the input from local people that are directly impacted?

ELIZABETH LEIGHTON: In the past, in the negotiation of AMAP up until now, I think the Federal agencies have relied on the Inuit Circumpolar Conference (ICC) as the representative of Native peoples in the Arctic for the U.S. I think, as I have discovered with the conservation of flora and fauna initiative, that the ICC has been very helpful and is a good resource, a good representative, but we need to go further than that. We have sent out information on a much wider basis in Alaska. It may be that now is the time to make that recommendation to EPA and NOAA as the leaders of this effort to undertake a more comprehensive distribution of information and seek comments, particularly because of the human health component. One other thing I should add; Denmark was the lead country, but I know that the International Union for Circumpolar Health participated in the drafting of the proposal on human health for monitoring.

CHUCK DEGNAN: One of the most bothersome parts is that the people who are the decision makers and gate keepers for any type of policy respond to power groups. In the implementation process the smaller communities are forced into large expenses to go through the administrative process to address problems. Now it may not seem as an important issue for the majority of the people, but I want to particularly emphasize the problems it causes the people who live in rural communities and that needs to be addressed with sensitivity to individual people's lives.

ELIZABETH LEIGHTON: I would like to talk with you afterwards on your suggestions, and how, at this stage, the rural communities could be involved.

OPERATIONAL ISSUES AND REQUIREMENTS

Wednesday, January 20, 1993

MMS POST-LEASE REGULATORY REQUIREMENTS AND EXPERIENCES WITH FLOATING DRILLING UNITS IN THE ARCTIC

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INTRODUCTION

Prevention is a key ingredient in assuring the continuation of safe operations on the OCS. The Minerals Management Service (MMS) regulatory program identifies specific requirements of industry for the prevention of accidents which could threaten life, property, or the environment. The emphasis for this discussion is on exploratory drilling with arctic-class floating drilling systems. This paper will discuss the MMS prevention regulations, operating capabilities of these systems, how they are regulated, and present the operating experiences to date in the U.S. Beaufort and Chukchi Seas. The contingency plans which provide the operating guidelines for floating drilling systems during severe weather and ice are also discussed.

CHALLENGES

Offshore oil exploration must be conducted in a manner which mutually exists with the other uses of the OCS, and which protects the region's valuable resources. There are a number of special challenges which must be met by operators drilling on the arctic OCS. These include: dynamic weather; complex logistics; subfreezing temperatures; and seasonal ice requiring the use of special procedures for the protection of men, equipment, and the environment. The challenges of operating on the arctic OCS have been met and should not be viewed as unmanageable problems.

FLOATING DRILLING SYSTEMS

Floating drilling units are used in water depths which exceed the capabilities of bottom-founded units. In the arctic, they operate as part of a system which includes icebreakers; supply ships; and environmental monitoring, analysis, and forecasting personnel. The systems owned by Canmar and Gulf Canada have been the only ones used in the Beaufort and Chukchi Seas to date.

The Canmar *Explorer* drill ships have conventionally shaped hulls which have been ice strengthened for Arctic service (Figure 1). The drill ships can generally operate on location in conditions ranging from 4/10ths ice concentration at breakup into 1-ft (roughly 30-cm) thick total ice coverage at freezeup (Beaufort Sea Steering Committee Reports 1991). The *Kulluk* is a second-generation floating drilling unit formerly owned by Gulf Canada and now owned by Canmar. The unit is a nearly round vessel with an inverted conical hull (Figure 1). The *Kulluk* was developed to extend the floating drilling season and is capable of continuously operating while breaking level, first-year ice four feet (1.2 m) thick moving at 1 foot per second (0.3 m/s)

(Beaufort Sea Steering Committee Reports 1991). A number of articles have been published about both drilling systems (Hinkel and Thibodeau 1988, Pidcock and Fowler 1991, Gaida et al. 1983, Loh et al. 1984, Todd 1978).

Both companies maintain Arctic Class IV icebreakers and supply vessels in their fleets to support the drilling units. An Arctic Class IV designation means the icebreaker is capable of travel through ice 4 feet (1.2 meters) thick at the speed of at least 3 knots (1.5 m/s). These vessels are used to break and deflect hazardous ice. They also provide services such as storage, transportation, oil spill response, scientific research capabilities, and anchor handling support. Icebreakers can extend the typical drilling season beyond the normal window; however, such extensions may result in increased downtime (Hnatiuk and Wright 1984).

THE OPERATING ENVIRONMENT

From a drilling operation perspective, the Arctic seasons can be generally described in terms of ice conditions: open water (summer), broken ice during freezeup (fall) and breakup (spring), and solid ice (winter). The Arctic floating drilling systems are generally limited to late breakup through early freezeup. It should be noted that ice can be present anytime during the year in concentrations (or conditions) which will require the suspension of operations.

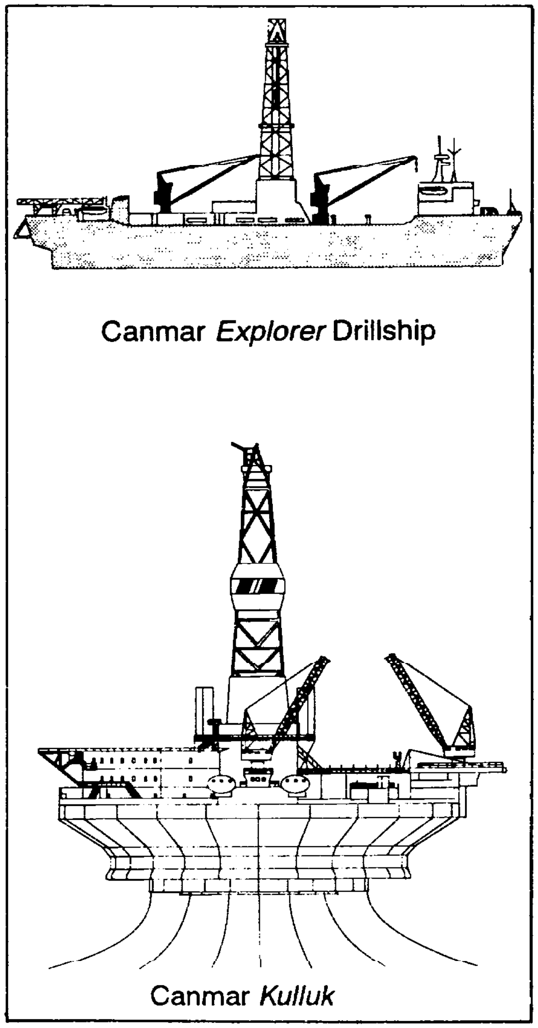

Figure 1. Canmar *Explorer* Drillship and *Kulluk* Floating Drilling Unit.

Understanding and predicting environmental conditions is necessary for planning site-specific operations. In both the Beaufort and Chukchi Seas, first-year and multi-year ice are of great concern to floating drilling unit operations because of stationkeeping capabilities and the potential for damage ice can present to the drilling unit and/or the wellbore. In nearly all cases, the observed meteorologic and oceanographic conditions have been less severe than predicted, providing a level of conservatism in operations planning.

PREVENTION

Prevention of accidents and oil spills is primarily the responsibility of the lessee. The MMS prevention regulations (30 CFR 250) establish performance standards with which the lessee must comply when conducting OCS operations. Complimenting the prevention requirements are preparedness and planning. The Alaska OCS Region has strict requirements for contingency planning and oil-spill-response drills to ensure that a lessee is prepared to respond to, and clean up, any spill which might result from OCS operations.

In carrying out the Department of the Interior's responsibility to ensure safe and pollution-free OCS activities, the MMS requires operators to obtain several permit approvals prior to conducting operations. These permits and the MMS prevention rules are discussed below.

It is important to note that the Alaska OCS is in an exploration phase. Development will require additional and extensive MMS and public reviews. Operations will be governed by another stringent set of safety, pollution prevention, and planning requirements.

Exploration Plan

The EP includes a description of the drilling system, with an emphasis on the safety and pollution-prevention equipment and procedures. A discussion of the type and sequence of exploratory activities and a timetable which outlines the activity from start to finish are also required. The EP describes the anticipated environmental conditions based on historical information. An assessment of the expected effects is included to identify any potential adverse and unavoidable effects on the environment. A complete listing of EP content requirements can be found in the MMS offshore operating regulations (Code of Federal Regulations Subchapter B 1991).

Application for Permit to Drill (APD) and Well Design

The APD discusses well-specific information, including the drilling, logging, casing, cement and drilling-mud programs; anticipated pressures; geologic objective(s); well-control equipment, procedures, and tests; and the maximum environmental conditions that the rig is designed to withstand (Code of Federal Regulations Subchapter D 1991). A mud program is developed by the lessee based on expected downhole conditions and reviewed by MMS as part of the well plan. A ready-mixed heavyweight mud system, called kill mud, must always be available in reserve as a contingency for unexpected downhole conditions. Adequate mud supplies must be on the rig or readily available to ensure the ability to maintain well control. The APD must be approved by the MMS before drilling can commence. The MMS also uses the APD process to ensure all other required permits have been obtained by the lessee. A conservative approach to the wellbore design and the drilling unit capabilities is viewed by MMS as necessary for safe operations.

Floating Drilling Unit Requirements

Several special requirements are placed on Arctic floating drilling systems. The lessee must provide information and any supporting evidence to the MMS that the drilling rig and equipment are capable of performing the proposed activity at the proposed drilling location under all anticipated environmental conditions. Current documentation of operational capabilities issued by the American Bureau of Shipping, or other appropriate classification society, and either a United States Coast Guard Certificate of Inspection or Letter of Compliance are required by the MMS. Final approval to use the floating drilling unit at a specific location is given by the MMS after considering all the site-specific environmental conditions that could occur while the drilling unit is at the well location.

Site Clearance

Site clearance is also required before a drilling unit can be moved to the drilling location. This involves a survey of the seafloor for unique biological communities and archaeological resources. Site clearance also involves a high-resolution survey for any seafloor or shallow geological conditions, such as shallow gas, faulting, permafrost, and ice gouging, which might pose a hazard to drilling. The resulting survey information is reviewed by MMS to ensure appropriate precautions have been built into the drilling program.

Blowout Prevention (BOP) Systems

The BOP systems are designed and installed to ensure well control. Redundancy within the BOP system is required by the MMS to ensure safety and reliability, including: multiple pipe rams; a shear ram capable of cutting drill pipe; and redundant controls including multiple remote control panels. In some instances, completely redundant BOP stacks are kept in the proximity of the drilling location. The use of non-freezing fluids are necessary for protection of the BOP system from freezing.

Glory Hole

Protection of the subsea BOP equipment and wellhead is vital for floating drilling systems in the Arctic. In areas where ice gouging is evident, the MMS requires the BOP stack to be placed in a glory hole. The glory hole is dredged into the seafloor with a special bit to a depth such that the top of the BOP stack is below the deepest ice gouge in the area. Typical glory hole dimensions are 20 feet (6.1 m) in diameter and up to 40 feet deep (12.2 m). Two recent papers have been published regarding the technical aspects of glory hole drilling (Meadows and Gilbert 1989; Shields 1991).

Training of Drilling Personnel

Well control, safety, and environmental training requirements are outlined in the MMS regulations for all personnel associated with the drilling operation. The MMS has a certification program for well-control schools consisting of basic and periodic refresher training which must be completed by all drilling personnel prior to working on the OCS. The training requirements involve "hands-on" and written testing designed to ensure that drilling personnel are capable of operating safety systems and implementing well control procedures.

Weekly well-control drills with variations of personnel and situations are required. These drills ensure the preparedness of all drilling crews to deal with a well-control emergency. The MMS also has requirements for other drills, including fire, oil spill, hydrogen sulfide, and abandon ship.

Inspections

The Alaska OCS Region employs a near-continuous inspection strategy to ensure that drilling operations are conducted in a safe and environmentally sound manner. The MMS inspects the drill rig and equipment prior to commencement of operations. During drilling operations, the MMS inspector conducts daily inspections and observes critical operations to ensure the operator is in compliance with the approved permits, plans, and lease stipulations. Verifying records is another important aspect of the MMS inspection program. The MMS also actively inspects approved training facilities with both announced and unannounced inspections to ensure adequacy of the facilities and training programs.

Critical Operations and Curtailment Plan (COCP)

A COCP details the criteria and structured procedures for suspending operations and ultimately securing the wellbore prior to weather or ice conditions which could exceed the operating limitations of the drilling unit. The COCP further details the conditions and procedures for disconnecting and moving the drilling unit off location after the well has been secured, should the environmental conditions exceed the floating drilling unit's capability to maintain station. Curtailment of operations consists of various stages of "alerts" indicating deteriorating meteorological, oceanographic, or wellbore conditions (Table 1). Higher alert levels require increased monitoring, the curtailment of lengthy wellbore operations, and, if conditions warrant, the eventual securing of the well. Ensuring adequate time to safely and efficiently suspend operations, secure the well, and move off location is a key component of the COCP. Further details on the COCP are available in a paper presented at the 1992 IADC/SPE Drilling Conference (Regg and Kuranel 1992).

Table 1. COCP Alert Summary Table.

Alert Level	Meaning	Drilling Response	Support Response
↓	↓	↓	↓
Increasing Alert	Deteriorating environment or well conditions; Decreasing time available to secure in advance of hazard condition.	Increasing restrictions on wellbore activities	Increasing: Surveillance, Monitoring, Forecasting, Ice breaking
↓	↓	↓	↓

OPERATING EXPERIENCES

Floating drilling systems have been used to drill approximately 50 exploration wells in the U.S. and Canadian Arctic since 1976. Eleven of these wells have been drilled in the U.S. (Figure 2). Several of the wells required two seasons to complete, mainly due to multi-year, multi-well drilling programs; ice conditions; and a conservative approach to late-season operations. Hazardous ice floes have been the predominant reason for suspended floating drilling operations in the Beaufort Sea to date. Conversely, most Chukchi Sea suspensions have been due to winds and waves.

For all operations, the number of days suspended as a percentage of "Total Days" ranged up to 51% (Table 2). "Total Days" includes the number of days to drill, evaluate, and abandon the well, as well as the time for glory hole operations. The Corona well had the highest suspension percentage. The high value for the Corona well can be accounted for by noting that the operator made several unsuccessful late-season attempts to construct the glory hole. Whale migration restrictions at Corona prohibited ice-management activities during late September through October 1985, resulting in 32 days of suspended activities. This demonstrates the

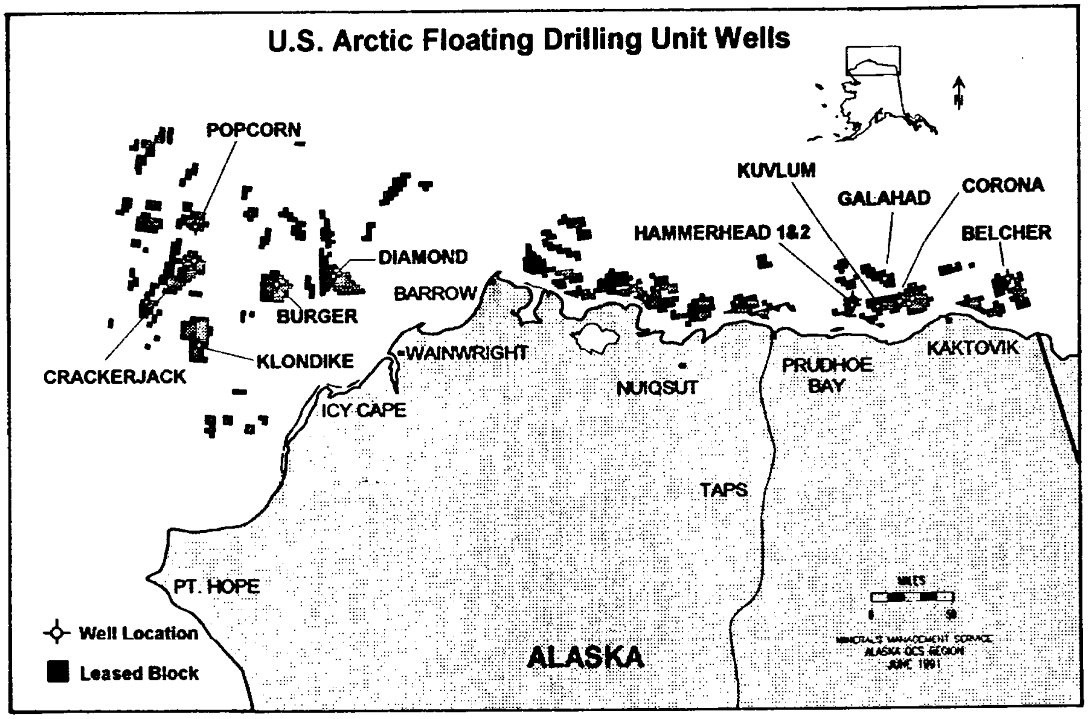

Figure 2. U.S. Arctic Floating Drilling Unit Wells.

Table 2. Floating Drilling Unit Experiences — U.S. Arctic OCS.

Well	Year	% Suspended	Reason/Remarks
Beaufort Sea			
Hammerhead1	1985	24	WOI: 10 days off well *
Hammerhead2	1986	4	WOW; 0 days off well **
Corona	1985-86	51	WOI; 42 days off well ***
		(24)	(If no whale restriction)
Belcher	1988-89	20	WOI; 12 days off well
Galahad	1991	0	Late start; no WOW/WOI
Kuvlum	1992	32	WOI; 14 days off well
Chukchi Sea			
Klondike	1989	1	WOW; 0 days off location
Burger	1989-90	7	WOW; 2 days off location
Popcorn	1989-90	7	WOW; 2 days off location
Crackerjack	1990-91	36	WOI; 18 days off location
Diamond	1991	10	WOW/WOI; 2 days off location

* WOI – Wait on Weather
** WOW = Wait on Ice
*** Includes 32 days off location in 1985 due to whale migration restriction (no ice breaking).

importance of both ice management to the floating drilling units, and the effect of seasonal drilling restrictions on the time available to drill.

In 1992, drilling operations at the eastern Beaufort Sea Kuvlum location had to contend with several large multi-year ice floes. These floes were responsible for suspending operations on 32 percent of the "Total Days" with the *Kulluk* drilling unit off location a total of 14 days.

As noted earlier, a key component of the COCP is to ensure there is adequate time to suspend operations, secure the well, and, if necessary, move the drilling unit off location. The COCP has been effective in ensuring the continued safety of floating drilling operations in the arctic. A wide range of COCP actions have been successfully implemented in response to environmental conditions approaching the drilling system's capabilities. In situations requiring the suspension of operations and wellbore securing, the well has been abandoned consistent with MMS rules.

CONCLUSIONS

The MMS regulations have been developed to ensure safe operations and to protect the structural integrity of floating drilling units proposed for use under the dynamic environmental conditions of the arctic OCS. Operations contingency plans such as the COCP have been developed and implemented to ensure the safety of operations under prevailing arctic weather and ice conditions.

Industry and the MMS continue to support research on sea ice, sea ice monitoring, and new technology. The results of research efforts and past drilling experiences are continuously being assessed for application to more efficient, safe, and economic floating drilling operations, especially as activities proceed towards the deeper waters and more severe ice conditions in the Arctic. The MMS is continually assessing its regulatory program emphasizing accident and oil-spill prevention and planning requirements. The expanding information base coupled with the experience gained, the emphasis on safety, and a conservative approach to conducting operations have contributed to the conduct of safe operations in the challenging frontier of the Alaska Arctic OCS waters. Continued emphasis on prevention will ensure future floating drilling operations are conducted in a safe and environmentally sound manner.

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OIL SPILL RESPONSE PREPAREDNESS

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OIL-SPILL-CONTINGENCY PLAN (OSCP) 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 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:

- 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.

- An identification of response equipment which is committed and available (onsite, 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-knot 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.

- 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.

- A plan for inspecting and maintaining response equipment.

- 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.

- 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.

- 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 material, and the ultimate disposal options available.

- 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.

- 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.

- 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, and representatives of the USCG, 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 area, 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 to better understand existing technology.

QUESTIONS AND DISCUSSION

CALEB PUNGOWIYI: Last summer or last spring, the Arctic Research Council issued a paper stating that there currently did not exist technology to clean up oil in ice infested waters. What is your response to that statement from the Arctic Research Council?

TOM MURRELL: From a generic standpoint I think I would disagree with that. The capability to clean up oil in the arctic depends an awful lot on the environmental conditions at the time of the spill. Let me put on another chart here. I kind of anticipated some of these questions. This one doesn't necessarily relate entirely to the arctic, but it does relate to spill response. When we talk about the arctic we talk about several different seasons. We talk about a very short open water season, which is very analogous to other parts of the world. Some parts of the arctic have a very long solid ice period where it is essentially frozen ice. There are also parts of the arctic where they have broken ice most of the year; very, very tough dynamic conditions to clean up in. In response to your questions, there are time when you can use conventional clean up techniques in the open water. They will work as well in the arctic as they do elsewhere. There will be times when the ice is frozen completely over and you can work on the ice and clean up oil on top of the ice, under the ice. There will be times when the ice is moving very fast and it will be completely broken up and you may not be able to respond with anything other than maybe burning. So I guess the answer is there are times that they can respond to a spill in the arctic and there are times that they can't respond to a spill in the arctic. But that is true everywhere in the world.

CALEB PUNGOWIYI: A couple more questions. Last summer, Alaska Clean Seas had proposed to do a demonstration of such a burn in the Beaufort Sea. It was approved by MMS and other Federal agencies, except for EPA who had some concerns about the proposed burning for environmental reasons. Is it because they have different standards for the environment compared to MMS?

TOM MURRELL: As I understand it, there was a problem with EPA actually going through the permitting process of allowing the company to dump the oil in the water. It was a timing criteria where EPA had a certain amount of time to process the permit in order to get it done for the 1992 season. Essentially the time ran out. EPA pretty much failed to act on the permit request by the company. But I might also add that there are other offshore burn tests that are being planned and that, hopefully, will take place this year. There is an offshore burn test that is currently being proposed and being sponsored in part by the Minerals Management Service, Environment Canada and others offshore Newfoundland. That particular test we hope will take place this year and will give us much of the same information from the Alaska Clean Seas-Coast Guard burn. There is also another burn test that is being currently proposed to take place offshore Russia. It is just in the very preliminary stages right now. The Coast Guard is proposing that, it is just sort of a transformation of what was being proposed in the Beaufort Sea. Now it is going to hopefully take place in Russian waters this year. That is in the very, very preliminary stages right now. In fact, they have just had meetings in the last couple of weeks. I believe they have presented it to the Regional Response Team here last week. So hopefully, we will have some additional information on burning.

CALEB PUNGOWIYI: A last question, you mentioned the amount of oil that would be considered a major spill to be 5,000 barrels per day. What is the rate that Kuvlum is currently capable of producing?

TOM MURRELL: As I understand, Jeff (Walker) said this morning that it was tested at 3,400 barrels per day...

CALEB PUNGOWIYI: So in other words, for you to consider something major it would have to be something bigger than Kuvlum?

TOM MURRELL: I am not sure what you mean by major. The test rates and what a well will flow are really two independent things. When we start talking about a worst case situation an open hole flow of oil, that can vary from a very small amount to a very large amount depending on the pressure and what kind of obstructions there are in the well. The 5,000 barrel per day figure is a figure that has been pretty much bantered around for the last several years and agreed upon by most of the agencies as a realistic worst case situation for exploratory operations. I think we have to recognize that there will be many instances, if there was a blowout, that the flow rate would be much less. There could be some instances where the flow rate could be more. I think it is a good planning standard and that is pretty much what we have adopted. I think it has pretty much stood the test of time anyway.

PAM MILLER: I was wondering about the upcoming burn plans for this summer, since Federal agencies are participating in the design of those, will there be any opportunity for public comment?

TOM MURRELL: Are you referring to the Russian burn?

PAM MILLER: Yes, and the Newfoundland burn, as well.

TOM MURRELL: The Newfoundland burn is pretty well along in its permitting process. I guess I am not really sure what the Canadians did for public input into that particular process. I really can't answer that. But it is a good opportunity, I am glad you asked that question, because Ed Tennyson, who is with our Technology Assessment and Research branch will be here on Friday to talk to ITM. He is going to be talking about our research program. He is the one who has been very much in charge of that whole effort and I sure that he will be happy to answer that question.

OIL AND GAS EXTRACTION POINT SOURCE CATEGORY OFFSHORE SUBCATEGORY EFFLUENT LIMITATION GUIDELINES AND NEW SOURCE PERFORMANCE STANDARDS

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BACKGROUND

The Clean Water Act invests in the U.S. Environmental Protection Agency (USEPA) the authority to regulate discharges to waters of the United States. National Pollutant Discharge Elimination System (NPDES) permits specify the standards a discharger or a group of dischargers must meet. USEPA issues regulations which help guide NPDES permit writers. The regulations are just one of the many tools USEPA permit writers use as a basis for writing NPDES permits. Examples of other tools include water quality standards, effluent discharge data, and ocean discharge criteria. Examples of other tools include water quality standards, effluent discharge data, and ocean discharge criteria.

After more than 10 years, EPA has issued Best Available Technology Economically Achievable (BAT) guidelines and New Source Performance Standards (NSPS) for offshore oil and gas dischargers. BAT is the pollution control technology "existing" sources and "new" dischargers must use and NSPS is the cutting edge of pollution control technology that "new" sources are required to use.

Prior to the final guidelines/standards being issued, USEPA permit writers were mandated to use their Best Professional Judgement (BPJ) to issue permits. Permits to date have requirements based on <u>proposed</u> guidelines and standards in conjunction with technical expertise. The final guidelines set limits and mandate the use of specific technology; the limits established and technology mandated are similar to the current permits requirements.

THE NEW RULES

Both "new" and "existing" sources are affected by the new rules. "New" sources must comply with the New Source Performance Standards. "Existing" operations and "new" dischargers must comply with the final BAT guidelines. Production and development operations are "new" sources. Exploration activities are NOT "new" sources.

In Alaska, the Minerals Management Service is only leasing exploration activities. Since exploration is not a "new" source, the final New Source Performance Standards will have little effect on offshore exploration permits in Alaska.

For "existing" sources, those that may be production or development operations, the new rules have little effect in Alaska. As noted above, Best Professional Judgement was used to establish permit conditions. The conditions established are similar to the new requirements; permits which will be reissued will not be substantially impacted by the new rules.

A few differences do exist and will generate changes to permits issued in the future. The most significant change is the addition of a numeric toxicity limit for the discharge of muds and cuttings. For existing permits, permit writers in Region 10 used the proposed toxicity criterion as a basis for their BPJ evaluation of muds/additive systems discharged. Now that the guidelines have been signed, permit writers will incorporate the BAT-based toxicity limit.

Table 1 details a few of the Guidelines. This Table should not be used as a summary of the rules which are found in 40 CFR Part 435.

Table 1. BAT Final Rule (Affects only New and Existing Discharges).

BAT Final Rule (Affects only New & Existing Dischargers)		
Wastestream	Alaska	"Lower 48"
Muds & Cuttings	Discharge OK seaward of shore - toxicity NTE 30,000 ppm SPP - no free oil - no discharge diesel - Hg NTE 1 mg/kg in barite - Cd NTE 3 mg/kg in barite	No discharge 0-3 miles Beyond 3 miles: - toxicity NTE 30,000 ppm SPP - no free oil - no discharge diesel - Hg NTE 1 mg/kg in barite - Cd NTE 3 mg/kg in barite
Produced Water	Oil & Grease - NTE 42 mg/l max. daily - NTE 29 mg/l avg. daily	Oil & Grease - NTE 42 mg/l max. daily - NTE 29 mg/l avg. daily
Well Treatment, Workover & Completion Fluids	Oil & Grease - NTE 42 mg/l max. daily - NTE 29 mg/l avg. daily	Oil & Grease - NTE 42 mg/l max. daily - NTE 29 mg/l avg. daily
Deck Drainage	No free oil	No free oil
Produced Sand	No discharge	No discharge

IMPORTANT!

In the Offshore subcategory, the only new and existing dischargers in Region 10 that are subject to the above limitations are:
- all exploration operations
- currently permitted production & development operations (e.g., Endicott)

Currently permitted production and development operations in Cook Inlet are not subject to these limitations because they are in the Coastal subcategory of oil and gas discharges.

Current and future NPDES permits issued by Region 10 for the Alaskan OCS will not, in all cases, be as shown above. This is because of the effect that other permit-writing tools (e.g., § 403(c), water quality standards) will have on the development of limits.

SUMMARY

In summary, the guidelines and standards do not have much effect in Alaska. This is due to several factors, including the overall status of exploration activities in Alaska and how Region 10 has issued permits in the past.

EPA'S OUTER CONTINENTAL SHELF AIR REGULATIONS

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BACKGROUND

On September 4, 1992, the Environmental Protection Agency (EPA) published the Outer Continental Shelf (OCS) Air Regulations, codified at 40 CFR Part 55. An overview of the rule's purpose, structure, and general procedures will serve as the framework to describe the specific requirements for OCS sources adjacent to Alaska including: permitting procedures, control requirements, area-wide permits for exploration, public notice and comment, and future requirements.

EPA developed the OCS rule in response to §328 of the Clean Air Act (the Act) as amended on November 15, 1990[1]. The Act transferred authority to regulate air emissions from OCS sources, except those OCS sources adjacent to the States of Texas, Louisiana, Mississippi, and Alabama, from the Minerals Management Service to EPA. §328 directed EPA to establish requirements to control air pollution from OCS sources to attain and maintain Federal and state ambient air quality standards and to comply with the requirements of Part C of Title I (more commonly referred to as prevention of significant deterioration, or PSD). For sources located within 25 miles of states' seaward boundaries, such requirements must always be the same as if the OCS source were located in the corresponding onshore area (COA). New sources must comply immediately, existing sources have until September 4, 1994, to comply.

OCS SOURCE DEFINITION

Any equipment, activity or facility which:

- emits or has the potential to emit any air pollutant,
- is regulated or authorized under the OCS Lands Act and,
- is located on the OCS or in or on the waters above the OCS.

The definition above is contained in §328. §328 also specifies that emissions from vessels that service or are associated with an OCS source must be treated as direct emissions from the OCS source when the vessel is en route to or from the source and within 25 miles. This

[1]42 U.S. C. 7401, *et seq.*

effectively increases the emissions of the OCS source for purposes of modeling and permitting. At the present time, all OCS sources subject to 40 CFR Part 55 are engaged in the exploration or development and production of oil and gas. A drill ship is considered to be an *OCS source* and must receive a permit before commencing any drilling operation.

The rule contains two regulatory regimes: a nearshore regime that extends seaward 25 miles from states' seaward boundaries and an outer regime that begins where the nearshore regime ends and extends seaward to the limits of the U.S. jurisdiction. Sources in both regimes must comply with the requirements of §55.13, EPA's PSD requirements, and to the extent that they relate to ambient standards, new source performance standards (NSPS), and the national emissions standards for hazardous air pollutants (NESHAPS). EPA plans to revise §55.13 to include the Federal operating permit program and the enhanced compliance and monitoring regulations when promulgated[2]. In addition, sources in the nearshore regime are subject to the applicable state and local requirements of the COA, as set forth in §55.14. For Alaska, the COA can simply be considered the State of Alaska.

In the nearshore regime EPA had very little discretion regarding the OCS requirements. EPA reviewed the onshore rules and incorporated those that could be applied to OCS sources, with the exception of administrative and procedural requirements. It is necessary for EPA to incorporate the onshore requirements into Federal law before they can be enforced on the OCS, because by definition the OCS lies outside state jurisdiction. §55.14 will be updated on a routine basis to incorporate any changes made to the onshore requirements.

The rule regulates only those pollutants and their precursors for which there exist state or Federal ambient air quality standards. EPA has set national ambient air quality standards (NAAQS) for six pollutants: lead, particulate matter, carbon monoxide, sulfur dioxide, nitrogen dioxide, and ozone. Some states have set ambient standards for additional pollutants and in such cases requirements related to those pollutants are included in §55.14.

The Administrator may delegate authority to implement and enforce the OCS requirements within the nearshore regime to a requesting state or local agency. A delegation request should demonstrate that; there is an OCS source adjacent to the state, that Part 55 has been adopted into state law, and the agency has the authority and resources to implement and enforce the requirements. A delegated agency will use its own administrative and procedural requirements to implement and enforce the OCS requirements. Such requirements will include public notice and comment procedures, and may possibly include hearing boards, and the issuance of variances.

The requirements that apply to a particular OCS source may vary depending on its distance from shore, the attainment status of adjacent onshore areas, whether the source is "new" or "existing" as defined in §328, and whether the rule is administered by EPA or a delegated agency. For clarity, all further discussion of the requirements applicable to OCS sources adjacent to Alaska are predicated on the following statements.

- All OCS sources adjacent to Alaska are new OCS sources.
- EPA administers the rule.
- The COA is Alaska, and Alaska state requirements apply in the nearshore regime.

[2]Proposed Rule, 40 CFR Part 55, *Federal Register* Vol. 56, No. 234

REQUIREMENTS OF THE NEARSHORE REGIME

The owner or operator of a new source proposing to locate within 25 miles of the Alaska state seaward boundary will be required to submit a notice of intent (NOI) to the EPA Region 10 Office and to the state air pollution control agency. The NOI must include specific information about the proposed source necessary to determine the source's projected onshore impacts and the applicability of onshore requirements, such as the proposed location and the estimated emissions from the source. A complete list of the information to be submitted appears in §55.4.

The NOI serves two purposes. First, the NOI triggers the COA designation process; for OCS sources north of Alaska, the COA will be the State of Alaska by default. For exploratory sources, the COA is always the nearest onshore area. If exploration is followed by construction of a production facility, the COA for that source will be designated according to the procedures of §55.5. Second, the NOI will trigger EPA review of the requirements of the OCS rule to determine whether they are "consistent" with the requirements of the COA. If the requirements are inconsistent, EPA will initiate a rule update to assure that the proposed new source is subject to the same requirements that would apply if the source were proposing to locate onshore. The OCS source cannot submit a permit application until the rule update is proposed, and the final permit cannot be issued until the rule update is final.

OCS sources adjacent to Alaska must comply with the state PSD program, an opacity limit, and perform a risk assessment for the nearest population center. Briefly, PSD requirements include preconstruction modeling to determine increment consumption and verify that the source will not cause an exceedance of the NAAQS, possible preconstruction or post-construction monitoring, and the application of the best available control technology (BACT). For exploration operations, typical BACT requirements will consist of technology to reduce nitrogen oxides (e.g., injection timing retard), a smokeless flare, and use of low sulfur fuel. If an operator believes that compliance with a control technology requirement is technically infeasible or will result in an unreasonable threat to health and safety, the operator may request an exemption from that requirement. Exemption requests will normally be considered during the permitting process and are discussed in more detail below. Until there is an operating permit program for onshore sources, the PSD permit functions as both a permit to construct and a permit to operate.

REQUIREMENTS OF THE OUTER REGIME

Operators proposing to locate in the outer regime adjacent to Alaska will face permitting and control requirements nearly identical to those in the nearshore regime. Federal rather than state PSD requirements apply but the two programs are nearly identical. State requirements for opacity and risk assessment will not apply in the outer regime. The most significant difference between the two regimes is the lack of procedural requirements that must be completed prior to the submittal of a permit application. Because there is no need to determine a COA or maintain consistency with onshore requirements the NOI, COA, and rule update procedures are unnecessary.

EXEMPTIONS

An unusual feature of the OCS rule is the provision for exemptions from control technology requirements. Congress recognized that many applicable onshore rules were adopted without the consideration of operating conditions on the OCS. An exemption may be granted when a control technology requirement is technically infeasible or will cause an unreasonable threat to health and safety. Exemption requests should accompany the permit application. Each request must be accompanied by suggestions for substitute controls, an estimate of the added emissions due to the substitutions, and preliminary information regarding the acquisition of any offsets that will be required if the exemption is granted. The request must include information that demonstrates that compliance with a requirement would be technically infeasible or cause an unreasonable threat to health and safety. When an exemption is granted the permitting agency must impose another requirement as close in stringency to the original requirement as possible. Emissions that result from an exemption must be offset by emission reductions not otherwise required by the Act.

The public will have the opportunity to comment on exemption requests during the notice and comment period for the permit application. If a delegated agency is implementing the OCS rule, that agency must reach a consensus decision on any exemption request with the Minerals Management Service and the U.S. Coast Guard. If consensus is not reached, the exemption request is automatically referred to the Administrator for decision. In such cases, separate public notice and comment procedures will apply to the permit application and the exemption request. The final decision by the Administrator must be incorporated into the permit issued by the delegated agency. The rule also provides a procedure to submit an exemption request when no permit is required. All exemption decisions may be appealed to the Administrator.

AREA-WIDE PERMITS

The development of area-wide permits is a relatively new concept that originated onshore to address asphalt batch plants. These sources are analogous to drill ships in the sense that they are movable stationary sources and EPA plans to use the same basic approach to permitting both types of sources. The advantage of an area-wide permit is that it will allow an operator to drill multiple exploratory wells over a period of years without getting a separate permit for each well. The permit will be valid for two to five years, be limited to a specified geographic area, and be based on the maximum potential impact as modeled by the applicant. This approach has the potential to significantly reduce the time and money expended on permitting exploratory operations.

QUESTIONS AND DISCUSSION

MAUREEN MCCREA: I know what the OCSLA is, but I don't know what a PSD is?

ALISON BIRD: PSD is shorthand for Prevention of Significant Deterioration. It is mandated by Part C. of Title 1 of the Clean Air Act. To comply with Part C, EPA issued regulations and they are contained in 40 CFR 52.21. States can take delegation of PSD program if they have acceptable regulations. So a lot of states including Alaska adopted PSD requirements. It is basically a preconstruction permitting program. In Alaska it acts as an operating permit program too. If there isn't an operating permit program, and you violate the terms under which you were allowed to construct, then you are in violation of the PSD permit.

NANCY SWANTON: Do you anticipate having an area-wide permit in place for the Beaufort Sea for the 1993 drilling season? And, if not, what are your thoughts right now with regard to handling the needs?

ALISON BIRD: We hope to have an area-wide permit in place by then. I think that we have enough time to do it. It is a matter of negotiating between EPA and the source as to what the terms of the area-wide permit are going to be. As I mentioned there isn't a lot of precedent even onshore. So if the source chooses to they can get an area-wide permit, but maybe not exactly on the terms that they want. They will have to sacrifice something in order to get the permit submitted on time for us to review it. On the other hand, there is enough time for everybody to get what they want. It just depends on how the process goes.

PAM MILLER: I was just curious to know a little bit more about monitoring requirements, who does it, and how often, and what type of equipment is required?

ALISON BIRD: Well, it varies. There are several kinds of monitoring. First of all, there is preconstruction monitoring; post-construction monitoring; process monitoring; and ambient monitoring. It is usually the source's obligation to do the monitoring and EPA determines what the monitoring requirements are. A lot of it is discretionary and it is decided by the regional meteorologist based on what he feels the quality of the database is to start with and whether or not the initial monitoring results bear out what the model said was going to happen. There is a lot of variation. There is also source specific monitoring of individual pieces of equipment. That is fairly standardized.

MARINE MAMMALS

Wednesday, January 20, 1993

MARINE MAMMAL MANAGEMENT SYSTEMS

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Jack Lentfer is a member of the Marine Mammal Commission who lives in Homer, Alaska. He has been a wildlife biologist with the U.S. Fish and Wildlife Service and the Alaska Department of Fish and Game. His area of marine mammal specialization is polar bears. Mr. Lentfer received B.S. and M.S. degrees in wildlife management from Montana State College.

The primary groups involved with marine mammal management in Alaska are the Federal government, the State of Alaska, and Native coastal residents. International agreements are also a part of marine mammal management.

Much of the authority for marine mammal management is contained in the Marine Mammal Protection Act of 1972, as amended in 1981, 1986, and 1988. The general intent of the Act is to prevent the depletion of marine mammal species and populations as a result of human activities and to restore species and populations that have been depleted as a result of human activities. The primary objective of marine mammal management under the Act is to maintain the health and stability of the marine ecosystem. Whenever consistent with this objective, the goal is to obtain an optimum sustainable population keeping in mind the carrying capacity of the habitat.

Under the Act, the Secretary of Commerce is responsible for all cetaceans and pinnipeds except walruses. Responsibility has been delegated to the National Marine Fisheries Service. The Secretary of the Interior is responsible for walruses, polar bears, sea otters, manatees, and dugongs. Responsibility has been delegated to the Fish and Wildlife Service. The Act established the Marine Mammal Commission and the Committee of Scientific Advisors on Marine Mammals to overview and provide advice to Federal agencies on actions needed to implement the Act. The Marine Mammal Commission has no regulatory authority.

A key provision of the Marine Mammal Protection Act is the moratorium on the taking of marine mammals in U.S. waters, with taking defined as harassing, hunting, capturing, or killing, or attempting to harass, hunt, capture, or kill. The Act provides for waiving the moratorium on taking and returning marine mammal management authority to states. The State of Alaska considered requesting return of management until the late 1980s, but is no longer doing so. The State is actively involved, however, in assessing and regulating human activity as it affects marine mammal habitat under state jurisdiction, conducting cooperative and contractual studies with Federal agencies, and working with Native user groups as they become more involved with marine mammal management.

Another key provision of the Act is the exception to the moratorium on taking which allows Alaska Natives to hunt marine mammals for subsistence and handicraft purposes, provided taking is not wasteful. In recent years Native user groups have become organized and are becoming more active in management. These groups include the Eskimo Whaling Commission, Eskimo Walrus Commission, Alaska and Inuvialuit Beluga Whale Committee, Alaska Sea Otter Commission, North Slope Borough, and Indigenous Council for Marine Mammals.

International agreements also play a role in management. The International Whaling Commission authorizes the taking of bowhead whales, based on cultural and subsistence needs. Agreements on polar bears include the five-nation Agreement on Conservation of Polar Bears and the Beaufort Sea Polar Bear Management Agreement between the Inuvialuit Game Council of the Northwest Territories, Canada, and the North Slope Borough of Alaska. Representatives of Russia and the United States are exploring the possibility of a management agreement for the shared population of polar bears in the Chukchi and Bering seas. Management agreements with Russia have also been suggested for other shared populations of marine mammals in the Chukchi and Bering seas.

The Marine Mammal Protection Act authorizes the Secretaries of Interior and Commerce to issue permits allowing the take of non-depleted marine mammals incidental to commercial fisheries. The Act was amended in 1981 to allow the Secretaries to waive the general permit requirement when only small numbers of marine mammals were involved and the effects of the take would be negligible. In 1988, fishermen were exempted from both the general permit and "small take" provision for a period of five years, while the National Marine Fisheries Service obtained better information on marine mammal-fisheries interactions and developed an alternative regime to govern such interactions. The Service's recommended regime was provided to Congress in November 1992. Among other things, it recommends retaining the Act's goals of maintaining marine mammal populations at optimum sustainable levels and reducing incidental take to as near zero as feasible. It recommends that the Secretaries be given authority to authorize the incidental take in fisheries of depleted as well as non-depleted species and populations, including species and populations listed as endangered and threatened under the Endangered Species Act, when such taking would not significantly slow recovery. It recommends criteria for classifying fisheries, and a procedure for estimating biologically acceptable removal levels, taking into account the status, and any uncertainties concerning the status, of the affected marine mammal stocks.

The Marine Mammal Protection Act also provides that the Secretaries of Interior and Commerce may authorize the incidental, unintentional taking of small numbers of both depleted and non-depleted marine mammals by U.S. citizens engaged in non-fisheries activities (e.g., in offshore oil and gas exploration and development) if after notice and opportunity for public comment, the Secretary (1) finds that the taking will have a negligible impact on the affected species or stock, and will not have an unmitigable adverse impact on the availability of the species or stock for Native subsistence uses and (2) by regulation, prescribes permissible methods of taking and requirements for monitoring and reporting such taking. This provision has been, and is being used, by both the National Marine Fisheries Service and the Fish and Wildlife Service to authorize the unintentional taking of bowhead whales, beluga whales, walruses, polar bears, and ice seals incidental to oil and gas exploration and development off Alaska.

The Marine Mammal Protection Act requires development of conservation plans for species designated as depleted and encourages development of conservation plans for non-depleted species and populations that might benefit from such plans. The National Marine Fisheries Service has started but not completed conservation plans for northern fur seals and harbor seals. Conservation plans drafted by the Marine Mammal Commission for walruses, sea otters, and polar bears are being finalized by the Fish and Wildlife Service.

Marine mammals are also protected by the Endangered Species Act which requires recovery plans for endangered and threatened species. Plans have been prepared for humpback whales, right whales, and Steller sea lions, but not for bowhead whales. Another provision of the Endangered Species Act directs consultation with the Secretary of Commerce or Interior to ensure that any action authorized, funded, or carried out by any Federal agency is not likely to jeopardize the continued existence of any endangered or threatened species, or result in the destruction or adverse modification of habitat critical to the survival of the species. If the Secretary finds this will occur, he must suggest reasonable and prudent alternatives which he believes could be taken by the Federal agency or applicant in implementing the proposed agency action.

Congress will consider reauthorization of the Marine Mammal Protection Act in 1993. Topics likely to be considered include: the recommended regime to govern fisheries-marine mammal interactions; Native subsistence taking; taking and permits for public display, scientific research, small takes, and importation; sport hunting of polar bears and implementation of habitat protection provisions of the International Polar Bear Agreement; and trade and embargo concerns.

QUESTIONS AND DISCUSSION

TOM NEWBURY: You mentioned that when the Marine Mammal Protection Act will be reviewed that part of that deals with fisheries-marine mammal interactions, what are some of the changes that might be made there?

JACK LENTFER: The National Marine Fisheries Service in the recommendations that have already gone to Congress has set up a system for determining an allowable take of marine mammals incidental to commercial fishing operations. They call this the PBR - Potential Biological Removal. If Congress were to act on this, it could set a cap on the numbers of marine mammals that could be taken by fisheries and possibly by other activities outside of fisheries.

BRUCE MATE: Jack, you indicated that the new system will involve a new term, "Potential Biological Removals." Removals are more like capture, hunt, kill than the old term "take," which included harassment. The new system isn't removing the consideration of "take?" "Take" is still left in the regulations, correct? They aren't just looking at animals removed from the environment?

JACK LENTFER: No, take, in the broadest sense, will still include harassment and these types of things. But the fisheries regime, as I understand it, is involved specifically with removal.

BRUCE MATE: Can I ask you some specifics about the permit changes you expect to see happen in science, capture and display? My understanding is that those removals will also be part of the same removal quota that the fisheries will be working with. Also, if there were a natural or man-induced disaster that killed a lot of animals, the "fisheries" quota might be exceeded and fishing in all areas might be closed immediately. Is that your understanding of that?

JACK LENTFER: It is my understanding that this is a possibility, yes.

BRUCE MATE: That has some really enormous consequences for everybody in this room. I just want everybody to know it because if, as a scientist, I go in and get a permit and my expectation is to do work in September and there is something that happens in April and the entire quota is taken by some disaster, I will not be able to do my work in September. And there will be other people that may be in that same situation. I only bring it up so that everyone can comment during the open time period when these amendments are being considered.

JACK LENTFER: I would guess, as a scientist, if your taking were live capture and release, and if the animals were not removed from the population, this would be in a different category than if you removed animals from the population for scientific study. Animals that were removed from the population would go into the PBR, but I doubt that animals that were taken for study but not removed from the population would go into the PBR.

BRUCE MATE: Thank you. One last question with regard to the changes you expect to see suggested for the permit system, could you be more specific about what changes you expect to see in that permit area?

JACK LENTFER: There is some discussion about streamlining the permit process so that they didn't have the lengthy review process; that Fish and Wildlife Service and National Marine Fisheries Service had the authority to authorize certain types of permits within a 30 day period.

LISA ROTTERMAN: Two quick questions for you, Jack. The first one is very quick. Has the Marine Mammal Commission yet had an opportunity to review the amendments coming from Region 7 of the U.S. Fish and Wildlife Service? And if so, does the Marine Mammal Commission have any kind of a formal opinion on that package yet?

JACK LENTFER: It is being circulated and so far there has not been consultation within the Commission as to what kind of position to take on their proposed amendments.

LISA ROTTERMAN: A second question which is related: Has the Commission had an opportunity to put out a formal statement in response to the National Marine Fisheries Service's proposal regarding fisheries and marine mammal interactions?

JACK LENTFER: No, we have not done that either. The copy that I received, I have had less than a week. So we have not reviewed that either.

LISA ROTTERMAN: What some folks have said off the record is that they feel that package may be, the quote that I have heard several times is "dead on arrival." If that were the case, what would happen? So if that package as it now stands were rejected, what would happen in terms of the Marine Mammal Protection Act reauthorization process and particularly fishery interaction rules? What are the possibilities?

JACK LENTFER: I assume NMFS would have to go back to the drawing board and they would have to put some interim regulations in place. They could extend the present five year interim exemption where fisheries operations did not have to get a small take exemption. Possibly this would be extended until they came up with a new set of recommendations.

CALEB PUNGOWIYI: On this new regime that is being proposed by National Marine Fisheries Service, back in 1988 when the waiver was provided for the fisheries, they were to do a five year study on the effects of commercial fishing on the removal of marine mammals. Has that study been done; have they come out with a report that backs up this new regime?

JACK LENTFER: I am not aware of a report, *per se*. I think a lot of their things have been incorporated into the new regime. I don't know if we have National Marine Fisheries Service represented, Ron Morris are you up on this?

RON MORRIS: The data has been analyzed under much pressure and it is being used, but it is not in report form since 1988. But the data has been collated and it is available for people to look at but it hasn't been issued in any report form.

CALEB PUNGOWIYI: The same question that Lisa asked, if this Potential Biological Removal is going to set a limit on how much can be taken, our question would be how does that affect the Native exemption and the taking of marine mammals by the indigenous people in the Bering Sea?

JACK LENTFER: That is a very good question, a key question. I went through the regime when I received it to see if that was addressed specifically and I don't believe it is. It looks like it is kind of glossed over. I think that is part of what the reauthorization hearings will be about and it will be debated in Congressional hearings within the next four to five months.

CALEB PUNGOWIYI: The oil industry, in the past, has been reluctant to apply for a permit for the taking of marine mammals during the exploration process. A couple of years ago, Shell Western was taken to court. Before that court matter was resolved they did finally get the permit from Fish and Wildlife to take marine mammals. You mention in here about the permits for industry, are there going to be changes in regard to the permit process?

JACK LENTFER: Again, this could happen during the reauthorization hearings. I don't have too much insight into that. I think some of the glitches that went on have been worked out and things are proceeding more smoothly with regard to these incidental take permits that are issued by Fish and Wildlife Service and NMFS.

RON MORRIS: The incidental take for the oil industry will be reevaluated in five years. At this point, as far as the National Marine Fisheries Service is concerned, every oil industry activity that has gone in the arctic has had the appropriate incidental take applications submitted to us. I only know of one far off case, I think it was Halliburton that was going to do some seismic work near the Russian line, and they didn't apply for one. But all of our animals have been protected or permits have been applied for and received.

THE EXPANDING ROLE OF ALASKA'S INDIGENOUS PEOPLES IN MARINE MAMMAL MANAGEMENT AND RESEARCH

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The indigenous people of Alaska are increasingly becoming involved in decisions about the use of marine mammals, the use of marine environments in the areas in which they live, and in marine research, including research on marine mammals. The primary purposes of this paper are to briefly:

1) provide background necessary for interpreting this trend in the context of broad trends in policy concerning research and environmental protection of the arctic, including some discussion of policy recommendations of indigenous, academic and governmental entities relevant to the role of indigenous people in marine mammal and other natural resource issues;

2) provide specific information about the Indigenous Peoples' Council for Marine Mammals (IPCMM), a recently-formed coalition of groups sharing, among other goals, the goal of enhancing the role of Alaska's indigenous peoples in marine mammal management and research, including a few examples of the recent activities of the IPCMM and its member commissions; and

3) comment on factors that can and will affect the success of attempts to integrate and communicate diverse cultural perspectives concerning the study and use of marine mammals and marine ecosystems, and thus, that will affect the long-term role of indigenous or other entities in studies of, and decisions about marine mammals and the ecosystems in which they live.

BACKGROUND

The significance of the activities of Alaska's indigenous peoples in marine mammal issues, including the formation and activities of the IPCMM and its member commissions, goes beyond any specific effects on marine mammal management, marine mammal research, or the status of any particular marine mammal species. The larger significance of the existence and actions of groups such as the IPCMM stems from the fact that they are manifestations of a changing arctic policy in which indigenous people will likely play an expanded role in natural resource management and research in regions in which they live. This change results from several factors including: increasing demands by indigenous arctic residents; increasing support for various indigenous perspectives from non-indigenous entities, especially western social scientists; and from the effect of these forces on national and international policy makers. As it is necessary to understand this background in order to fully understand recent developments regarding the role of indigenous people in marine mammal issues, selected, but representative statements of particular perspectives are presented and discussed.

Indigenous Perspectives

It is important to understand that Alaska's indigenous people have been, and are becoming increasingly vocal and active in discussions of natural resource use. In statements issued by diverse groups, representing organizations including individual villages, regional entities (e.g., the Bering Sea Coalition and the North Slope Borough), and international bodies (e.g., the Inuit Circumpolar Conference), indigenous peoples are requesting and, increasingly more often, demanding, that they have a direct role in research occurring in their region and in decisions about the environment of their region. At a 1985 conference on arctic policy, an indigenous leader (Ahmaogak 1986) made the following comments:

> "It is of the utmost importance that Arctic residents be involved in both the formulation and implementation of Arctic research policy...As residents of the Arctic, we want to become more involved in research and policy decisions that affect us. We intend to move forcefully in whatever forums are available to us...(T)here should be provisions made for obtaining the basic data needed for the sound management of subsistence use Arctic animals. This lack of critical data is particularly obvious for such important subsistence use animals as the...walrus...This lack of critical data...seems to assure continued controversy regarding harvest levels, industrial impacts, and management schemes...We also wish to clearly state that we, as Arctic residents, want to be involved in the gathering of such data and in the formulation of management plans for our subsistence use animals."

Indigenous leaders, such as L. Merculieff, one of the original founders of both the Bering Sea Coalition and the IPCMM, have also been clear in stating their views about the importance of integrating traditional knowledge into decision-making processes relating to the study and use of ecosystems in their region and, relatedly, about the ramifications of the exclusion of indigenous people and their knowledge:

> "...Aboriginal groups feel...their voices and their knowledge of the environment are falling on deaf ears" (Merculieff 1990:10). "There is, in the Native community, a growing sense of disenfranchisement and distrust of western institutions with a consequent growth of legal and civil confrontations...(P)art of these failures can be attributed to the lack of understanding of the difference in world-views and the role the lack of understanding plays in the success or failure of everything we do to provide solutions to human survival" (Merculieff 1990:16). "...(C)oastal peoples in the Bering...", Chukchi and Beaufort Seas, and the North Pacific Ocean "...fully understand that the lack of recognition of traditional ways of knowing....and the lack of meaningful participation in decisions which affect what and how research and management is conducted in the ecosystems in which they live, serve to undermine the strength of the cultures and source of sustenance of coastal peoples." (Merculieff, L. A., unpublished discussion paper for the Bering Sea Coalition).

At the international level, indigenous leaders have stated that "the direct involvement of indigenous peoples in all decision making processes concerning the management, research and allocation of resources" is required to ensure subsistence harvesting by indigenous people can continue (Simon et al. 1991).

Perspectives of Social Scientists

Numerous social scientists have also concluded that there is a need for **direct** participation by indigenous peoples in decisions about wildlife management and research (e.g., Bielawski 1984; Gunn et al., 1988; Weetaluktuk 1979), and, generally, in decisions about human uses of the environment in regions in which they live. Relatedly, and also in agreement with views expressed by indigenous leaders, many social scientists have repeatedly recommended that indigenous ecological and environmental knowledge be incorporated in such decisions, and that there be greater emphasis on effective cross-cultural communication of results from western scientific research to the villages (Bielawski 1984). Feit (1988) reaches conclusions similar to Merculieff's (1990, unpubl. manuscript) regarding the ramifications of exclusion of indigenous people and their knowledge from the decision-making processes, i.e., that it is likely that continued failure to have direct involvement of indigenous peoples in wildlife management will lead to further disintegration of relations between western and indigenous cultures, further breakdown of indigenous cultures, with resultant damage to the wildlife populations and ecological systems upon which the indigenous people depend (Feit 1988; Merculieff, unpubl. manuscript). Hopkins et al. (1990) concluded that scientists and managers can derive important benefits from knowledgeable indigenous people and warned resentment generated by the exclusion of indigenous people could harm scientific inquiry in the arctic.

Citing specifically the example of the relationship between the Alaska Eskimo Whaling Commission and the National Marine Fisheries Service in the regulation of the Alaskan harvest of bowhead whales as a beneficial and desirable relationship among indigenous people and governmental entities, an international working group of social scientists recently gave a strong endorsement to co-management (e.g., of wildlife) relationships in which "...user groups and public authorities jointly establish cooperative arrangements to improve and implement management systems... (Western Regional Science Association Working Group 1992)."

Perspectives of International Bodies

The International Union for the Conservation of Nature and Natural Resources of the Commission on Ecology has established a Working Group on Traditional Ecological Knowledge (Freeman and Carbyn 1988). A commission of the United Nations has stated that "...the ability of Indigenous people to apply and to develop" their ecological "knowledge and to share this knowledge with others is vital for overcoming environmental degradation throughout the world (Egede 1992:21)."

U.S. Government Perspectives

U.S. government policy statements regarding the role of indigenous peoples in natural resource research and decision-making are less ambitious and enthusiastic than those of indigenous leaders, the aforementioned social scientists, or cited commissions within the United Nations. However, certain entities within the U.S. government have issued policy statements calling for an expanded role for indigenous people and their knowledge in decisions about the use and study of arctic environments.

U.S. arctic policy objectives call for: a) increased involvement of indigenous people and their knowledge in research and habitat use decision-making, b) the undertaking of multidisciplinary studies to improve knowledge of the marine environment, and c) the promoting of "scientific research on...aspects of science which are most advantageously studied in the Arctic" (Interagency Arctic Research Policy Committee, 1987:xi). The statement entitled "Principles for the Conduct of Research in the Arctic," which was prepared by the Interagency Social

Science Task Board, at the direction of the Interagency Arctic Research Policy Committee (the entity established to develop national Arctic research policy), states:

> "The following...principles are to be observed when carrying out or sponsoring research in...northern regions or when applying the results of this research...This statement addresses the need to promote mutual respect and communication between scientists and northern residents. Cooperation will contribute to a better understanding of the potential benefits of Arctic research for northern residents and will contribute to the development of northern science through traditional knowledge and experience...Reasonable opportunities should be provided for the communities to express their interests and to participate in the research...The researcher should, where practical, incorporate the following elements in the research design: a) Use of local and traditional knowledge and experience..." (U. S. Arctic Research Commission 1992: Appendix C).

The U. S. Arctic Research Commission is currently turning its attention to the "...need for meaningful participation of indigenous people in the planning, conduct and application of...(arctic)...research" (U.S. Arctic Research Commission 1988).

Thus, statements from both indigenous leaders and the U.S. government stress communication, cooperation and participation, and the potential for contributions to northern science from traditional knowledge. However, the emphasis for a **direct** indigenous decision-making role appears to be absent from current governmental policy statements. To the knowledge of this author, it is not yet clear how "meaningful participation" will be defined at the federal level, and thus, to what extent governmental policy will aid indigenous people in their empowerment endeavors in the natural resource management and research arenas. Moreover, typical federal procedures for making research and management decisions about natural resources in general, and about marine mammals in particular, do not afford indigenous peoples a direct role in the making of such decisions. More typically, and increasingly, indigenous people are included as advisors, with no actual decision-making role. One striking example of the disparity existing between the goals of indigenous people for involvement and current federal government procedures is the absence of an indigenous Alaskan on the Steller Sea Lion Recovery Team. Current U.S. governmental procedures do not generally afford indigenous people the role they have requested in natural resource management. However, increasingly, indigenous organizations are initiating marine mammal management, and, to a lesser extent, research, activities on their own, sometimes in collaboration with western scientists.

THE INDIGENOUS PEOPLES' COUNCIL FOR MARINE MAMMALS (IPCMM)

Purpose and Goals

As noted above, indigenous leaders have said that indigenous people intend to move ahead forcefully to become involved in natural resource and environmental research and decision-making and they have. One initiative taken by Alaska's indigenous peoples to increase their involvement and effectiveness in, specifically, marine mammal issues, is the formation in Dec. 1991 of the Indigenous Peoples' Council for Marine Mammals (IPCMM) (originally named the Indigenous Council for Marine Mammals, and renamed in the late 1992). The IPCMM is currently comprised of nine organizations that recognized that they had overlapping goals, common needs, and mutual concerns. These organizations, listed in alphabetical order, are the:

Alaska and Inuvialuit Beluga Whale Committee
Alaska Eskimo Whaling Commission (AEWC)
Alaska Sea Otter Commission (ASOC)

Arctic Marine Resources Committee
Bristol Bay Native Association
Eskimo Walrus Commission (EWC)
North Slope Borough (NSB) Department of Wildlife Management
Pribilof Aleut Fur Seal Commission
Southeast Native Subsistence Commission.

Thus, the IPCMM is a coalition comprised of autonomous organizations. These organizations meet as peers to address issues of mutual concern and interest and they arrive at decisions by consensus.

The goals of this coalition include, but are not limited to, the following:

a) to enhance information sharing and other communication amongst indigenous communities and organizations;

b) to have direct involvement of indigenous peoples in marine mammal management and research

c) to facilitate the development of new, and expansion of existing, indigenous research programs on marine mammals and the marine environment

d) to enhance the use of traditional knowledge into management and research processes

e) to facilitate the development if indigenous marine mammal management programs and to facilitate co-management agreements for marine mammals in which indigenous organizations and the U.S. government share management responsibilities

f) to insure the continued use of marine mammals by indigenous peoples

g) to maximize the efficiency and effectiveness of the indigenous community on issues of common concern through the pooling of knowledge, experience and resources, and if consensus is reached, to present a unified indigenous position on marine mammal issues

Relevant Activities

Both the IPCMM itself, and its member organizations, have taken steps that enhance the role of indigenous peoples in marine mammal issues. While it is beyond the scope of this paper to review these activities fully, a few examples are given below.

1) **MMPA reauthorization.** A primary focus of the IPCMM in 1992 and early 1993 was the upcoming (1993) reauthorization of the Marine Mammal Protection Act (MMPA), including the review of draft and regional proposals for amendments prepared by the U.S. Fish and Wildlife Service and by the EWC. As of the beginning of February, 1993, it had not yet been decided whether the IPCMM would develop a document regarding the MMPA and potential amendments to it, or whether individual commissions would pursue their own proposals.

2) **Marine mammal management.** The EWC and the ASOC are both involved in developing management plans for walrus and sea otters, respectively, and representatives of both organizations have participated in groups advising the federal government in its development of management plans for these same species. Both groups have either contracted with and/or hired biologists to aid in the development of these plans.

The IPCMM issued a resolution to the North Pacific Fisheries Management Council supporting the establishment of a "no bottom-trawl zone" around the Pribilof Islands to protect vital fur seal, sea lion and sea bird habitat.

3) **International agreements**. The NSB Department of Wildlife Management and the Inuvialuit Game Council initiated, signed and implemented the NSB and the Inuvialuit Game Council Management Agreement for the Polar Bears of the Southern Beaufort Sea. With western scientists acting in an advisory capacity, the participants in this agreement set harvest limits for both Canadian and Alaskan indigenous hunters for the population of polar bears shared across the Canadian and U.S. borders.

Staff of the EWC participated in the development of the Protocol of Intentions on the Conservation and Regulated Use of the Bering and Chukchi Seas Polar Bear Population Common to the United States and Russia, signed in October 1992 by representatives of the two governments. This "Protocol of Intentions," calls for "coordination and cooperation with international and Native organizations whose activities are connected with the study and conservation of polar bears... ." It specifically calls for the inclusion of representatives of Native peoples on working groups to prepare proposals for a formal management agreement for the Bering and Chukchi polar bear populations.

4) **Research programs**. Many of the organizations within the IPCMM have ongoing, or plan to initiate, research programs. A few examples will be given here. The NSB Department of Wildlife Management has an active research program on the bowhead whale, including survey work, harvest monitoring, etc. The AEWC developed a proposal regarding traditional knowledge of the bowhead. Both the IPCMM and the ASOC hired western scientists to provide staff support to their respective commission members. In the case of the ASOC, the biologist will develop both a general sea otter management plan and specific management plans for various regions. The Alaska and Inuvialuit Beluga Whale Committee secured funds to initiate research on the Beluga whale. This committee is working with biologists from the Alaska Department of Fish and Game in this endeavor.

5) **Harvest monitoring**. The Rural Alaska Community Action Program (RurAL CAP), acting for the IPCMM, entered into a cooperative agreement with the Alaska Department of Fish and Game on a program to determine the harvest of sea lions and harbor seals by indigenous people. RurAL CAP is acting in an advisory capacity to ADF&G and is acting as an intermediary between ADF&G and indigenous marine mammal organizations concerning this project.

6) **Enforcement and education**. Many of the commissions within the IPCMM are, or have previously been, involved in providing information to villages about legal issues affecting marine mammals.

The most noteworthy action taken recently in the area of enforcement was the primary role taken by the EWC as part of its ongoing efforts to halt the illegal harvesting of walrus. The EWC asked the U.S. Fish and Wildlife Service to initiate an investigation, termed operation "Whiteout" that resulted in the arrest and conviction of several walrus hunters for the wasteful take of walrus.

7) **Traditional knowledge**. Several proposals were developed by indigenous entities (AEWC and IPCMM) that can be used in the future to seek funding for activities aimed at the documentation and integration of traditional knowledge of marine mammals.

Final Remarks

As noted throughout this paper, the role of Alaska's indigenous people in marine mammal issues is currently expanding. However, at this time it is unclear to what extent indigenous people will achieve goals such as co-management, the development of integrated research programs, the widespread acceptance of traditional forms of knowledge, etc. That is, it is currently unclear what the **long-term** role of indigenous people in marine mammal issues will be, regardless of the rather clear current trend towards increasing involvement. Governmental support and support of the general public will be critically important, as program establishment and execution will require considerable financial resources. Governmental support to date has been lukewarm, at best, and, thus, the perceptions of the public will become increasingly important if indigenous groups expect to attempt to move beyond the current status quo to roles with greater direct responsibility.

It is the personal opinion of this author that several factors will be paramount in determining the long-term role of indigenous people or any other group in activities affecting marine mammals. First, and foremost, will be the status of the marine mammal populations themselves. Second, will be the ability of the indigenous, or any other, organization to aid in the assessment of that status and to affect the status in a positive manner. If indigenous people are successful in ensuring or even improving the health of marine mammal populations, their role in marine mammal research and management will likely increase. If they are not successful, or even if the primary public perception is that they are not contributing to that positive outcome, then it is likely that either the status quo will be maintained or that their role will be diminished. Thus, a third factor will be the ability of indigenous groups and leaders to gain broad support for their positions. In particular, support for key initiatives from the environmental community will be crucial. Currently, there is widespread dissatisfaction with the approaches of the resource management agencies towards management and study of many natural resources. Many people and groups are receptive to new approaches. Thus, the present time is a critical one and the actions of the indigenous community on key, highly visible issues, such as the decline of the Steller sea lion, will, I believe, impact the long-term role of indigenous people in the natural resource area more broadly.

The current complexity and seriousness of issues involving marine mammals demands that all interested parties, regardless of their cultural and political backgrounds, come together to seek solutions in an atmosphere of mutual respect, mutual trust, and with open minds. The extent to which such effective communication, mutual respect, and mutual trust can be established among people from diverse cultural backgrounds will be critical in determining the future role of indigenous people in marine mammal issues. There are obstacles. For example, many individuals that are not trained in the western sciences do not understand the research process, nor do they understand the differences between applied and basic research, or the differences between the process of applying information to achieve social change, the expression of political opinion and the non-political process of acquisition of needed information. Most non-scientists are unaware of the great diversity in training among "scientists" or even "biologists." Most non-scientists do not understand the highly personal nature of basic scientific inquiry, and the unique perspectives, methodologies, and approaches that scientists bring to their work. These obstacles have already led to difficulties for scientists working on behalf of indigenous organizations (personal observation). Conversely, many scientists, particularly those who do not themselves conduct long-term research, often discount or even dismiss the value of local and traditional knowledge. Often western scientists are unwilling to listen to a style of presentation of information that is different from that to which they are accustomed. In general, it will be important for all participants to remember to treat each other fairly, to be willing to discuss perspectives and differences, and to avoid "knee-jerk" responses that are borne, usually, from ignorance. Bureaucrats, hunters, policy-makers, political leaders and scientists, must be willing to understand that there are profound differences both among and within people holding any of these, or other, labels. They must evaluate, as possible, the **intent** of their cross-cultural colleagues and then if finding common ground, communicate to arrive at solutions. Current resource and habitat management issues require that all interested parties come together with open minds and ears to seek solutions to complex problems, be it western researchers being willing to listen to indigenous elders or vice versa.

If truly innovative and cross-cultural solutions are to be found to the challenges of today's and the future's environmental and natural resource issues, all participants in the solution must be willing to put aside cultural and racial biases. All participants must be willing to at least honestly evaluate, and to attempt to understand, perspectives differing from his or her own.

Solutions to problems involving marine mammals and their environments will require that both indigenous and western entities be capable of putting aside intra and inter-cultural territorially. Control for control sake is a concept that must be shed, by the government, and by all organizations. All cultural and political groups must be willing to be self-critical, and to avoid falling into dogmatic traps, realizing that no culture or philosophy has a monopoly on either wisdom or ignorance. All organizations, cultures and communities have both enlightened and ignorant elements. Self-critical and self-enforcing actions such as those taken by the EWC to stem wasteful take of walrus need to be applauded and rewarded both within and outside of the culture taking the laudable action.

In the end, it will be the future health and well-being of marine mammal populations against which all management and research endeavors, regardless of cultural origin, will be evaluated.

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SEASONAL MOVEMENTS AND DISTRIBUTIONAL PATTERNS OF POLAR BEARS IN THE BERING/CHUKCHI SEAS

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INTRODUCTION

Approximately 75% (range 57-81%) of the 1980-1988 average subsistence annual harvest of 128 polar bears (*Ursus maritimus*) in Alaska (range 89-292) has occurred in western Alaska (Schliebe 1986, 1990). The early research effort on polar bears in Alaska was concentrated in the Cape Lisburne to Barrow area, while more recent research has focused on the Beaufort Sea from Barrow eastward into Canada. A research project on polar bears that seasonally occur in waters of western Alaska was initiated in spring 1986 with the capture and the fitting of satellite telemetry collars on ten adult females. The primary objective of this project is to determine the population size and status of polar bears that occupy the Chukchi and Bering seas. The purpose of this presentation is to describe the seasonal movement and distributional patterns of polar bears that occupy the Chukchi and Bering seas.

METHODS

Capture and marking activities were limited to western Alaska from 1986 through 1989. but was expanded into a cooperative research with Russian scientists in 1990 when it became apparent from satellite tracking data that the population of bears was shared with Russia (Garner et al. 1990, Garner and Knick 1991). A total of 130 different female polar bears have been captured and fitted with satellite collars between 1986 and 1992. Satellite telemetry has provided data on polar bear movements in western Alaska that was impossible to collect prior to the development of this technology (Fancy et al. 1988, Harris et al. 1990). Inherent failure rate of the collars is approximately 10% (Garner et al. 1989).

Satellite collars transmit signals to overflying satellites which process these signals and calculate location of the transmitter (Fancy et al. 1988). The duty cycle used for polar bears in western Alaska was a 3-day cycle. Multiple locations are recorded during each transmission cycle, but only one location per transmission cycle was used to examine movement and distributions. This location was selected using a combination of location quality parameters and the relationship of the various locations to the previous location. Movement vectors were determined using great circle methods and a 24-hour rate of movement was calculated based upon the hourly movement rate. Seasonal designations correspond to pack ice conditions as follows: maximum ice cover 1 January - 30 April; receding ice pack 1 May - 15 August; minimum ice pack 16 August - 15 October; advancing ice pack 16 October - 31 December.

RESULTS

Movement data from 120 female polar bears fitted with satellite telemetry transmitters during 1986 - 1992 in western Alaska and eastern Russia indicate widespread movement of polar bears

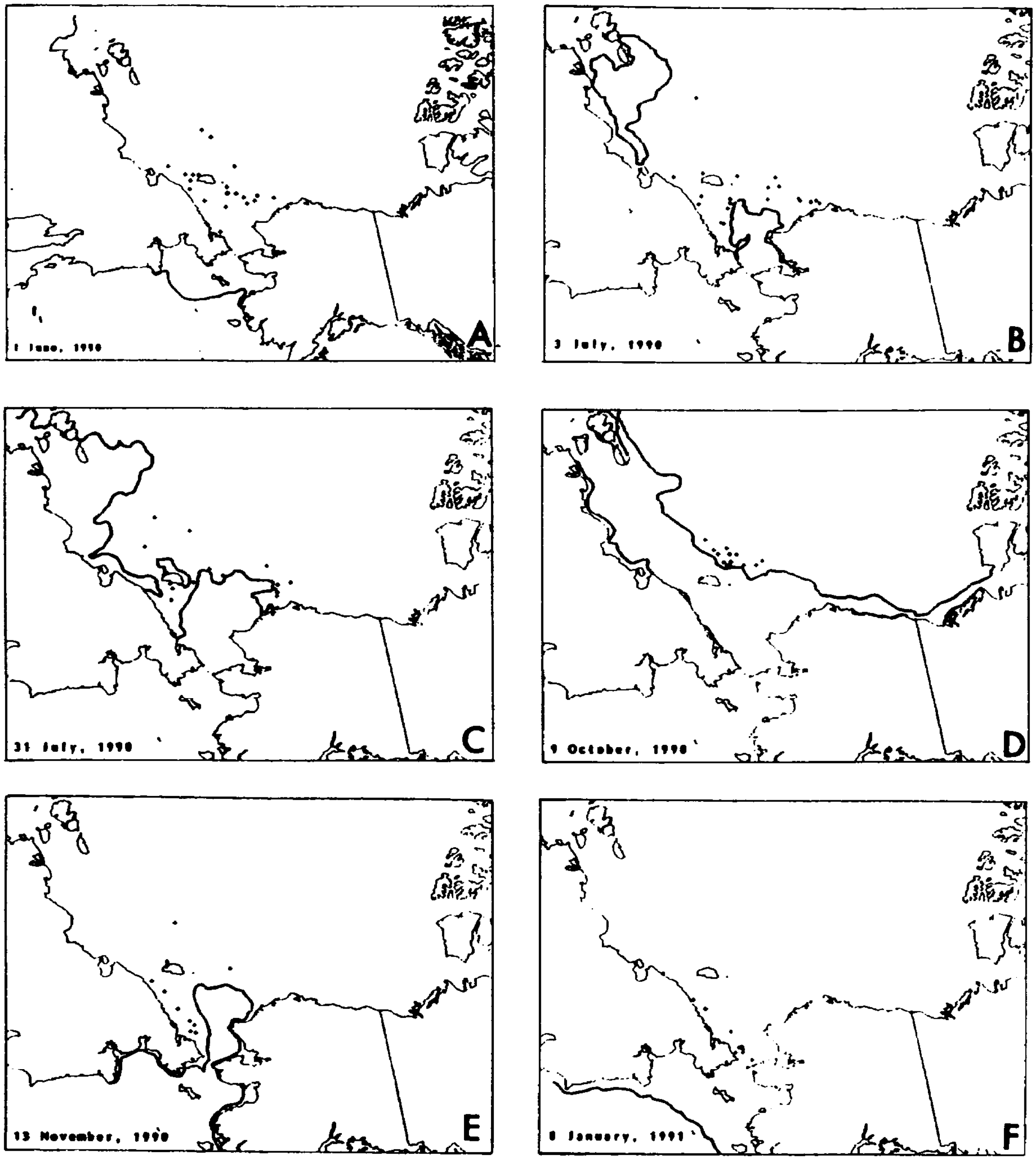

Figure 1. Distribution of marked female polar bears in relation to the edge of the seasonal pack ice, June 1990 through January 1991 (ice edge is depicted by dark line).

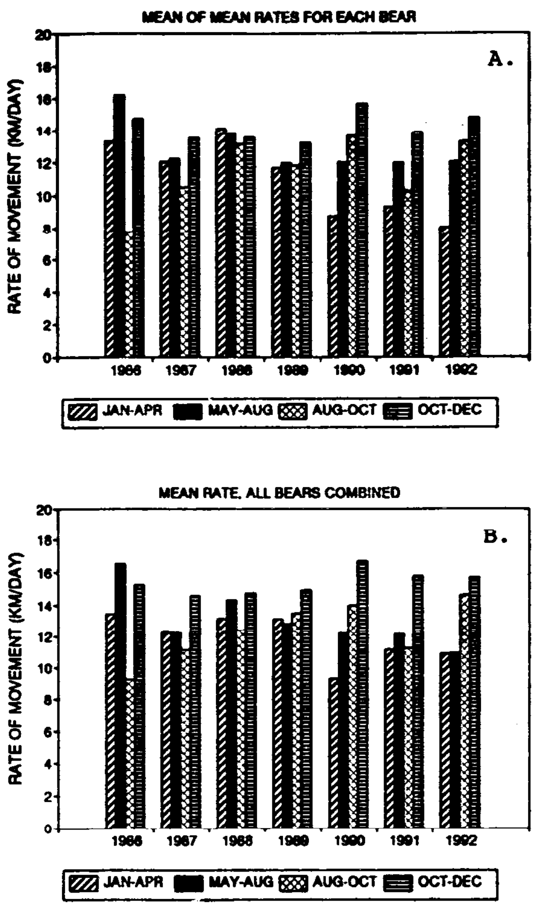

Figure 2. Seasonal rates of movement (km/day) of satellite instrumented female polar bears, 1986 through 1992. A) Rate calculation based upon mean rate for individual bears. B) Rate calculation based upon all bears.

between the two countries. Alaskan waters of the northern Bering Sea and the Chukchi Sea are seasonally occupied by polar bears from November through March each year. This seasonal occupation is directly related to ice pack distribution and timing (Figure 1). Bears move north into the northern Chukchi Sea and northeast into the northeastern East Siberian Sea during spring with the receding pack ice. Bears remain associated with the pack ice during the summer months, then advance south and southeast with the advancing ice edge during fall. The northern Bering Sea is normally occupied by mid-December each year.

Daily movement rates were lowest during maximum and minimum ice periods, 11.0 and 11.5 km/day respectively (Figure 2). As expected, daily movement rates during periods of ice pack change were higher. with the rate during ice pack advance (14.2 km/day) higher than during ice pack retreat (12.9 km/day). Minimum cumulative distance moved for six bears during a 12 - 20 month period averaged 5,550 km (range 4,650 - 6,339 km), while area occupied by the six bears averaged approximately 250,000 km^2 (range 145,000 - 351,000 km^2). These ranges are much larger than reported for polar bears in Canada (2,300 - 22,900 km^2; Schweinsburg and Lee (1982) and also larger than ranges of bears in the Beaufort Sea (average 96,924 km^2; Amstrup 1986). Marked bears were annually present in U.S. waters for only 25-30% of the year, with the highest proportions of marked bears occurring during the winter and spring months (Garner et al. 1990).

Limited maternal denning has been documented in western Alaska, with a majority (>95%) of maternal dens occurring in Russian territory on Wrangel and Herald islands and along the northern coastline of the Chukotka Peninsula. Several dens on pack ice northeast of Wrangel Island have also been recorded.

SUMMARY

Data from 120 female polar bears fitted with satellite telemetry transmitters during 1986 - 1992 in western Alaska and eastern Russia indicate widespread movement of polar bears between the two countries. Alaskan waters of the northern Bering Sea and the Chukchi Sea are seasonally occupied by polar bears from November through March each year. Bears move north into the northern Chukchi Sea and northeast into the northeastern East Siberian Sea during spring with the receding pack ice. They remained associated with the pack ice during the

summer months, then advanced south and southeast with the advancing ice edge during fall. The northern Bering Sea is normally occupied by mid-December each year. Area occupied by six bears with locational data >300 days averaged approximately 250,000 km^2 (range 145,000 - 351,000 km^2). Marked bears were annually present in U.S. waters for only 25-30% of the year, with the highest proportions of marked bears occurring during the winter and spring months. Limited maternal denning occurs in western Alaska, with a majority (>95%) of maternal dens occurring in Russian territory on Wrangel and Herald islands and along the northern coastline of the Chukotka Peninsula.

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QUESTIONS AND DISCUSSION

CALEB PUNGOWIYI: There is always discussion or talk that the Beaufort Sea population is separate from the Chukchi population. Is there...

GERALD GARNER: Jack hypothesized that the Beaufort and the Chukchi populations were somewhat separated from the imaginary line that went off some 45° from Point Lay. There has been some discussion about moving that down to Icy Cape. What we have seen from the work that I am doing in western Alaska and work that Steve Amstrup is doing in northern Alaska, is that there are bears that have been radio collared in northern Alaska that we catch in western Alaska. But they always go back to northern Alaska, except in one or two notable instances. One of those was a bear that denned in the Barter Island area, wound up denning on Wrangel Island. Another instance is a bear that just went over the pole and is now off the northern coast of Greenland. We have not had any of the bears that we have captured in western Alaska that have moved past Prudhoe and again they have returned to western Alaska. The one area where there is confusion is between those bears that are captured between Point Lay and Barrow. You can capture the animals there but until you have followed those animals for one or two years, you don't know who they belong to. This is an area where there is interchange between bears from western Alaska and from northern Alaska. The genetic work that we have done has indicated that there is very low difference, from the mitochondrial DNA. It appears that there is a level of separation but it is not a wall. There is interchange.

DON HANSEN: As you mentioned Gerald, you aren't able to put tags on the males but do you have any indication whether the males have comparable movements?

GERALD GARNER: The information on male movements is primarily from northern Alaska, the work that Steve Amstrup is doing and the work that Jack did in the past. All of that information relies on mark-recapture or mark and showing up in a kill at some later time. There is some indication that there is some movement but unfortunately using those methodologies you will not detect long range movements and if there is some type of cycle you won't detect that. We don't really know what males are doing. There appears to be a breeding population or a breeding area that lies to the west of Barrow, between Barrow and say, Point Lay, or excuse me, all the way down to Cape Lisburne. In the spring you'll find an inordinately large number of adult males in that area compared to other age and sex classes. This has been my experience. I don't see that down south of Point Hope, north of Savoonga.

RAY EMERSON: When you were talking about your movement patterns, do you factor out the ice movement itself? There are some bioenergetics there that they are probably just riding the flow.

GERALD GARNER: This results are confounded with ice movement. The thing that we have not overlaid on these movement rates or vector analyses is at the same time, sometimes bears are moving with ice, therefore getting a partial free ride. Sometimes they are moving against ice. When they are moving north during the spring, when ice is receding, many times they are actually moving against the ice flow.

HANDBOOK FOR OIL AND GAS OPERATIONS IN POLAR BEAR HABITATS

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Dr. Joe Truett has worked on a variety of environmental research projects on Alaska's Outer Continental Shelf since the mid-1970s. Most of his work during this period was sponsored by one or more of the Bureau of Land Management, the National Oceanic and Atmospheric Administration, and the Minerals Management Service, and was conducted through LGL Ecological Research Associates. Dr. Truett currently works as an independent contractor, but is completing the project described at this meeting under the auspices of LGL.

Oil exploration and development activities in polar bear habitats come with a responsibility to protect human life and property from bears and to avoid unnecessary disturbance or harm to bears. The purpose of this handbook, now nearing completion, is to help industry operators minimize polar bear-human encounters and to suggest ways of alleviating problems when encounters are unavoidable. To these ends, it addresses several topics: (1) polar bear biology, (2) what attracts bears to industry sites, (3) systems for detecting bears that approach camps, (4) bear deterrence, (5) personnel responsibilities and training, (6) relevant laws and regulations, and (7) design and operation of industry camps. It also provides a step-down protocol for responding to bear encounters. Guidelines are presented for preparing site-specific bear interaction plans for operations that are to be conducted in bear habitat.

Polar bears come equipped with extraordinary physical abilities and senses. OCS operators planning and operating camps must be aware of the capabilities of these bears, because their strength, agility, sense of smell, and curiosity comprise a particularly effective combination for finding, entering, and exploring sites of operation.

Several distributional and behavioral characteristics of polar bears help operators determine the best strategies for avoiding problems. Most, but not all, bears frequent shallow nearshore areas only in winter when ice covers the water. During this time they feed mainly at the outer edge of the fast ice or beyond where broken ice enables them to better catch seals. Seals are the mainstay of their diet, but they may locate and attempt to exploit other potential food sources — including garbage, industrial materials, and even humans — by the techniques they use for detecting and catching seals.

Once a bear finds a camp or other industrial site, it will often approach and enter the site. Food or garbage odors emanating from camps are particularly enticing. If the bear gets a food reward, it is almost certain to investigate similar situations thereafter.

When encountered close at hand by humans, many bears will move away, but others may not. Female bears with cubs may attack people to protect their young. Other attacks may have predatory intent; these are more likely to result in human deaths. Appropriate responses to bear attacks may help persons being attacked to survive, but the best defense is to avoid close encounters in the first place.

Bears are attracted to sites of human activity primarily in search of food, although other motivations such as general curiosity or shelter-seeking may sometimes be involved. Bears can smell food odors at great distances, especially strong odors such as garbage or exhaust from camp kitchens, and may travel many kilometers upwind seeking out the source.

Bears may investigate camps even when conventional foods are absent. The stimuli for such investigations are sometimes unclear to people. The bears sometimes consume items not viewed by humans as food, e.g., plastic, vinyl, ethylene glycol antifreeze, and drilling mud additives. Sometimes bears visiting sites of operations seem to be seeking sanctuary from open water or weather. However, the main attraction is strong food odors, and reducing these is a major step toward keeping bears from coming to industry sites.

Bear detection systems at industry sites help prevent bear-human conflicts by giving early warning of a bear's presence. Various systems have been used: (1) humans or dogs as monitors, (2) trip wires and electronic detectors, (3) remote sensing devices such as surveillance radar and infrared imagers and sensors, and (4) floodlights.

Different types of operations, e.g., seismic trains, drilling operations, or temporary field camps, may call for different detection systems. Human monitors are useful at most kinds of operations, often in conjunction with floodlights, trip wires, or some other mechanical or electronic system. Tripwire systems have proved useful and cost effective at gravel- and ice-island drilling operations. New developments in microwave, radar, and infrared security systems may in the near future make these remote-sensing devices practical for relatively permanent sites of operation.

Systems to deter bears from places where they are not wanted often are necessary. Currently, many of the deterrence techniques available are not legal to use by unauthorized persons in the United States because their use may constitute the "take" of a bear, which is illegal under the Marine Mammal Protection Act. Deterrence techniques that are usually illegal under this Act include using noisemakers such as cracker shells, screamers, and bangers; human and dog monitors approaching or pursuing bears; driving bears with helicopters and ground-based vehicles; and firing projectiles such as plastic bullets and rubber batons. Whether it is legal to use taped sounds, electric fences, and chemical sprays to deter bears is unclear.

Only passive devices such as physical barriers, bear-proof containers for food and garbage, artificial lighting, and chemical coatings on materials are generally considered legal for industry personnel to use. Because it is illegal for unauthorized persons to use active deterrence systems, and because obtaining the timely assistance of authorized persons may be difficult, avoiding situations where active deterrents are necessary is the best strategy.

Three categories of personnel are responsible for dealing with polar bear problems at arctic operations sites: (1) bear monitors, (2) monitor supervisors, and (3) all other personnel. Bear monitors (or "watches") are responsible for bear detection, maintenance of personnel warning systems, and personnel safety. Monitor supervisors oversee all aspects of on-site safety and observation related to polar bears. All other personnel are responsible for reporting and responding to bear visits as required by the monitor and monitor supervisor.

Bear monitors and monitor supervisors are best selected from among specific kinds of individuals. Monitors ideally have a strong sense of responsibility, good observational abilities, patience, an interest in safety, and a basic knowledge of bear biology. Monitors may simultaneously have other responsibilities such as loader operator, ice surveillance crew member, or safety officer. In any case, monitors need special training in observation, recording and reporting, and in the use of some kinds of deterrents. Monitor supervisors are best selected for their supervisory skills, their ability to communicate with others, and their understanding of the need for consistency and accuracy in reporting.

Training programs for all personnel are crucial for safe operations in polar bear habitats. Availability of effective personnel trainers and training materials is highly desirable. All personnel must know their responsibilities, and how to carry them out under various circumstances and various types of operations.

Federal, State, and Borough governments all have laws or regulations that affect industrial interactions with bears and bear habitat. The Federal laws and regulations governing "take" of bears probably affect most industry operations more than do State or Borough regulations, which relate mostly to protection of bear habitat or bears as a subsistence resource.

The U.S. Minerals Management Service (MMS) is the Federal agency that controls permitting related to oil and gas operations in polar bear habitat. Permit requirements often include stipulations from other Federal agencies and from State agencies. A recent development in permitting is the opportunity for each proposed operator to obtain authorization from the U.S. Fish and Wildlife Service for any unintentional "take" of a polar bear during the operation.

Proper design and operation of industrial sites go far toward preventing problems with polar bears. Reducing the attractiveness of the site to bears, training personnel how to react to bears, and installing appropriate detection and deterrent systems should be planned in advance of site construction and operation.

Basic rules for effective site design and operation are:

- Locate the site where bears are normally scarce,
- Reduce the attractiveness of the site to bears,
- Make work areas and potential bear hiding places inaccessible to bears,
- Design the placement of facilities to enhance visibility,
- Teach personnel about bears and bear behavior,
- Establish strict rules for handling and storing food and garbage,
- Make detailed plans for detecting bears and accommodating their presence,
- Design the site to facilitate deterrence, and
- Have a contingency plan in case detection and deterrence systems should fail.

The details and applicability of these rules will vary among the various kinds of sites. Seismic operations, drilling and production facilities, temporary camps, winter roads, and aircraft operations are all different in their specific needs.

A protocol for dealing with bear encounters (Figure 1) should be adopted at work sites and explained to personnel during training sessions. The protocol should explain personnel responsibilities, provide information on agency personnel to contact if this becomes necessary, and lay out the course of action to follow when a bear is discovered near or in an industry camp.

A bear interaction plan is required to be submitted when operations are planned in polar bear habitat. This plan should describe site location and layout, site operations, and bear observation and reporting methods. It should include a risk assessment section that delineates

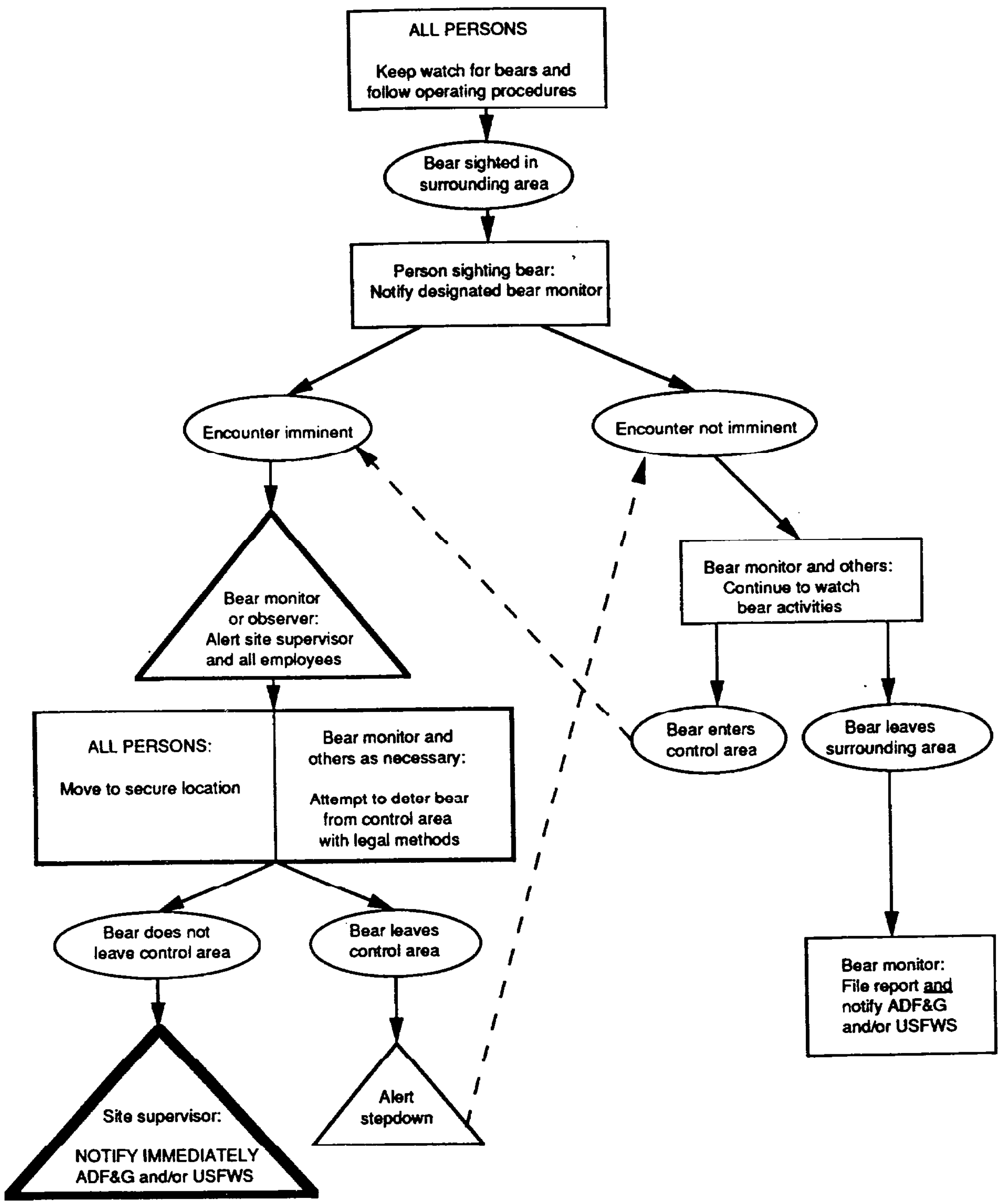

Figure 1. Polar bear encounter protocol.

the locations of specific areas in and around the camp where risks from bears are high, where risks are moderate, and where personnel can find refuge from bears.

QUESTIONS AND DISCUSSION

TOM LOHMAN: At the very end of your presentation you said that polar bear interaction plans are going to be required with drilling operations, is that correct?

JOE TRUETT: Yes.

TOM LOHMAN: We've had a great reluctance, in fact, outright refusal by the State of Alaska to include polar bear interaction plans on state lands or waters; the State saying that it is a Federal responsibility. Is anybody in the room, any of the Federal people in the room, working with the state to try to work out that problem?

LORI QUAKENBUSH: I work for Fish and Wildlife Service. I understood that that was for a specific situation. I believe you are talking about the coal company on the west coast?

TOM LOHMAN: That is just one. It is not a one time situation. We've had refusal on some of the drilling operations, in fact the ones proposed coming up in the Colville area.

LORI QUAKENBUSH: I was only familiar with the one on the west coast where it was actually, I believe, a native-run company. In that case, the State decided not to push the issue. But we were informed by the State that they would be requiring it for other things.

TOM LOHMAN: Thanks, Lori. We can talk about it later. We have as much trouble watching our own people over in the coal projects as we do watching industry. Also, for Gerald, were there any observed interactions or avoidances of the drilling operations that took place in the Chukchi Sea with the collared bears that you were talking about?

GERALD GARNER: There were no bears in the area. The thing I didn't mention because we didn't have time was that in the Chukchi Sea the past activity all occurred in open water. None of the collared bears have been near those facilities at that time. When they come south, they are on the ice edge. They may float by.

DISTRIBUTION AND ABUNDANCE OF BELUGA WHALES AND SPOTTED SEALS IN THE CHUKCHI SEA, INCLUDING RECENT FINDINGS AT KASEGALUK LAGOON

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INTRODUCTION

Beluga whales (*Delphinapterus leucas*) and spotted seals (*Phoca largha*) are seasonally the most abundant marine mammals in the Kasegaluk Lagoon region of the northeastern Chukchi Sea. They regularly use the coastal zone and lagoon waters during summer and autumn. Belugas feed, calve, and probably molt in nearshore waters. Spotted seals haul out to rest on sand bars and spits, and may feed in marine waters or on anadromous fishes in estuaries and rivers. Both belugas and spotted seals are important subsistence resources for local residents. The village of Point Lay regularly harvests belugas and in some years belugas may make up over 50% of the annual harvest of wild foods. Despite the large numbers of beluga whales and spotted seals using Kasegaluk Lagoon and their importance to coastal residents, prior to 1989 there were no systematic studies of either species in this region.

In 1989-1991, the Minerals Management Service (MMS) funded the Alaska Department of Fish and Game (ADF&G), under subcontract to LGL Alaska Research Associates, Inc., to investigate the use of Kasegaluk Lagoon by spotted seals and beluga whales by conducting aerial surveys. In addition, a joint project was conducted in 1991-1992 by ADF&G, the North Slope Borough (NSB), and Texas A & M University, with supplemental funding from MMS, to attach satellite-linked transmitters to spotted seals to investigate their movements and habitat use. This report summarizes the findings of these studies (see Frost et al. 1992, 1993, and Lowry et al. 1993 for complete presentation of study results).

METHODS AND RESULTS

Aerial surveys for belugas were conducted during early to mid-July 1990-1991 using a high-wing twin-engine Aero Commander Shrike. Surveys were conducted at 305 m altitude and a ground speed of approximately 220 km/hr. A combination of pre-selected transects and search surveys was used to provide the best possible coverage between Barrow and Cape Sabine (Figure 1). One observer sat on each side of the aircraft and counted belugas within a strip extending out 0.9 km from the flight line. Whenever animals were sufficiently concentrated, they were photographed using color slide film. Belugas were counted by projecting slides on a white paper screen and marking each animal.

Belugas were seen on every survey during 3-14 July 1990 and 4-16 July 1991. Maximum counts were 1,212 in 1990 and 938 in 1991, compared to maxima of 670-1761 during 1978-1987 (Table 1). It is not clear whether differences in annual maxima represent inter-annual differences in abundance or simply differences in the proportion counted. Counts may be affected by weather, water turbidity, behavior, and distribution, as well as the actual number of animals present.

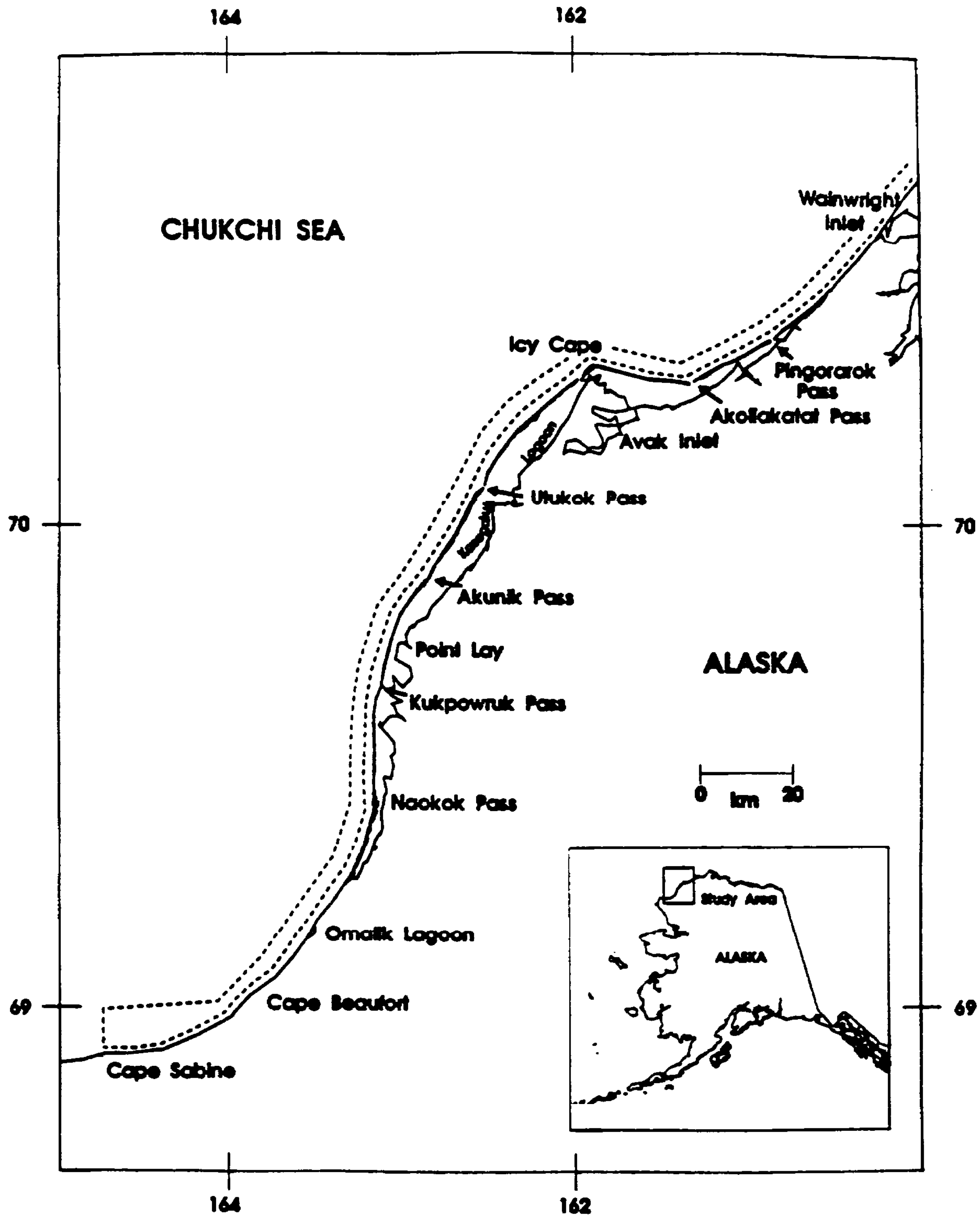

Figure 1. Map of the Kasegaluk Lagoon study area in the northeastern Chukchi Sea. Dashed lines indicate standard transects flown during beluga whale surveys.

Table 1. Maximum counts of beluga whales seen on aerial surveys in the Kasegaluk Lagoon region, 1978-1991.

Year	No. of Surveys	Maximum Count: Location(s)	Number	Date
1978	1	Kukpowruk Pass	879	7/10
1979	3	Akoliakatat Pass	1761	7/15
1981	5	Akunik Pass (70) Icy Cape (600)	670	7/8
1987	9	Omalik	930	7/6
1990	12	Omalik	1212	7/5
1991	12	Naokok Pass	938	7/6
1992	9	Naokok Pass	916	7/7

The earliest and largest sightings of belugas were at the south end of the study area near Omalik Lagoon. Later sightings occurred near the passes north of Point Lay and in the pack ice off Icy Cape. Data from other years indicate that whales sometimes arrive by 22 June and always leave the area by late July. The presence of nearshore gravel beds and warm, low-salinity water probably combine to make this region important as a place for belugas to molt. It is unclear how much feeding occurs in the area.

The beluga harvest at Point Lay usually occurs during early July. Local boats cooperate to drive belugas to shallow water near the village where they are killed. Since 1977 the average annual harvest of belugas by Point Lay has been 23-25, with a range of 0-64. For the period 1986-1991, the annual average was 35.

Aerial surveys for spotted seals were conducted during several five to seven day survey periods spread over the open water season in 1989-1991. Survey aircraft included a Cessna 206 on floats, an Aero Commander Shrike, and a Cessna 207 on wheels. A single observer sat in the right front seat facing the barrier islands and passes. Altitude varied depending on weather, but was usually 305 m in 1989 and 914 m in 1990-1991. Seals were counted with the aid of 7-power binoculars while the aircraft circled each haulout. Large groups of seals were photographed using black and white T-max film. Negatives were enlarged to 20 x 25 cm prints and counts were made by marking each seal on a mylar overlay.

Surveys for spotted seals were flown between Naokok Pass at the south end of Kasegaluk Lagoon and Pingorarok Pass at the northeast end. Spotted seals were seen hauled out only on particular spits and shoals near Utukok Pass, Akoliakatat Pass, and Avak Inlet. None were observed hauled out at the passes south of Point Lay. They were present in the area from mid-July through early November. Numbers counted were highly variable but exceeded 1,000 on many days in July, August, and September (Figure 2). The maximum count was about 2,200. Water level and weather both appeared to affect the number of seals that hauled out. Few seals were present in late October and November. During this time they were hauled out on broken ice near the passes.

Spotted seals were very responsive to disturbance by aircraft. Because they were so responsive, survey altitude was increased from 150-305 m in 1989 to 914 m in 1990-1992. Even at 914 m, they sometimes moved off the haulout and into the water when the aircraft was 2 km away. Statistical analysis of the response of seals to the survey aircraft at different altitudes indicated that it is necessary to fly at altitudes greater than 986 m to have a greater than 50% chance of not disturbing a group of seals. Seals were much less responsive to aircraft when they were hauled out on ice in autumn.

During 4-7 August 1991, satellite-linked transmitters were attached to four spotted seals in Kasegaluk Lagoon. These units transmitted data for 64-259 days, and provided information on movements and diving behavior. The last signal was received on 12 April 1992. A fifth transmitter was attached to a seal at Kasegaluk Lagoon in August 1992. That unit was still transmitting through December 1992.

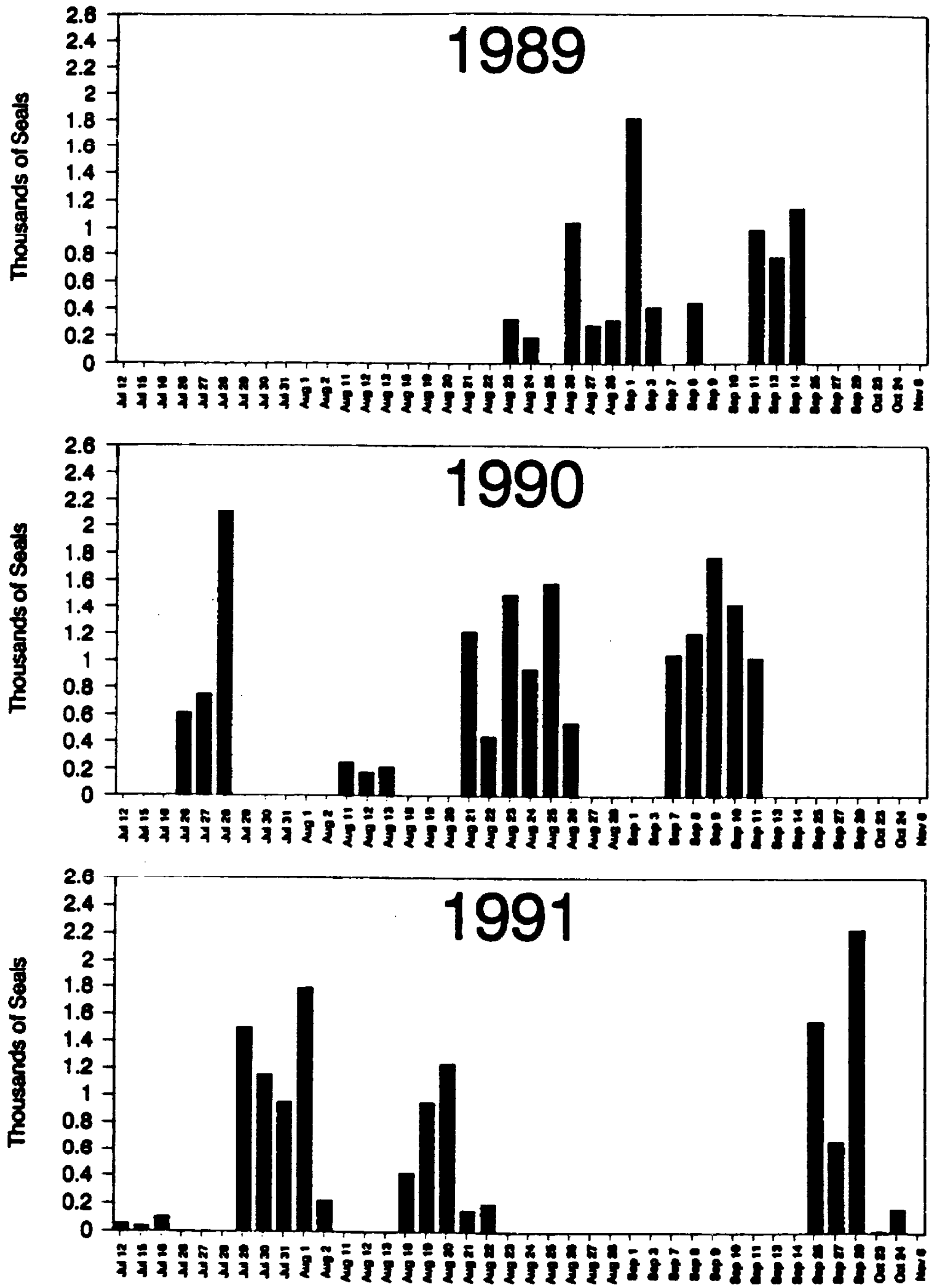

Figure 2. Maximum combined daily counts of spotted seals made at haulouts in Kasegaluk Lagoon in 1989, 1990, and 1991.

Hauling out bouts of seals were irregular, infrequent, and of variable duration. During August-October, when seals were hauling out on land, individual seals spent 1%-14% of their time hauled out. The four seals combined spent 6% of their time on land and 94% of their time at sea. During November through mid-April, the average amount of time hauled out on ice was also 6%, with a range from 0%-51%. Mean duration of a hauling out bout on ice was 5.8 hr. During August-October, seals hauled out with equal frequency at all hours of the day. In November-February, peak haulout occurred during 0200-0700 hrs and 1700-2100 hrs. In March-April seals hauled out mostly during midday, from 1100-1600 hrs.

During the time that transmitters were functional, the seals moved over great distances. Minimum distances over which seals were tracked ranged from 2,300 to 9,600 km. During August-October, seals made trips to sea from coastal haulouts in the eastern Chukchi Sea. Most of the tagged seals used both Akoliakatat and Utukok passes at different times throughout the autumn. Usually their movements to sea were to the southwest. Two seals spent most of their time between Kasegaluk Lagoon and Point Hope and up to 200 km off shore. One seal made two trips from Kasegaluk Lagoon to just north of Bering Strait and back.

Seals began their southward migration in late October and November. Two of the three with functional transmitters went into Kotzebue Sound where they hauled out at known haulouts. All three passed through Bering Strait during 4-23 November. Two then moved to the west, briefly using haulouts on the Chukotka Peninsula, and the third went into Norton Sound. All were near Saint Lawrence Island in mid-December. After December, seals moved generally southward, presumably with the advancing sea ice front.

Data from satellite-tagged seals has provided significant new insight into the behavior and movements of spotted seals. Tagged seals moved much greater distances and spent much less time hauled out during late summer and autumn than was expected. Data clearly indicate that many more spotted seals use the Kasegaluk Lagoon region than are counted during surveys. Hauling out is not synchronous, and some seals were away from haulouts when counts were made. When 2,200 seals were counted in September 1991, only 1 of 4 tagged seals was hauled out in Kasegaluk Lagoon. Additional tagging studies will continue to add to our understanding of distribution, abundance, and habitat use by spotted seals.

SUMMARY

The Kasegaluk Lagoon region provides important habitat for spotted seals and beluga whales, with several thousand beluga whales and spotted seals using the area each year. Peak use by beluga whales is from late June until late July. Spotted seals are present and haul out from mid-July until freeze-up in late October or November.

Preliminary satellite-tagging studies have shown that spotted seals spend on average only 6% of their time hauled out on land or on ice. During summer and autumn when they are in the Chukchi Sea, they may travel long distances and spend several weeks at sea between haulout bouts in Kasegaluk Lagoon. These studies demonstrate that aerial surveys provide only minimum estimates of the abundance of spotted seals.

Future studies should continue to monitor distribution and abundance of belugas and spotted seals by aerial surveys. In addition, satellite-linked telemetry should be used to learn more about movement patterns and behavior or both species.

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QUESTIONS AND DISCUSSION

NORA FOSTER: Am I correct in saying that you observed by your satellite the spotted seals feeding off of Point Hope and Cape Lisburne, in that area?

KATHY FROST: Yes.

NORA FOSTER: What are they feeding on?

KATHY FROST: Our guess is fish, Nora. That is kind of the state of the knowledge. By the time the hunters get them hauled out at Utukok Pass, they have been travelling for 24 to 26 hours, and so by and large their GI tracts are empty. Based on other studies and collections from other areas, Arctic cod is probably a likely candidate. If they are feeding in the nearshore area or more particularly when, I suspect crangonid shrimps are a fairly big player in there. The sand shrimps, the crangonid shrimps, are very abundant along that coastline. I think the belugas are probably also taking crangonids.

FALL DISTRIBUTION AND RELATIVE ABUNDANCE OF BOWHEAD, GRAY AND BELUGA WHALES IN THE ALASKAN CHUKCHI SEA, 1982-91

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INTRODUCTION

In September 1989, the Minerals Management Service (MMS) awarded the Maritime Services Division of Science Applications International Corporation (hereafter SAIC; formerly SEACO/SAIC) a 3-year contract to monitor the fall distribution of endangered whales, and secondarily all other marine mammals in the Alaskan Chukchi Sea via aerial surveys. The study area extended from the Bering Strait to 73°N latitude between 154°W and 169°W longitude, and thereby included MMS Chukchi and Hope Basin Planning Areas and the western portion of the Beaufort Sea Planning Area (Figure 1a). Several marine mammal species seasonally occur in this region. In fall, bowhead whales (*Balaena mysticetus*) and gray whales (*Eschrichtius robustus*)[1], both Federally listed as endangered species, co-occur in the northeastern portion of the study area, while beluga whales (*Delphinapterus leucas*) and several species of pinnipeds occur throughout the region. Bowhead whales were the species of principal interest during the study due to their endangered status and because they are the focus of an annual subsistence hunt by Alaskan Eskimos. Results of the 3-year study were subsequently integrated with the marine mammal sighting database from aerial surveys conducted each fall 1982-88, with a summary review of all data presented in Moore and Clarke (1992).

METHODS

Line transect and search aerial surveys were flown in a Grumman Goose (G21G) over portions of the Alaskan Chukchi Sea study area each fall 1982-91. The study area was divided into survey blocks (Figure 1b), such that one or, with favorable conditions, two blocks could be surveyed completely on one flight. Surveys in blocks north of 72°N latitude commenced in 1987. During surveys, two principal observers maintained a continuous watch for marine mammals from large port and starboard side windows in the aircraft cockpit, while an observer/recorder entered flight data on a portable computer at a window seat aft of the cockpit. Surveys were usually flown from mid-September through October, although effort varied among years. From 1982-87, survey effort shifted between the Alaskan Beaufort and Chukchi seas depending on the timing of the bowhead whale migration and ongoing offshore oil and gas exploration activities. In 1988, the survey period was limited to 1-16 October, with effort focused on the northern half of the study area. Surveys were directed solely to the Alaskan Chukchi Sea study area from 1989-91, however, dedicated surveys were restricted to the periods 3-11 October and 26 October-7 November in 1990, due to the appropriation of the aircraft and crew for search and rescue operations. Surveys were flown at 305 to 458 m altitude, at speeds of 222 to 296 km/hr.

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[1]Gray whales were removed from the list of endangered species on 30 December 1992.

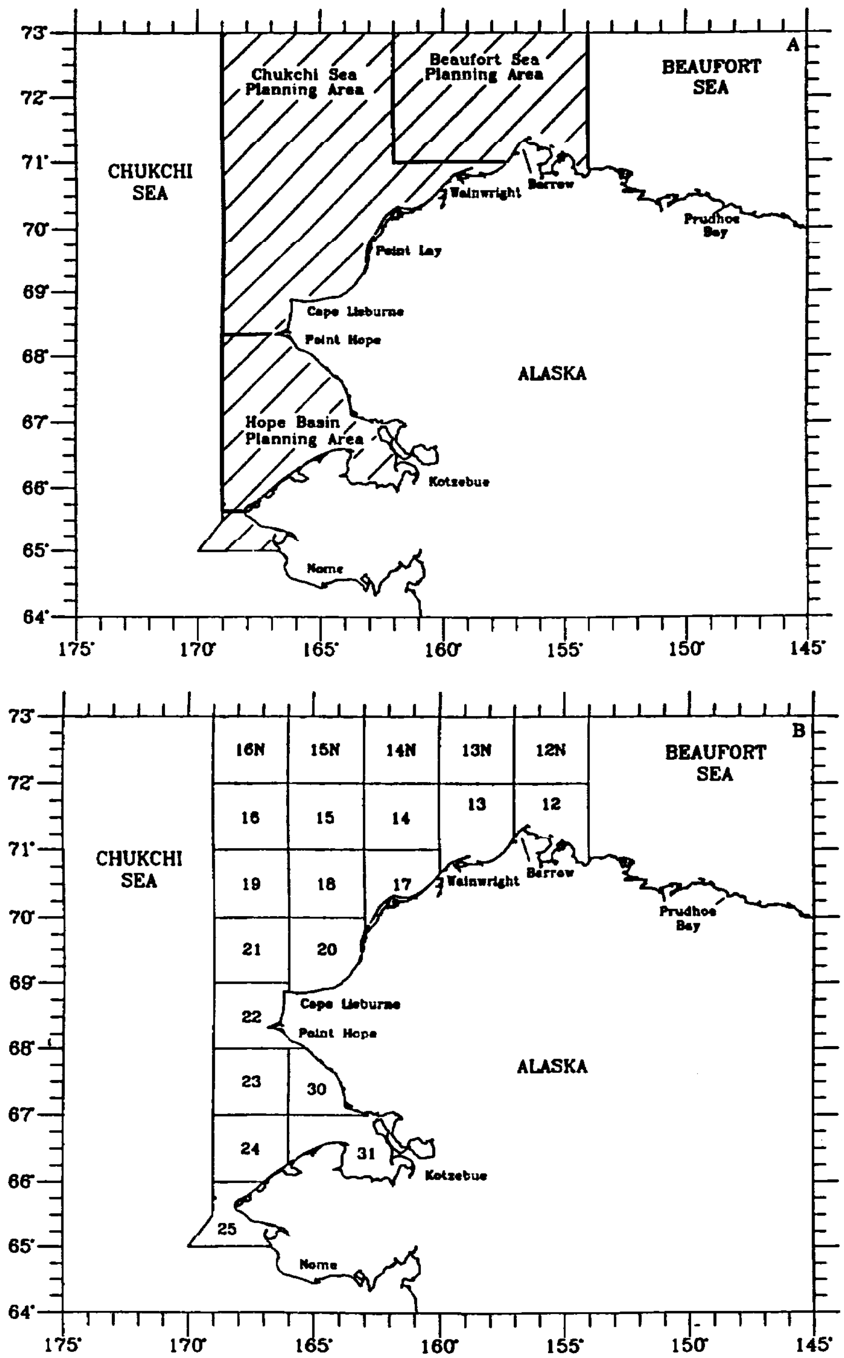

Figure 1. Chukchi Sea study area depicting the boundaries of the Chukchi and Hope Basin Planning Areas, and the western portion of the Beaufort Sea Planning Area (A); survey blocks in the Alaskan Chukchi Sea study area (B).

The higher altitudes were maintained when weather permitted to maximize visibility and to minimize aircraft disturbance to marine mammals.

BOWHEAD WHALES

There were 49 sightings for a total of 190 bowhead whales in the study area from 16-30 September, 146 sightings for a total of 265 bowhead whales from 1-15 October, 72 sightings for a total of 97 bowhead whales from 16-31 October, and 267 sightings for a total of 552 bowhead whales overall 1982-91 (Figure 2a). Bowhead distribution was predominantly nearshore between Smith Bay (*ca.* 154°W longitude) and Point Barrow, and occurred within oil and gas lease area boundaries there during each period (Moore and Clarke 1993). In the northeastern Chukchi Sea, bowhead distribution was predominantly between shore and lease area boundaries south to *ca.* 70°10'N latitude, with a few sightings near or within lease area boundaries in the north-central Alaskan Chukchi Sea. Cumulative (1982-91) bowhead whale relative abundance was highest in survey block 12 (2.47 whales/survey hour), and block 13 (0.68 whales/survey hour), where whales were seen feeding in some years, and block 18 (0.81 whales/survey hour; Figure 2b) where whales were seen breaching and flipper slapping in some years.

Bowheads were seen in the study area from 18 September through 31 October over the 1982-91 survey seasons. However, some whales were seen in the study area prior to the onset of surveys in 1984 and 1987-91 (Moore 1992). The timing of the bowhead migration into the Chukchi Sea during the survey season, inferred from cumulative (1982-91) daily random-only sighting rates in survey blocks 12 and 12N, reflected relatively high sighting rates on 18 and 22 September, followed by relatively low rates in late September that increased to sighting rate peaks on 11 and 15 October (Figure 3a). Bowhead swimming direction was significantly clustered about 272°T in the western Beaufort Sea and about 248°T in the northeastern Chukchi Sea (Figure 3b). These two swimming direction data sets were significantly different from each other (Watson $U^2=0.356$, $p<0.02$), suggesting that most bowheads approach Point Barrow on a westerly course, then turn and swim southwest after passing the Point. Bowheads seen north of 72°N latitude in the north-central Alaskan Chukchi Sea do not seem to fit this paradigm, however. Whales seen north of 72°N exhibited headings between 180° and 300°T, with an average swimming direction of 267°T ($r=0.73$, $p<0.05$; $n=6$). This heading was not significantly different from the average swimming direction of whales south of 72°N in the Chukchi Sea (Watson $U^2=0.030$, $p<0.50$), suggesting that whales seen north of 72°N latitude in the Alaskan Chukchi Sea may be part of a general west-southwest dispersion pattern rather than a dichotomous component of the migration. Fall sightings of bowheads along the Chukchi Peninsula coast (see Moore and Reeves 1993) suggest some bowheads may occur in the south-central Alaskan Chukchi Sea during late October and November, although none were seen there during this study.

GRAY WHALES

There were 60 sightings for a total of 174 gray whales from 16-30 September, 63 sightings for a total of 115 gray whales from 1-15 October, 44 sightings for a total of 135 gray whales from 16-31 October, and 167 sightings for a total of 424 gray whales overall 1982-91 (Figure 4a). No gray whales were seen in 1985, and the three gray whales seen in 1988 were those trapped in the heavy ice north of Point Barrow. The overall pattern of gray whale distribution highlights the importance of coastal waters between Point Barrow and Wainwright, and offshore areas in the north-central and south-central Alaskan Chukchi Sea. Gray whale distribution in survey blocks 14 and 14N appears related to prey availability near Hanna Shoal. Although Hanna Shoal has not been sampled for gray whale prey, the occurrence of feeding whales there (indicated by whales with mud plumes) and not elsewhere in the northern Chukchi Sea suggests that these

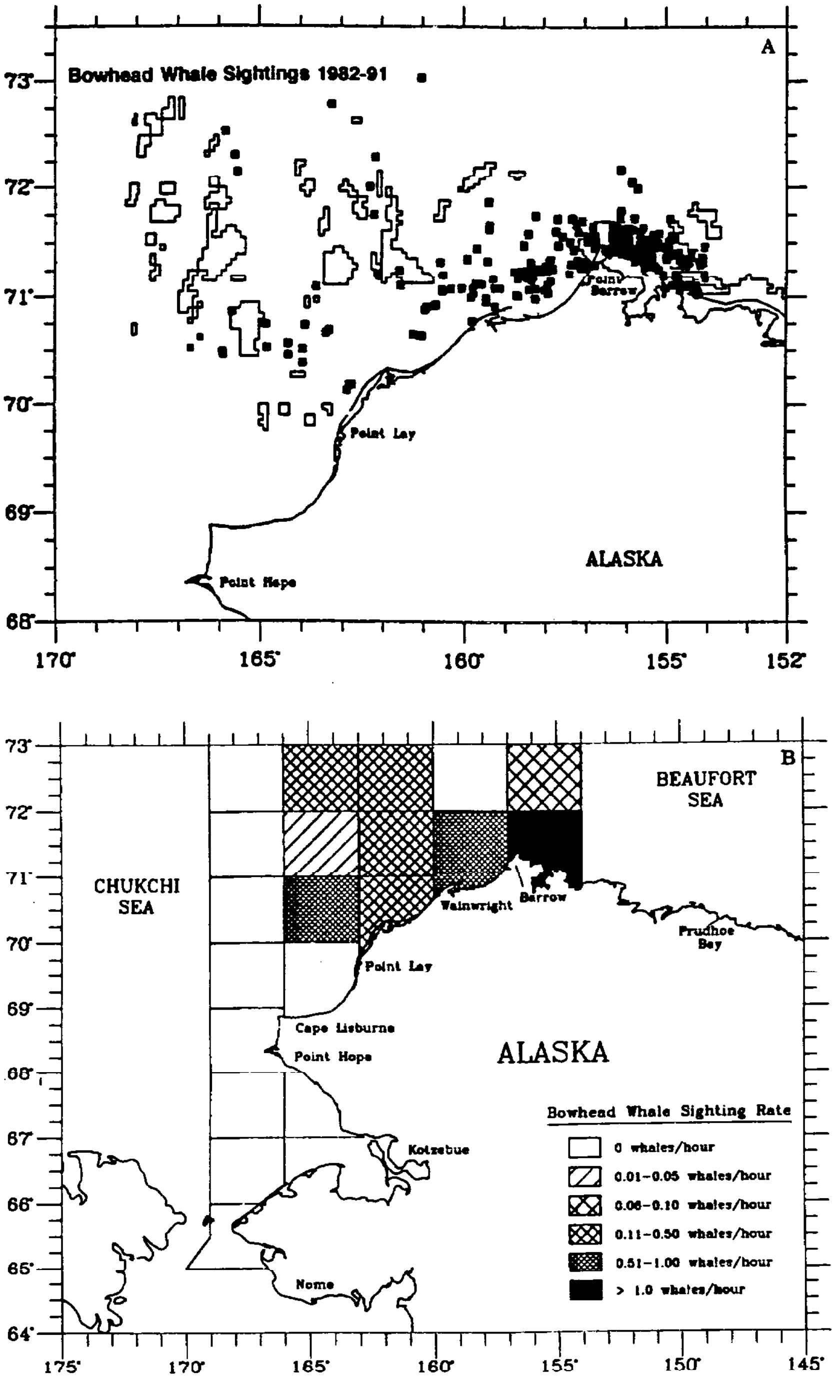

Figure 2. Cumulative (1982-91) bowhead whale distribution relative to oil and gas lease areas (polygons) depicting 267 sightings for a total of 552 whales (A); and bowhead whale relative abundance in the study area (B).

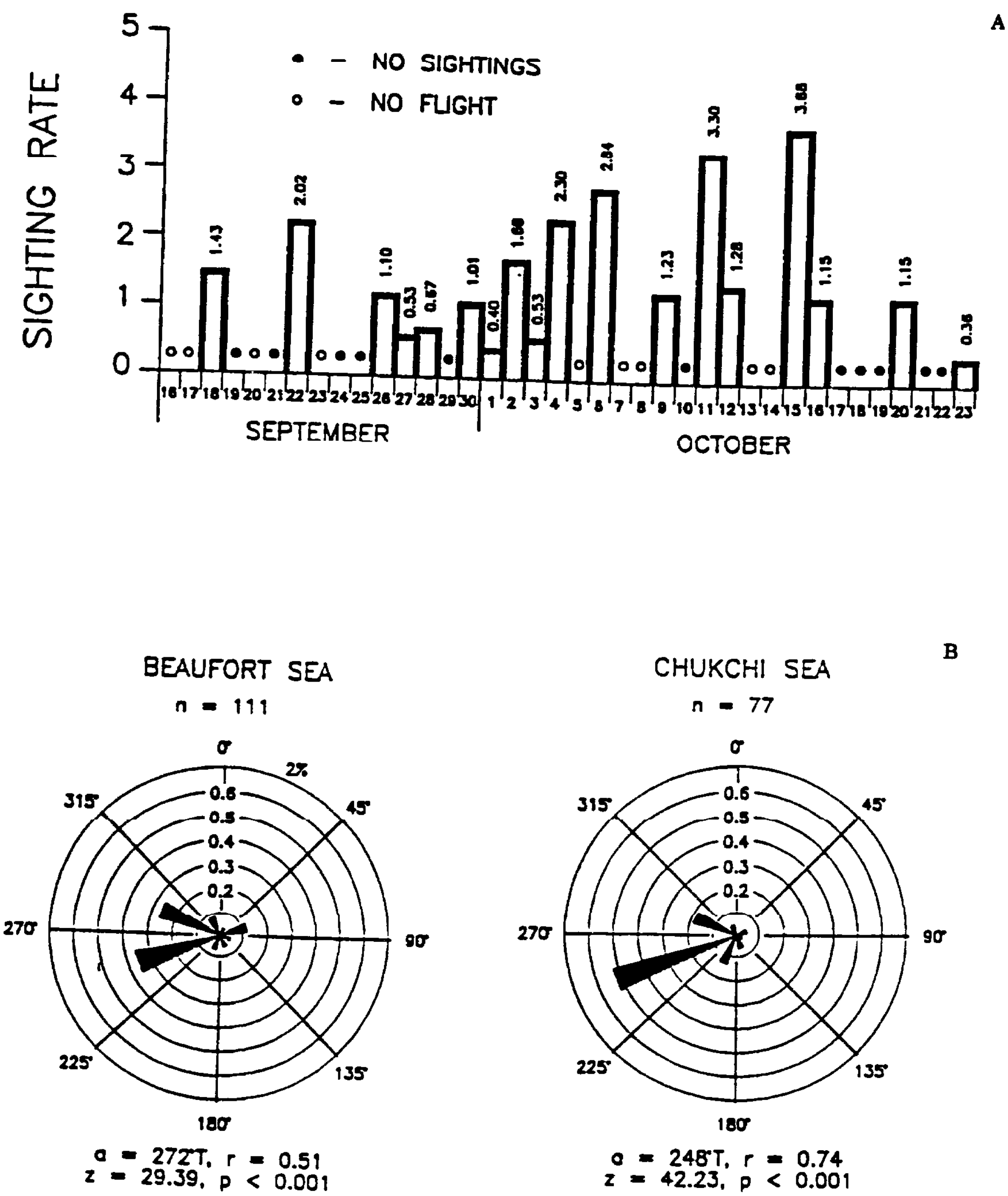

Figure 3. Bowhead whale migration timing into the Chukchi Sea as indicated by daily random-only sighting rates in survey blocks 12 and 12N (A); bowhead whale swimming direction in the western Beaufort and Alaskan Chukchi seas (B).

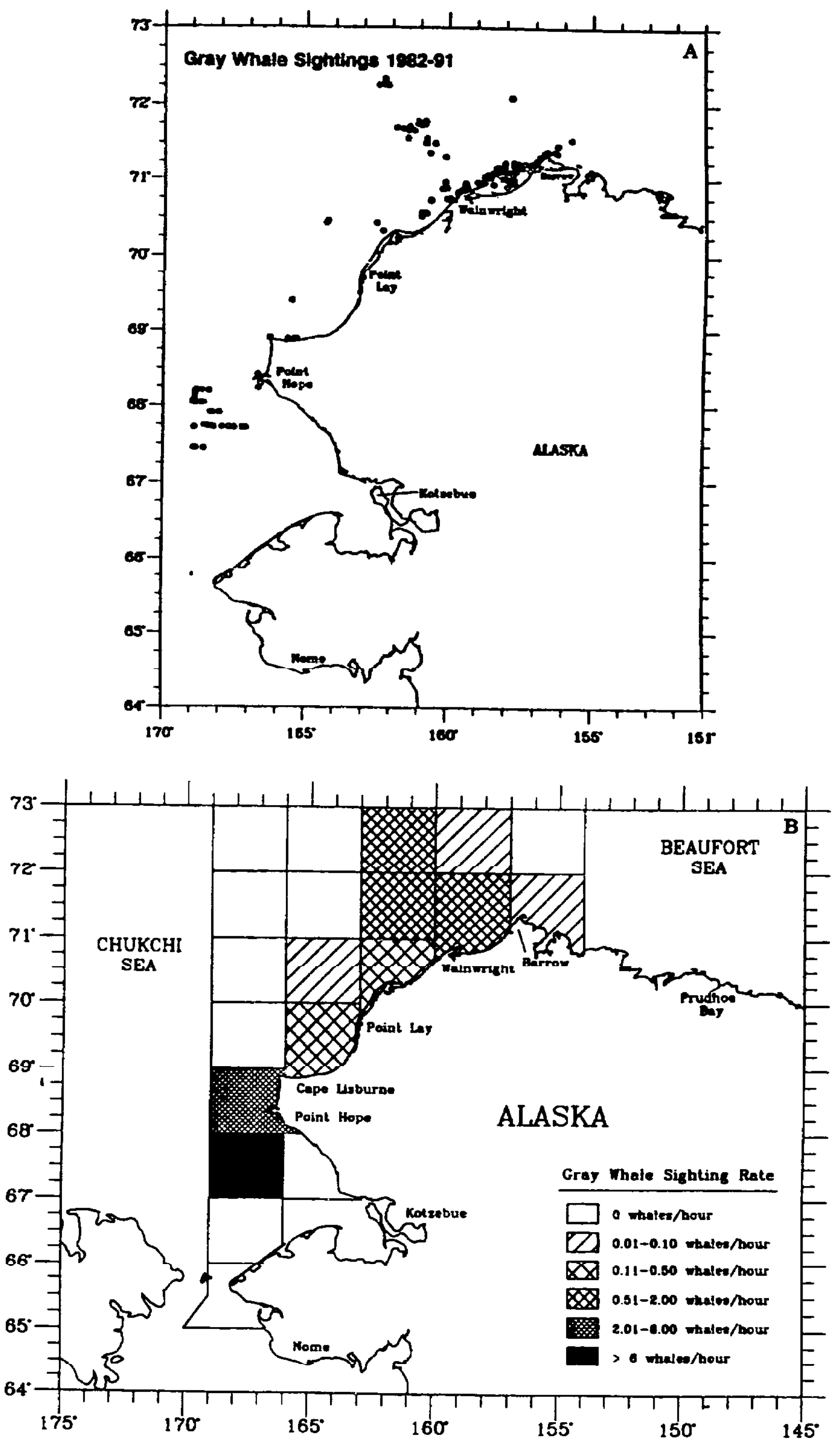

Figure 4. Cumulative (1982-91) gray whale distribution depicting 167 sightings for a total of 424 whales (A); and gray whale relative abundance in the study area (B).

waters represent a feeding area that the whales move into when ice recedes. Gray whale relative abundance was highest in survey block 23 (11.23 whales/hour) and block 22 (5.19 whales/hour), with lesser indices calculated for block 13 (1.17 whales/hour), block 14 (0.68 whales/hour) and block 14N (0.62 whales/hour; Figure 4b). Gray whale relative abundance decreased in the northern blocks (12,13,14,14N) and increased in the southern blocks (22,23), in the latter half of October, suggesting that grays begin their fall migration from the Chukchi Sea by mid-October. Gray whale swimming direction was significantly clustered about 239°T ($p<0.05$), although the actual course that whales take as they migrate from the Chukchi Sea is unknown.

BELUGA WHALES

There were 487 sightings for a total of 3,972 beluga whales in the study area from 1982-91 (Figure 5a). Beluga distribution was relatively nearshore east of Point Barrow, but dispersed west of there, with whales seen as far north as *ca.* 74°N and as far south as *ca.* 69°30'N latitude in the Alaskan Chukchi Sea. Over half of the total number of whales (51%, n=2,024) were seen in two of the heavy-ice years (1983,1988). Beluga relative abundance was highest in block 16N (24.5 whales/hour) and block 12 (10.14 whales/hour; Figure 5b). Relative abundance in survey blocks 14N, 15N and 16N was three to eight times higher than in blocks 14, 15 and 16 suggesting that more belugas occur in the northern waters of the study area than in waters farther south. Beluga fall migration timing and route in the Chukchi Sea are not well understood (Clarke et al. 1993). Swimming direction was significantly clustered about 252°T ($p<0.001$) for whales seen from 154° to 157°W longitude, and about 249°T ($p<0.001$) for belugas seen west of there. These data sets were not significantly different (Watson $U^2=0.105$, $p<0.50$) suggesting that belugas disperse southwest from the western Beaufort Sea across the Alaskan Chukchi Sea.

SUMMARY

All three cetacean species reviewed here occur in coastal waters from about Point Lay to Smith Bay in the MMS Chukchi Sea and western Beaufort Sea Planning Areas each fall. Bowhead and gray whales feed there and belugas migrate through these waters. In addition, gray whales feed and beluga and bowhead whales migrate through offshore waters in the northern Chukchi Sea Planning Area. Gray whales feed in the Hope Basin Planning Area at least through late October in some years, and opportunistic sightings suggest that some bowhead whales may migrate through the area in late fall.

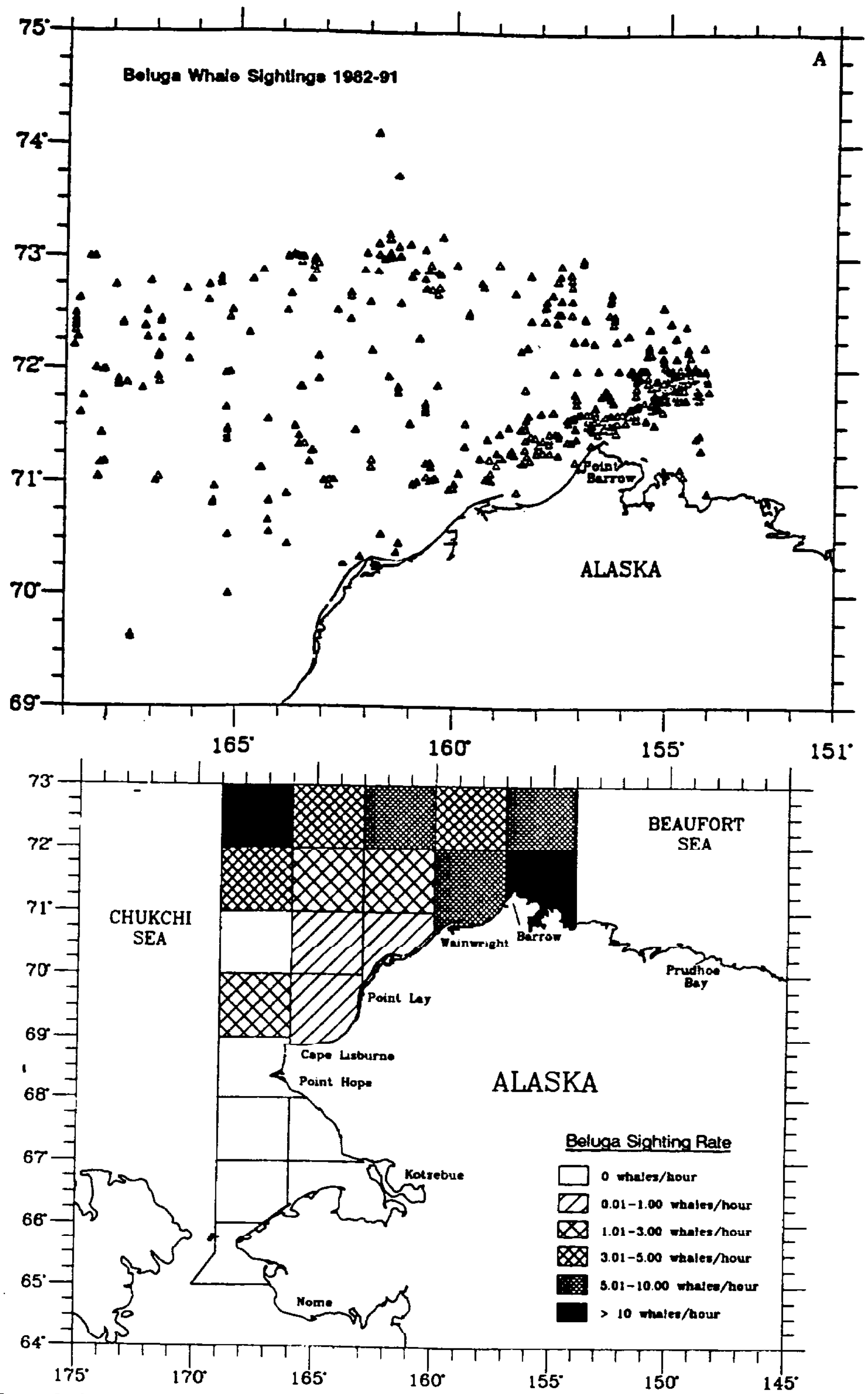

Figure 5. Cumulative (1982-91) beluga whale distribution depicting 487 sightings for a total of 3,972 whales (A); and beluga whale relative abundance in the study area (B).

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QUESTIONS AND DISCUSSION

BOB DAY: You said that off of Barrow, in this plume east of Point Barrow, that the bowheads are feeding primarily on euphausiids?

SUE MOORE: I believe so. That is what the stomach data generally showed.

BOB DAY: Now are they ever feeding on copepods, like some of those larger oceanic copepods that are advected north into the Chukchi?

SUE MOORE: Well, they do feed on copepods, but I think the stomach data, which Kathy (Frost) would know more about, suggest that in Barrow they are feeding more likely on euphausiids.

KATHY FROST: Most of the Katovik whales are eating copepods. The Katovik whales are eating more copepods than the Barrow ones.

MARINE MAMMAL SURVEYS AND SUBSISTENCE COORDINATION DURING INDUSTRIAL ACTIVITIES IN THE BEAUFORT SEA

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INTRODUCTION

Since 1989, ARCO Alaska, Inc. and AMOCO Production Co. are the only two oil and gas companies which have conducted exploratory drilling operations in the Beaufort Sea.

Three of ARCO's four drilling operations took place from bottom-founded units. The units were towed to location and maintained in a warm standby mode until after the fall bowhead migration had been declared over. These three operations were: The Stinson #1 project (1989-90) located in State of Alaska waters offshore from Brownlow Point (west Camden Bay) employing Global Marine's Concrete Island Drilling System (CIDS); Fireweed #1 project (1990-91) 13 miles offshore Camp Lonely west from Harrison Bay using CANMAR's Single Steel Drilling Caisson (SSDC/MAT); and the Cabot #1 project (1991-92) 28 miles east from Point Barrow also using the SSDC/MAT.

The fourth exploratory program (Kuvlum #1 in 1992) was carried out in west Camden Bay waters that exceed the depth capabilities of any existing bottom-founded unit. The operation therefore employed the BeauDril conical floating platform *Kulluk* and its associated ice management, supply, and oil spill response vessels during the season of open water and new fall ice formation. ARCO announced a promising oil and gas discovery at Kuvlum #1 and is presently seeking all necessary permissions to follow that up with a second year's exploratory work in summer 1993.

AMOCO completed the Belcher prospect exploratory well located well offshore in the eastern Beaufort in 1989. This project employed the *Kulluk* floating platform. In 1991 the Galahad prospect north from Camden Bay was drilled using CANMAR's *Explorer II* drillship.

Marine geophysical work was carried out at various locations in the east, mid, and western Beaufort Sea at different times during 1989 and 1990. However, no seismic programs that overlapped the bowhead whale migration were staged in either 1991 or 1992.

THE MARINE MAMMAL MONITORING EFFORT

All the offshore oil and gas exploratory operations described here contained specific monitoring programs, the emphasis of which was invariably upon the bowhead whale migration. Prior to 1990, specific monitoring plans were designated and supervised by the Minerals Management Service (MMS) in the case of Outer Continental Shelf (OCS) operations, and by the Alaska Department of Natural Resources for operations undertaken in state waters. ARCO's Stinson #1 project is the only one which fell within the latter category.

Beginning in 1988, a group of oil and geophysical companies began a process of applying to National Oceanic and Atmospheric Administration/National Marine Fisheries Service (NOAA/NMFS), the agency responsible for management supervision and enforcement of rules governing the "incidental, non-intentional take of six species of whales and seals" during the course of otherwise legal and permitted exploratory operations. These rules were published in July 1990. They prominently featured the requirement to conduct site specific monitoring programs at each individual exploration location. In previous years, off-site studies or scientific experimental programs were sometimes conducted in addition to site specific monitoring. But since 1990, the aim has focused on the effort to determine whether or not "takes" occur as a consequence of assumed industrial "noise disturbance," especially to migrating bowheads.

Following the 1990 season, the first to which the new incidental take rules applied, a joint agency monitoring guidelines workshop was held in Seattle. Agency personnel from NMFS, the MMS, U.S. Fish and Wildlife Service (USFWS) and appropriate Alaskan regulatory authorities; representatives of the scientific community, scientific contracting firms, environmental organizations, Alaskan whaling associations, and oil industry all participated in hammering out a set of monitoring guidelines which have determined both the scope and the elements of every program undertaken since their adoption.

Disturbance by industrial noise is thought by some to constitute the most likely cause of taking. Some, but by no means all, past monitoring reports appear to contain evidence that bowheads avoid moving into and through industrially ensonified zones close to the noise source. Many senior eskimo whaling captains have expressed the view that the bowhead migration has been influenced in this fashion which, in some instances, has caused the whales to swim further offshore from areas where they had been successfully hunted in past years (Griffeth 1992).

The result is that the monitoring guidelines adopted in 1990 require industry offshore operators to employ three methods of seeking evidence on the matter of "takes" by noise disturbance: (1) Aerial surveying for distribution and relative abundance of marine mammals within a 40 kilometer radius of offshore exploratory operations plus behavioral observations intended to document any noted changes in such assumed indicators as swim speed and direction, respiratory rates, etc; (2) Visual observations made from aboard drill rigs and support vessels; (3) Acoustic monitoring encompassing both the acoustic localization of calling marine mammals in relation to the industrial noise source, and precise physical acoustic measurements of that source and the characteristics it exhibits as it moves through the marine medium (transmission losses, received sound levels, etc.). Although Beaufort Sea late summer/early fall environmental conditions (below minimum flight ceilings and, above all, sea ice conditions) have precluded carrying out all these three elements on every monitoring program so far conducted under the adopted guidelines, a substantial body of data has been acquired.

It is important to indicate here the range of variation which has characterized each of the fall migration monitoring efforts since 1989. That year was exceptional in that calm seas and very little ice were present until well into mid-October. This allowed ARCO to move the CIDS to the Stinson location relatively early (mid-August) where it remained on warm standby until the conclusion of the bowhead migration. The monitoring effort consisted of shipboard observations, physical acoustic measurements, and localization of calling marine mammals. It was also one of two instances in which migrating bowheads approached the drill rig within <200m and were observed from the deck of the CIDS (Hall and Francine 1990 and 1991).

1990 was also ice free during the migration, although high sea states were responsible for curtailing a good deal of planned marine seismic acquisition work. Even so, ARCO's Fireweed operation mounted a full visual observation and acoustical program. This was the second instance under review here where migrating bowheads passed very close by an offshore drilling unit operating at warm standby (Hall, et al. 1991). Western Geophysical Company, which conducted various seismic programs between Harrison and Camden Bays in 1990, sponsored an aerial monitoring program in conjunction with its work (Brueggeman et al. 1990). ARCO independently reported on its components of the 1990 seismic work (ARCO 1991).

ARCO's Cabot exploratory prospect and AMOCO's work at Galahad prospect took place in 1991, the first from the bottom-founded SSDC/MAT unit and the second from the *Explorer II* drillship. Moving, dynamic ice throughout virtually the whole season created severe difficulties in carrying out the acoustic localization components of both programs although conditions at Cabot did permit the acquisition of some calling data. Aerial surveys were conducted at both locations and the results for Cabot reported in Gallagher, et al. 1992a and for Gallagher et al. 1992b. A final report on monitoring activities at ARCO's Kuvlum #1 location in 1992 will be available in April 1993. Moving ice floes significantly impacted the Kuvlum exploration effort, and early sea ice freeze-up conditions curtailed effective aerial observations for migrating bowheads for all but one day in October, although it is clear the whales continued moving past the area despite the ice conditions.

The very nature of site specific monitoring requirements has meant that no definitive conclusions on the issue of takings at the locations discussed here can be made without reference to a broader area of coverage. However, it would appear that migrating bowheads do maintain a relatively greater distance from operations conducted from floating units and their associated support vessels than they do from other offshore operations which, in at least several cases, includes active seismic work. What combination of human-caused activities (e.g., noise disturbance), natural environmental conditions (sea ice, feeding opportunities for bowheads), and bowhead behavioral responses that account for variations in the annual fall migration may be very difficult to determine solely from site specific monitoring programs. At the same time, they do greatly enrich the database on a major set of those variables.

Finally, all operations discussed here include the additional component of monitoring for polar bear activity. In years of summer ice concentrations (1991, 1992), polar bears are routinely included in the sighting data if they appear either within visual sighting distance of the drilling platform, any of its associated support vessels, or from aerial surveys. In the case of winter operations, detailed reports of polar bear sightings from the frozen-in bottom-founded rigs are made as part of regularly scheduled observations made from the rig deck. At some point, polar bears have been observed near or adjacent to all the exploration programs reviewed above.

PLANS OF COOPERATION AND OTHER COORDINATION WITH NORTH SLOPE INUPIAT COMMUNITIES

The single most important area of contact — and potential conflict — between offshore oil and gas operations and the resident Inupiat communities of the Beaufort Sea involves the traditional fall bowhead whale hunts by Kaktovik, Nuiqsut, and Barrow. During the 1970s up through 1984, this issue was addressed by the imposition of seasonal drilling restrictions which precluded the majority of offshore seismic and drilling activity once the annual fall bowhead migration had begun in early September.

Since, clearly, oil and gas exploration in all but the shallower nearshore waters could not be accomplished under such severe restrictions, industry sought to create a conflict avoidance mechanism that would allow both parties to accomplish their aims during the usual open water window that extends into October. The result, beginning in 1985, was a negotiated agreement between industry, the Alaska Eskimo Whaling Commission (AEWC) and the communities of

Nuiqsut and Kaktovik. This agreement was termed Cooperative Programs for the Beaufort Sea, or more popularly, The Oil/Whalers Agreement. Its central features were: The establishment of a radio communication system between all whaling vessels from the Nuiqsut and Kaktovik communities and all offshore industry operations so that industry could be alerted to avoid any possible conflict situations with active whaling crews; a system of mutually agreed reporting procedures; and, industry commitments to render emergency assistance to whaling crews in distress should such situations arise (and they have on various occasions).

In the years since 1985, the agreement has been amended to take account of the substantial body of experience which has accumulated. The title of the 1992 agreement was "Conflict Avoidance Procedures for the Beaufort Sea" and resulted from pre- and post-season meetings in Deadhorse between signatory parties. One item of particular importance concerned the perception that industry, through its own required marine mammal monitoring programs, might be in a position to provide direct assistance to the hunting effort. Industry, the AEWC, and the whaling captains have been especially sensitive to this perception and have taken particular pains to avoid communicating real-time location information on the positions of migrating bowheads that might be interpreted as direct industry involvement in the hunt. However, once a whale has been successfully struck and landed by a traditional whaling crew, the agreement does make provision for industry to provide logistical assistance to the whalers to insure that meat spoilage does not occur and that the butchered product is efficiently transported to the whaling community. This provision mainly touches the Nuiqsut whaling crews whose camps are located on Cross Island, north of Prudhoe Bay, and some seventy miles by boat back to the village. In 1992 the Nuiqsut whalers acquired a small barge following a successful grant application to the Bureau of Indian Affairs (BIA) to meet this need directly themselves.

A second major concern of North Slope residents with respect to offshore oil and gas exploration involves oil spill planning and preparedness. Numerous community meetings have been held in which this topic has been addressed. ARCO has taken a special interest in working directly with Nuiqsut, Kaktovik, and Barrow by sponsoring the training (a forty-hour, hands-on course with refreshers) of ten person oil spill response teams in each of these communities. Team members serve as key environmental advisors to ARCO spill response managers (helping to identify sensitive shorelines and wildlife areas, advising on winter on-ice operations, serving as liaison to their respective communities). Trained team members have also regularly participated in on-site response exercises at the drill rigs themselves. The first teams were trained in 1989 and 1990. Subsequently, Alaska Clean Seas — the industry North Slope oil response coop — has also recruited and trained additional local community members as responders.

A third area of coordination between industry and the North Slope villages involves local hire initiatives. ARCO in its operations — including offshore programs — has aggressively recruited employees from the local communities. As a result, anywhere from 15 to 30% of those employed on all projects beginning with Stinson in 1989 have been Alaska Native Slope residents.

CONCLUSION

Coordination with the North Slope Inupiat communities to insure joint use of the Beaufort Sea during the bowhead whale migration appears to have succeeded. While outstanding questions remain about what influences, with what effects, are produced by industrial operations on migrating bowheads, the evidence acquired to date through monitoring programs appears to indicate that the whales maintain some distance from floating drill rig operations whereas they have closely approached operations employing bottom-founded units. The degree to which avoidance of the floating rigs by whales impacts the traditional whale hunt remains under discussion by industry and the Inupiat whalers.

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QUESTIONS AND DISCUSSION

TOM NEWBURY: I wanted to say that I appreciate your frankness about the observations at Kuvlum. I appreciate also the distinction you made between the results of monitoring at bottom-founded operations and floating operations with ice management vessels. Right now there is no distinction between the monitoring guidelines for bottom-founded operations and for floating operations. There is just one set of guidelines that was developed at a National Marine Fisheries Service-MMS sponsored meeting. I think in the future it would be worthwhile to discuss a distinction in the monitoring guidelines for bottom-founded operations as opposed to floating operations, particularly considering that at bottom-founded operations sightings have been made visually from the rig.

BOB GRIFFETH: Well, Tom just as long as you don't try to cut us out of the summer work. One of the problems is, of course, that we have to have joint use of the same area in what conceivably is a competition with migrating whales. And the fact that if you are in water over 85 ft deep you simply must use a floating operation using existing equipment. By the way, there are only two units in the world that can do this bottom-founded, well there are three actually. And as a consequence of that, it is a structure potential conflict. But you are right that more careful attention should be paid to the fact that one is, at least from the point of view of noise disturbance, obviously one is a more potent source than the other.

REACTIONS OF MIGRATING BOWHEAD AND BELUGA WHALES TO NOISE FROM SIMULATED INDUSTRIAL ACTIVITIES IN ICE LEADS DURING SPRING

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Underwater sound is important to marine mammals in sensing their environment and in communicating with one another. Underwater sound attenuates slowly in seawater, and strong sounds are often audible many kilometers away. Many activities associated with offshore hydrocarbon exploration and production introduce man-made noise into the sea. This noise may sometimes interfere with ("mask") the abilities of marine mammals to hear calls from other marine mammals, or to hear other important natural sounds. In addition, certain man-made sounds cause changes in marine mammal behavior, sometimes to the point of displacing them from favored locations.

Prior to 1989, all work on reactions of bowhead whales to industrial sounds had been done during late summer or autumn when the whales were in open water or at most light ice (Richardson and Malme 1993). The applicability of these results to the heavier ice conditions present in other seasons was uncertain.

In spring, the Western Arctic population of bowheads migrate north to Point Barrow, and then east across the Beaufort Sea to Canadian waters, following leads and cracks in the ice when possible. Belugas take a generally similar route, although many of them tend to be farther offshore.

To date, offshore exploration has not been permitted during spring in or near the main lead system around northwestern Alaska. The National Marine Fisheries Service concluded in 1988 that "...development and production activities in the spring lead systems used by bowhead whales for their migration would be likely to jeopardize the population. ...NOAA Fisheries will reconsider this conclusion when new information...become[s] available". Noise from oil industry operations was one of NMFS' concerns. The Minerals Management Service funded our study in order to provide some of the data needed for a re-evaluation of the question of jeopardy.

The primary objectives were (1) to determine the physical acoustic conditions prevailing in spring lead systems, insofar as these would affect the likely radius of influence of man-made noise; (2) to determine the short-term behavioral reactions of bowheads and (when possible) belugas to platform and icebreaker noise; and (3) to coordinate with other studies and hunters to maximize data collection and avoid interference.

METHODS

During the springs of 1989-91, LGL Ltd. and subcontractor Greeneridge Sciences Inc. used an underwater sound projector to broadcast recorded industrial sounds into the water along the spring migration route of bowheads and belugas. One crew travelled out onto the ice by helicopter in order to deploy the underwater sound projector and to make ice-based observations of whale behavior close to the projector during playback and control periods. Another crew in a Twin Otter aircraft obtained aerial observations of the distribution, movements and behavior of the whales as a function of distance from the projector under playback and control conditions (Richardson et al. 1991).

In 1989-90, we tested the reactions of bowheads and belugas to playbacks of the steady, low-frequency sound from a drilling operation on a grounded ice pad. The projected sounds dropped below the natural ambient noise level and became inaudible at distances ranging from 1 or 2 km on days of high ambient noise to 10 km or more on days of low ambient noise (average about 5 km from the projector). In 1991 we tested the reactions to playbacks of the more variable sound from an icebreaker (*Robert LeMeur*) breaking ice. The icebreaker sounds varied in level as the ship moved forward into the ice, came to a stop, backed up, and repeated the cycle. The frequency content of the icebreaker sounds was also broader and more variable than that of the drilling sounds.

For logistical and other reasons, the area east of Point Barrow is the most practical area for the study. We consulted annually with the Barrow Whaling Captains' Association (BWCA) and North Slope Borough Department of Wildlife Management to ensure that the work was done in a manner that did not interfere with the bowhead hunt or with any whale census activities planned for the year in question. In 1989-91, it was agreed that the study could be done in an area east of Point Barrow. Almost all sound playbacks had to be done from pack ice, because very few whales travel along the landfast ice edge in the area well to the east of Point Barrow. In 1991, with the agreement of the BWCA, some playbacks were done from the landfast ice edge closer to Barrow after spring whaling had ended and when there was no whale census. Additional fieldwork planned for 1992 was postponed to a later year at the request of the BWCA and North Slope Borough because of their concerns that it might be perceived as interfering with the full-scale bowhead census that was attempted in 1992. (There had been no full-scale census in 1989-91.)

RESULTS

Bowhead Whales

During the playbacks of steady drilling sound in 1989-90, we often saw migrating bowheads passing within 1 km or less of the operating projector, well within the ensonified area. There was evidence that some migrating bowheads diverted their courses enough to remain a few hundred meters to the side of the projector on most occasions. However, some bowheads came within 200 m of the operating projector, most notably on a day when the only available lead through otherwise-heavy ice passed within 200 m of the projector. There was no evidence that bowhead migration was blocked by the projected drilling sounds, and no evidence that they avoided the projector by distances exceeding 1 km. We began to follow some bowheads when they were as much as 5 km from the operating projector, but we did not see diversion of migration paths until the whales were within a few hundred meters.

Although bowheads often approached well within the ensonified region, several aspects of their behavior were altered to a statistically significant degree when they came within 1 km. Less consistent and less conspicuous behavioral changes extended out to at least 2 km and possibly as much as 2-4 km. In particular, bowheads approaching the projector sometimes turned more frequently than normal, slowed down, or exhibited altered surfacing and respiration patterns (Richardson et al. 1991).

Overall, we found that bowheads migrating through the leads in spring showed no obvious reaction to the steady low-frequency drilling noise when its received level (RL) was low, up to ~12 dB above ambient. Subtle changes in behavior became evident when the RL was ~12-18 dB above ambient. When ice conditions allowed, bowheads often diverted to avoid RLs more than ~25 dB above ambient. When the only migration corridor through the ice passed close to the noise source, migration was not blocked by exposure to steady drilling sounds at levels 40+ dB above ambient.

The above conclusions were based on the 1989-90 playbacks of one type of steady low-frequency drilling sound. Responsiveness of spring-migrating bowheads in other situations, and to other types of sounds, may differ. To test that possibility, in 1991 we did further playbacks with the more variable icebreaker sound. Unfortunately, weather and ice conditions at Barrow were very poor for our purposes during the spring of 1991. We obtained only a few preliminary data from the icebreaker playbacks. Those limited data showed that a few bowheads continued to migrate past the projector within the area ensonified by the varying icebreaker noise. However, more fieldwork is needed to obtain enough data to compare the relative responsiveness of bowheads to steady vs. variable sounds.

Beluga Whales

Belugas showed no obvious reaction to the steady drilling sound until they approached within 200-400 m. Even then the reactions were inconsistent and brief. Belugas continued past the operating projector after, at most, a few minutes hesitation. Some individuals approached well within 100 m, where levels of the steady drilling sound were 30 dB or more above the natural ambient level. As in the case of bowheads, more data on their reactions to the more variable icebreaker sounds are needed. However, at least a few migrating belugas came well within the ensonified area without evidence of hesitation or diversion.

The beluga is one of the few species of marine mammals for which hearing sensitivity has been measured at low as well as high frequencies (Johnson et al. 1989). Belugas have very sensitive hearing at high frequencies, but at low frequencies they can hear only strong sounds. This may be a major part of the reason why spring-migrating belugas came quite close to the projector when it was broadcasting industrial sounds, which are predominantly at low frequencies. We suspect that no reactions were seen at distances more than 200-400 m because that was the maximum distance at which belugas could hear the low frequency drilling sounds, even though hydrophones sensitive to low frequencies could usually detect these underwater sounds as much as several kilometers away from the projector.

CONCLUSIONS

Playbacks of continuous low-frequency drilling noise did not cause biologically significantly alterations in the migration route of bowhead whales visible in open water amidst the pack ice and in parts of the nearshore lead system during spring migration east of Point Barrow. There were, however, small-scale alterations in the courses of some individual whales that came within 1 km. There were also statistically significant changes in many other aspects of the behavior of bowheads approaching within 1 km of the projector. A few behavioral variables were apparently affected at distances out to 2-4 km. The biological significance of these changes in bowhead behavior is less obvious; most aspects of behavior that were affected near the noise source were affected for only about ½-1 hour. These results all refer to one particular type of continuous low-frequency drilling sound. Additional data are needed to determine how migrating bowheads react to other types of man-made sounds that might occur in the leads during spring.

The underwater sound playback techniques that we have used have limitations. They cannot perfectly reproduce all attributes of the underwater sound field from a large oil industry operation, and do not reproduce attributes that a whale might sense by other cues like vision or olfaction. However, the playback method provides a way to obtain some data on the potential effects of noise from industrial operations before any operations of those types have begun. Like any other data, the significance of these playback results must be interpreted carefully. However, playbacks provide some of the information needed for a re-evaluation of the question of possible jeopardy to bowheads migrating through leads around northern Alaska in spring.

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QUESTIONS AND DISCUSSION

DON HANSEN: I wonder if you would clarify something? You said that for the belugas, you didn't have any reactions to the ice breaker noise?

JOHN RICHARDSON: As I said, we have very few data and one would not want to draw conclusions from them yet. We did see some belugas that swam within a few hundred meters of the projector with no evidence of hesitation or diversion. At that distance we could very easily detect and measure the sound level from that projector in the water.

DON HANSEN: The ice breaker noise, some of those noises are of a higher frequency aren't they?

JOHN RICHARDSON: There were some higher frequency components. Thus, one would suspect that belugas might react to it at a considerably greater distance than they did relative to the steady, low-frequency drilling sound. Information from studies in the Canadian High Arctic back in the mid- to late 1980s would lead one to suspect that belugas might react to weak sounds from a distant ice breaker.

BOB DAY: One question I had is with respect to the sound environment along the North Slope. I don't know much about sound in water, but it has always been my impression that the rate of movement can be strongly affected by density, and especially where you have strong salinity fronts, for example, in fresh water inputs in the marine environment, say the Colville River or the Sag, one of those. You can actually have a sound barrier produced, sound bouncing off that salinity front. Has anybody pondered that in terms of long-term management for places to locate drilling rigs as a possible sonar shield?

JOHN RICHARDSON: You are certainly right that those kinds of effects occur. They are things that we measure when we try to determine the sound exposure levels during our experiments. However, I don't recall anybody using one of those phenomena as a criterion in choosing rig locations.

PAM MILLER: I was just curious to know, and perhaps Dr. Griffeth would be interested in chiming in on this too, most of the research that I am familiar with concerning effects of industrial activities concerns basically short-term responses. So I am very interested to know what type of research you feel needs to be done to really get at the question of cumulative and long-term impacts of industrial activities?

JOHN RICHARDSON: You are quite right that that has always been a major problem. Studies like the one I have discussed here look at short-term behavioral reactions. The link between short-term reactions and long-term effects on individuals and populations, which are ultimately what people are most concerned about, is tenuous at best. One type of study that can be done involves long-term monitoring of distribution and movement patterns. That should be done before, during and perhaps even after industrial activities take place in an area. These types of studies often don't get started in time to provide adequate "before" data. The MMS-funded distributional work on arctic whales is a good example of a long-term monitoring program for distribution and movement patterns. Similarly, we have tried to interpret distributional data on bowheads around the oil rigs that were operating extensively in the summering grounds of the bowheads in the Canadian Beaufort back in the early 1980s. However, it is difficult to obtain enough information in a systematic way over a long enough period, including pre-development as well as development years. Another approach is to address the question of habituation. This might be done by going back to the same animals repeatedly, using radio tags to relocate them, and testing whether their sensitivity to noise changes after repeated exposures. That approach has been attempted once, during a study funded by Amoco and done by D. Wartzok et al.

BOB GRIFFETH: It is probably just the irony of the situation, but increasingly since the incidental take regulations were promulgated in July 1990 and the guidelines that were subsequently issued from joint agency monitoring workshops honed the kinds of questions that industry is being asked to address very specifically, to site-specific monitoring for takes. They are saying we don't want you to do anything else except this. So while the question that you raise is a reasonably good one, it is not cheap either way, but the point is that we are obligated to fulfill our first obligation which is site-specific monitoring for determining the level of takes. And probably it is an artifact of the Marine Mammal Protection Act, I think.

STEVE LANDINO: John, I was wondering, subsequent to your next round of studies, if you plan to project noises from more than one ice breaker at the same time rather than just the single?

JOHN RICHARDSON: Well, there are lots of things like that that we have thought of as being nice things to do, but most of them are not in the plans. It takes a long time to get an adequate sample of observations of the types we need. Hence, the number of different stimuli that we can test is very limited. There is a long list of things that we would like to do, but practically we can't do more than a few of them.

MOVEMENTS AND DIVE HABITS OF BOWHEAD WHALES FROM SATELLITE-MONITORED RADIO TAGS

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Twelve bowhead whales (*Balaena mysticetus*) were radio tagged from 30 August to 5 September 1992 off the Mackenzie River delta in the Canadian Beaufort Sea. The purpose of the project was to acquire dive habits and movement data from the end of the open water feeding season in the Canadian Beaufort Sea and similar information on the fall migration west through the Alaskan Beaufort. The tags were Argos (satellite-monitored) radio tags with customized controller boards packaged in a cylinder (2" diameter and 6" long). They were attached by means of a 150# compound crossbow and a subdermal folding barb at each end of the cylinder.

Whales were tagged at close range from a platform extending 2 m over the starboard bow of the 14 m research vessel *Annika Marie*. Tags were located on the back of the whale approximately 2 m behind the blow hole. All tags were applied within a single week to subadult whales in an area of 40 square kilometers.

The tags monitored information on dive durations, depths and temperatures during eight daily summary periods. Each tag transmitted 256 bits of information whenever it surfaced. Without a duty cycle, estimated transmitter life was 32 days. It took two sequential transmissions to provide a full suite of sensor data for the previous 6-hr summary period.

The movements of eight whales were tracked for periods varying from 4-34 days and distances of 500 km to nearly 5,000 km. Over 12,000 km of movements were tracked during the course of 123 tag days. The longest attachment was confirmed by a message from one tag after 50 days. Six of the tags stopped functioning due to low battery power (a monitored variable).

While some individuals stayed in the vicinity of Mackenzie Bay, others concentrated activities around Herschel Island and Demarcation Bay before heading west. The concentration of activity around Herschel Island and Demarcation Bay adds credence to the suggestion that these areas are important feeding areas for bowhead whales prior to the fall migration. Most of the animals spent their time inside the 500 m contour but some went into deeper waters directly north of the Mackenzie Bay/Herschel Island complex. This suggests there is not a highly cohesive migration. Instead, individual whales migrate at their own pace and initiation of the western movement is not from a single well defined environmental cue.

Two whales moved west of Prudhoe Bay. One whale was tracked across the Chukchi Sea following the heavy ice edge to Wrangel Island and then south. This is the first documentation of bowhead migration through the Chukchi Sea and evidence of the importance of the ice as a major migratory cue.

The sensor data acquired from these tags suggest that bowhead whales conduct longer dives and spend a higher percentage of their time submerged than any other species of baleen whale. Specific information on maximum duration of dives, maximum surfacing periods, deepest dives and percentage of time spent at different dive depths is presently under analysis and will be part of the project's final report to Minerals Management Service.

Tags identical to those used on bowhead whales will be applied to sperm whales in the Gulf of Mexico in 1993. Sperm whales are reputed to be the longest and deepest diving of all cetaceans. The sperm whale research is sponsored by the Gulf Region of Minerals Management Service.

QUESTIONS AND DISCUSSION

DON HANSEN: You mentioned about that one anomaly, where whales surface in ice to breathe but the transmitter is not exposed and results in the illusion of longer dives and less time at the surface. I was wondering whether that could be occurring more often? In other words, whales, in fact, may be spending more time on the surface rather than what you said, five percent, due to where the tag is located on the whale versus what the whale is doing?

BRUCE MATE: Yes, you are right. There is a potential bias, even in open water, but we have enough information in open water from this and other species to feel confident that there is a real difference between bowheads and other species. We actually locate this tag a little differently on the bowhead than we would on another baleen whale species. On other baleen whales, we would locate the tag 1-2 meters behind the blow hole. Bowheads have a conspicuous neck that wouldn't surface in that area, so the tag is located farther back. Our field observations suggested that the tag surfaced quite regularly. The presence of a high proportion of short duration dives also suggests we are not missing much. If, for instance, the tag were only exposed as the whale fluked up on a "terminal dive," we would not have seen short dives in open water. We are confident that bowheads really are substantially different, both in the durations of dives and percentage of time submerged. But there is the potential for some bias, such as I mentioned in the ice. And I would emphasize again, I am sharing with you preliminary information and it should not be quoted until our analyses are completed. There is about an 18% error rate in Argos data and we have rushed to eliminate much of the errored information to share this preliminary evaluation with you today, but we are not done.

CALEB PUNGOWIYI: Could the battery situation be developed where you could track these animals for a longer period of time, like out to their wintering areas?

BRUCE MATE: Yes, we will get to that point. We originally planned to use different software to reduce the transmission rate to 8 hr/day. That would have probably tripled the duration of operation from transmitting 24 hr/day as we did this summer. The smaller prototype unit I showed you has less batteries, but will have a location-only capability with a very short transmission so we can extend its operation to four to six months; I believe hydrodynamic drag contributes a lot to tag loss, especially when large animals travel at high speeds routinely. This would promote pressure necrosis and tag loss. By the way, we have seen right whales in the North Atlantic after they lost their tags, and there was little swelling, no tissue sloughing, and no significant scarring. We are quite pleased that whales do not react adversely to tagging. We believe the tags do not cause the whales problems, and thus we are collecting data from healthy "normal" individuals.

AERIAL SURVEYS OF ENDANGERED WHALES IN THE BEAUFORT SEA, FALL 1992: PRELIMINARY FINDINGS

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INTRODUCTION

Bowhead whale monitoring by the Environmental Studies Unit, Alaska OCS Region, Minerals Management Service (MMS), has become an important component in mitigation of potential effects of offshore exploration, especially through its determination of the timing and axis of the fall bowhead migration in arctic waters. The MMS (or, previously, the Bureau of Land Management) has funded bowhead whale surveys in the Beaufort and Chukchi Seas since 1978. In 1987, Alaska OCS Region staff formed the MMS Bowhead Whale Aerial Survey Project (BWASP) to conduct aerial surveys of the fall bowhead whale migration in the Beaufort Sea.

The goals of the ongoing MMS program follow:

1. Provide real-time data to MMS and the National Marine Fisheries Service (NMFS) on the general progress of the fall migration of bowhead whales across the Alaskan Beaufort Sea, for use in implementing overall seasonal drilling restrictions and limitations on geological/geophysical exploration;

2. Monitor temporal and spatial trends in the distribution, relative abundance, habitat, and behaviors (e.g., feeding) of endangered whales in arctic waters;

3. Provide annual analyses of long-term interyear trends in the median depth (or north-south positioning) of the migration axis for bowhead whales;

4. Provide an objective wide-area context for management interpretation of the overall fall migration of bowhead whales and site-specific study results;

5. Monitor behaviors, swim directions, dive times, surfacing patterns, and tracklines of selected bowhead whales;

6. Record and map beluga whale distribution and incidental sightings of other marine mammals; and

7. Determine seasonal distribution of endangered whales in other planning areas of interest to MMS.

METHODS

The study area for the 1992 aerial surveys includes the Beaufort Sea between 140°W and 157°W longitudes south of 72°N latitude (Figure 1).

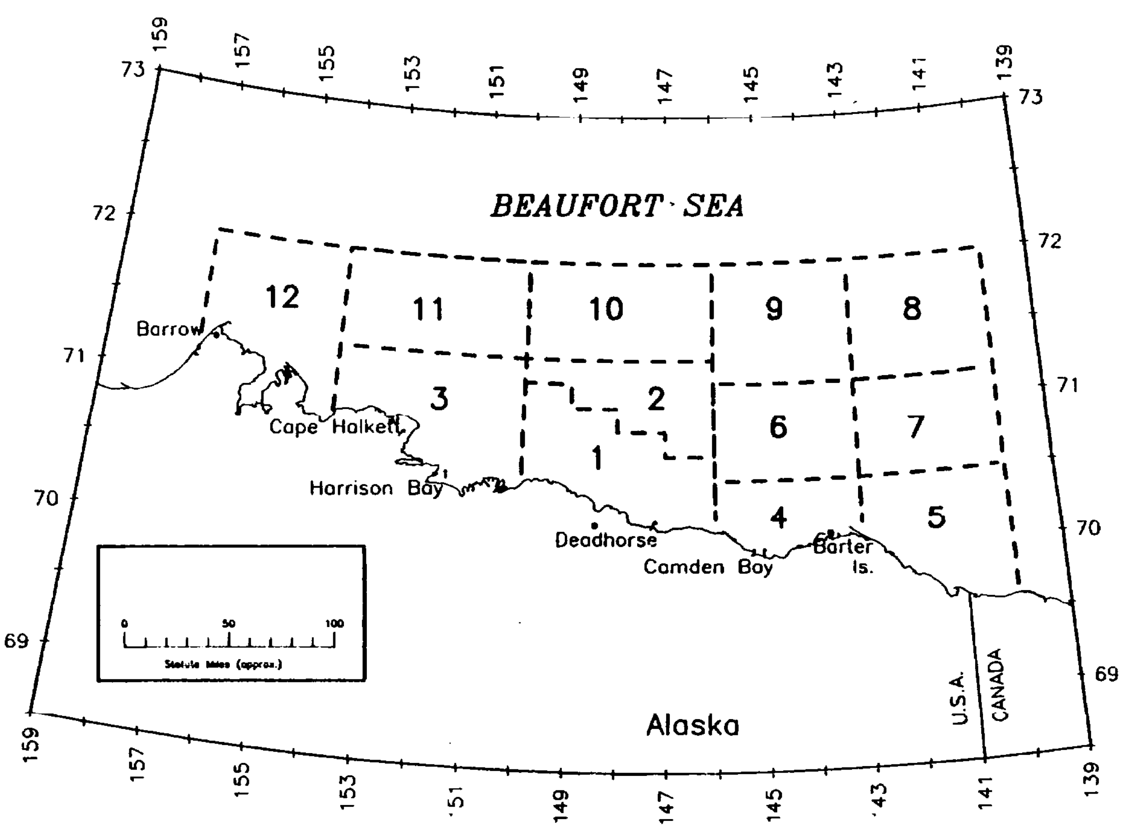

Figure 1. Fall 1992 study area showing study blocks.

Aerial surveys were flown August 31 through October 23, 1992 in a de Havilland Twin Otter Series 300 equipped for arctic operation and aerial surveys of endangered whales, with bubble windows for downward visibility.

Data collection and analyses replicated standard procedures developed and used in past years (1979-1991). These methodologies are described in detail elsewhere and incorporated herein by reference (Treacy 1988, 1989, 1990, 1991, 1992).

Two basic types of aerial survey data--random-transect surveys and search surveys--were collected to accomplish the listed objectives:

1. Random-transect surveys were flown in survey blocks to determine bowhead whale distribution patterns, to estimate relative abundance and density, and to determine the location of the migration axis. Whales recorded, regardless of distance from a random-transect line, are used in determining the median and mean water depths at bowhead

sightings. Only those whales sighted within one kilometer of a random-transect line are included in calculating densities.

2. Search surveys were flown to locate whales and observe their behavior enroute to transect blocks or when diverting from transects to monitor selected pods. Search surveys did not follow a preset flight pattern, but data from non-random surveys were considered combinable with random-transect data to obtain distribution patterns, relative abundance, and behavior of whales and other marine mammals.

RESULTS

The Fall 1992 season (from August 31, 1992 through October 23, 1992) was notable for its moderately heavy sea-ice, similar to conditions for the Fall 1984 and 1985 surveys.

During the Fall 1992 season, the MMS BWASP conducted whale surveys over enough kilometers (44,645 km) of arctic water to circumnavigate the planet. The number of kilometers surveyed, mostly over the Alaskan Beaufort Sea, was the highest since the inhouse project began in 1987 and does not count miles flown overland en route to and from the study area. The average survey flight was almost 1,000 km.

The longer flights resulted from improved flying weather this fall and an improved fuel capacity in the Twin Otter aircraft used by the project. The duration of each flight varied with survey conditions, but some were up to 7 hours long. As a result of the improved weather and fuel capacity, total flight hours greatly exceeded our 150 hour goal proposed in the Fall 1992 Project Management Plan.

Preliminary totals of MMS arctic surveys from August 31, 1992 to October 23, 1992 include: 315 bowhead whales, 635 beluga whales, 45 bearded seals, 606 ringed seals, 203 polar bears, 1 walrus, 5 unidentified cetaceans, and 163 unidentified pinnipeds observed during 205.78 hours of survey effort that included 98.93 hours on randomized transects. The last sighting of bowhead whales during this Beaufort Sea study occurred on October 21, 1992. No other species were observed.

Total numbers of polar bears and ringed seals observed were the highest since 1982. The numbers of beluga whales and bearded seals were the highest noted since this inhouse study began in Fall 1987. In addition to the large number of polar bears (n=203), there were many sites where polar bears had killed other mammals (n=27) and polar bear tracks (n=636) noted over much of the study area. On September 12, 1992, project personnel spotted a dead bowhead whale just east of Kaktovik, Alaska, in association with several polar bears. On October 4, 1992, a high count of 30 polar bears was noted near this carcass.

The project extended its work an additional 3 days in October 1992 in order to monitor a large concentration of over 100 bowhead whales that appeared to be feeding near Point Barrow, Alaska. The concentration of whales was first noted on October 15, 1992, and was subsequently monitored until it dispersed on October 21, 1992.

DISCUSSION

Daily information on bowhead distribution, movements, and behavior during the westward migration of the whales across the Alaskan Beaufort Sea was communicated daily to the Regional Supervisor, Field Operations, Alaska OCS Region, MMS, in Anchorage, Alaska for use in implementing permit restrictions, as needed, for drilling and seismic explorations. Data showing daily flight effort, sightings of bowhead whales, and other information received from a survey sponsored by ARCO Alaska Inc. at Kuvlum Prospect, were also telefaxed to MMS, Anchorage. All daily reports were made available to NMFS in Anchorage.

Data on observed sea ice conditions from each day's flight were communicated to the U.S. Navy/National Oceanic and Atmospheric Administration Joint Ice Center for continued use in ground-truthing satellite imagery. The previous day's data on the bowhead whale migration was transmitted to the Alaska Eskimo Whaling Commission (AEWC). Field coordinations were continued with the oil industry-whalers' conflict avoidance group located in Deadhorse, Alaska.

A dead bowhead whale, spotted by project personnel on September 12, 1992, was reported to NMFS, the oil industry-whalers' conflict avoidance group, and AEWC.

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MONITORING MARINE MAMMALS IN THE CHUKCHI SEA DURING INDUSTRIAL ACTIVITIES USING ICE-MANAGEMENT TECHNIQUES

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Studies were conducted to determine the response of walruses to exploratory drilling operations at two remote prospects in the northern Chukchi Sea between June 29 and October 8, 1991. Drilling or icebreaker operations were conducted by Shell Western E & P, Inc. at the Crackerjack Prospect between July 5 and August 30, and by Chevron U.S.A. at the Diamond Prospect between August 31 and October 5. Monitoring studies covered a broader period in order to characterize walrus use of the prospects before and after operations. The Crackerjack and Diamond drill sites are approximately 312 km and 175 km west of Barrow, Alaska, respectively. Pack ice limited actual drilling of the wells to 31 of 57 (54%) days at Crackerjack and 27 of 36 (75%) days at Diamond. Operations at each drill site involved two Arctic Class 2 icebreakers, one Arctic Class 3 icebreaker, one drillship, one barge with tug, and two Puma helicopters. An Arctic Class 4 icebreaker was also used at the Crackerjack site from August 28 to 30. The current studies were a continuation of a 3-year marine mammal monitoring program that began in 1989.

Aerial surveys and vessel-based observations were conducted at each prospect. Aerial surveys were flown from a Twin Otter aircraft at a 305 m altitude in a 100 km x 45 km grid consisting of 9 north-south transect lines spaced 11.1 km apart. The middle transect (line 5) included the drill site, and the actual number of transects lines flown each day varied from about 7 lines at the more distant Crackerjack Prospect to 9 lines at Diamond Prospect, in order to accommodate aircraft fuel range. The length of the transect lines also varied according to ice conditions. The southern ends of the lines usually corresponded to the ice edge and the northern ends to approximately 90-100% ice coverage since most walruses occur in lower percentages of ice cover. Surveys were flown before, during, and after drilling or icebreaker operation at each prospect in order to assess changes in walrus distribution and behavior relative to operation activities. In addition, vessel-based observations were conducted from the Class 3 icebreaker, *Robert LeMeur*, by trained marine mammal observers during the entire period of operations. Acoustic measurements were also conducted to characterize the sound levels of the *Robert LeMeur* during icebreaking activities.

There were almost 110,000 sightings of walruses recorded during 44,685 km of aerial survey effort during the monitoring program. Approximately 13% (14,593) of the walruses sighted occurred in the survey grid at Crackerjack during 11,812 km (26%) of all effort. Seventy of these sightings were recorded on 4 flights before operations, 14,522 sightings on 21 flights during operations, and 1 sighting on a single flight after operations. Over four times as many sightings were made outside the survey grid during flights between Barrow and the prospect. The highest single day walrus count totaled 18,134 individuals, of which 5,090 were found in the survey grid. Approximately 29% (31,779) of the walruses sighted occurred in the survey grid at Diamond during 7,588 km (17%) of all effort. These included 7,021 sightings recorded on 3 flights before operations, 9,163 sightings on 4 flights during operations, and 15,595 sightings on 3 flights after operations. Fewer than 5% of the sightings were recorded outside of the grid during transit flights. The highest single day count was 10,119 walruses, all of which occurred in the grid. Over 94% of the walruses encountered during the Crackerjack and Diamond monitoring programs were associated with the pack ice.

Walruses occurred across the entire southern margin of the pack ice surveyed between 157°-168°W. Most walruses observed during the Crackerjack monitoring program were considerably (>55 km) east of the drill site, primarily along or near (<24 km) the ice edge. Those recorded in the Crackerjack grid were closely associated with larger aggregations, which moved northeastward and northward out of the region by early August. The Crackerjack drillsite, therefore, appeared to be on the western periphery of the area used by walruses during the northward migrations, and walrus occurrence at Crackerjack appeared to be transitory. Conversely, most walruses observed during the Diamond monitoring program were in the survey grid. In addition, walruses observed earlier in the season were south of the Diamond drill site. The Diamond drill site, therefore, appeared to be in the area used by walruses during the northward and early southward migrations. Relatively large aggregations of walruses occurred north of this drill site, in the vicinity of Hanna Shoals during September and October, suggesting that the Diamond drill site is south of an important walrus feeding area. Use of the area was strongly associated with the presence of pack ice.

The broadscale effects of the drilling/icebreaker operations on walruses were evaluated from the survey aircraft according to four parameters: (1) density, (2) association with pack ice, (3) distance from ice edge, and (4) distance from sound source. Only one of these parameters, (4) distance from sound source, indicated a possible change in the distribution of walruses related to icebreaker operations at Diamond. The recorded number of walruses tended to increase with increasing distance (0-48 km) from the sound source on 2 of 3 days suitable for analysis. Movements of the animals, however, appeared to be more strongly influenced by the location, configuration, and composition (concentration and floe size) of the pack ice. Detection of broadscale changes may have been limited by the spacing of the flightlines, which was dictated by the inherent variation of the navigation system and the need to minimize aircraft-caused disturbance on adjacent flightlines. The inability to detect such changes at this scale, for multiple parameters, suggests that the responses were subtle, short term, localized, and/or confounded by other factors such as environmental conditions or walrus social behavior.

Small scale responses relative to distance from various icebreaker activities were evaluated from the *Robert LeMeur* for 487 groups of walruses. Reaction rates were highest for icebreaking (30% or 43 groups), slightly lower (27% of 344) for running, maneuvering, or jogging and lowest (6% of 100) when the vessel was drifting or anchored. Almost half of the observation time was associated with the vessel drifting/anchored, and approximately equal proportions (15-22%) of time were associated with each of the other activities. The most frequently elicited reaction was attentiveness (63%), followed by movement away (18%), escape or splash into water or from ice flow (15%), and lastly, approach (4%). The proportion of walruses reacting to the icebreaker operations, relative to distance, was highest (62% of 93 groups) when within 0.46 km of the icebreaker, intermediate (45% of 94) between 0.46-0.93 km, and lowest (3% of 297) beyond 0.93 km. These results show that walruses responded to the icebreaker over a range of distance and during all vessel activities, but reactions primarily occurred within 0.93 km of vessel when it was moving under power or icebreaking.

In addition to the observations of walruses, a series of acoustic measurements were made as part of the environmental monitoring program. These measurements were made when the *Robert LeMeur* was involved in ice management activities at the Crackerjack Prospect. The purpose of the measurements was to determine the underwater and airborne radiated noise and underwater source level spectra. Sonobuoys were used to obtain the data. The highest recorded radiated noise levels were produced during full power operation while the *Robert LeMeur* pushed against a stationary pressure ridge. The overall source level was 189 dB re 1 μPa at 1 m for this condition. The source levels and spectra for ice management at this site were comparable to data obtained previously at other sites. Because of high transmission loss for under-ice propagation, the estimated audible range for full power operation was 12 km when based on a comparison with ambient noise associated with moderate sea state at the ice edge. A limited set of airborne data was obtained and analyzed. These data showed that the underwater radiated noise from ice management activities was considerably higher relative to normal underwater ambient noise levels than was the airborne radiated noise component when compared to airborne ambient noise data over open water.

The results of the study show that potential for take was low relative to the size of the population because: (1) walruses were dispersed over a broad area, even at Diamond, (2) activities of the drillship and icebreakers were largely confined to the drill site, (3) broadscale responses to the operation, as reflected in changes in walrus distribution, were not consistent among four parameters used to measure effects, (4) smaller scale measurements from the *Robert LeMeur* indicated that behavioral responses of walruses were largely limited to the immediate vicinity of the icebreaker, and (5) the dynamic movement of the pack ice (12-24 km/day) likely reduced exposure time of hauled-out walruses to the underwater radiated noise levels that were estimated to reach ambient levels at 12 km from the icebreaker.

BIRDS

Thursday, January 21, 1993

USE OF KASEGALUK LAGOON, CHUKCHI SEA, ALASKA, BY MARINE BIRDS

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INTRODUCTION

This study was designed to determine the use of the Kasegaluk Lagoon system in the northeastern Chukchi Sea (Figure 1) by birds. The communities of Point Lay and Wainwright are located along this section of the Chukchi Sea coast of Arctic Alaska. Residents of these communities use local marine bird and mammal resources for subsistence. In 1989, 1990, and 1991 oil and gas wells were drilled on leases in the Chukchi Sea offshore from the Kasegaluk Lagoon area; this area may be the focus of petroleum exploration and development activities in future years. As a consequence, there has been a need for more information on the temporal and spatial distribution and abundance of birds and mammals in and adjacent to the Kasegaluk Lagoon area.

BACKGROUND

About 100 species of birds have been recorded in various marine and terrestrial habitats in the Kasegaluk Lagoon region (Roseneau and Herter 1984). Of these 100 species, only 13-15 are relatively common. In particular, four species or species groups of waterfowl — geese such as black brant (*Branta bernicla nigricans*) and greater white-fronted geese (*Anser albifrons frontalis*), eiders (*S. mollissima v-nigra, S. spectabilis, S. fischeri and Polysticta stelleri*) and oldsquaw (*Clangula hyemalis*) — are known to use habitats in and adjacent to Kasegaluk Lagoon for nesting (eiders), molting (eiders and oldsquaw), and feeding (all species). Several of these waterfowl are important in local and national economies: thousands of eiders (and a few oldsquaws) are harvested by subsistence hunters throughout the Bering-Chukchi-Beaufort region, and Federal and state agencies have expressed concern over declining populations of some eiders. Thousands of black brant and greater white-fronted geese are harvested by hunters along the Pacific Flyway in Western North America.

Of about 40 species of shorebirds known to occur in the region, only six — red and red-necked phalaropes (*Phalaropus fulicarius* and *P. lobatus*, respectively), pectoral sandpiper (*Calidris melanotos*), dunlin (*C. alpina*), western sandpiper (*C. mauri*) and semipalmated sandpiper (*C. pusilla*) — are common in tundra nesting habitats, in barrier island-lagoon habitats, or adjacent coastal marsh habitats. In addition, Pacific and red-throated loons (*Gavia pacifica, G. stellata*), black guillemot (*Cepphus grylle*), arctic tern (*Sterna paradisaea*) and glaucous gull (*Larus hyporboreus*) use habitats in and adjacent to Kasegaluk Lagoon for feeding and/or nesting (Roseneau and Herter 1984).

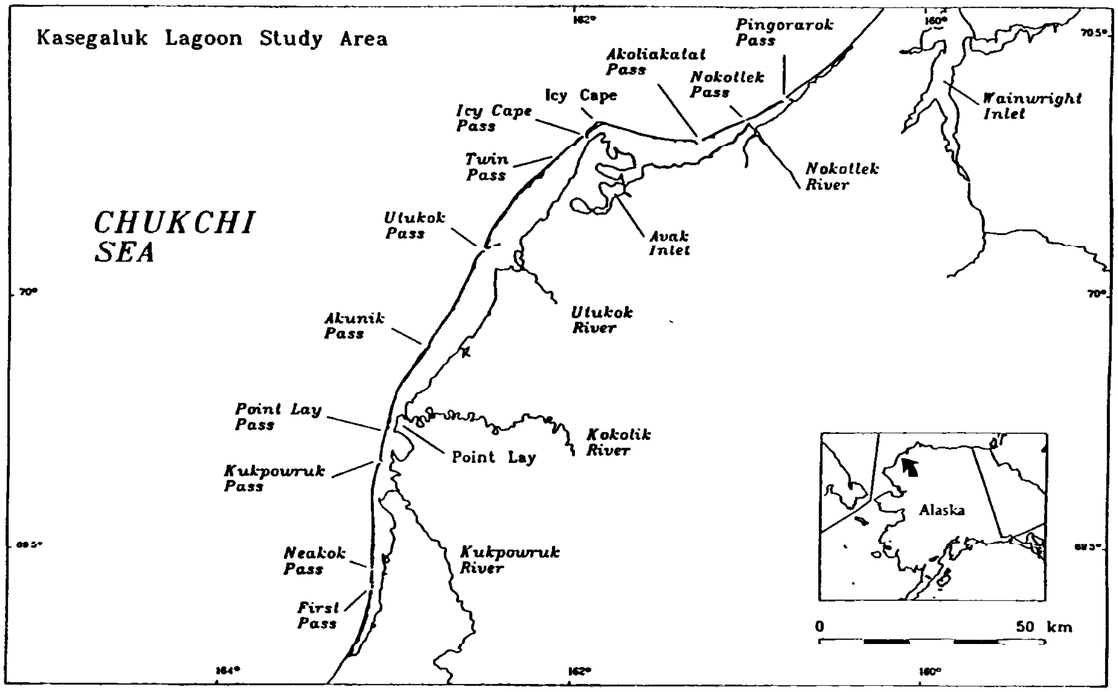

Figure 1. Kasegaluk Lagoon study area, Chukchi Sea, Alaska.

Before this study began we speculated that bird use of Kasegaluk Lagoon may be quite similar to that of other Arctic lagoons that have been studied in Alaska. Information in the literature indicated that the oldsquaw, eiders, glaucous gull and phalaropes were the dominant bird species during most of the open water season in Kasegaluk Lagoon, a situation that is very similar to other lagoons along the Arctic coast of Alaska. Possible exceptions to this generality were the presumed larger numbers and higher densities of common eiders in the Kasegaluk Lagoon area. Several thousand black brant were also reported to pass through the Kasegaluk Lagoon area during fall migration (Lehnhausen and Quinlan 1982). Some of these species, such as the oldsquaws and some of the eiders, reportedly arrive in mid- to late summer (late July through August) to feed and molt (Lehnhausen and Quinlan 1982, Roseneau and Herter 1984, Gill et al. 1985). It was reported that large numbers of eiders may molt offshore from Kasegaluk Lagoon and that eiders aggregated in marine and lagoon habitats, especially near the passes linking lagoons with the nearshore Chukchi Sea. It was also reported that geese may concentrate in marsh habitats along the mainland shoreline of the lagoon (Roseneau and Herter 1984).

Table 1 describes the expected relative abundances, habitat types used and periods of occupancy of birds in the Kasegaluk Lagoon area, based on this historical information. The four dominant species or species groups of birds suspected to be present in the Kasegaluk Lagoon system during the spring through fall open-water period were (1) brant, (2) eiders, (3) oldsquaws and (4) shorebirds (Lehnhausen and Quinlan 1982, Roseneau and Herter 1984).

OBJECTIVES

The overall objective of this part of the study was to determine the uses by birds of the Kasegaluk Lagoon area. There was sufficient information in the literature from previous work in

Table 1. Total number of bird sightings and individuals seen both on- and off-transect during 5 aerial surveys in Kasegaluk Lagoon, Chukchi Sea, Alaska, 24 August to 11 September 1989.

Species	No. Sightings	% of All Bird Sightings	No. Indiv.	% of All Indiv. Birds	Species	No. Sightings	% of All Bird Sightings	No. Indiv.	% of All Indiv. Birds
Yellow-billed Loon	4	0.1	5	0.0	Greater White-fronted Goose	49	1.5	1,329	0.6
Pacific Loon	114	3.5	200	0.1	Canada Goose	4	0.1	55	0.0
Red-throated Loon	76	2.3	122	0.1	Black Brant	543	16.7	143,918	70.2
Unid. Loon	42	1.3	79	0.0	Tundra Swan	28	0.9	71	0.0
All Loons	236	7.3	406	0.2	All Waterfowl	1,873	57.7	195,015	95.1
Black Guillemot	8	0.2	10	0.0	Unid. Phalarope	7	0.2	39	0.0
Parasitic Jaeger	6	0.2	6	0.0	Dunlin	1	0.0	5	0.0
Long-tailed Jaeger	3	0.1	7	0.0	Whimbrel	1	0.0	1	0.0
Glaucous Gull	910	28.0	2,687	1.3	Black-bellied Plover	10	0.3	28	0.0
Herring Gull	1	0.0	1	0.0	Lesser Golden Plover	3	0.1	9	0.0
Arctic Tern	12	0.4	20	0.0	Unid. Plover	2	0.1	12	0.0
All Seabirds	940	28.9	2,731	1.3	Unid. Small Shorebird	94	2.9	6,595	3.2
Red-breasted Merganser	44	1.4	2,239	1.1	Unid. Large Shorebird	3	0.1	6	0.0
Northern Pintail	55	1.7	967	0.5	All Shorebirds	121	3.7	6,695	3.3
Greater Scaup	2	0.1	76	0.0	Northern Harrier	2	0.1	2	0.0
Unid. Scaup	17	0.5	421	0.2	Golden Eagle	1	0.0	1	0.0
Oldsquaw	478	14.7	24,679	12.0	Bald Eagle	1	0.0	1	0.0
Common Eider	437	13.5	7,046	3.4	Gyrfalcon	2	0.1	2	0.0
Unid. Eider	3	0.1	54	0.0	Snowy Owl	62	1.9	64	0.0
Black Scoter	3	0.1	18	0.0	All Raptors	68	2.1	70	0.0
White-winged Scoter	9	0.3	200	0.1	Common Raven	3	0.1	3	0.0
Surf Scoter	80	2.5	1,155	0.6	Snow Bunting	2	0.1	31	0.0
Unid. Scoter	4	0.1	69	0.0	Northern Wheatear	3	0.1	4	0.0
Unid. Diving Duck	109	3.4	12,552	6.1	Unid. Passerine	2	0.1	10	0.0
Lesser Snow Goose	8	0.2	166	0.1	All Passerines	10	0.3	48	0.0
					All Birds	3,248	100	204,965	100

Kasegaluk Lagoon, Peard Bay and other lagoons that had been studied to indicate that Kasegaluk Lagoon was generally similar in form and function to other lagoons, such as Simpson Lagoon and lagoons farther east in the Alaskan Arctic. At the same time, it was suspected that there were some characteristics of the Kasegaluk Lagoon system that may be distinct from other Arctic Alaska lagoons, as follows:

1) The Alaska Coastal Current flowing into the Chukchi Sea from the Bering Sea may influence ecological processes in the Kasegaluk Lagoon area.

2) The passes leading into Kasegaluk Lagoon may attract many species of vertebrates (marine mammals, birds, fish), and these areas may be of special importance in this arctic lagoon system; such large concentrations of vertebrates at passes are not typical of Beaufort Sea lagoons.

3) Much of Kasegaluk Lagoon, especially the southern portion, appears to be quite shallow (< 1 m) and may not support key species of vertebrates to the same extent as deeper lagoons elsewhere.

4) Unlike the situation in most Beaufort Sea lagoons, temperature and salinity regimes in the Kasegaluk Lagoon system appear to be greatly influenced by periodic heavy rainfall in the western De Long Mountains and resultant increased discharges from the Utukok, Kokolik and other rivers that feed into the lagoon. These changes in temperature and salinity

probably influence the distribution of invertebrates and perhaps some of their vertebrate predators (e.g., birds and marine mammals).

Our approach to this study included reliance on existing relevant information coupled with a focused program of research on the key species of birds in the lagoon system. The study was structured to test the following general premise:

Kasegaluk Lagoon supports special habitat uses (alternatively, typical habitat uses) by vertebrates, uses that are not duplicated (alternatively, are duplicated) in lagoon habitats elsewhere in the Alaskan Arctic.

We carried out a study that involved (1) a review of information (and re-analysis of some data) concerning bird use of the Kasegaluk Lagoon area, the Peard Bay-Franklin Spit area, and lagoons in the Alaskan Beaufort sea, and (2) an aerial survey program that quantitatively sampled various regions and major habitats in and adjacent to Kasegaluk Lagoon.

STUDY AREA

Kasegaluk Lagoon is situated along the Chukchi Sea coast of Alaska about 300 km SW of Point Barrow, Alaska (Figure 1). The lagoon extends from about 69°16'N, 163°18'W in the southwest to about 70°30'N, 160°25'W in the northeast. Icy Cape, located at 70°20'N, 161°51W, is a prominent coastal feature situated about two-thirds of the way north along the outer coast of Kasegaluk Lagoon. In total, the lagoon is about 200 km long — 135 km from the extreme southwest end to Icy Cape, and 65 km from Icy Cape to the extreme northeast end. The rolling foothills of the De Long Mountains are immediately adjacent to the southern end of Kasegaluk Lagoon. Farther north, virtually the entire mainland shoreline of the lagoon is backed by low tundra bluffs; vertical relief along these bluffs varies from near sea-level in river deltas and creek mouths to nearly 10 m along some sections at the north end of the study area.

Five major rivers or inlets drain into Kasegaluk Lagoon: the Nokotlek River and Avak Inlet flow into the northern part of the lagoon, and the Utukok River, Kokolik River, and Kukpowruk River drain into the southern part of the lagoon. Several well vegetated islands with high vertical relief are present in the deltas of the Utukok and Kukpowruk rivers. Most of these islands are covered with tundra vegetation, have extensive lakes and ponds, and are separated from the mainland by river channels and mudflats.

Barrier islands of silt, sand, and gravel shelter the entire length of Kasegaluk Lagoon except where passes allow an exchange of water between the lagoon system and the Chukchi Sea. In total 11 sets of passes breach the barrier islands, eight southwest of Icy Cape and three northeast of Icy Cape (Figure 1). The largest passes (i.e., those that appear to allow the greatest exchange of water) are Utukok Pass, located southwest of Icy Cape, and Akoliakatat Pass, Nokotlek Pass, and Pingorarok Pass, all located northeast of Icy Cape (Figure 1).

Barrier islands and shoals on the lagoonward sides of the islands are generally devoid of vegetation except for the region south of Utukok Pass. Barrier islands in this region, and especially in the region south of Kukpowruk Pass are low and subject to flooding during periods of high water. Such periodic flooding has created extensive marshes with small lakes, ponds and luxuriant vegetation on these sections of the barrier islands. Islands and portions of islands on the lagoon-side of the barrier islands farther north support far less vegetation, with the exception of the shoals and small islets adjacent to the barrier islands 5-10 km north of Point Lay. These islets have extensive patches of lyme grass (*Elymus* spp.).

Kasegaluk Lagoon varies considerably in width and depth. The northeastern portion of the lagoon (northeast of Icy Cape) is relatively deep (3-4 m in many places), is no wider than 8 km at its widest point off the mouth of Avak Inlet, and lagoon waters are relatively clear. Southwest of Icy Cape the lagoon is shallow (generally less than 2 m), no wider than 10 km at its widest point off the mouth of the Utukok River, and is turbid. The most southwesterly part of the lagoon (i.e., the area southwest of the Kukpowruk River delta) is very shallow — only a few centimeters deep in many areas. Mudflats in this area are often exposed and are mostly covered with an orange/red-colored algae. The lagoon waters and beaches adjacent to Akoliakatat and Nokotlek passes are the only other regions of the study area where primary production is evident. In this part of the lagoon green algae (probably *Ulva* spp.) is visible in the water column, on the lagoon bottom, and washed-up on beaches, especially in late summer.

The influence of lunar tides is relatively inconsequential in the Kasegaluk Lagoon area — daily fluctuations are generally less than 15 cm. Winds, however, appear to play a very important role in regulating water levels in Kasegaluk Lagoon. Winds from the north or east appear to result in a mass transport of water offshore, thereby lowering lagoon water levels. Winds from the south or west drive water into the lagoons, thereby causing water levels to rise. Sustained winds may cause water levels to rise or fall to extreme levels. Extensive areas of mudflats may be exposed in the shallow southern part of the lagoon (e.g., south of the Kukpowruk River delta), and in the shallow area around Icy Cape, when sustained winds prevail from the north or northeast. In contrast, water levels may rise nearly 1 m or more in these same areas when sustained strong winds blow from the south or southwest. During periods when lagoons are filling, distinct plumes of clear marine water are visible as intrusions into the lagoon. Conversely, during periods when lagoons are draining, distinct plumes of turbid lagoon water are visible flowing out into the nearshore marine system. Wind direction and speed, as well as water levels, may change considerably from one day to the next, and may vary considerably from one end to the other of the 110-nautical mile-long lagoon system.

Seaward of the barrier islands water depths increase to 10 m within about 2 km of shore. The exception is Blossom Shoals at Icy Cape where water as shallow as 5 m extends seaward at least 5 km. Bottom substrates are composed of beds of gravel along most of this section of the Chukchi Sea coast, especially south of Point Lay and the area northeast of Icy Cape (Lewbel 1984).

Kasegaluk Lagoon is ice-covered for about 7 months — from early November through late May or early June. The nearby Chukchi Sea freezes in late November, and in some years ice may remain in the Blossom Shoals-Icy Cape area until early July.

Habitats in the study area are of four general types (Figure 2); (1) mainland shoreline, (2) mid-lagoon, (3) barrier island, and (4) nearshore marine. **Mainland shoreline** habitats consist of coastal tundra interspersed with ponds, lakes, streams, marshes, rivers and river deltas. The lagoon margin of the mainland shoreline consists of a sand or mud beach. During low-water periods this habitat is continuous with adjacent mud and sand flats. **Mid-lagoon** habitats are relatively uniform throughout the study area. Except for the shallow areas east of Icy Cape, and the area at the extreme southern end of the study area, both of which are exposed during low water, this habitat consists exclusively of lagoon waters. **Barrier island** habitats consist mainly of sand and gravel beaches and beach ridges with little vegetation cover except for the southern sections of the barrier islands (i.e., mostly south of Point Lay). In the north, most of the barrier island chain and adjacent lagoon-side shorelines are devoid of vegetation and consist of gravel, sand and mud beaches, shoals, spits and islets. The passes connecting the lagoon with the Chukchi Sea are major features of this habitat type. **Nearshore marine** habitats are relatively uniform along the entire length of the study area except adjacent to the passes and near Icy

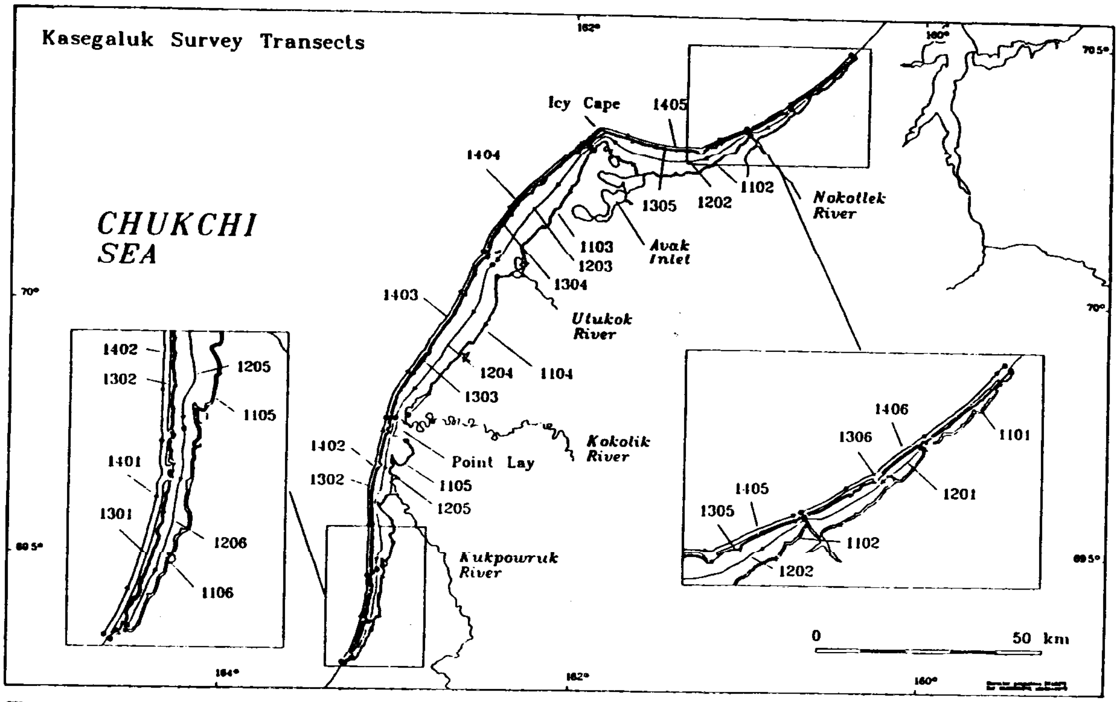

Figure 2. Locations and numbers of aerial survey transect lines in the Kasegaluk Lagoon study area.

Cape-Blossom Shoals. Near passes seaward flowing plumes of lagoon water may be extensive, and near Icy Cape-Blossom Shoals waters are shallow and the general orientation of the coast changes from N-S in the south to E-W in the north.

METHODS

We surveyed four separate strips of habitat in the Kasegaluk Lagoon study area (Figure 2). One strip was along the mainland shoreline and sampled most shoreline, coastal marsh and river delta habitats used by geese and some ducks, and tundra habitats used by a variety of terrestrial birds and mammals. A second strip was through mid-lagoon habitats and sampled areas used by feeding seaducks, and seabirds. A third strip was along the lagoonside shoreline of the barrier islands and sampled (1) all of the major passes from the marine system into the lagoon and (2) barrier island shoreline habitats used by resting and feeding waterfowl (geese and ducks), shorebirds, gulls and terns. The fourth strip was located in the nearshore Chukchi Sea about 0.5 km seaward of and parallel to the barrier islands, and sampled marine habitats used by seabirds and marine waterfowl (phalaropes, gulls, terns, guillemots, brant, eiders, oldsquaws, etc.). Each of these survey strips was approximately 200 km (110 nmi) in length, and was subdivided into six shorter transects (Figure 2). Each transect was further subdivided into 1-min. time intervals that corresponded to about 3-3.5 km at a survey speed of approximately 175-200 km/hr.

SURVEY TECHNIQUES

Complete aerial surveys of the study area were conducted on each of two consecutive days, weather permitting. In 1989, sets of surveys were at about 1 week intervals between 24 August and 11 September. In 1990 sets of surveys were at about two week intervals between 27 July and 10 September. Surveys in 1991 were designed to provide supplementary information for the entire lagoon system in the late July-early August period, and to provide more information on the distribution and abundance of brant. Pairs of surveys were flown twice in 1989 (24-26 August and 3-4 September), and an additional single-day survey was flown on 11 September 1989 (5 surveys). Pairs of surveys were flown four times in 1990 (8 surveys in the period 27 July-10 September). In 1991 a single pair of surveys of all transects was flown on 30 July-1 August, and another set of surveys designed to count brant was conducted on 26 August (4 surveys).

Most aerial surveys for this study were conducted from a float-equipped Cessna 206 with an ARNAV-50 long range navigation (LORAN) system for determination of transect start and end points and locations of important features in the study area. In 1991 two surveys (on 30 July and 1 August) were conducted in an Aero-Commander Shrike with the same type of navigation system. Since the survey path was adjacent to a shoreline in all surveys, geographic features were also used to determine the start and end points of transects. Surveys were conducted with one observer in the front right seat and one in the rear left of the aircraft.

All surveys were conducted at an altitude of approximately 45 m ASL and at a ground speed of approximately 175 km/h, which is standard procedure for accurately surveying marine birds from the air (Bradstreet 1979, McLaren 1982). Observers dictated into portable tape recorders all sightings made both on-transect (within a 200 m strip on each side of the aircraft) and off-transect (beyond the transect strip). Information recorded included systematic details about the transect and each sighting. The floats on the Cessna 206 aircraft obstructed downward visibility and precluded observation directly under the aircraft, so the inner edge of each transect strip was about 50 m to the side of the flight track, and the outer edge was 250 m to the side.

An audio-intervalometer was used to divide all transects into 1-min time-periods that corresponded to transect segments of approximately equal length (assuming constant ground speed). This procedure fixed the position of each sighting within approximately 3 km. For each time-period (transect segment) the general and specific habitat type was recorded. This procedure enabled the calculation of animal densities on a per-time-period basis as well as on a per-transect or per-habitat type basis. On-transect observations were used to calculate the numbers of birds seen per sq km and on- plus off-transect observations were used to calculate the numbers of birds seen per linear km.

RESULTS

Aerial surveys of Kasegaluk Lagoon in 1989, 1990, and 1991 indicated that waterfowl were by far the most abundant group of birds present in the area, notwithstanding different sampling efforts during the three years of study (Tables 1-3). In 1989, 1990, and 1991, 57.7%, 41.7%, and 30.8%, respectively, of all bird sightings and 95%, 69.1%, and 61.8%, respectively, of all individual birds recorded were waterfowl, mainly black brant and oldsquaws. Brant used the lagoon during mid- to late August through early September primarily for staging (feeding and resting) prior to continuation of their southward migration. As many as 40% of the entire Pacific Flyway brant population were recorded in the study area in late August of 1989 and 1991.

Oldsquaws using the lagoon were primarily molting males, as in other Alaskan Arctic lagoon systems. Glaucous gulls, arctic terns and small shorebirds were also present in the Kasegaluk Lagoon system in large numbers and these species were also considered to be key species. Glaucous gulls nested on the barrier islands and grassy islets along the lagoon barrier island margin, and were more common and concentrated in late July-early August 1990 when several dozen whale carcasses were present along the lagoonside beach of the barrier island adjacent

Table 2. Total number of bird sightings and individuals seen both on- and off-transect during 8 aerial surveys in Kasegaluk Lagoon, Chukchi Sea, Alaska, 27 July to 10 September 1990.

Species	No. Sightings	% of All Bird Sightings	No. Indiv.	% of All Indiv. Birds	Species	No. Sightings	% of All Bird Sightings	No. Indiv.	% of All Indiv. Birds
Yellow-billed Loon	14	0.2	18	0.0	Unid. Duck	4	0.1	33	0.0
Pacific Loon	126	1.7	166	0.1	Lesser Snow Goose	23	0.3	1,033	0.5
Red-throated Loon	215	3.0	311	0.1	Greater White-fronted Goose	187	2.6	10,098	4.6
Unid. Loon	16	0.2	18	0.0	Canada Goose	7	0.1	106	0.0
All Loons	371	5.1	513	0.2	Black Brant	858	11.8	82,906	38.1
Black Guillemot	1	0.0	1	0.0	Tundra Swan	46	0.6	138	0.1
Thick-billed Murre	2	0.0	2	0.0	All Waterfowl	3,019	41.7	150,492	69.1
Small Alcid	1	0.0	1	0.0	Lesser Sandhill Crane	7	0.1	25	0.0
Pomarine Jaeger	1	0.0	1	0.0	Red Phalarope	8	0.1	59	0.0
Parasitic Jaeger	34	0.5	54	0.0	Northern Phalarope	1	0.0	1	0.0
Long-tailed Jaeger	5	0.1	6	0.0	Unid. Phalarope	81	1.1	3,101	1.4
Unid. Jaeger	5	0.1	5	0.0	Long-billed Dowitcher	3	0.0	83	0.0
Black-legged Kittiwake	38	0.5	733	0.3	Dunlin	8	0.1	279	0.1
Glaucous Gull	2,282	31.5	15,490	7.1	Bar-tailed Godwit	1	0.0	3	0.0
Herring Gull	3	0.0	3	0.0	Black-bellied Plover	16	0.2	71	0.0
Sabine's Gull	17	0.2	58	0.0	Lesser Golden Plover	13	0.2	209	0.1
Arctic Tern	718	9.9	11,294	5.2	Unid. Plover	1	0.0	4	0.0
Aleutian Tern	2	0.0	5	0.0	Unid. Small Shorebird	387	5.3	30,441	14.0
Unid. Tern	1	0.0	6	0.0	Unid. Large Shorebird	89	1.2	4,395	2.0
Northern Fulmar	2	0.0	2	0.0	All Shorebirds	608	8.4	38,646	17.8
All Seabirds	3,112	43.0	27,661	12.7	Northern Harrier	3	0.0	3	0.0
Red-breasted Merganser	65	0.9	4,555	2.1	Rough-legged Hawk	1	0.0	1	0.0
Green-winged Teal	11	0.2	53	0.0	Golden Eagle	5	0.1	5	0.0
Northern Pintail	301	4.2	6,969	3.2	Gyrfalcon	4	0.1	4	0.0
Greater Scaup	1	0.0	60	0.0	Peregrine Falcon	3	0.0	3	0.0
Oldsquaw	796	11.0	33,084	15.2	Short-eared Owl	2	0.0	2	0.0
Common Eider	609	8.4	6,540	3.0	Snowy Owl	78	1.1	79	0.0
King Eider	1	0.0	4	0.0	All Raptors	96	1.3	97	0.0
Unid. Eider	1	0.0	2	0.0	Common Raven	5	0.1	9	0.0
White-winged Scoter	1	0.0	4	0.0	Snow Bunting	9	0.1	120	0.1
Surf Scoter	56	0.8	348	0.2	Unid. Passerine	15	0.2	86	0.0
Unid. Scoter	2	0.0	5	0.0	All Passerines	29	0.4	215	0.1
Unid. Diving Duck	50	0.7	4,534	2.1					
					All Birds		7,242		217,649

to Point Lay. Arctic terns, and probably a small number of Aleutian terns, also nested in the study area, mainly on the barrier islands and on the grass-covered islets 5-10 km northwest of Point Lay.

About half of all bird sightings during both years of surveys were in lagoon habitats, mainly along the lagoon-barrier island margins. Nevertheless, three of the five key species examined in detail in 1990 (brant, glaucous gull and arctic tern) plus 'All Birds' showed a preference for 'Ocean Beach' habitat. Only the oldsquaw and arctic tern showed a preference for the passes joining the lagoon with the nearshore Chukchi Sea. Arctic terns and small shorebirds showed a strong preference for mudflat habitats exposed during strong northerly or northeasterly winds. Under these conditions mudflats were exposed mainly in shallow regions of the lagoon, i.e., in the extreme southwestern part of the study area (south of Neakok Pass) and in the area immediately east of Icy Cape. Only small shorebirds showed a preference for coastal marsh habitats.

Although several key bird species recorded during aerial surveys of Kasegaluk Lagoon (oldsquaw, glaucous gull, small shorebird) are also key bird species in other Alaskan Arctic

Table 3. Total number of bird sightings and individuals seen both on- and off-transect during 3 aerial surveys in Kasegaluk Lagoon, Chukchi Sea, Alaska, 30 July to 26 August 1991.

Species	No. Sightings	% of All Bird Sightings	No. Indiv.	% of All Indiv. Birds	Species	No. Sightings	% of All Bird Sightings	No. Indiv.	% of All Indiv. Birds
Yellow-billed Loon	2	0.1	2	0.0	Black Brant	274	7.3	56,472	39.7
Pacific Loon	48	1.3	55	0.0	Unid. Goose	1	0.0	4	0.0
Red-throated Loon	73	1.9	82	0.1	Tundra Swan	14	0.4	35	0.0
Unid. Loon	12	0.3	14	0.0	All Waterfowl	1,158	30.8	87,918	61.8
All Loons	135	3.6	153	0.1	Lesser Sandhill Crane	8	0.2	21	0.0
Parasitic Jaeger	37	1.0	41	0.0	Red Phalarope	4	0.1	4	0.0
Long-tailed Jaeger	21	0.6	22	0.0	Unid. Phalarope	29	0.8	191	0.1
Unid. Jaeger	1	0.0	1	0.0	Dunlin	4	0.1	22	0.0
Black-legged Kittiwake	106	2.8	1,482	1.0	Bar-tailed Godwit	1	0.0	2	0.0
Glaucous Gull	1,449	38.5	6,498	4.6	Black-bellied Plover	11	0.3	35	0.0
Sabine's Gull	27	0.7	125	0.1	Lesser Golden Plover	4	0.1	39	0.0
Arctic Tern	305	8.1	7,210	5.1	Unid. Plover	7	0.2	11	0.0
All Seabirds	1,946	51.7	15,379	10.8	Unid. Small Shorebird	346	9.2	37,196	26.2
Red-breasted Merganser	13	0.3	588	0.4	Unid. Large Shorebird	53	1.4	817	0.6
Green-winged Teal	8	0.2	31	0.0	All Shorebirds	459	12.2	38,317	26.9
Northern Pintail	202	5.4	2,699	1.9	Rough-legged Hawk	1	0.0	1	0.0
Oldsquaw	249	6.6	17,095	12.0	Golden Eagle	9	0.2	9	0.0
Steller's Eider	3	0.1	30	0.0	Gyrfalcon	2	0.1	2	0.0
Common Eider	267	7.1	2,993	2.1	Short-eared Owl	2	0.1	2	0.0
King Eider	6	0.2	32	0.0	All Raptors	14	0.4	14	0.0
Surf Scoter	5	0.1	140	0.1	Common Raven	5	0.1	11	0.0
Unid. Diving Duck	3	0.1	1,016	0.7	Snow Bunting	1	0.0	3	0.0
Lesser Snow Goose	13	0.3	238	0.2	Unid. Passerine	38	1.0	391	0.3
Greater White-fronted Goose	97	2.6	6,499	4.6	All Passerines	44	1.2	405	0.3
Canada Goose	3	0.1	46	0.0					
					All Birds		3764		142207

lagoon systems, the most abundant species of bird recorded in Kasegaluk Lagoon, the black brant, has not been a key bird species in similar barrier island-lagoon systems studied in the Alaskan Arctic, with the possible exception of Peard Bay.

Both the richness and diversity of bird species using Kasegaluk Lagoon were greater than we anticipated at the outset of this study (Table 4). The **species diversity** indices computed for Kasegaluk Lagoon (0.844 and 0.7496 in 1990 and 1991, respectively), and the Peard Bay-Franklin Spit area (0.772 in 1983) were over 100% greater than those computed for similar Beaufort Sea lagoon systems. In the Beaufort Sea, one species, the oldsquaw duck, has made up, on average, over 90% of all bird sightings during 11-years of systematic surveys. The overwhelming dominance by a single species in Beaufort Sea lagoon systems is reflected in the low **species diversity** for this area — 0.1744 and 0.2462 for 1990 and 1991, respectively, in Central Beaufort Sea lagoons, and 0.342 for 11 ANWR lagoons in 1983. All of these lagoon systems were sampled using similar aerial survey sampling procedures.

Information from the literature and from three years of aerial surveys is consistent with the premise presented at the outset of this study: ***"Kasegaluk Lagoon supports special habitat uses by vertebrates, uses that are not duplicated in lagoon habitats elsewhere in the Alaskan Arctic."*** Compared to other lagoons elsewhere in Arctic Alaska, Kasegaluk Lagoon does support special habitat uses by vertebrates. The large number of brant that use the study area makes it distinct from other Arctic Alaska lagoon systems. The large numbers of spotted seals and belugas present in the study area, as discussed by Frost and Lowry (1992), further exemplify the distinct nature of the Kasegaluk Lagoon area.

Table 4. Comparisons of various characteristics of barrier island-lagoon systems in the Beaufort Sea and Chukchi Sea, Alaska.

Characteristics		Central Alaska Beaufort Lagoons 1990 (a)		Central Alaska Beaufort Lagoons 1991 (a)		11 ANWR Lagoons 1983 (b)	
Species Richness (d) (No. of species seen)		29		29		24	
Shannon-Weiner 'H' (e) - (p)(log p)		0.1744		0.2462		0.3417	
Relative Abundance (%) of Top Five Ranking Species or Species Groups	1	Oldsquaw	90.20	Oldsquaw	88.88	Oldsquaw	78.87
	2	Common Eider	3.00	Common Eider	4.42	Sm. Shorebird	13.92
	3	Glaucous Gull	1.70	Glaucous Gull	1.59	Black Brant	2.18
	4	Black Brant	0.70	Surf Scoter	1.47	Glaucous Gull	2.04
	5	Surf Scoter	0.63	G.W.-f. Goose	1.11	Arctic Tern	1.25
		Peard Bay 1983 (c)		Kasegaluk Lagoon 1990 (a)		Kasegaluk Lagoon 1991 (a)	
Species Richness (d) (No. of species seen)		37		48		37	
Shannon-Weiner 'H' (e) - (p)(log p)		0.7723		0.8442		0.7496	
Relative Abundance (%) of Top Five Ranking Species or Species Groups	1	B-1. Kittiwake	27.63	Black Brant	39.51	Black Brant	40.16
	2	Oldsquaw	27.13	Oldsquaw	15.76	Sm. Shorebird	26.45
	3	Arctic Tern	19.13	Sm. Shorebird	14.51	Oldsquaw	12.16
	4	Glaucous Gull	12.59	Glaucous Gull	7.38	Arctic Tern	5.13
	5	Black Brant	4.97	Arctic Tern	5.38	Glaucous Gull	4.62

a Central Beaufort Lagoons and Kasegaluk Lagoon data are from fixed-wing aircraft aerial surveys during 27 July – 10 September 1990, and 18 July – 26 August 1991 (this study).
b Arctic National Wildlife Refuge (ANWR) data are from fixed-wing aircraft aerial surveys during 4 August – 8 September 1983 (Brackney et al. 1985: Append.).
c Peard Bay data are from helicopter aerial surveys of shorelines and open lagoon habitats during 15 July – 25 August 1983 (Gill et al. 1985).
d "Species Richness" is the total number of species recorded during the aerial surveys. Unid. small and large shorebirds were the only 'species groups' included in this measure.
e Shannon-Weiner Diversity Index, $H = -\sum (p)(\log p)$. See Pielou (1974:290).

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	4	Black Brant	0.70	Surf Scoter	1.47	Glaucous Gull	2.04
	5	Surf Scoter	0.63	G.W.-f. Goose	1.11	Arctic Tern	1.25

Characteristics		Peard Bay 1983 (c)		Kasegaluk Lagoon 1990 (a)		Kasegaluk Lagoon 1991 (a)	
Species Richness (d) (No. of species seen)		37		48		37	
Shannon–Weiner 'H' (e) - (p)(log p)		0.7723		0.8442		0.7496	
Relative Abundance (%) of Top Five Ranking Species or Species Groups	1	B-1. Kittiwake	27.63	Black Brant	39.51	Black Brant	40.16
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e Shannon–Weiner Diversity Index, H = - (p)(log p) . See Pielou (1974:290).

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QUESTIONS AND DISCUSSION

TOM NEWBURY: On your slide about the diversity index, I am wondering where Simpson Lagoon would fall on that and whether, in fact, Kasegaluk is outstanding or whether that is a characteristic of lagoons in the Chukchi side? In other words, does the Chukchi coastline support a higher diversity than the Beaufort coastline?

STEVE JOHNSON: Yes, it does. That is my main point, that the Chukchi Sea lagoons, such as Peard Bay and Kasegaluk Lagoon have a much higher species diversity than Beaufort Sea lagoons, probably because of a variety of weather and oceanographic factors, including the fact that several large rivers run into the Kasegaluk Lagoon system.

TOM NEWBURY: Then you would expect Simpson (Lagoon) to fall right in with the ANWR (Arctic National Wildlife Refuge) lagoons?

STEVE JOHNSON: The two histogram bars on the far right of my slide included Simpson Lagoon. Those histogram bars represented the two study areas that we sampled as part of the Beaufort Monitoring Program; they included Gwydyr Bay and the Leffingwell Lagoon area.

DESIGN AND TESTING OF A MONITORING PROTOCOL FOR BEAUFORT SEA WATERFOWL AND MARINE BIRDS

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Dr. Stephen Johnson has worked at LGL for the past 18 years and presently is Senior Vice-President of the Canadian company. Over the past 22 years Dr. Johnson has worked in arctic regions of Alaska, Canada, Greenland, Svalbard, Norway and Russia. His areas of research have included coastal ecosystem processes, seabird ecology and physiology, waterfowl ecology, and marine mammal ecology and behavior. Dr. Johnson received his B.S. at Humboldt State College, his M.S. at Kansas State University, and his Ph.D. at the University of British Columbia. He also conducted postdoctoral research at the University of Alaska, Fairbanks, and at the University of Auckland, New Zealand.

INTRODUCTION

In late September 1983, an MMS/NOAA-sponsored workshop (Dames and Moore 1984) was held in Girdwood, Alaska, to develop a monitoring strategy for the Alaska Beaufort Sea. The concept of monitoring Beaufort waterbirds is based on the following conclusions of the 1983 workshop:

- Marine birds are abundant and are a biologically and socially important component of the nearshore Beaufort Sea ecosystem.
- Some species of Beaufort Sea marine birds, especially marine waterfowl such as the oldsquaw duck (*Clangula hyemalis*), are ubiquitous, relatively easy to detect and count, and have been well studied prior to industrial development; therefore they are appropriate candidates for monitoring.
- A monitoring protocol should be designed to insure that industry-related influences on marine birds are discernible from other natural influences, i.e., should involve a rigorous design and statistical approach that includes both experimental (Industrial) and Control areas and draws on all relevant historical information collected in the study area.

The 1983 workshop identified several potential waterbird species for initial monitoring. The oldsquaw duck was selected over other species because it is the most abundant and widespread local waterbird in the nearshore Beaufort Sea, the zone where virtually all exploration and development have occurred in the Beaufort marine system. Data presented at the workshop confirmed that during the summer open-water period oldsquaws represent most of the avian biomass in the nearshore Beaufort environment. Most other species occur in smaller numbers or are transients in the study area, so none of these species were thought to be suitable candidates for a monitoring program. During July and August, when oldsquaws molt their feathers, they are flightless and they are thought to be particularly vulnerable to water-borne contaminants and disturbances.

A monitoring program that is designed to detect the influences of industry activities on nearby birds must test specific hypotheses that relate to (1) the birds chosen to be monitored, and (2) the types of industry activities in the study area. The following null hypotheses were constructed with such factors in mind:

H_o1: There will be no detectable change in relative densities of molting male oldsquaws in selected Beaufort Sea index areas.

H_o2: Changes in male oldsquaw distribution patterns are not related to OCS oil and gas development activity.

Hypothesis (1) relates to the possibility of a rather large-scale and long-term change in relative densities in Industrial vs. Control study areas. Hypothesis (2) concerns relationships between oldsquaw densities and short-term localized variations in human disturbance.

STUDY AREAS

The Jones-Return Islands Industrial Area

The Minerals Management Service identified the Jones-Return island chain, west of Prudhoe Bay, Alaska, as the Industrial study area for this study (Figure 1). These islands have remained relatively undeveloped over the past two decades although there has been significant oil and gas exploration and development on the adjacent mainland tundra.

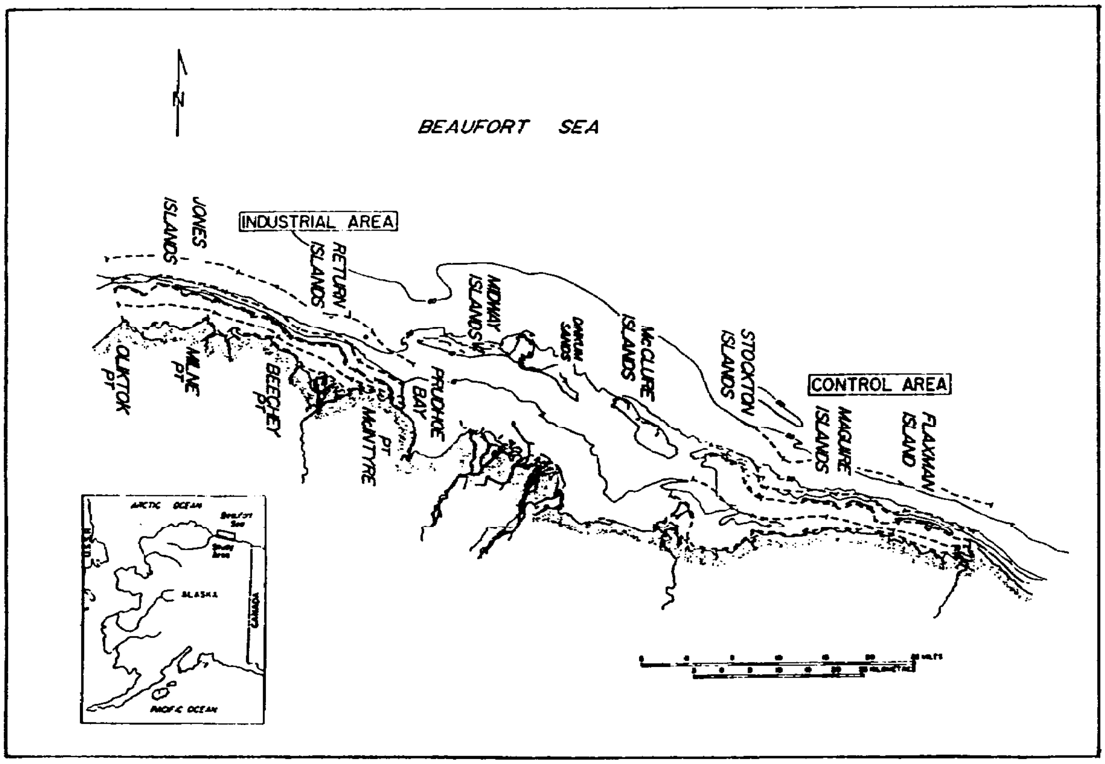

Figure 1. Central Alaska Beaufort Sea with Industrial and Control study areas.

The Stockton-Maguire-Flaxman Islands Control Area

The Stockton-Maguire-Flaxman islands area (Figure 1), located about 50 km east of the Industrial area, was selected as the Control area for the study. The area is similar in structure and size to the Industrial area, it is used extensively by oldsquaws and other waterbirds, and there was a base of historical aerial survey data for use in statistical analyses and comparisons.

The Control area is situated along a part of the Beaufort Sea coast where very little coastal or nearshore industrial activity has occurred. Although several oil wells have been drilled during winter on or adjacent to a few of the islands in the Control area (e.g., Challenge Island), and on the adjacent mainland tundra (e.g., Pt. Thompson), the area is relatively pristine and undisturbed compared to the Industrial study area.

METHODS

Schedule of Surveys

Based on the results of earlier studies and on the results of the preliminary regression analyses, the appropriate period for surveys of marine birds in both Beaufort study areas (Industrial and Control) was from mid-July until late August, i.e., during the oldsquaw molt period.

Surveys should be conducted as quickly as reasonable, and should not be conducted during periods or in areas of high winds (>20 kts) and heavy ice (>30% cover). Since we recommended that surveys start on 15 July, after ice break-up has usually occurred in the marine system, heavy ice-cover would be less of a problem in the future than during some previous years when some surveys began before ice breakup. During some years, ice and associated fog persist in nearshore and offshore marine regions of the Beaufort Sea throughout the summer. In such years we recommended that only barrier island and lagoon transects be surveyed, so that at least those data would be comparable from one year to the next.

Data Recording

Recording of aerial survey data was standardized according to procedures established during a set of structured surveys conducted in early August 1989. During those surveys we adopted 30-sec time-period intervals for recording the numbers of birds on- and off-transect and for recording an array of information about the survey conditions and prevailing environmental conditions. For each 30-sec interval, factors recorded included amount of ice on- and off-transect, wave height, glare on the water surface, wind speed and direction, proximity to barrier island or other structure, apparent type and level of human activity on- and off-transect during the time period, and changes in any particular variable noted during that 30-sec interval. The 30-sec periods have been used in most waterbird surveys in the study area since 1980; compared to 1- or 2- min intervals, they provide better documentation of locations where birds concentrate and where habitats change along transects. Consequently data collected at 30-sec intervals are more useful than data collected by longer intervals, especially if they might be mapped or included at a later date in a database or in a Geographic Information System (GIS). It was recommended that information be collected for all species of birds and mammals observed on and off the transects.

Surveys are flown with two prime observers at an altitude of 45 m and at a ground speed of 180 km/hr. Transect width is 400 m, 200 m on each side of the aircraft; clinometers are used to calibrate distances from the aircraft. Observers are trained to count large numbers of birds in dense concentrations through a series of training sessions (Johnson and Gazey 1992).

During aerial surveys, tape recorders are used to record information about the birds, their habitats and environmental conditions during the survey. Data are later transcribed and coded onto standard coding forms that provide for accurate recording of all of the information described above. Linear and areal densities are computed for all species sighted on-transect during all surveys; linear densities are also computed for on+off-transect sightings. These data are manually and computer verified, validated, and then computer tabulated by species, year, date, time-period, transect, and observer.

RESULTS

Analyses of nine years of historical aerial survey data in the design phase of this study indicated that oldsquaw ducks represented on average about 93% (Figure 2) of all birds of all species seen both on- and off-transect in the central Alaska Beaufort Sea. Correlation analyses also indicated that densities of oldsquaws along barrier island transects best reflected overall densities of oldsquaws in the study area during the sampling periods. Other studies indicated that undisturbed oldsquaws showed a strong diel periodicity in behavior and abundance at barrier island locations near the Jones-Return islands, and that oldsquaw distribution near barrier islands was significantly related to wind speed and direction. The results of these and other studies helped in the selection of potential predictor variables for use in preliminary analyses of historical data; multivariate statistical analyses were designed to isolate the most important determinants of oldsquaw density on transects in the study area (Johnson 1990).

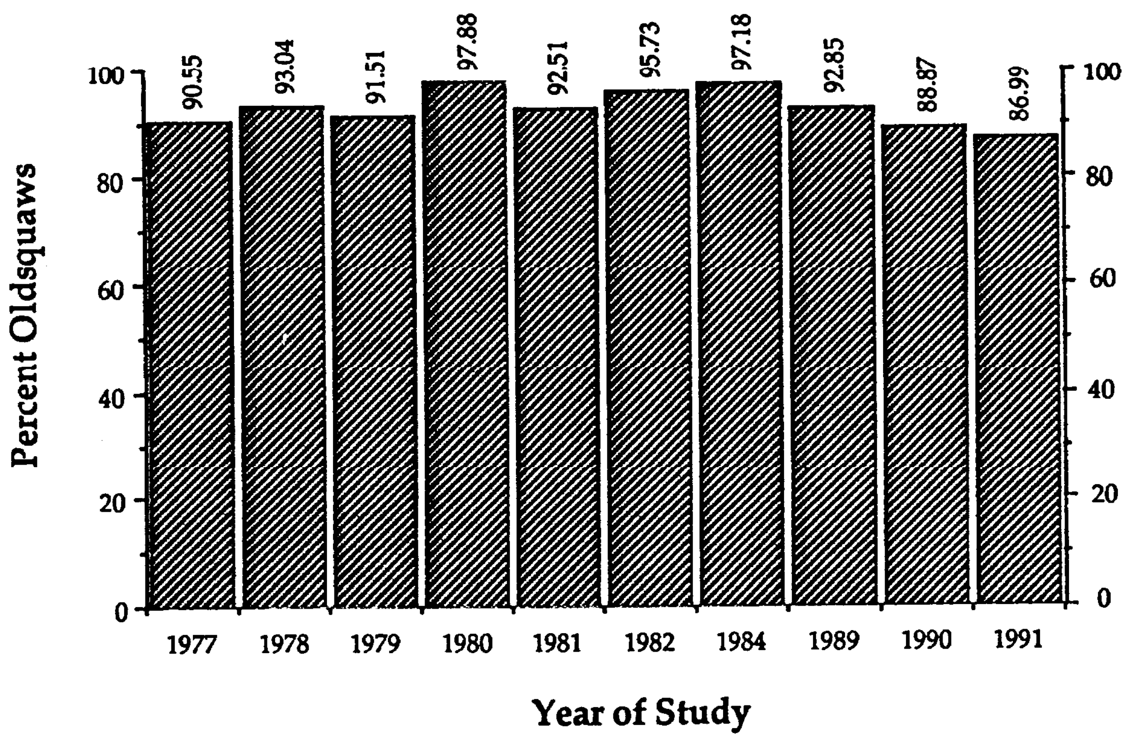

Figure 2. Oldsquaw sightings as a percent of all waterbird sightings in the central Alaska Beaufort Sea, 1977-1982, 1984, and 1989-1991.

The relevant predictor variables (independent variables) selected for use in these preliminary multiple regression analyses of oldsquaw density (dependent variable = DENSTRAN) on transects in the study areas were as follows:

1. Year of study (YEAR).
2. Time of the year (day of the season) that sampling occurred (DAY and DAYTRAN).
3. Time of day that sampling occurred (TIME).
4. Water depth in the sampling area (DEPTH and DEPTRAN).
5. Location of transect along an east-west axis (WESTEAST and WESTRAN).
6. Proximity of transect to a barrier island (DIST, DISTRAN, and HABITAT).
7. Wind speed and direction in the sampling area during the sampling period (WDIR, WSPD, ORDWND, NECOMWND, NCOMWND).
8. Percent ice-cover on-transect in the study area during the sampling period (ICE and ICETRAN).
9. Wave height on-transect during the sampling period (WAVE and WAVETRAN).
10. Study Area (AREA), i.e., Industrial vs. Control.

Earlier analyses, and analysis of residuals from this multiple regression analysis, indicated that some variables should be transformed to satisfy various assumptions of the parametric general linear modeling (glm) statistical procedures used in this study.

Two multiple regression analyses of oldsquaw densities were conducted: (1) for oldsquaws on transects surveyed during the open-water season (5 June to 23 September), and (2) for those on transects surveyed during the peak period of molt by male oldsquaws (15 July to 25 August). Results of analyses of the 9 years of historical data (1977-1984 and 1989) indicated that several variables and combinations of variables (interaction terms) were highly significant in predicting oldsquaw density on transects in the study area (Table 1). In particular DAY, WAVETRAN, HABITAT, YEAR x AREA, TIME x HABITAT, HABITAT x ICETRAN and WDIR x WSPD were statistically significant predictors of oldsquaw density in one or the other of the two analyses. HABITAT was a particularly important predictor variable, especially in combination with TIME and ICETRAN, and this factor was selected to represent the proximity of the transect to the barrier islands in the study area.

The results of the multiple regression analyses helped in the design and implementation of the full season sampling programs in 1990 and 1991, and in the formulation of a specific analysis of covariance (ANCOVA) model suitable to analyze 1990, 1991, and any subsequent comparable data collected in the Industrial and Control study areas.

Sampling was conducted in such a way as to obtain oldsquaw density data and associated environmental data for the following spatial and temporal categories:

- Two study areas (Industrial and Control).

Table 1. Summary of results of multiple regression analyses of historical oldsquaw density data collected in the Jones-Return Islands area, Beaufort Sea, Alaska, during 1977-1984 and 1989. *

		5 June to 23 September (Squared Multiple R = 0.574, n = 474)			5 June to 23 September (Squared Multiple R = 0.661, n = 275)		
Independent Variables	Degrees of Freedom	Coefficients	F-Ratios	Nominal P Values	Coefficients	F-Ratios	Nominal P Values
CONSTANT	N/A	-2.179	N/A	N/A	-1.269	N/A	N/A
YEAR	1	-0.038	1.30	0.256	-0.076	3.30	0.070
DAY	1	0.097	19.62	*≤0.001***	0.099	0.17	0.678
DAYTRAN	1	-0.001	0.15	0.702	-0.001	0.08	0.774
TIME	1	0.001	1.02	0.314	0.001	1.34	0.248
WESTEAST	1	-0.054	0.52	0.474	-0.128	1.89	0.170
WSPD	1	0.003	0.00	0.965	-0.025	0.17	0.680
WDIR	1	-0.003	0.83	0.362	-0.007	2.86	0.092
*WDIR*WSPD*	1	0.000	1.68	0.196	0.000	7.44	*0.007***
ICETRAN	1	-0.047	0.11	0.745	0.374	1.51	0.220
WAVETRAN	1	-0.376	6.81	*0.009***	-0.457	6.63	*0.011***
*HABITAT(1-5)****	4	-0.229; 3.911; -4.105; 1.51	4.22	*0.002***	-1.645; 3.244; 2.415; 3.258	1.58	0.180
AREA	1	-0.010	0.00	0.989	-1.121	1.38	0.241
*YEAR*AREA*	1	0.016	0.12	0.732	0.153	7.36	*0.007***
HABITAT(1-5)*DAYTRAN	4	-0.000; 0.000; 0.000; 0.000	2.38	0.051	0.000; 0.000; -0.000; -0.00	1.20	0.310
*HABITAT(1-5)*TIME*	4	0.002; -0.003; 0.002; -0.00	13.62	*≤0.001***	0.002; -0.003; 0.001; -0.00	7.34	*≤0.001***
HABITAT(1-5)*WSPD	4	0.004; -0.006; 0.062; -0.04	2.01	0.093	0.003; 0.004; 0.034; -0.077	1.44	0.221
HABITAT(1-5)*WDIR	4	0.001; 0.000; -0.002; 0.004	0.91	0.457	0.003; 0.003; -0.002; 0.000	0.67	0.616
HABITAT(1-5)*WAVETRA	4	0.227; 0.329; -0.754; 0.080	2.36	0.052	0.359; 0.198; -1.030; 0.210	1.16	0.329
*HABITAT(1-5)*ICETRAN*	4	-0.357; 0.001; -0.051; 0.11	2.32	0.057	-0.322; 1.181; 0.195; -0.89	3.66	*0.007***

* See Appendices 2 and 3 for a complete listing of the regression models and analysis of variance tables.
** Nominal P values ≤ 0.050 were considered to be statistically significant.
*** Habitats are as follows: 1 = S of barrier islands, 2 = mid-lagoon, 3 = mainland shoreline, 4 = nearshore marine, and 5 = offshore marine. Habitat 1 is omitted because it is the 'standard' against which others were compared in this analysis.

- At least three habitat strata: (1) barrier island habitat, (2) mid-lagoon habitat, (3) mainland shoreline habitat.

- Four transects within each habitat stratum per area.

- One 4- to 5-week sampling period during the peak of the oldsquaw molt period (mid-July to late August).

- Six to eight relatively evenly spaced survey dates within the single 4- to 5-week sampling period.

For every transect surveyed, we determined the number and density of oldsquaw present, presence of human disturbance, wave height, ice cover and wind.

This sampling approach provides the replicated and structured data necessary to isolate the effects of the variables known to affect oldsquaw densities. The experimental design is compatible with the powerful ANOVA and ANCOVA statistical procedures that we have used to separate the effects of factors and covariates.

In order to test the two null hypotheses presented at the start of this exercise, i.e., to test whether there have been regional or local changes in densities of molting male oldsquaws that may be attributable to industrial activities, we recommend continued use of the analysis of covariance statistical approach. The 5 factors are year (Y), area (A), habitat (H), transect (T), and disturbance level (D; see Table 2), and the five covariates considered were wind speed (WSPD), wind direction (WDIR), northern component of wind (NCOMWND), wave height (WAVE) on

Table 2. Ordinal scale for recording types of industry activities and disturbance levels that may affect oldsquaw densities in the Jones-Return Islands, Beaufort Sea, Alaska. Values are assigned separately for each transect during each survey date.

Activity Index	Disturbance Level	Type of Industry Activity
1	Nil	No human activity or disturbance in area of interest.
2	Low	Infrequent* low-level aircraft overflights, boat traffic or human activity on land or in the water during the survey period in the area of interest.
3	Moderate	Regular** low-level aircraft overflights, boat traffic or human activity on land or in the water during the survey period in the area of interest.
4	High	Frequent*** low-level aircraft overflights, boat traffic or human activity, and/or spillage of low levels of toxic materials (oil, fuel) and associated clean-up activities on land or in the water during the survey period in the area of interest, and/or semi-permanent structures established in the area with frequent presence of humans and associated activity.
5	Extreme	Major spill of toxic materials (oil, fuel) and associated clean-up activities on land or in the water during the survey period affecting a large area, including the area of interest, and/or permanent structures established in the area with near-continuous presence of humans and associated activity.

* Less than five known occurrences during the 24-hr survey period. Low-level overflight ≤500' altitude.
** Five to nine known occurrences during the 24-hr survey period.
*** Ten or more known occurrences during the 24-hr survey period.

transect, and percent ice cover (ICETRAN) on transect; wave height (WAVE) was the single covariate remaining after completion of further analyses. The replicates are the six to eight days of surveys within the single 4- to 5-week sampling period.

The ANCOVA model most appropriate and best suited to test for significant differences in oldsquaw densities over space and time is as follows:

Density=Mean+WAVE+D+A+Y+AY+H(A)+YH(A)+T(AH)+YT(AHA)+error

Parentheses indicate that some factors are nested within others, e.g., H(A) is interpreted as habitat nested within area. The ANCOVA model is nested (habitat within study area, transect within habitat) and factor effects are mixed, i.e., some are fixed and some are random. Year, area, and disturbance are fixed effects, but habitat and transect are considered random effects. Wave height is the single covariate included in this final model.

Because of the nested design and mixed (random and fixed) effects, tests of significance of the various terms and interactions in the analysis model involve error terms that are specific to the particular test, i.e., terms other than residual error are sometimes used as the denominator of the F-ratio. We have followed the appropriate analysis of covariance (ANCOVA) procedures, as suggested by Bliss (1970), Huitema (1980), and others. The ANCOVA identifies how much of the variation in densities of oldsquaws is attributable to each factor, i.e., year, study area, disturbance, habitat, transect, and to the single covariate, wave height.

The main objective of this study was to devise field and analytical methodology suitable for long-term monitoring of the numbers of molting oldsquaws in relation to potential regional effects ($H_0 1$) and local effects ($H_0 2$) of industrial activity. After an initial season of field tests (1989), two seasons of systematic field data were collected (1990-1991). However, it is premature to try to evaluate the correctness of the null hypotheses, and particularly $H_0 1$, after only two years of systematic surveys. Thus, interpretations of hypotheses given here are included primarily as an illustration of how such interpretations can be made after more data are collected, not as definitive tests of the hypotheses.

$H_0 1$ concerns the possibility of a long-term, i.e., year-to-year, change in oldsquaw densities in the Industrial area that is not paralleled by a corresponding change in the Control area. In our analyses of variance and covariance, the year x area interaction term, ay, provides a test of $H_0 1$ after allowance for other factors such as habitat, specific transect, local disturbance, various interaction terms, and (in ANCOVA) covariates such as wind speed or wave height. Based on two years of systematic sampling there is no statistically significant evidence of such a change; the ay term was non-significant in all ANOVA and ANCOVA models. If systematic surveys are continued in subsequent years when industrial activities in nearshore areas are consistently greater (or less) than in 1990-1991, a corresponding statistical test of the ay term can be used to evaluate whether there is a corresponding long-term change in oldsquaw densities.

$H_0 2$ concerns the possibility that human activities in particular parts of the Industrial (or Control) study areas may have localized influences on oldsquaw densities. In our analyses of variance and covariance, the disturbance term, D, provides a test of $H_0 2$ after allowance for other factors such as area, year, habitat, specific transect, various interaction terms, and (in ANCOVA) covariates such as wind speed or wave height. Based on two years of systematic sampling, there is no statistically significant evidence of such a change; the D term was non-significant in all ANOVA and ANCOVA models (Table 3).

The test of $H_0 2$ is potentially more meaningful than is the test of $H_0 1$ when only a few years of systematic data are available, given the much larger number of error degrees of freedom for the present test. Nonetheless, great caution is necessary in interpreting the results. There were relatively few transect/data combinations with known human disturbance in 1990, and virtually none in 1991. In this situation, the test has little power to detect a biologically significant disturbance effect even if a strong effect exists.

As mentioned earlier, an important issue in a monitoring program of this type is the degree to which the sampling and analytical procedures are able to test critical hypotheses. In this study we considered the degree to which the current model can be improved, i.e., made more powerful, in order to detect smaller percentage changes in the adjusted mean density of oldsquaws for the two terms in the model (disturbance and year x area interaction) that relate to the two hypotheses being tested. We assumed that current conditions would prevail in future years, i.e., only three levels of disturbance at the same relative frequencies would continue to be recorded, and residual error within each cell (year, area, habitat and transect combination) would remain the same.

It is clear that for localized disturbance effects, the current annual level of sampling (seven or eight surveys/season) is adequate to detect, over a 2-year or longer period, a 7-8% change (at a 95% confidence level) in adjusted mean oldsquaw density on disturbed vs. undisturbed transects (Figure 3).

Table 3. Results of ANOVA and ANCOVA tests of 1990-1991 oldsquaw density data. Three cases are presented: Case A = no covariates; Case B = one covariate, wind speed (wspd); Case C = one covariate, wave height (wave).

Term	SSQ	SSQ(test)	df	df(test)	MS	MS(test)	F	p
Case A: No Covariates, R squared = 0.797								
d	2.824	244.964	2	310	1.412	0.790	1.787	0.169
a	78.087	586.592	1	4	78.087	146.648	0.532	0.506
y	28.662	53.180	1	4	28.662	13.295	2.156	0.216
ay	28.587	53.180	1	4	28.587	13.295	2.150	0.216
h(a) *	586.592	185.968	4	18	146.648	10.332	14.194	***0.000***
yh(a)	53.180	14.951	4	18	13.295	0.831	16.007	***0.000***
t(ah)	185.968	244.964	18	310	10.332	0.790	13.074	***0.000***
yt(ah)	14.951	244.964	18	310	0.831	0.790	1.051	0.402
Case B: Covariate = WSPD, R squared = 0.807								
wspd	10.553	232.366	1	308	10.553	0.754	13.988	***0.000***
a*wspd	3.278	232.366	1	308	3.278	0.754	4.345	***0.038***
d	2.212	232.366	2	308	1.106	0.754	1.466	0.232
a	36.553	571.781	1	4	36.553	142.945	0.256	0.640
y	16.094	56.291	1	4	16.094	14.073	1.144	0.345
ay	15.338	56.291	1	4	15.338	14.073	1.09	0.355
h(a)	571.781	181.09	4	18	142.945	10.061	14.208	***0.000***
yh(a)	56.291	15.061	4	18	14.073	0.837	16.819	***0.000***
t(ah)	181.09	232.366	18	308	10.061	0.754	13.335	***0.000***
yt(ah)	15.061	232.366	18	308	0.837	0.754	1.109	0.342
Case C: Covariate = WAVE, R squared = 0.804								
wave	9.151	235.813	1	309	9.151	0.763	11.991	***0.001***
d	2.798	235.813	2	309	1.399	0.763	1.833	0.162
a	78.659	538.830	1	4	78.659	134.708	0.584	0.487
y	34.520	54.179	1	4	34.520	13.545	2.549	0.186
ay	27.544	54.179	1	4	27.544	13.545	2.034	0.227
h(a)	538.830	182.133	4	18	134.708	10.119	13.313	***0.000***
yh(a)	54.179	14.552	4	18	13.545	0.808	16.754	***0.000***
t(ah)	182.133	235.813	18	309	10.119	0.763	13.259	***0.000***
yt(ah)	14.552	235.813	18	309	0.808	0.763	1.059	0.393

Underlined terms in boldface italics are statistically significant ($p \leq 0.05$).

For the year x area interaction term, however, the current level of sampling is sufficient only to detect a 130-140% change in the adjusted mean density of oldsquaws over a 2-year period. Although the performance of the model is not appreciably improved by increasing the number of samples within a year, it is markedly improved if the number of years of sampling is increased beyond two years. With three years of sampling one could detect a 50% change in adjusted mean density. The current analysis indicates that a 12% difference could be detected only after about 11 or 12 years of surveys.

We are confident that the monitoring plan presented here is the most appropriate and statistically defensible approach given the present state of information. However, as mentioned in our previous report (Johnson 1990), it is inevitable that, after several years of data collection and subsequent analyses, it will be necessary to further modify some aspects of the field procedures or some of the analyses to further improve the study.

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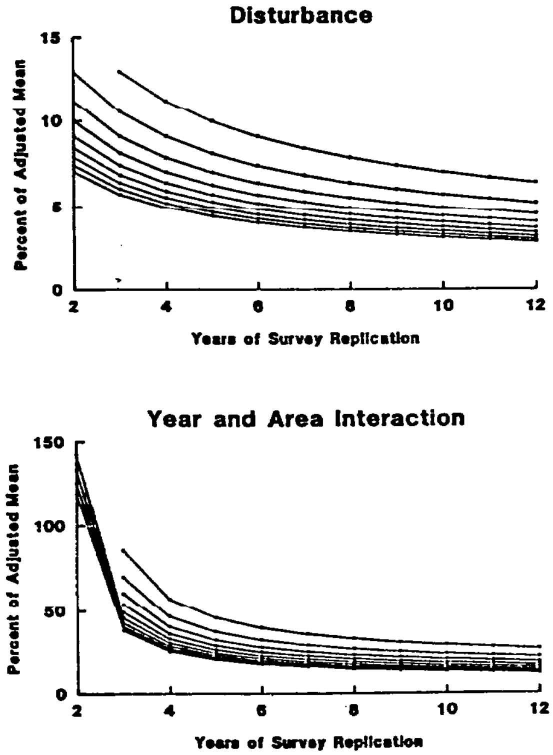

Figure 3. Percent change (95% confidence level) in the adjusted mean density of oldsquaws for tests of disturbance (top) and year x area interaction (bottom), given different amounts of sampling. Each line on the top and bottom plots represents a different intensity of within-year sampling, i.e., the bottom lines represent 10 replicate samples per year, and the top lines represent 2 replicate samples per year. The abscissa represents the number of replicate years of sampling, and the ordinate represents the percent change in the mean density of oldsquaws

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QUESTIONS AND DISCUSSION

BOB DAY: I guess I have more of a comment than anything. As I understand it there is still quite a bit of controversy in many environmental monitoring groups in terms of is there such a thing as an indicator species. The importance of one, the adequacy of one, not just in the bird world but with a lot of people who have been doing long term ecological monitoring. I guess I wanted to throw that out first and then make a second point. I guess that I am a little haunted by the fact that you are taking a species that is extremely wide-spread and forms an average of 93% of all the birds out there. That doesn't seem, from my limited experience, to really respond to a whole lot of disturbance in general anyway, and then you pick that as the species that you are monitoring. Were there some other species that you would have perhaps preferred that were not abundant enough?

STEVE JOHNSON: We actually did a series of studies back in the early 1980s looking at the effects of disturbance on oldsquaws. We found that in fact they were quite responsive to man-made disturbances. So we thought, and we still think, that they are a good species for this kind of monitoring program. We did some fairly detailed behavioral studies at Thetis Island in 1980 where we looked at oldsquaw behavior 24 hours-a-day for several weeks during an undisturbed period and then during a disturbed period. This study showed remarkable changes in their behavior and distribution in relation to disturbance. We actually feel fairly good about using oldsquaws as an indicator species here. There are a number of other species that one could use in a monitoring program, but one would design a different kind of monitoring program for those species. One could use phalaropes, glaucous gulls, or eiders, but the numbers are small, and the timing of the program would change, as well as the sampling approach. Oldsquaws, we think, are the best species for monitoring, because of their overwhelming abundance, because we know that they are sensitive to disturbances, because of their presence in both industrial and control areas, and because there is an extensive historical base of data. Some have argued that geese may be a better species for monitoring, but geese are more terrestrially oriented, and this program was specifically designed to look at the nearshore Beaufort Sea's marine environment, rather than the terrestrial environment. Most of the other species, including other seaducks, just aren't abundant enough.

CALEB PUNGOWIYI: Just to follow up on what he said, from my personal observation, oldsquaws are less apt to take flight when approached by man compared to other birds such as pintails, geese, eider ducks. Also they are more productive, they lay more eggs than any of the other birds. They lay 8 to 12 eggs in one setting. I have some concerns about why they were selected as the target species to be monitored. The other thing was that there has been a sharp decline in Steller eiders and spectacled eiders. In your studies, what have you seen in comparison to these other birds in these barrier islands?

STEVE JOHNSON: To my knowledge, we have never seen those species in our study area during the period when we were actually conducting the sampling. Occasionally we see them during spring migration, but they are virtually non-existent in these particular Beaufort Sea barrier island lagoon habitats. In the Kasegaluk Lagoon area we did see small numbers of Steller's eiders — small flocks. But probably no more than a dozen or so during the three years of study there. We did see one or two small groups of spectacled eiders offshore from Kasegaluk Lagoon on one set of surveys that we conducted there. We could see that there were quite a few eiders offshore from our study area, so we spent one day sampling there. They were mostly king eiders and common eiders, but we also may have seen a few small flocks of spectacled eiders out there. We saw no Steller's eiders offshore Kasegaluk Lagoon. Again, getting back to this point of why we chose oldsquaws for the Beaufort monitoring program — for other species there just isn't enough data for the rigorous statistical analyses that are required for this type of study. Common eider and king eider are isolated to one or two little shoals in the Cross Island area, and there are a few common eider nesting on the barrier islands. I don't think one could design a monitoring program of this type — for the nearshore Beaufort Sea — around any other species.

CRAIG ELY: Regarding the suitability of oldsquaw, I think that Steve mentioned that these are birds during the flightless period. Waterfowl when they are flightless are much more wary than when they are flighted. That is pretty much common knowledge. So the time of year is really important too in assessing the adequacy of an indicator species.

POPULATION AND PRODUCTIVITY MONITORING OF SEABIRDS ON LITTLE DIOMEDE ISLAND

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Seabird populations and productivity were monitored on Little Diomede Island in 1991 and 1992 (Fowler 1992, Fowler in prep.). Little Diomede Island was chosen as a monitoring site because of the sensitivity of its location and because vast numbers of seabirds breed on the island. Little Diomede Island is located in the Bering Strait and is therefore at high risk of contamination if oil was spilled in the northern Bering or southern Chukchi Sea. The island supports large least and crested auklet colonies (*Aethia pusilla* and *A. cristatella*). Auklets nest underground in rock crevices and feed on zooplankton (copepods and euphausiids). Little Diomede is the largest auklet colony in the northern Bering Sea (Sowls et al. 1978). Other than auklets, the most abundant breeding species are black-legged kittiwakes (*Rissa tridactyla*) and common and thick-billed murres (*Uria aalge* and *U. lomvia*). Both kittiwakes and murres generally feed on fish and nest on cliffs.

The objectives of the monitoring program on Little Diomede Island was to establish permanent study plots and to monitor populations and productivity of auklets, kittiwakes and murres, using standardized U. S. Fish and Wildlife techniques.

Little Diomede Island is characterized by steep talus slopes and a flat boulder strewn top 425 m above sea level. The major talus slope areas with high densities of nesting auklets are on the west side of the island above the village and on the east side of the island in a major drainage basin. The northern and southern ends are dominated by cliffs rising to approximately 50m above sea level with dense kittiwake and murre colonies. Seabird populations on Little Diomede Island were first surveyed by Kenyon and Brooks (1960) and again by Biderman and Drury (1978) during the Outer Continental Shelf Environmental Assessment Program.

The study plots for murres and kittiwakes were established in early June before most birds had begun laying. Replicate population counts of cliff nesters were obtained during late incubation to mid chick-rearing when numbers of adults on the cliffs varied the least. Numbers of adult murres and kittiwakes and active kittiwake nests were counted on each plot. To assess productivity, the study plots were visited every 3 to 5 days, weather permitting. Presence of adults, chicks, and eggs was recorded at each breeding site when feasible.

While it is relatively easy to count cliff-nesting birds, it is much more difficult to obtain good counts of birds that nest underground. The method that has been most widely used to count auklets is to count the number of birds that are roosting on the surface of rocks on a talus slope. Study plots for auklets were randomly selected from an area above the village of Ignalook on the western side of the island. A single observation point was used and the number of auklets on the surface of each plot was counted using a high powered spotting scope. Auklets were counted on the surface of the study plots during their morning peak activity period. A sample of least and crested auklet nests were followed in 1991 and 1992 to estimate productivity.

From 1991 to 1992, population counts of black-legged kittiwakes on our plots decreased, but numbers of murres did not change. There were significantly fewer adult black-legged kittiwakes and active kittiwake nests in 1992 (769 and 526, respectively) than in 1991 (922 and 594, respectively). There were no significant differences in numbers of murres but both species had higher mean counts in 1992 (372 and 433 for common murres, 482 and 487 for thick-billed murres during 1991 and 1992, respectively).

There were no differences in productivity between 1991 and 1992 for kittiwakes or murres. The number of kittiwake chicks per nest was 0.24 and 0.19 in 1991 and 1992. Hatching was significantly earlier (Median test P=0.001) for black-legged kittiwakes in 1992 than in 1991 (median hatching dates were 25 July 1991 and 18 July 1992). The number of murre chicks per site was 0.40 and 0.51 for common murres and 0.56 and 0.36 for thick-billed murres during 1991 and 1992, respectively. There were not sufficient data to calculate hatch date for murres in 1992.

Auklet surface counts can be presented in many different ways. Bedard (1969) suggested using the second, third, and fourth highest counts per plot during the prelaying period to estimate density. Using this method, there were significantly more auklets in 1992 than in 1991 (Table 1). Before the beginning of egg-laying, the number of least and crested auklets on the surface (using Bedard's method) was 17.4 and 3.0 per 100m^2 in 1991 and 21.1 and 5.1 per 100m^2 in 1992.

Table 1. Number of least and crested auklets per 100m^2 on the surface during the peak activity period on Little Diomede Island in 1991 and 1992 during prelaying, incubation and chick-rearing periods. Bedard's method uses the second, third, and fourth top counts per plot during prelaying. Maximum-day method uses the maximum count per plot per day for each period. Differences between years were tested with a paired comparison two-tailed t-test (n=30 plots).

		Least auklets			Crested auklets		
Method	Period	1991	1992	P	1991	1992	P
Bedard		17.4	21.1	0.0001	3	5.1	0.0001
Maximum-day	Prelaying *	15.0 ± 3.57 ****	18.3 ± 3.80	0.0001	3.1 ± 0.82	4.3 ± 0.82	0.0005
Maximum-day	Incubation **	16.4 ± 3.74	18.8 ± 1.10	0.0001	7.4 ± 1.45	8.4 ± 2.61	0.04
Maximum-day	Chick-rearing ***	9.2 ± 3.02	10.0 ± 3.90	0.03	4.7 ± 1.92	6.5 ± 2.41	0.0001

* Laying commenced approximately 30 June 1991 and 24 June 1992.
** Incubation lasted between 01 July – 03 August 1991 and 25 June – 24 July 1992.
*** First chick hatched after 03 August 1991 and 24 July 1992.
**** 95% confidence intervals.

The average of the maximum number of auklets counted on the surface on the plots per day is another method of comparing surface counts. This method showed that counts varied throughout the breeding stages, i.e., prelaying, incubation, and chick-rearing, in both years (Figure 1). Highest counts of least auklets occurred during prelaying and early incubation, while counts of crested auklets peaked during mid- to late incubation. Counts for both species were lowest during the chick-rearing period. Using the maximum daily surface counts for comparison between years, both species of auklets had significantly higher densities for all breeding periods in 1992 (Table 1).

In 1977, Biderman and Drury (1978) estimated the auklet colony size on Little Diomede Island by taking the maximum number of auklets counted in an area and extrapolating to the whole

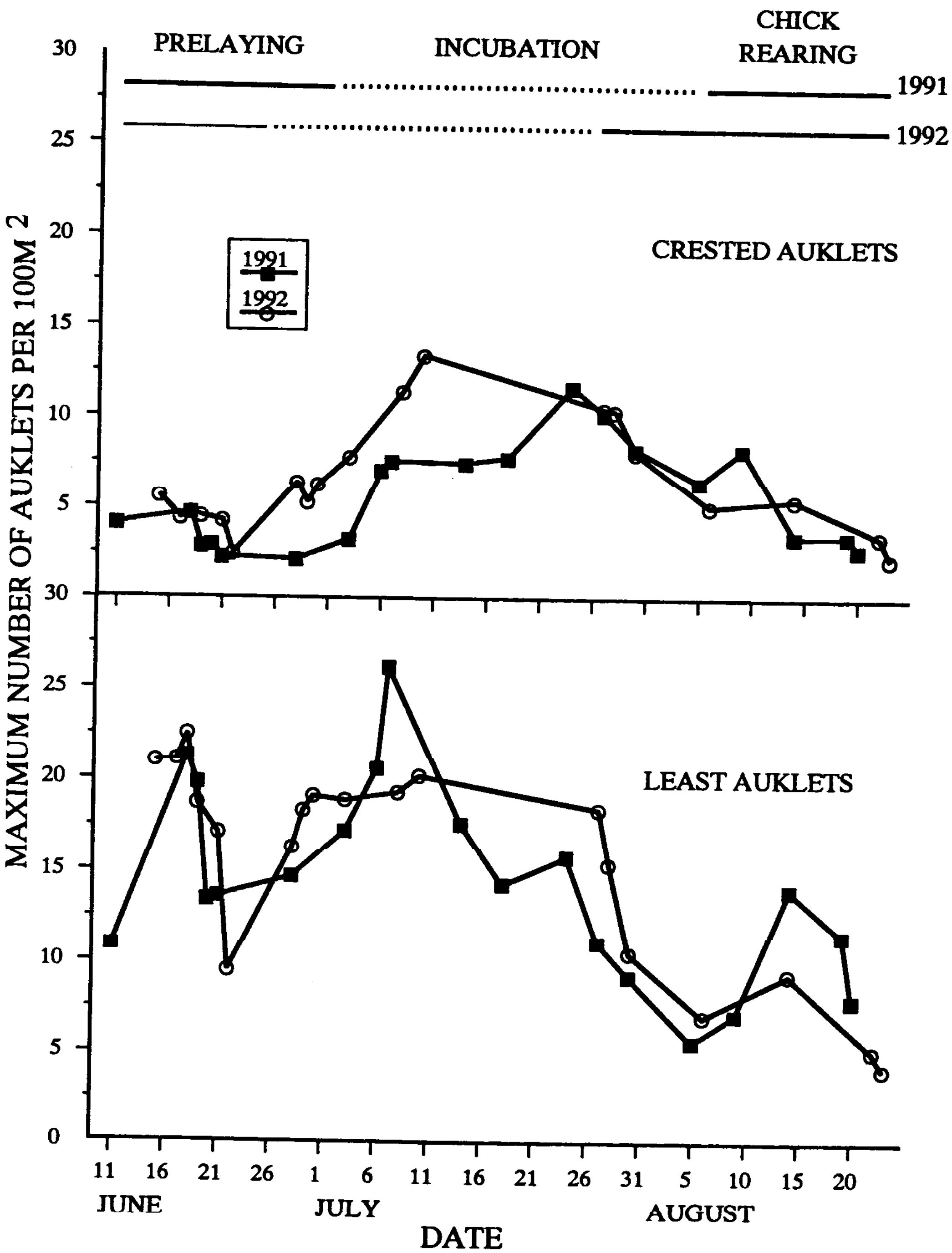

Figure 1. Daily maximum number of auklets per $100m^2$ on Little Diomede Island during 1991 and 1992.

colony. Using their estimate of talus slope area (1.5 million m^2), and our maximum count per plot, our estimates of least and crested auklets on the surface of the talus are 412,500 and 207,000 in 1991 and 391,500 and 219,000 in 1992, respectively. Our counts are not directly comparable to Biderman and Drury (980,000 and 135,000 for least and crested auklets), because they included estimates of auklets that were under the talus as well as on the surface.

The number of least auklet chicks per nest was significantly lower in 1991 (0.04) than in 1992 (0.54). Hatching was significantly earlier (Median test P=0.0001) for least auklets in 1992 (29 July) than in 1991 (06 August). There was no difference in the number of crested auklet chicks per nest (0.62 and 0.53 for 1991 and 1992, respectively). Data were insufficient to calculate median hatching dates for crested auklets.

Boat surveys of all seabirds on Little Diomede Island were conducted in early July in 1977 by Biderman and Drury (1978) and in 1991 during this project. A comparison of the seabird numbers is shown in Table 2. These numbers suggest that murres, puffins and pigeon guillemots may have declined and black-legged kittiwakes may have increased on Little Diomede Island since 1977. Murre populations on Little Diomede Island, for example, were estimated to be between 50,000 and 200,000 by Kenyon and Brooks (1960) (these estimates were obtained from land). Biderman and Drury (1987) estimated murre populations to be below Kenyon and Brooks' (1960) minimum estimate and the 1991 number was almost half Biderman and Drury's (1978) estimate. Our kittiwake estimate falls within the range of Kenyon and Brooks (1960). These estimates, unfortunately, are point estimates. Without associated error estimates, confidence interval calculations and other statistical comparisons are not possible.

Table 2. Comparison of 1977 and 1991 seabird surveys of Little Diomede Island. Data are number of adults; the numbers in parentheses are number of nests.

	Little Diomede Island	
	1977 *	1991 **
Black-legged Kittiwakes (Rissa tridactyla)	17,390	35,911 (32,277)
Murres (Uria spp.)	46,075	29,485
Horned Puffins (Fratercula corniculata)	8074	2393
Tufted Puffins (Fratercula cirrhata)	665	433
Glaucous Gulls (Larus hyperboreus)	136	187
Pelagic Cormorants (Phalacrocorax pelagicus)	159	103 (63)
Pigeon Guillemots (Cepphus columba)	275	95

* Census figures from 15 July boat count of Little Diomede Island, Biderman and Drury (1978).

** Census figures from 2 – 5 July boat count of Little Diomede Island, Fowler (1992).

Fowler — Population and Productivity Monitoring of Seabirds on Little Diomede Island

Little Diomede Island is the largest seabird colony in this part of the U. S. arctic, but there are three other seabird colonies in this area. There are long-term data on murres and kittiwakes from these colonies that can be compared to Little Diomede Island. Cape Lisburne and Cape Thompson are north of Diomede and Bluff (in Norton Sound) is south of Diomede. From 1977 to 1992 murres have increased and kittiwakes have not changed at Cape Lisburne (Denlinger et al. in prep.). Murres have declined and kittiwakes have not changed from 1960 to 1988 at Cape Thompson; the decline in murres occurred between 1960 and the late 1970 (Fadely et al. 1989). At Bluff, from 1979 to 1989, there was no change in the murres and kittiwakes (Murphy 1991), but murres declined in the early 1970s (Murphy et al. 1986). In summary, murres declined at two colonies (Cape Thompson and Bluff) prior to 1980. After 1980, murres declined at one colony (Little Diomede Island). Kittiwakes may have increased at one colony (Little Diomede Island) from 1977 to 1991 but did not change at the other three colonies. These long-term changes contrast with those of the more southerly Pribilof Islands where generally murres have not changed (Byrd 1989). Black-legged kittiwakes, on the other hand, declined prior to 1984 and there has been no decline from 1984 to present (Byrd 1989, Dragoo et al. 1991). This disparity in changes of seabird populations suggests that factors regulating seabird population vary among these colonies.

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PHYSICAL AND BIOLOGICAL STRUCTURE OF SEABIRD FOOD WEBS ON THE NORTHERN BERING AND CHUKCHI SEA SHELF

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INTRODUCTION

The continental shelf of the northern Bering Sea and Chukchi Sea, encompassing the Bering Strait, constitutes the largest shelf sea and has one of the most productive biological regimes in the World Ocean (Coachman and Shigaev 1992). Northward advection of nutrient-rich Bering Sea water by the Anadyr Current promotes high primary productivity (Springer and McRoy 1992), and sustains a huge biomass of zooplankton (Springer et al. 1989), marine mammals (Frost and Lowry 1981, Fay 1982), and seabirds (Springer et al. 1987). The feeding ecology of seabirds and their distribution in relation to local oceanography has been well-described (Bedard 1969, Drury et al. 1981, Springer et al. 1984, Springer and Roseneau 1985, Piatt et al. 1988, 1990a, 1991; Harrison 1990, Hunt and Harrison 1990, Hunt et al. 1990, 1991; Haney 1991, Schauer 1991), although most of these studies have been site-specific. In the first overview of seabird ecology for the entire region, Springer et al. (1987) showed that there were two distinct environmental settings in the northern Bering-Chukchi ecosystem that lead to characteristic pathways of energy flow through pelagic food webs to avian consumers. The physical and biological structure of these environments are the subject of this paper.

OCEANOGRAPHY

Three distinct water masses, each with distant origins, move northward through the Bering Strait (Coachman et al. 1975). Anadyr Water, a "river" of cold, high-salinity (ca. 32.8-33.0 ppt), nutrient-laden oceanic water that originates along the slope of the Bering Sea continental shelf, flows northward through western Anadyr Strait and Bering Strait, and finally into the central Chukchi Sea where it blends with Bering Shelf Water. As much as 72% of the water transported through Bering Strait during summer may come through Anadyr Strait (Overland and Roach 1987). Alaska Coastal Water originates in the Gulf of Alaska. This warm, low salinity (ca. <32.0 ppt) water hugs the Alaskan coast and retains its character throughout the Bering and Chukchi seas. It is influenced seasonally by freshwater runoff from major rivers (Yukon, Kuskokwim). Bering Shelf Water is the resident water mass of the central shelf region south of St. Lawrence Island. Intermediate in character (ca. 32.0-32.8 ppt) between Anadyr and Coastal waters, Bering Shelf Water is advected northward around both sides of St. Lawrence Island, and then flows through Bering Strait where it eventually blends with Anadyr Water.

BIOLOGICAL PRODUCTION

Nutrients and Primary Production

Primary production in the northern Bering and Chukchi Sea ecosystem is largely a function of two factors: nutrient concentrations and water column stability. Three major production centers are recognized (Springer and McRoy 1992, Coachman and Shigaev 1992). The first center is in the large gyre of Anadyr water in the Gulf of Anadyr. Production is initiated when nutrients from deep waters rise into the euphotic zone as the Anadyr Current shoals off Cape Navarin. Downstream of the upwelling, stratification develops in the upper water layers and primary production at the center of the gyre attains 700 g C m^{-2} y^{-1}. As the Anadyr current transits the northern gulf, lateral mixing reduces stratification, thus diminishing production (Coachman and Shigaev 1992).

Turbulent mixing in Anadyr Strait interrupts the developing bloom but "resets" the system, allowing another center of high production (up to 770 g C m^{-2} y^{-1}) to form downstream in northern Chirikov Basin. Production is enhanced because freshwater runoff from Siberia, thermal stratification, and layering all serve to increase stability of the water column just south of the Bering Strait (Coachman and Shigaev 1992).

Passage through the Bering Strait "resets" the system again, and a major production center develops in more stable water downstream in the central Chukchi Sea, corresponding in area to the "pool" of Shelf/Anadyr water. Primary production in this center (up to 830 g C m^{-2} y^{-1}) is extremely high and rivals the highest levels observed anywhere else in the World Ocean (Springer and McRoy 1992).

Average areal production in Anadyr waters of the Gulf of Anadyr (400 g C m^{-2} y^{-1}), Chirikov Basin (360 g C m^{-2} y^{-1}), and Chukchi Sea (420 g C m^{-2} y^{-1}) far exceeds that of Bering Shelf Water (160 g C m^{-2} y^{-1}) and Alaska Coastal Water (50 g C m^{-2} y^{-1}) as measured in the southeastern Bering Sea. These high levels of production are typical of upwelling systems (Table 1, Springer and McRoy 1992).

Table 1. Areal primary production and carbon flux to seabirds in the Bering Sea and other regions.

Oceanic Region	Area (km^2)	Primary Production ($gC/m^2/y$)	Bird Biomass (kg/km^2)	Carbon Flux ($mgC/m^2/d$)
N. Bering-Chukchi	217000	324	15.5	0.65
SLI-Chirikov	99000	360	12.5	0.55
Bering Strait	55000	360	17.1	0.73
Chukchi	62000	420	18.8	0.73
S.E. Bering Shelf	133000	---	18.6	0.49
Inner shelf	39000	50	16.3	0.41
Middle shelf	45000	166	21.2	0.41
Outer shelf	34000	162	36.1	0.68
Slope	14000	50	29.8	0.56
California	163000	130–300		0.20–0.40
Oregon	22000	300	---	0.86
George's Bank	52000	265–455	---	0.47

Data from Wiens and Scott 1975, Schneider et al. 1986, 1987, and Briggs and Chu 1987. (Southeast Bering Sea biomass and flux calculated from 1980 data in Schneider et al. 1986, 1987).

Zooplankton

Zooplankton abundance and distribution in the Bering Strait region are closely related to current and production regimes described above (English, 1966, Springer et al. 1989). Among the copepods, the large, oceanic species *Neocalanus cristatus*, *N. plumchrus*, *Eucalanus bungii*, and *Metridia pacifica*, predominate in Anadyr Water, routinely attaining average densities of 2-4 g_{dry} m^{-2}. They are replaced in Shelf waters largely by a single species, *Calanus marshallae*, with typical densities of 0.2-1.2 g_{dry} m^{-2}. Nearshore in Alaska Coastal Water, *C. marshallae* is replaced by a number of small species, particularly *Acartia longiremis* and *Eurytemora* spp. Biomass densities in coastal water are typically less than 0.5 g_{dry} m^{-2}. Some species are widely distributed in all water types (e.g., *Pseudocalanus* spp., *Oithona similis*), but owing to their smaller sizes, add little to the total standing biomass.

Alaska Coastal Water is remarkable for its overall low abundance of zooplankton. *C. marshallae* is a good indicator of Bering Shelf waters, with highest densities found in Shelf Water northeast of St. Lawrence Island, and east of the 32.4 ppt salinity isopleth in the central Chukchi pool. Similarly, oceanic copepods are tightly associated with Anadyr Water below Bering Strait, and are most abundant west of the 32.4 ppt salinity isopleth in the central Chukchi. Spatial segregation of Anadyr and Shelf copepods in the pool area suggests that Anadyr and Shelf waters retain their identity despite mixing in the Bering Strait.

Some of the primary production in the Bering-Chukchi system goes toward secondary production, but most zooplankton biomass is produced in the south and advected northward through the region. Reproduction and growth of most oceanic zooplankton occurs in April-May on the Bering Sea shelf and slope. It takes about 6 weeks for currents to carry this biomass to the northern shelf, producing a peak biomass there in early July.

Pelagic Fish

Compared to plankton, there has been little directed study of pelagic fishes in the region (Alverson and Wilimovsky 1966, Wolotira et al. 1979), although much can be inferred from diet studies of piscivorous marine birds and mammals (Frost and Lowry 1981, Lowry and Frost 1981, Springer et al. 1984, 1987; Bradstreet et al. 1986, Piatt et al. 1988, 1991).

Alaska Coastal waters contain a greater diversity of pelagic fishes than Shelf waters. Common forage species in Coastal Water include (in approximate order of abundance): sandlance (*Ammodytes hexapterus*), saffron cod (*Eleginus gracilis*), Arctic cod (*Boreogadus saida*), herring (*Clupea harengus*), and capelin (*Mallotus villosus*). Many demersal species occur there also, including a variety of sculpins (Cottidae) and flatfishes (Pleuronectidae). Sandlance and saffron cod are more common south of Bering Strait, whereas Arctic cod are more abundant in the Chukchi Sea.

Although capelin and sandlance are found in open waters, the abundance of Arctic cod exceeds that of all other fish combined by 1-2 orders of magnitude in the Chukchi Sea (Alverson and Wilimovsky 1966). Limited studies indicate a similar trend for the Chirikov Basin and Bering Strait (Frost and Lowry 1981, Springer et al. 1987). From St. Lawrence Island to the northeastern Chukchi Sea (excluding inner Norton Sound where saffron cod predominate), Arctic cod are the overwhelmingly dominant prey of piscivorous seabirds. South of St. Lawrence Island, Arctic cod are replaced by walleye pollock (*Theragra chalcogramma*), which rarely venture into the strait region.

Like zooplankton, there are strong associations between some fish species and water masses (e.g., saffron cod and Coastal Water) whereas some fish are more cosmopolitan (e.g., Arctic cod). Strong associations may be related to water temperature preferences (Methven and Piatt 1990), species-specific food requirements, or to substrate requirements (e.g., sandlance require shallow, sandy substrates). In contrast to zooplankton, fish are more abundant in coastal waters than in open shelf waters (Alverson and Wilimovsky 1966, Piatt et al. 1991). Stratification and stability of the water column may play an important part in determining the relative abundance and distribution of fishes in different water masses (Methven and Piatt 1990). Pelagic fish may also seek out, or be entrained in, eddies and gyres where plankton are concentrated (Schumacher and Kendall 1991).

SEABIRD COMMUNITIES

Piscivore Distribution

Piscivorous seabirds, including common and thick-billed murres (*Uria aalge* and *U. lomvia*), guillemots, horned puffins, kittiwakes, *Larus* gulls, and cormorants, are mostly coastal in distribution. The largest breeding colonies are found on St. Lawrence Island, near Pt. Hope in the northeast Chukchi Sea, and on the Diomede Islands in the Bering Strait. Small colonies dot the entire Siberian coastline. Because these seabirds are constrained to forage near (+ 70 km) their colonies during summer, colonies and major at-sea aggregations coincide spatially. However, many birds are also found at great distances from colonies. Some of these are probably post-breeding (September) or failed breeders from colonies, but many are probably resident non-breeders. A large fraction (20-40%) of seabird populations in summer are comprised of sexually immature birds (1-5 y of age) that are not constrained to forage around colonies (Ainley et al. 1990, Briggs et al. 1987).

At the largest scale, the distribution of piscivorous seabirds is defined by where birds do <u>not</u> occur, i.e., in areas of mixed water. Few seabirds are found in the Coastal-Shelf transition zone, or in the stream of Anadyr and Anadyr-Shelf mixed waters. This is consistent with observations that pelagic fish avoid mixed waters (Piatt et al. 1991). On a smaller scale, birds are most abundant on the shelves around St. Lawrence and Diomede islands, around headlands in the Alaska Coastal stream, and in a number of eddies in the Chukchi Sea. This is consistent with observations that fish are more abundant in Alaska Coastal waters and that fish aggregate in eddies. Whereas at-sea data are lacking (but see Schauer 1991), it appears that the Siberian coast supports only small, dispersed colonies. It may be that populations on the Siberian Coast are limited by foraging habitat.

Planktivore Distribution

Planktivorous seabirds, largely auklets and phalaropes, have a markedly different distribution from piscivorous seabirds. Planktivores are conspicuously absent from Alaska coastal waters, and Coastal-Shelf transitional waters. There are few colonies, but they are enormous and positioned strategically in Anadyr and Bering straits. Least and crested auklets are extremely abundant around the west end of St. Lawrence Island, and also north along the border of the Anadyr Current. Few are found in the downstream plume of Anadyr Water, beyond about 100 km from colonies. In Bering Strait, least auklets are most abundant to the south in Shelf Waters, and crested auklets dominate to the west where they straddle the mixed zone of Anadyr-Shelf waters. Again, planktivores are scarce in the plume downstream of Bering Strait, and most forage within 100 km of the Diomede islands. Large concentrations of planktivores, almost entirely red phalaropes (but also parakeet auklets), are found in the central Chukchi Sea. In contrast to piscivores, phalarope aggregations are extended along a southeast to northwest axis, and appear to straddle mixed waters rather than avoid them.

Several factors contribute to this restricted distribution pattern. At the largest scale, auklets are constrained by breeding activities (June-September; Piatt et al. 1990a) to forage within a limited distance from colonies. As with piscivores, however, a large proportion (20-40%) of auklets are potentially non-breeders (Jones 1992). One might expect non-breeding birds to exploit more distant hotspots, if they were suitable. Some of the habitat within range of colonies that contain few auklets corresponds to areas of high turbulence.

More so than abundance, prey density and accessibility appear to determine auklet distribution. Auklets prefer to forage in stratified Shelf/Anadyr water where pycnoclines (and zooplankton) rise toward the surface in response to topographic features or at the border of upwelling and fronts (Hunt et al. 1990, Hunt and Harrison 1990, Hunt et al. 1992). Auklets may also be found in abundance just on the other (mixed) side of the Anadyr-Shelf frontal zone (Haney 1991) or along the border of upwelled waters on the west coast of St. Lawrence Island (Bedard 1969, Springer and Roseneau 1985).

Phalaropes (mostly red phalaropes) replace auklets as the dominant planktivore in the Chukchi Sea. They eat a wide variety of planktonic prey, including amphipods, copepods, mysids and small euphausiids (Divoky 1984, Brown and Gaskin 1988). Away from the coast, where they may forage in the littoral zone, concentrations of red phalaropes are almost always associated with convergent fronts where plankton accumulate in surface slicks (Brown and Gaskin 1988). The vast majority of phalaropes in the Chukchi Sea straddle the mixed water zones marking the convergence of Anadyr Water from the south and Shelf/Anadyr/Coastal waters from the east.

Energetics and Carbon Flux

The rate of energy and carbon flux to seabird populations (Table 1) is calculated from the numbers of each species present, and the metabolic requirements for individuals of each species. From a population standpoint, planktivorous auklets are overwhelmingly dominant south of the Bering Strait. Phalaropes replace auklets as planktivores in the Chukchi Sea, and our numbers are similar to the 1 million estimated by Divoky (1987). Murres (spp.) and kittiwakes are the most abundant piscivores in all subregions, and are most abundant in the Chukchi Sea.

Taking into account the differences in body size between species and subregional areas, the relative trophic importance of each species is dramatically different from their numerical abundance. Carbon flux to piscivores rivals that of planktivores south of Bering Strait, and is an order of magnitude greater in the Chukchi Sea. The Bering Strait and the Anadyr Strait support a nearly equal density of auklets. Taking total areas into account, however, it is clear that Anadyr Strait is the nucleus for auklet populations in the region. These estimates do not even account for much (if any) of the huge populations of auklets on the Siberian Coast, which probably forage in Anadyr Water before it enters Anadyr Strait. Some of the disparity between regional populations may relate to breeding habitat, which is very limited in Bering Strait. Total seasonal (122 d) food consumption is similar in all three subregions (29,000 mt; 21,100 mt; 21,900 mt; in Saint Lawrence Island-Chirikov Basin, Bering Strait, and Chukchi Sea, respectively). Whereas half of all food consumed below Bering Strait goes to planktivores (49% of 411 mt d^{-1}), most goes to piscivores (88% of 179 mt d^{-1}) in the Chukchi Sea.

The trophic importance of piscivores is mostly due to the large numbers of murres. In terms of carbon flux, these large-bodied alcids dominate in all shelf seabird communities from central California to the Chukchi Sea (Wiens and Scott 1975, Briggs and Chu 1987, Schneider et al.

1987, this study). In contrast to more southern coastal areas, where Common Murres predominate, and to the oceanic Aleutian islands where Thick-billed Murres predominate, Thick-billed murres are about equally as abundant as common murres in the Bering Strait-Chukchi region. As noted by Springer et al. (1987), this is a direct consequence of having two distinctly different pelagic environments (oceanic vs. coastal) side-by-side in the region. Thick-billed murres are adapted for oceanic conditions, and although they rely heavily on pelagic fish, they also forage on a wide variety of oceanic prey including euphausiids, amphipods, and squid. Common murres feed almost exclusively on pelagic schooling fish during summer.

With extremely productive Anadyr waters, a massive concentration of planktivores, and proximity of coastal and oceanic environments that support both species of murres, the northern Bering-Chukchi system rivals or exceeds most other shelf and upwelling systems that have been studied in terms of carbon flux to seabird populations (Table 1). With a high proportion of small-bodied auklets, the standing biomass of seabirds is lower than in most other regions, but this is compensated for by the higher mass-specific metabolic rates of small species.

DISCUSSION

At the largest scale (100's km), the seabird community in the Bering Strait region is physically and biologically structured in a north-south direction by advection and upwelling of nutrients and biomass from the south. At intermediate scales (10-100's km) in an east-west direction, seabird distribution is well-defined by water masses, current flow, frontal zones, and water column stability. In turn, these water properties are influenced by bottom topography (including islands and headlands), tides, freshwater runoff, surface layering, and wind. Eddies driven by current flow (barotropic) and density differences (baroclinic) also appear to be common and important structural features in the region (Coachman et al. 1975).

At very fine scales (1-100's m), corresponding to a patch of plankton or school of fish, seabirds are often strongly correlated with prey schools below the surface (Piatt 1990, Hunt et al. 1990). At small (1-10's km) and intermediate scales, however, biological and physical constraints modify the patterns we observe (Schneider and Piatt 1986, Hunt et al. 1991, 1992). For example, zooplankton are abundant throughout their range in Anadyr/Shelf water, but planktivores select foraging areas at intermediate scales on the basis of distance to colonies, and at small to intermediate scales on the basis of prey availability and patch density. Auklets are limited in their diving ability (<10-25 m on average) and seek out dense plankton layers brought near the surface by upwelling or raised pycnoclines (Hunt et al. 1990, 1992). Surface-feeding phalaropes depend on the concentration of prey in convergent slicks (Brown and Gaskin 1988). Given the generally poor resistance of zooplankton to currents, it appears that physical structuring may be more important than biological factors in determining the distribution of planktivores at intermediate scales.

Little is known about the overall distribution of fish in the Bering Strait region, but we can assume that the presence of piscivores is a reliable indicator of fish concentrations (Hunt et al. 1991, 1992). However, piscivores require moderate to high density schools of fish for successful foraging (Piatt 1990), so patterns of distribution should also reflect physical mechanisms for concentrating prey of fishes. Furthermore, some deep-diving (>50 m) piscivores (murres, cormorants) can exploit all of the shelf water column, whereas others (kittiwakes, gulls) must rely on physical or biological mechanisms (e.g., fronts, diel migration) to bring fish to the surface. The abundance of piscivores in stratified coastal waters and offshore eddies, and their conspicuous absence from mixed and turbulent waters, suggests an important role for physical factors in structuring piscivore communities.

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QUESTIONS AND DISCUSSION

CALEB PUNGOWIYI: Two quick questions. One is on these two currents that move north, what is the typical depth of these currents?

JOHN PIATT: It is pretty well limited by the depth of the bottom there, they can't be any deeper than 50 m.

CALEB PUNGOWIYI: How far under the surface to they go?

JOHN PIATT: The Alaska Coastal Current is all one, sort of from top to bottom it is only 30 m. So pretty much it is all uniformly Alaska Coastal Water. But the Anadyr Current, once it comes into the central Chukchi, there is a large part that diverts off to the left, but a lot of the surface water, perhaps the top 10 m, 20 m continues north, and sort of splits off from there.

CALEB PUNGOWIYI: What was the timing of your nutrient studies, when was that done?

JOHN PIATT: I didn't do the nutrient studies. All of that work has been done by a lot of other people over the last 10 to 15 years. That was just one picture. There are several others that can be constructed. Typically, it takes weeks to months to map out that large of an area, the Bering and Chukchi. So that particular data was collected in July and early August, I believe, on a cruise. Typically, the months that this work is done is from May to August.

SATELLITE TRACKING AND STAGING ECOLOGY OF WRANGEL ISLAND LESSER SNOW GEESE

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Lesser snow geese (*Anser caerulescens caerulescens*) breeding on Wrangel Island (71°N, 179°W), in the Chukchi Sea, are the only population of lesser snow geese breeding in the Palearctic. This is one of the few waterfowl populations of Palearctic origin which is harvested, but does not breed on the North American continent. Management of lesser snow geese from Wrangel island is additionally complicated, as the population winters in two disjunct regions of the Pacific Flyway (Kozlik et al. 1959, Reinecker 1965, Syroechkovskiy and Litvin 1986, McKelvey et al. 1989), the largest (California) component of which mixes with lesser snow and Ross' Geese (*Anser rossi*) breeding in northern Canada. Harvest regulations have largely been directed toward this larger, Canadian segment of the "white goose" population in the Pacific Flyway, potentially compromising the Wrangel Island population which has been declining since the early 1970s (Bousfield and Syroechkovskiy 1985).

Attempts to monitor the Wrangel Island population have largely consisted of efforts to determine annual production on the breeding grounds (Baranyuk 1990), and from age ratio counts on the Yukon-Kuskokwim (Y-K) Delta, Alaska (Clark 1985; Wege 1987, 1988, 1989a, 1989b), and on the Fraser River Delta (Jeffrey and Kaiser 1979, McKelvey et al. 1989). Monitoring efforts on the Y-K Delta have been sporadic, in part, because it was not known if all geese from Wrangel Island used the Y-K Delta in autumn, and hence if age ratio counts obtained there are representative of all Wrangel Island lesser snow geese.

We initiated the current investigation as part of a larger project documenting the autumn migration of Wrangel Island lesser snow geese using satellite and conventional transmitters. The tracking of individual animals has enabled us to estimate the proportion of geese using the Y-K Delta in autumn, and address the adequacy of conducting adult-immature ratios on the Y-K Delta. We also present information on annual variation in reproductive success for this population, and provide the first detailed information on the distribution of lesser snow geese on the Y-K Delta in autumn, and the length of time individual geese remain there. Age-ratio comparisons with other autumn staging areas may provide insight into population distribution, and factors contributing to juvenile survival during migration.

We monitored the distribution, abundance, and productivity of lesser snow geese on the Yukon-Kuskokwim (Y-K) Delta, Alaska during September and October 1991, when the geese were en route from their nesting grounds on Wrangel Island, Russia to wintering areas along the Pacific Coast (Figure 1). Adult geese in brood flocks were captured on Wrangel Island and fitted with either satellite (PTT) transmitters or conventional (VHF) radio transmitters. All geese with active PTT transmitters and 43% of the geese with VHF transmitters still functioning used the Y-K Delta. Geese marked with satellite and VHF transmitters were first detected on the Y-K Delta on 19 and 25 September, respectively. Mean arrival time for PTT-marked geese was 2 October; geese remained on the Delta an average of 12 days (range 1 to 25 days), and corroborated similar information obtained from VHF radios. All PTT-marked geese were detected at least once on the mid-Delta, while three used the north Delta and one used the south Delta. Geese with

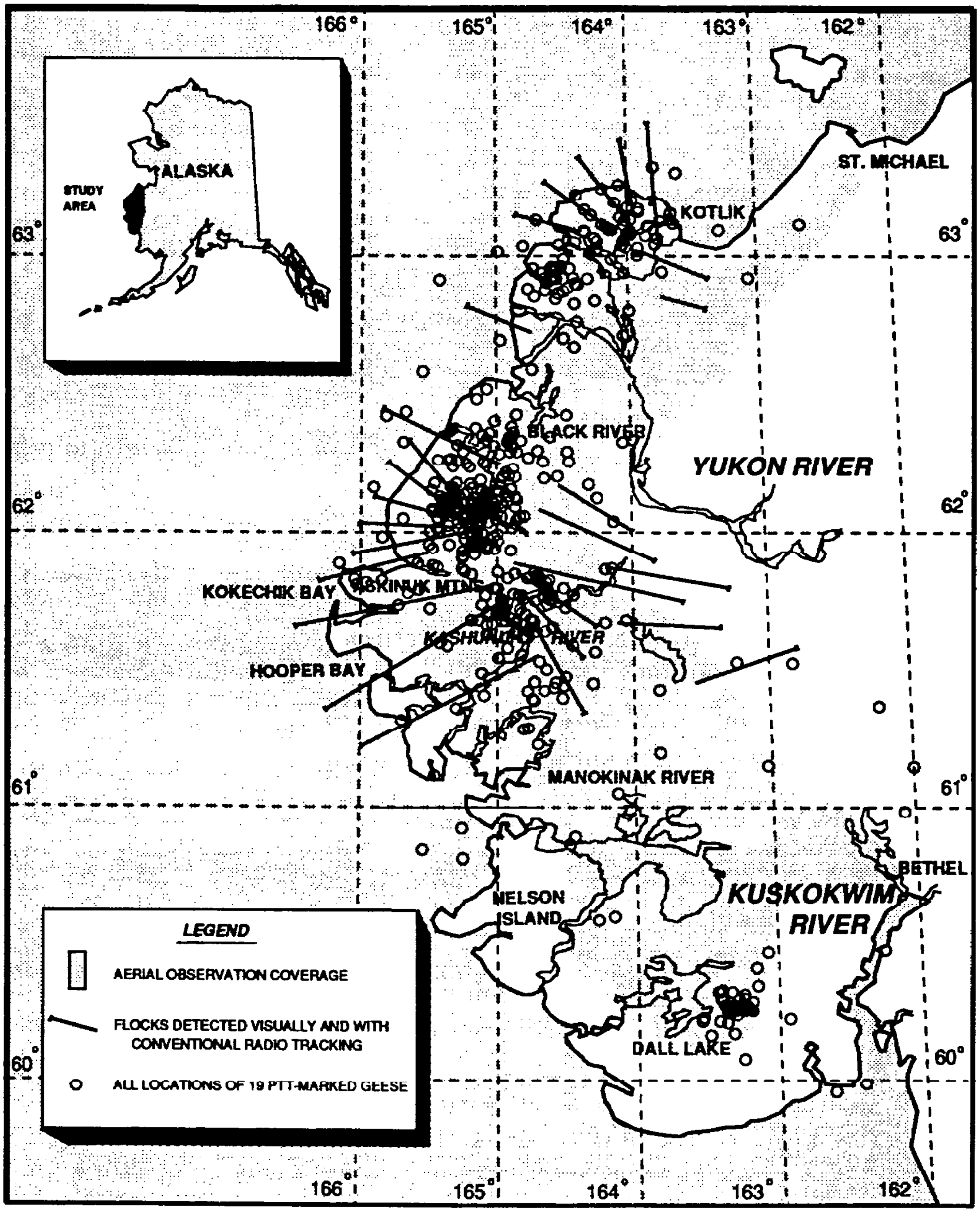

Figure 1. Distribution of Lesser Snow Goose flocks on the Yukon-Kuskokwim Delta, Alaska in autumn 1991.

PTTs used the same areas as unmarked geese and geese with VHF radios, except for the south Delta where only satellite data was obtained. Flocks averaged 1122 birds, and did not vary significantly in size during the study. Approximately 28% of the geese censused in photographic counts were immatures. Average productivity of the Wrangel Island population, as determined from the proportion of young in flocks using the Y-K Delta has varied from 0.5 to 42.1%, with a mean of 29% since 1975 (Figure 2). Age ratio estimates from the Y-K Delta were highly correlated with those from autumn staging areas further south, and may indicate that mortality of immature snow geese during the second half of their autumn migration to wintering areas is significant relative to many species of arctic-nesting geese. Information from PTT-marked geese indicated that the entire breeding component of the Wrangel Island population used the Y-K Delta.

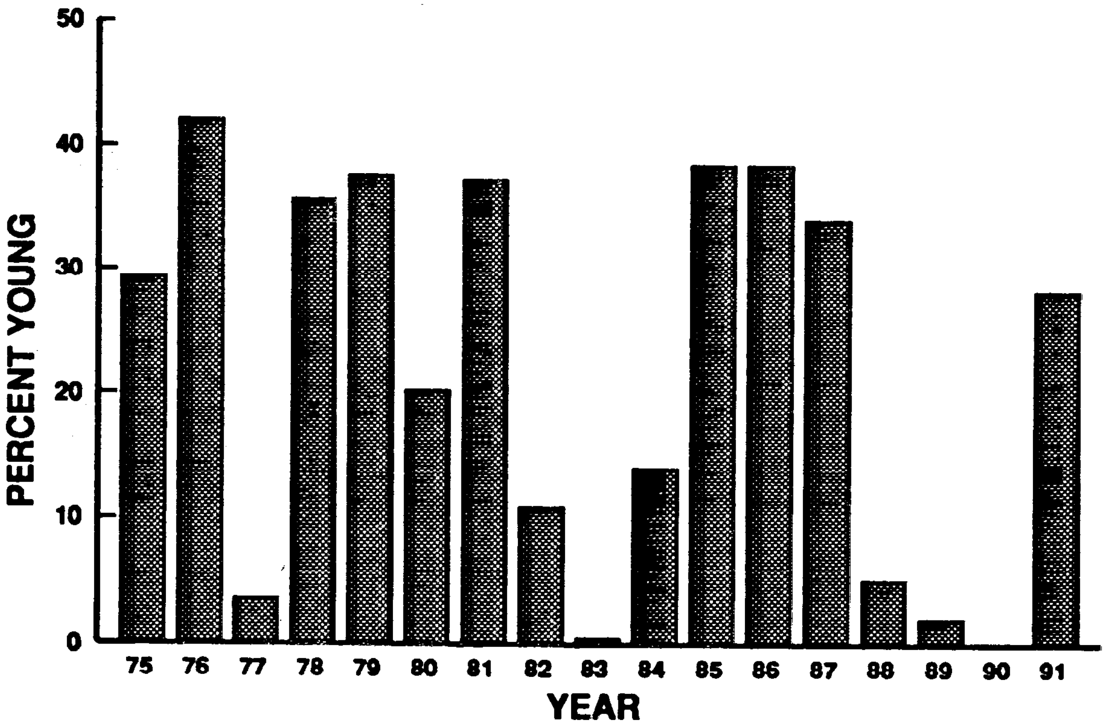

Figure 2. Proportion of immatures in flocks of Wrangel Island Lesser Snow Geese during autumn on the Yukon-Kuskokwim Delta, Alaska.

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SOCIAL AND ECONOMIC STUDIES

Thursday, January 21, 1993

SOCIAL INDICATORS OF TRADITIONAL AND WESTERN CUSTOMS IN COASTAL ALASKA

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Dr. Joseph Jorgensen, born and reared in Utah, received the Ph.D. in anthropology at Indiana University in 1964. He has held professorships at Antioch College, the University of Oregon, and the University of Michigan. He currently is professor of anthropology, University of California, Irvine. Dr. Jorgensen has conducted primary research among ten American Indian societies, 42 Alaskan Eskimo, Aleut, and Canadian Inuit villages, and several non-native communities in the United States. He has conducted comparative secondary research among 172 societies, languages, and environments in western North America.

Dr. Jorgensen is a Guggenheim Fellow, the recipient of two book awards and two Pulitzer nominations, and has delivered endowed lectures at the Universities of Kansas, Utah, South Dakota State, Victoria (B.C.), and Sao Paulo (Ford lectures to the Brazilian Anthropological Association). Since 1987 Jorgensen and his colleagues have been conducting a multi-method, multi-data, multi-variate, longitudinal analysis among about 1500 respondents in 40 Alaskan villages with the goal of creating two indicator systems sensitive to economic and social change.

In early 1987 our research team embarked on an analysis of contemporary life in 31 Alaskan villages located from Kaktovik on the coast of the Beaufort Sea (Arctic Ocean) to Kodiak City on Kodiak Island south of the Alaskan Peninsula.[1] We had been charged by the Minerals Management Service (MMS), U.S. Department of Interior, to develop two sets of indicators from several methodologies and several data sets which would be sensitive to social and economic change and which could be used, from time to time, to monitor conditions among villagers throughout coastal Alaska.

The rationale behind developing sets of social indicators is that small subsets of those indicators can be used to monitor Alaskan villages and determine whether oil-related activities are affecting them. It is frequently the case that multiple factors, rather than a single factor, account for social change. In order to know whether oil-related factors are responsible for changes wrought in villages, MMS requested that we pay special attention to distinguishing differences, should they exist, between natives and non-natives, between villages which possessed well-developed infrastructures and services and those that did not, and between Outer Continental Shelf (OCS) oil-related activities and other activities that may affect village organizations, village economies, village politics, and life within villages.

To determine whether differences at the level of the village obtained between natives and non-natives, we created two subsamples from our total sample in which the populations of *Native* villages are more than 75% natives, and those of *Mixed* villages are more than 25% non-natives. For many issues it was necessary to refine *Mixed:Native* contrasts, and in those instances contrasts between **natives** and **non-natives** were made.

We tested several other theoretical contrasts throughout the course of our research, dropping some and retaining others. A contrast between subsamples which distinguished villages which

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[1]The research design, including demographic information about the 31 villages and the seven regions in which they are located, appears in *Social Indicators Project II. Research Methodology: Design, Sampling, Reliability, and Validity* (1992). Ethnographic and historical information about the study villages and regions appear in *Social Indicators Project I. Key Informant Summaries* (1992).

gained more than 60% of its total income from commercial fishing and villages which gained less than 40% of its total income from commercial fishing proved to be important when the *Exxon Valdez* foundered in March, 1989, spilling eleven million gallons of North Slope crude oil into Prince William Sound. As the oil spread by wind and wave action, it moved around the Kenai Peninsula and into the commercial fishing waters of Kodiak Island fishermen. The spill, of course, also affected fishermen in Prince William Sound, the Alaska Peninsula, and Cook Inlet. We expanded our study to include a sample of villages affected by the spill. The research conducted among the villages affected by the spill will appear in the summer of 1993.

Here I focus on the research conducted between 1987 and 1990 among the samples and panels drawn from the original 31 study villages. The division of these samples into *Mixed:Native* contrasts is central to the following discussion. The *Mixed:Native* contrast is slightly more powerful than all others we made. In addition, we are not losing much information by focusing principally on this contrast because all *Mixed* villages are heterogeneous and have well developed infrastructures, and because all *Native* villages are homogeneous and all but two have weakly developed infrastructures.

Among all of the sets of hypotheses we tested while seeking to develop indicator systems, two stand out: one which accounts for differences between traditional customs and Western customs in village life, and one which accounts for differences between a dependency model of economic development and a Western model of capitalist development. Time constraints require that we focus our attention on only one of these: traditional customs and the factors which account for their persistence and for changes from them.

SOCIAL INDICATORS OF 'TRADITIONAL' CUSTOMS

At the outset of the research, a central issue in the social indicators project was defining and measuring 'traditional' customs. The items measuring traditional activities which survived our tests represent two dominant features of life in the bush, particularly native life (Eskimo, Aleut, Athapaskan): (1) communitarian acts and sentiments, examples of which are the sharing of resources and meals with relatives, wider networks of kinspersons, and friends beyond one's household, even one's village, and the maintenance of active interests in community affairs, in large part through participation in them; and (2) engaging in hunting, fishing, and other extractive activities — some solo and some with relatives or friends.

The items employed in our multivariate analyses indicate traditional customs in village Alaska. Some of the variables do not appear to be "traditional," such as voting in city council and village corporation elections, and attending public meetings. Yet we learned from our observations in the villages that village corporations and city councils are regarded as community instruments through which residents control local affairs and bring benefits to their communities. Attendance at public meetings, as well, are thought of as communal acts, not merely personal ones. Traditional people are engaged in community life, so we sought to measure that involvement as a persistence of a traditional practice, although in altered forms from before passage of the Alaska Native Claims Settlement Act (ANCSA) and before statehood.

The several waves of research demonstrate that high scores on "traditional" variables correlate with large, composite households, public sector employment, or with low incomes derived from multiple sources, many of them public transfers of various kinds. Table 1 arranges summary statistics by the total samples and by theoretical contrasts (*Mixed:Native*) for the pretest and posttest research waves for most of the variables used in the analysis of traditional customs. Differences between types of villages on more than half of the measures provided here are

Table 1. Contrasts between Pretest and Posttest samples, and between *Mixed-Native* contrasts within those samples, 32 AOSIS variables measuring respondent characteristics and traditional customs, 1987-1988 and 1989-1990.

	PRE 1987–1988 (N=548)	PRE MIXED (N=264)	PRE NATIVE (N=284)	POST 1989–1990 (N=308)	POST MIXED (N=170)	POST NATIVE (N=138)
ETHNICITY						
Native	79%*	59%*	95%	67%	48%*	91%
Non-native	21%	41%	5%	33%	52%	9%
AGE						
Mean	41.5	39.9*	43	42.4	39.9*	45.5
SEX						
Male	50.5%	44%*	57%	54%	45%*	64%
Female	49.5%	56%	43%	46%	55%	36%
EDUCATION COMPLETED						
Some High School	42%	38%*	47%	46%	43%*	50%
Some College or Beyond	33%	48%	19%	30%	42%	16%
SOURCE OF EMPLOYMENT						
Unemployed/Retired/Other	24%	19%*	29%	28%	25%	32%
Public Sector	37%	35%	39%	39%	42%	35%
Private Sector	39%	46%	32%	33%	34%	32%
EMPLOYMENT						
Md Months Employed	6	8*	3.7	8	9.9*	2.8
Persons Employed ≥ 4 Months	52%	73%	51%	60%	70%	48%
Persons Employed ≥ 10 Months	37%	44%	31%	44%	58%	28%
INCOME						
Median	$22,940	$34,185*	$16,000	$27,885	$38,172*	$19,017
Mean	$30,160*	$37,900	$22,980	$33,920	$39,270	$27,030
Income ≥ $50,000	18%	30%	7%	27%	38%	13%
HOUSEHOLD SIZE						
Mean	2.84	2.64*	3.06	2.8	2.7*	2.9
3 Persons or More	71%	62%	80%	68%	66%	72%
6 Persons or More	23%	16%	30%	20%	13%	29%
HOUSEHOLD TYPE						
Single-Conjugal-Nuclear	80%*	83%	78%	66%	73%*	57%
Stem-Joint-Denuded-Composite	20%	17%	22%	34%	27%	43%
LENGTH OF RESIDENCE						
≤ 5 years	17%*	24%*	10%	18%	28%*	5%
> 10 years	69%	55%	83%	56%	38%	78%
LAND MAMMALS						
% Hunters	34%	33%	35%	42%	37%	47%
Months Hunting	2.4	1.8	2.8	2.5	2.4	2.6
Days Hunting	20.5*	19.2*	21.4	11.5	12.6	10.5
SEA MAMMALS						
% Hunters	32%	16%*	44%	28%	12%*	48%
Months Hunting	4.3	4.2*	6.3	5.6	4.8*	6.3
Days Hunting	38*	35.5*	41.5	34.7	37.4*	34.1
CAMPING						
% Campers	49%	44%*	53%	42%	38%	47%
Months Camping	3	2.7*	3.2	2.4	2.4	2.4
Days Camping	13*	13.1	13.0	19.9	21.5*	18.2
FISHING						
% Fishers	41%*	36%*	46%	60%	55%*	69%
Months Fishing	4.3	5.1*	3.9	3.5	3.5	3.7
Days Fishing	20.9*	20.4	21.5	27.7	23.3*	32.4

Table 1. (Cont.)

	PRE 1987–1988 (N=548)	PRE MIXED (N=264)	PRE NATIVE (N=284)	POST 1989–1990 (N=308)	POST MIXED (N=170)	POST NATIVE (N=138)
SUBSISTENCE FOOD YESTERDAY						
Yes	64%	49%*	78%	58%	48%*	71%
SUBSISTENCE FOOD DAY BEFORE YESTERDAY						
Yes	61%	51%*	71%	57%	45%*	72%
EITHER DAY FOOD FROM OTHER HH						
Yes	37%*	49%	50%	36%	36%*	35%
MEALS WITH RELATIVES OTHER HOUSEHOLD PAST 2 DAYS						
1 or More	50%	43%*	56%	43%	33%*	54%
SUBSISTENCE MEAT AND FISH IN ANNUAL DIET ≥ 50%	54%	40%*	67%	47%	34%*	64%
SPEAK NATIVE LANGUAGE AT HOME						
Most of Time or Always	47%	35%*	55%	40%	30%*	48%
THINK ABOUT GAME AVAILABLE PAST 5 YEARS						
Decreased	30%	22%*	41%	35%	40%	29%
Increased	31%	40%	20%	20%	18%	22%
THINK ABOUT FISH AVAILABLE PAST 5 YEARS						
Decreased	46%	40%	54%	42%	56%*	26%
Increased	17%	22%	10%	16%	16%	16%
DAYS VISIT FRIENDS LAST WEEK						
3 or More	46%	44%	47%	43%	45%	41%
PUBLIC MEETINGS ATTENDED LAST MONTH						
1 or More	44%	41%	47%	48%	42%	54%
VOTE IN RECENT CITY COUNCIL ELECTION						
Yes	69%*	64%*	73%	57%	54%	60%
VOTE IN RECENT VILLAGE CORP ELECTION						
Yes	68%	63%*	72%	64%	60%	67%
SOCIAL TIES WITH PERSONS IN OTHER VILLAGES						
No Satisfaction	6%*	6%	5%	10%	12%	7%
Complete Satisfaction	22%	20%	23%	57%	51%	65%
FEELINGS ABOUT INCOME						
No Satisfaction	16%*	6%*	25%	25%	27%	22%
Complete Satisfaction	11%	13%*	10%	30%	29%	30%

(a) Asterisks (*) denote Pretest/Posttest and Mixed/Native contrasts significant at P .05. Pretest/Posttest contrasts are designated in the first column. Mixed/Native contrasts for the pretest sample appear in the second column and for the posttest sample appear in the fifth column. Significance of differences for Mixed/Native contrasts of nominal dichotomous variables are based on the test for the difference between proportions; the Kolmogorov–Smirnov two independent sample test is used for ordinal variables; and the t-test is used for interval variables.

significant. Of the 64 contrasts between *Mixed* and *Native* villages in the pretest and posttest samples, 38 of the differences would occur fewer than five times in 100 by chance.

Below our initial interests will be in determining the structure of traditional customs in modern villages in the pretest research wave and in the posttest wave. Next we account for the ways in which the pretest and posttest samples differ. Differences are clues to change, and social indicators should be sensitive to change, while also demonstrating stability and reliability.

Stationariness requires panel data. Whereas differences between pretest and posttest samples may suggest whether and what kind of changes have occurred between 1987-1988 and 1989-1990, because the posttest sample was drawn without replacement of the pretest sample, conclusions about change based on comparisons of pretest and posttest samples suffer from the threat of 'ecological fallacy' (or specification error). We controlled for ecological fallacy by embedding two panels in the research design. Panels are composed of subsamples of respondents drawn from the pretest samples and re-interviewed in two subsequent waves after their initial interviews. Space limitations do not allow us to present the panel analyses here, although we will refer to those analyses.

NATIVE PRETEST AND POSTTEST COMPARISON

The structure of traditional customs in *Native* villages differed little among the several research waves in any of our samples. The solution for the pretest *Native* sample (Figure 1) is representative. Let us focus our attention on it. In the pretest configuration the TRADITIONAL EXTRACTOR region forms two cylindrexes, one 'Sea Mammal Extraction' and the other 'Intense Extraction.' The posttest configuration for *Native* villages (Figure 2) is similar, but not identical. The difference between pretest and posttest solutions for respondents in *Native* villages is that the traditional customs in the posttest, especially the consumption of naturally-occurring resources and the communitarian behavior that accompanies consumption of those 'subsistence foods' are separated from the measures of sea mammal extraction. Thus, we label the areas in the TRADITIONAL EXTRACTOR region of Figure 2, 'Traditional Subsistence' and 'Intense Extraction.'

The HIGH INCOME regions of pretest and posttest configurations are similar in that they include only two items, income and satisfaction with income (**b, D2; I, E29**). And they are similar in that low income behaviors reflecting 'Traditional Recipients' are separated from the measures of high income and from the measures of 'Intense Extraction.' The 'Traditional Recipient' area in Figure 1 includes non-nuclear households, the receipt of food from persons in households other than the respondent's, and the attitudes that the availability of both game and fish have increased in the past five years. The 'Recipient' area in Figure 2 is almost identical to the pretest except that it includes long-term residence in the community and excludes non-nuclear households. This last is interesting and calls our attention to changes between pretest and posttest.

Unemployment is greater in the posttest than the pretest *Native* subsample, although posttest incomes are $3,000 higher ($2,000 in 1987-1988 dollars). The decrease in employment most likely accounts for the fitting of non-nuclear households with large households and other traditional features in the 'Traditional Subsistence' area in the posttest solution (Figure 2). Whatever the case may be, suffice it here to note that the differences between the pretest and posttest *Native* configurations are modest.

We can understand the similarities between the pretest and posttest configurations if we look closely at the sea mammal extraction variables within the 'Intense Extraction' cylindrex (Figure

VARIABLE		D1	D2	D3	VARIABLE		D1	D2	D3
PPEMP	A	-.80	.19	-.66	A26A	P	-1.36	-.23	-.66
RHHSI	B	.61	.10	-.26	A26B	Q	-1.35	-.74	-.26
RHHTYPE	C	-1.22	-.18	.44	A28	R	.06	.69	.44
CACT1	D	.84	-.25	.34	A30	S	-.07	.79	.34
CACT2	E	.64	.39	.22	A31	T	-1.51	.20	.22
CACT4	F	.54	.57	-.32	A32	U	-.78	.36	-.32
CACT5	G	.24	.73	.54	A36	V	-.61	.39	.54
CMN1	H	.79	-.02	-.09	D2	W	.24	-1.17	-.09
CMN2	I	.63	-.34	-.88	D13	X	.12	.44	-.88
CMN4	J	.92	.26	-.34	D16	Y	-.13	-.21	-.34
CMN5	K	.41	.18	.64	D19	Z	-.26	-.45	.64
RDAY1	L	.82	-.38	.74	D22	a	.06	-.41	.74
RDAY2	M	.86	-.31	.92	D25	b	-.50	.07	.92
RDAY4	N	.61	-.46	-.06	E12	c	-.47	.86	-.06
RDAY5	O	.67	-.06	.31	E29	d	-.15	-1.02	.31

Guttman-Lingoes' Coefficient of Alienation K = .187

TRADITIONAL EXTRACTORS

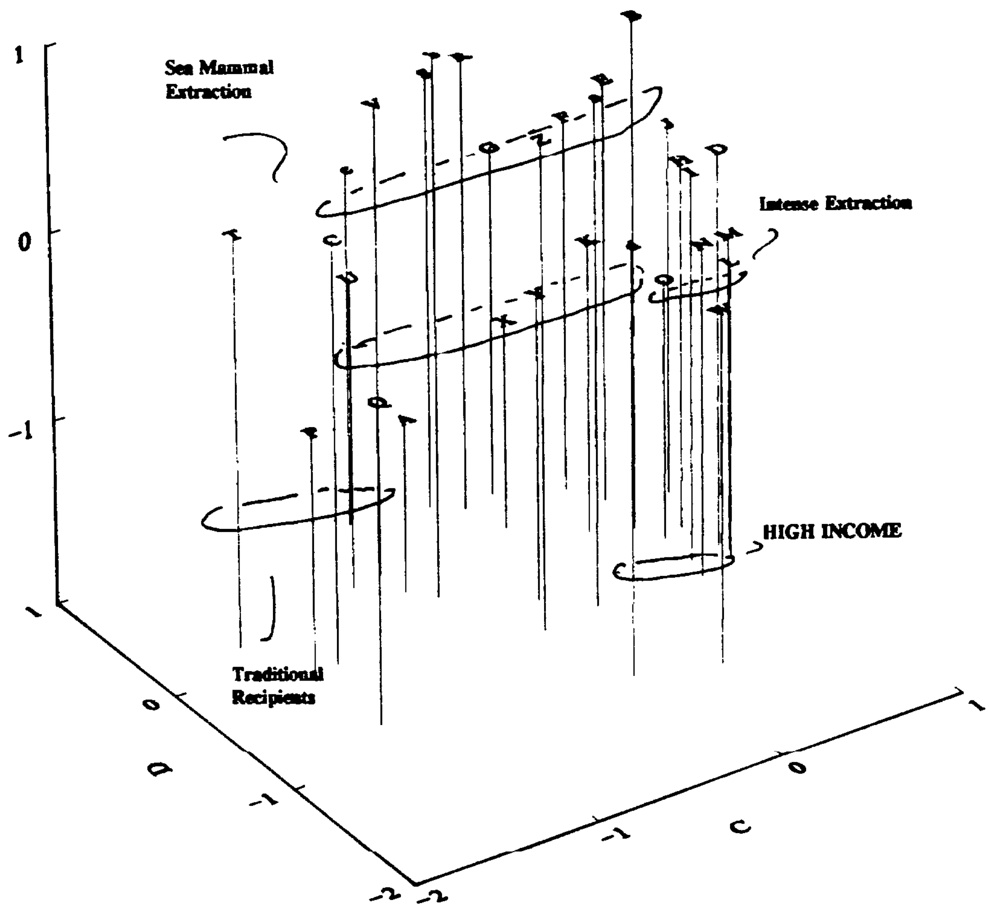

Figure 1. Structure of AOSIS traditional customs, Guttman-Lingoes' MDS configuration (3-D), 30 variables, N=285, native subsample of Pretest sample, 1987-1988.

VARIABLE		D1	D2	D3
PPEMP	A	-.28	-1.13	.08
RHHSI	B	.40	-.72	-.30
RHHTYPE	C	-.29	-.98	.31
CACT1	D	.60	.51	.07
CACT2	E	.45	.29	.30
CACT4	F	.37	.70	.35
CACT5	G	.02	.64	.48
CMN1	H	.39	.39	.01
CMN2	I	-.11	.22	.23
CMN4	J	.30	.56	.25
CMN5	K	.19	.62	.53
RDAY1	L	.32	.41	.03
RDAY2	M	.26	.17	.06
RDAY4	N	.25	.47	.40
RDAY5	O	.05	.53	.60
CREL1	P	-1.14	.05	.31
CREL2	Q	-1.22	.10	.27
CREL4	R	-1.18	.52	.00
CREL5	S	-1.09	.35	.22

VARIABLE		D1	D2	D3
A26A	T	-.19	-.21	-.84
A26B	U	-.03	-.88	-.66
A28	V	.73	-.36	.55
A30	W	1.00	-.76	.27
A31	X	-1.63	-.60	.06
A32	Y	.34	-.15	.74
A33	Z	.69	-.50	.41
A36	a	.23	-1.07	.51
D2	b	-.28	.86	-1.04
D13	c	-.30	-.02	.57
D16	d	.64	.06	-.71
D19	e	.54	.64	-.88
D22	f	.76	-.16	-.61
D25	g	-.79	-.45	-.48
E12	h	.47	-.41	-.98
E29	i	-.46	.30	-1.15

Guttman-Lingoes' Coefficient of Alienation K = .191

TRADITIONAL EXTRACTORS

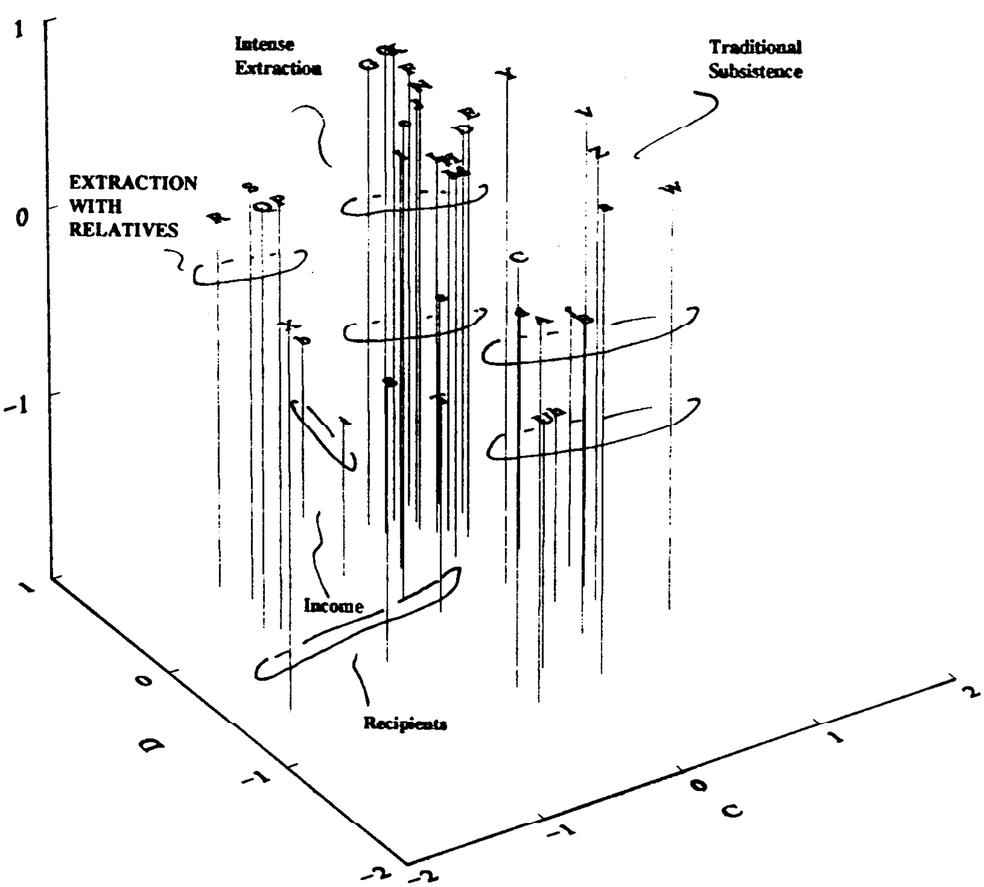

Figure 2. Structure of AOSIS traditional customs, Guttman-Lingoes' MDS configuration (3-D), 35 variables, N=142, native subsample of Posttest sample, 1989-1990.

2). The 'Intense Extraction' cylindrex incorporates sea mammal extraction and also some community variables that are only indirectly related to extraction: voting in the most recent city election (**e, D19**) and frequent visits with relatives in the past week (**c, D13**). Visiting increases with participation in extractive activities, but is negatively correlated with income. Increases in voting in city elections and visiting with relatives are likely due to the traditional practices of persons who engage in sea mammal hunting because if persons extract sea mammals, they extract other naturally occurring resources heavily and also practice most of the traditional customs we analyze here. The sea mammal extraction variables (**E, CACT2; I, CMN2; M, RDAY2**) form a simplex from right-center to left-center in the 'Intense Extraction' cylindrex. They are pulled toward, but not into the 'Traditional Subsistence' area. The differences from the pretest solution (Figure 1) suggested to us that economic factors had intervened between the pretest and posttest research waves. We will return to this topic.

Communitarian customs are the polarizing[2] facet if the 'Traditional Subsistence' cylindrex in Figure 2, and the directness of the relation between an item and communitarian customs is the modulating facet. Not only are traditional customs separated from extractive activities, but an inversion of modulating facets occurs between the pretest and posttest. Of the two radexes in the 'Traditional Subsistence' cylindrex, the higher one demonstrates the relationships between extractive activities and the consumption of the items extracted. So although subsistence consumption is fitted in the 'Traditional Subsistence' area, the positive relations between extraction (in the 'Intense Extraction' area) and consumption of naturally occurring species is obvious. But the separation of the two areas demonstrates that whether or not respondents are actively engaged in several forms of extraction throughout the year, or are engaged in but a few forms, or whether they do not engage in many extractive activities at all (the elderly, the infirm, persons in women-headed households), subsistence foods constitute large portions of their diets and communitarian customs are frequently practiced.

In turning our attention to the radex on the lower level of the 'Traditional Subsistence' cylindrex in Figure 2, we see fitted together measures of household organization (**B, RHHSI; C, RHHTYPE**), feelings about social ties with persons in distant communities (**h, E12**), and participation in village affairs (**f, D22; d, D16**). It is also the case that persons in the larger, frequently non-nuclear households who have resided in the village for the longest periods think that there are more fish available in the present than five years earlier (**U, A26B**), whereas persons most actively engaged in subsistence fishing and other extractive activities, think that fish are less available in the present than five years earlier.

One surprising difference between pretest and posttest solutions for the *Native* subsamples, is that length of residence correlates positively with household size and with household type in the pretest, but negatively with household size and positively with household type in the posttest. Table 1 demonstrates that the *Native* posttest sample has significantly more non-nuclear households than does the *Native* pretest sample and either of the *Mixed* subsamples. The households are also much larger than either of the *Mixed* subsamples, but smaller than the

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[2]A *Cylindrex* in "multidimensional similarity structure analysis" is a structure determined through non-metric, multidimensional structure analysis that looks like a roll of towels standing upright. Cylindrexes have three organizing characteristics: "(a) a polarizing facet that establishes in which direction a point lies from an origin; (b) a **modulating** facet that corresponds to the distance of the point from the origin; and (c) an **axis** along which these radexes are stacked" (see Ingwer Borg and James Lingoes *Multidimensional Similarity Structure Analysis*, 1987, New York: Springer-Verlag, p. 101). A *Radex* has a **center** which is central in terms of content (but not some mathematical property), a facet which defines different directions in space (its **polarizing** feature); and a facet that organizes the points into regions with different distances from the center (its **modulating** feature). Radexes may occur on a single plane or, as in the cylindrex, radexes may be stacked on two or more planes.

pretest *Native* sample. There are, then, more small, non-nuclear households among long-term residents whose incomes are low (the correlation between length of residence and income is also negative) in the posttest than in the pretest *Native* sample. Composite, stem, joint, remnant, and other non-nuclear households are indicators of changing household organizations and pooling of resources in response to economic exigencies. Thus, it appears that between the pretest and posttest, declining income influenced single persons living alone, conjugal pairs, and nuclear families to relocate, while causing the formation of several non-nuclear households. Nevertheless, average household size decreased from about 3.1 persons to 2.9.

The 'Traditional Subsistence' area in Figure 3 demonstrates that older persons, and persons in large and composite households have low incomes and are less actively engaged in subsistence extraction than younger persons, but are not less actively engaged in the consumption of naturally-occurring resources.

The loose simplex[3] in the left-center of Figure 2, labeled 'Recipients,' represents some special characteristics of the older native population. It comprises the receipt of food in the past two days harvested by others (**X, A31**, this item is pulled toward **Q, CREL2**, the variable measuring relatives with whom **R** hunts sea mammals), length of residence in the village (**g, D25**), and the attitude that the amount of game available has increased during the past five years (**T, A26A**). That attitude, of course, correlates with persons who hunt land mammals, but do not engage in many other subsistence activities, and also correlates with native persons — elders and the like — who receive products from the chase, but do not engage in the chase.

MIXED PRETEST AND POSTTEST COMPARISONS

The configuration for the *Mixed* posttest sample (Figure 4) reveals a few marked differences from the configuration for the pretest *Mixed* sample (Figure 3) and some interesting similarities with the configuration for the posttest *Native* configuration (Figure 2). Most obvious in the comparison of pretest with posttest respondents in *Mixed* villages is that the posttest has a definite HIGH INCOME region, whereas the 'high income' variables in the pretest are fitted as outliers to a single, large cylindrex. The cylindrex in the pretest is, to be sure, influenced by income as a modulating facet, pushing high income-related items to the right of the center, and low income-related items to the left. The posttest configuration (Figure 4) produces a HIGH INCOME region in which are fitted income (**b, D2**), satisfaction with that income (**l, E29**), voting in the most recent city council election (**e, D19**), frequently attending public meetings (**d, D16**), and the cognitive attitude that game are more plentiful in the present than five years earlier (**T, A26A**).

A greater proportion of high-earners in the posttest sample are employed in the public sector than is the case for the pretest sample. In addition, high earners in the posttest sample have resided longer in the villages in which they were interviewed, on average, than the higher earners in the pretest sample. Public sector employees are more often year-round residents of villages, more often participate in village affairs than do private sector employees, and are well represented among higher income earners in the posttest sample.

Table 1 supports the inference that private sector jobs were eliminated more quickly than public sector jobs in the late 1980s. It is the case that high earners in *Mixed* villages tend to have

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[3]A *Simplex* is "a chain of elements in which the **closeness** of the elements decreases monotonically as we move from any element towards either of the ends of the chain" (Borg and Lingoes, 1987, p. 91). Simplexes take several geometric forms, but they must lie on a curve that does not bend back on itself. In widely recognizable terms, a simplex is a simple, single dimensional Guttman Scale.

VARIABLE		D1	D2	D3	VARIABLE		D1	D2	D3
PPEMP	A	-.02	1.47	-.08	A26A	P	.46	.86	-.45
RHHSI	B	-.15	-.92	.15	A26B	Q	.32	1.09	-.77
RHHTYPE	C	-.80	-.60	-.69	A28	R	-.67	-.51	-.03
CACT1	D	.99	.05	.54	A30	S	-.69	-.86	.12
CACT2	E	-.29	-.41	.65	A31	T	-1.31	.86	.01
CACT4	F	-.40	.32	.75	A32	U	-.66	.09	-.19
CACT5	G	-.38	.25	.96	A38	V	-.88	.02	-.01
CMN1	H	.58	.28	.66	D2	W	1.23	-.28	-.04
CMN2	I	-.08	-.41	.60	D13	X	.91	.08	-.71
CMN4	J	.39	.56	.56	D16	Y	.66	-.48	-.30
CMN5	K	.00	.34	.63	D19	Z	.25	-.92	-.67
RDAY1	L	.62	-.24	.18	D22	a	-.45	-.19	.24
RDAY2	M	.40	-.57	.12	D25	b	-.33	-.55	-.45
RDAY4	N	.38	.12	.25	E12	c	-.70	.50	-.92
RDAY5	O	.44	-.17	.21	E29	d	.19	.01	-1.15

Guttman-Lingoes' Coefficient of Alienation K = .214

TRADITIONAL EXTRACTORS

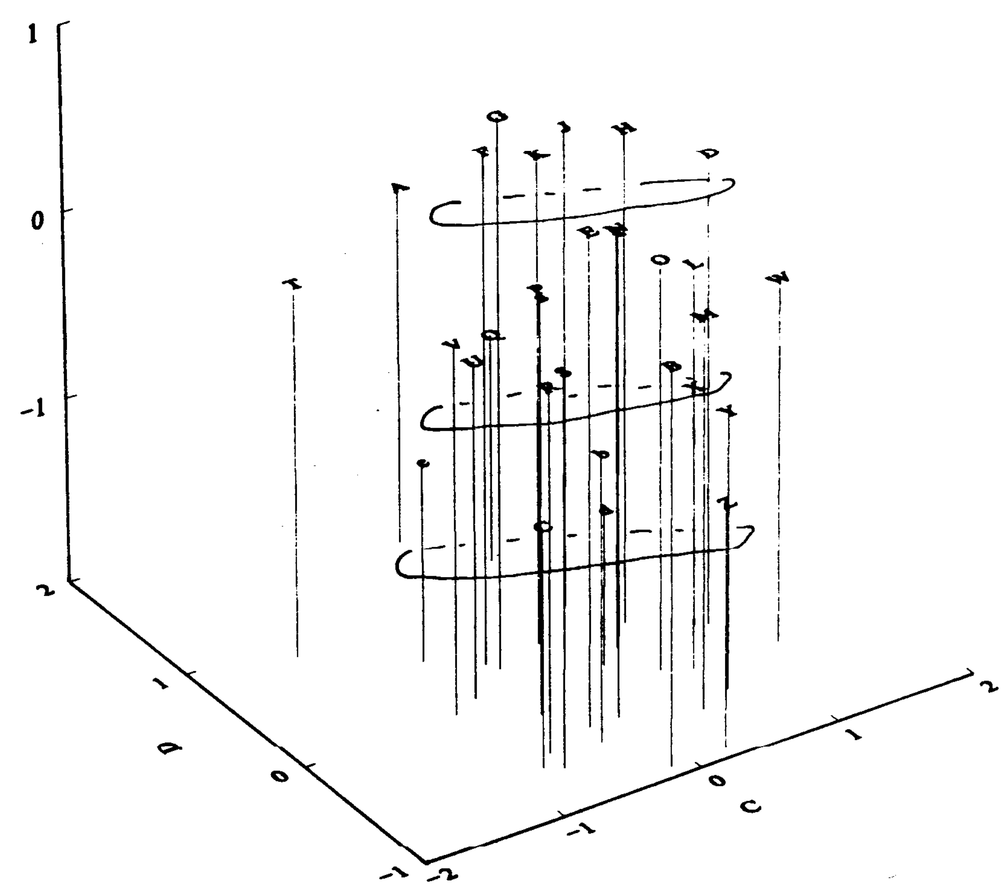

Figure 3. Structure of AOSIS traditional customs, Guttman-Lingoes' MDS configuration (3-D), 30 variables, N=265, mixed subsample of Pretest sample, 1987-1988.

VARIABLE		D1	D2	D3
PPEMP	A	.13	-1.08	.80
RHHSI	B	.47	-.19	-.78
RHHTYPE	C	1.03	-.48	-.51
CACT1	D	-.85	.46	.21
CACT2	E	.29	.86	.18
CACT4	F	-.28	.52	.08
CACT5	G	-.58	.63	-.34
CMN1	H	-.85	.68	.23
CMN2	I	.18	.64	.27
CMN4	J	-.19	.59	.04
CMN5	K	-.32	.72	-.30
RDAY1	L	-.44	.61	.29
RDAY2	M	.42	.73	.18
RDAY4	N	.00	.63	-.02
RDAY5	O	-.18	.71	-.42
CREL1	P	-.39	-.35	.97
CREL2	Q	-.63	-.58	.90
CREL4	R	-.48	-.38	.92
CREL5	S	-.79	-.29	.89

VARIABLE		D1	D2	D3
A26A	T	-.70	-.51	-.28
A26B	U	.09	-.87	-.88
A28	V	.75	.22	.02
A30	W	.81	.10	-.32
A31	X	1.13	-.96	.31
A32	Y	1.07	.35	.04
A33	Z	.57	-.12	-.13
A36	a	1.03	.00	-.12
D2	b	-1.03	-.59	-.88
D13	c	.26	.39	.96
D16	d	-.88	-.38	-.77
D19	e	-.49	.01	-.98
D22	f	.36	.41	-.81
D25	g	.59	-.22	.67
E12	h	.10	-1.18	.02
E29	i	-.62	-.96	-.55

Guttman-Lingoes' Coefficient of Alienation K = .171

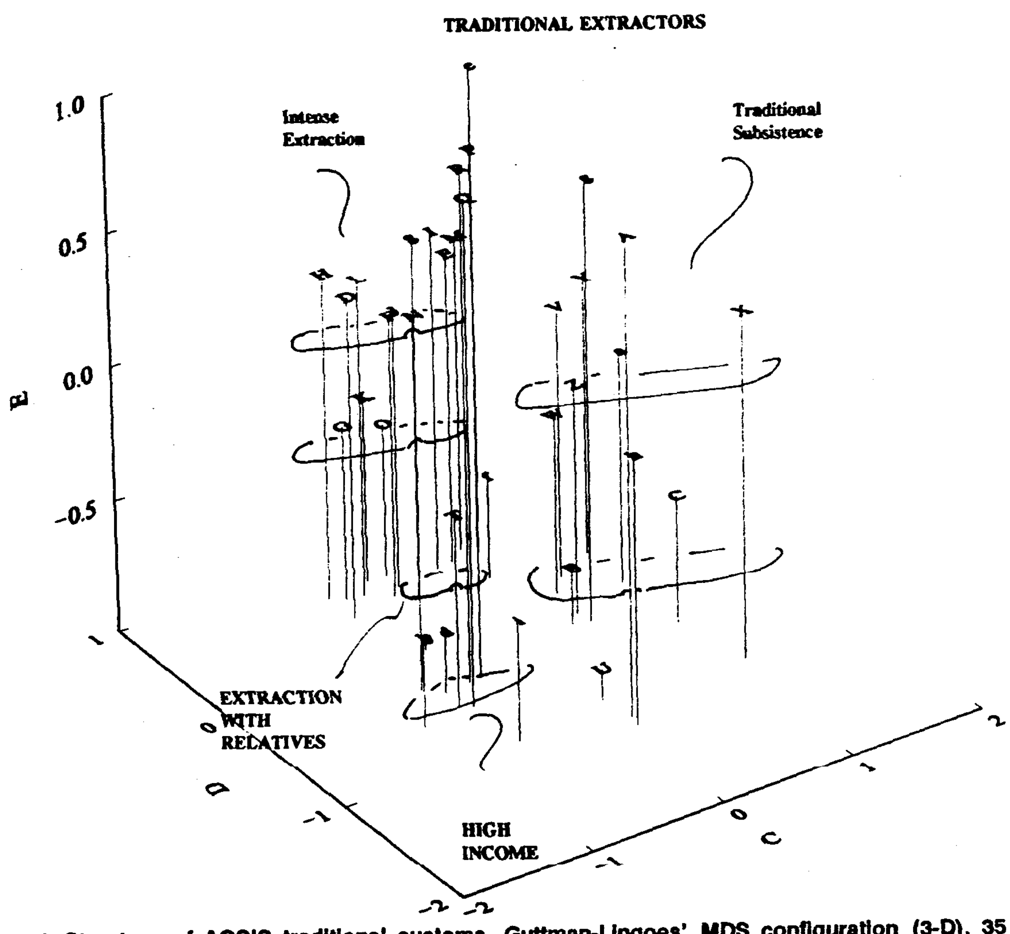

Figure 4. Structure of AOSIS traditional customs, Guttman-Lingoes' MDS configuration (3-D), 35 variables, N=168, mixed subsample of Posttest sample, 1989-1990.

smaller, nuclear, single person, or conjugal pair households. The large households, particularly non-nuclear forms, more frequently correlate with respondents who are long term residents, speak their native language at home, vote in village corporation elections, and observe the most traditional customs in consuming and sharing resources. Nevertheless, as income increases, household size also increases, suggesting that high income natives, in particular, have large households. On the other hand, the best predictor of larger households is non-nuclear household types, especially composite households.

Indeed, it is the last mentioned traits which, for the most part, define the 'Traditional Subsistence' area of the TRADITIONAL SECTOR in the posttest *Mixed* solution. As in the pretest sample, the evidence suggests that although some natives were high income earners, many of those persons observed customs we have classified as "traditional." If overall rates of employment dropped between pretest and posttest waves as our two samples suggest, the drop may have prompted some persons to relocate. What seems most likely is that native households with higher incomes in *Mixed* villages increased their extractive activities including, perhaps, more concerted extraction of less preferred species,[4] while households of elderly natives, or households headed by women benefitted from extraction through sharing. This accounts for the separation of the two cylindrexes in the TRADITIONAL region, and for the appearance of a HIGH INCOME region that comprises traits which are known to be characteristic of long-term non-native residents.

This brings us to an assessment of the TRADITIONAL EXTRACTOR regions in the *Mixed* village solutions. The 'Intense Extraction' area in Figure 4 demonstrates a structure we have observed in almost every solution we have obtained for every sample and every theoretical contrast in our research, namely: if persons engage in hunting a wide variety of sea mammals, or extracting a wide variety of fish, or establishing and residing in camps away from their residences, then they are likely to engage in all of these activities, to do so during several months of the year, and to allocate many days to these tasks. In addition, if they engage in these tasks they also hunt many varieties of land mammals and do so frequently. In the pretest sample for *Mixed* villages (Figure 3), we note that some persons hunt many species of land mammals, but engage infrequently in the other tasks. We identify those persons as high earners. It is evident that a large proportion of the land mammal hunters are non-natives,but we also note that participation in fishing (all measures, particularly days allocated to fishing throughout the year) increase with income and that the variables measuring those activities are fitted into a simplex directly beneath the land mammal simplex. We aver that a greater proportion of non-natives participated in land mammal hunting *and* fishing in the posttest than the pretest. The greater participation in subsistence extraction suggests an economic exigency, but it can as well reflect a more stable and older population in the posttest than the pretest *Mixed* subsample.

Land mammal extraction (**D, CACT1; H, CMN1; L, RDAY1**) is fitted on the left periphery of the radex (whose center is the camping variables (**F, CACT4; J, CMN4; N, RDAY4**) and on whose right periphery is fitted the sea mammal extraction variables (**E, CACT2; I, CMN2; M, RDAY2**) (the fishing variables are fitted at the lower radex, close to the center). The significance of the cylindrex is that all of the variables measuring sea mammal hunting, fishing, and camping correlate highly and positively with the traditional subsistence variables (subsistence food in recent meals, meat and fish in the annual diet, eating meals with relatives, speaking native language at home). Among them, only sea mammal extraction correlates negatively with income

[4]See Table 1 re land mammals, sea mammals, camping, and fishing. Significantly greater proportions of posttest respondents than pretest respondents participated in land mammal hunting and fishing. The reverse is true for sea mammal hunting and for camping, suggesting that non-natives increased their hunting and fishing activities.

(fishing and camping correlations vary between .01 and .10 with income, but are positive). The sea mammal set correlates most highly with the variables in the 'Traditional Subsistence' area. The variables measuring land mammal hunting correlate negatively (or near zero) with those items in the traditional set, and positively with income.

Thus the fitting of items within the 'Intensive Extraction' area distinguishes practices that are more exclusively native from land mammal hunting in which non-natives and natives engage. The separation of the 'Traditional Subsistence' area from the 'Intensive Extraction' area identifies customs observed by natives, even if they cannot or do not extract large varieties of naturally-occurring species on a regular basis. Those who cannot or do not extract — because of constraints caused by employment, physical impairment, age, or financial embarrassment — are recipients of those resources from donors who extract them. For example, recently eating a meal at a relative's home (**Y, A32**) is the best predictor of whether a person has received food extracted by someone in another household for a meal eaten by R in her/his own home yesterday (**X, A31**).

The EXTRACTION WITH RELATIVES region is fitted between HIGH INCOME and 'Intensive Extraction.' If persons form task groups with relatives and friends, they tend to do so for many activities. If they do not create regular task groups for one activity, they tend not to do so for a second or third extractive activity. All of these variables correlate negatively with income.

THE PERSISTENCE OF TRADITIONAL CUSTOMS

The evidence that traditional customs continue to be practiced in large, complex, multi-ethnic villages (*Mixed*) as well as small, simple, more homogeneous ones (*Native*) is considerable. Furthermore, the predictive power of sea mammal extraction is obvious in every sample and subsample we have analyzed. Whether some traditional practices wane among natives during periods of high employment and wax during periods of economic distress is not determined, and the effects exercised by age, ethnicity, education, and income have not yet been addressed. Although not shown here, in our analyses of the panels embedded in our pretest-posttest design, we determined that few differences and fewer significant differences occurred between the waves of the panels and the initial samples with which they were compared. (Re-interview responses were tested for significance of differences with initial responses obtained during the same research wave: for example, re-interview responses from panel members in 1989 were tested against initial responses from posttest sample respondents in 1989).

In the complete analysis, we addressed two types of validity issues in regard to the persistence and change among traditional customs. In the first we asked whether the results could be generalized to our total sample over time. In the second we addressed specification error. (Because the posttest sample was drawn without replacement of the pretest sample, we had to eliminate the threat of the ecological fallacy.) There is not sufficient time to explicate the analysis of the three research waves among our combined panel. Suffice it to say that we determined no artifacts of reactivity, history, or regression in our samples, and that panel results, over time, are highly similar to the pretest-posttest results.

As our research design unfolded, it became evident that regardless of the power of the theoretical contrasts between *Mixed* and *Native*, and *Hub* and *Periphery* villages, ethnicity (native or non-native, age, education, income, and residence in either commercial fishing or noncommercial fishing villages were especially important factors which had to be controlled if we were to understand the persistence of traditional customs on the one hand, and the adoption of Western, or non-traditional customs, on the other.

ETHNIC/RACIAL DIFFERENCES AND INDICATORS OF TRADITIONAL CUSTOMS AND ACTIVITIES

Native: Non-Native Contrasts

The most powerful contrast in the traditional customs and activities is not between village types, such as *Native v. Mixed*, but between natives and non-natives. Knowledge that a person is not a native is the best indicator that he or she does not engage in subsistence extraction activities, that subsistence foods were not eaten in the previous two days; that subsistence foods constitute small proportions of the annual diet, that few meals are eaten with relatives in other households, and that ties with persons in other villages are satisfactory or less than satisfactory.

The power of race/ethnicity is further evinced when the respondent has a native spouse. In those cases, the best prediction, still, is that no meals were eaten in relatives' homes during the preceding two days. Nevertheless, mixed racial couples are twice as likely as non-native couples to have eaten meals in relatives' homes and twice as likely as non-native couples to have received subsistence foods from persons in other households. Indeed, the best predictor of the source of subsistence foods for some of the meals eaten in the previous two days by mixed couples is someone other than the respondent (12% from someone in R's household, 53% from someone in a different household).

Tables 2 and 3 summarize several significant differences between **native** and **non-native** persons. Table 2 compares **natives** and **non-natives** over a range of variables. It presents the entire pretest-posttest sample of persons interviewed once and only once (initial interviews, *N=856*) without stratifying by village type. Table 3, which focuses on income alone, compares *Mixed* and *Native* villages while controlling for **native** and **non-native** respondents.

Table 2. Univariate comparisons of incomes, household sizes and types, and several measures of traditional communitarian customs, native and non-native respondents for entire Pretest-Posttest sample, N=856, 1987-1990.*

	Income		Household Type				Household Size		Total Types of Subsistence Acts		Subsistence Food in Meals: Yesterday	Subsistence Food in Meals: Day Before Yesterday	Subsistence Food in Meals: Harvest Person Not Self	Meals with Relatives Past Two Days	Visits Friends/ Relatives Past Week (Days)	Visits (Trips) Out of Village Past Year
	$40K	$40K	Single	Conjugal	Nuclear	Non-nuclear	Mean	6+	0	3+	Yes	Yes	Yes	1+	3+	3+
Native (N=619)	80%	20%	12%	22%	38%	28%	3	28%	24%	57%	74%	70%	80% (of 72%)	58%	48%	41%
Non-Native (N=212)	39%	61%	20%	39%	26%	15%	2	7%	39%	36%	30%	34%	61% (of 32%)	14%	39%	23%

* All differences between native and non-native distributions are significant at ≤ .01.

Table 3. Gamma (γ) coefficients, educational attainment by months of annual employment, controlling for income and ethnicity, *Mixed/Native* contrast for entire Pretest-Posttest sample, N=856, 1987-1990.

	NATIVE INCOME						NON-NATIVE INCOME					
	< $10k	< $20k	< $30k	< $40k	< $50k	< $50k	< $10k	< $20k	< $30k	< $40k	< $50k	< $50k
MIXED	.56	58	.71	.25	.61	.38	.60	.53	.01	.34	-.19	-.05
NATIVE	.60	.44	.32	.42	32	.55	a	.25	b	-.25	c	.16

(a) No non-native respondent earned less than $20,000 annually.
(b) One non-native respondent earned $30,000 annually. That person had some post-graduate education.
(c) Two non-native respondents earning between $40,000 and $50,000 annually have high school educations.

The factors of age, duration of residence in the village, and participation in resource extraction activities, taken jointly, mitigate some of the generalizations above. The manner in which these factors coalesce to alter the generalizations about non-natives are not obvious. If non-natives are between the ages of 35 and 59, have lived in the village for more than ten years, engage in hunting several species of land mammals *and* fishing for several species of fish *and* establishing camps for several extraction activities each year, the likelihood is from 40% to 50%, depending on the activity, that the respondent has eaten at a relative's home, or received food from a person in a household other than the respondent's, or gained more than 50% of the meat and fish in the annual diet from naturally occurring resources. Controlling for the factors just mentioned, then, a small percentage (6%, or 5 of 87) of middle-aged non-native respondents have acquired some of the subsistence and sharing customs of natives.

Income is another important factor in non-native participation in traditional subsistence activities. Sixty-two percent of non-natives engage in at least one of the following activities — hunting several species of land mammals, or harvesting several species of fish, or camping. In general, as income increases beyond $20,000 annually, so does the proportion of persons who extract resources. As income increases beyond $40,000 the proportions of persons engaged in two or three activities increases. In no income category does the proportion of persons engaged in two or more activities exceed 41% of non-native respondents.

Interestingly, the proportions of persons who engage in all three activities are greatest among non-natives who earn less than $20,000 (28%) and next greatest among those who earn more than $50,000 (21%) annually. Incomes greater than $50,000 annually, controlling for age (35 to 39) and duration of residence in the village (over ten years) is the best predictor or non-native participation in subsistence activities,[5] including receiving resources from others in the past two days and eating in relatives' homes. The prediction of participation in all three activities (41%) increases from 36% to 47% if we control for residence in *Comm Fish:Noncomm Fish* villages and source of employment (public or private sectors). Long-term, high earning, public sector-employed residents of villages in which noncommercial fishing does not dominate the local economy are more likely than long-term, high earning, private sector employees and employers of commercial fishing villages to engage in two or more subsistence activities (47% to 36%).

Non-natives do not participate in traditional activities at rates comparable to natives, although many of the factors that increase participation are now known, to wit: mixed marriages (native and non-native), long-term residence in a village (more than ten years), middle-age (35-39), high income (over $50,000) and employment in the public sector. Even if we exercise all of the controls, the best prediction is that if a person is a non-native, he or she participates in one or less subsistence activity, eats few subsistence foods, does not eat at the home of relatives, and does not receive subsistence foods from others. The reasons for public sector differences from private sector appear obvious, although non-trivial.

Regardless of whether natives reside in small, homogeneous village with well-developed infrastructures, a variety of public services, and a relatively complex local economy of public and private sectors,[6] participation in the hunting of several sea mammal species and doing so for

[5]69% in at least one activity, 41% in at least two activities, 21% in at least three activities.

[6]The homogeneous:heterogeneous contrast analyzed in this chapter is *Native:Mixed*. The other homogeneous:heterogeneous contrast in the study is *Periphery:Hub*. The *Comm Fish:Noncomm Fish* does not qualify as a contrast between heterogeneous and homogeneous. Even though all *Comm Fish* villages are heterogeneous, some of the *Noncomm Fish* villages, such as Bethel, Nome, and Barrow are also large,

45 days or more per year are consistent indicators of many traditional activities and customs, including the frequent hunting of several species of land mammals, the extraction of several species of fish, the establishment of several camps throughout the year to procure these resources, and the maintenance of equipment which makes camping and extraction successful. Non-natives do not harvest sea mammals, in part because most sea mammals are protected by Federal law and in part because sea mammal commodity by-products, such as oil, skins, fur, and ivory, are the only interests of non-natives in sea mammals. The commodity value is the only reason for which sea mammals would be harvested by non-natives.[7]

Sea mammal hunting also is a good indicator that subsistence foods comprise more than 50% of all foods consumed in the annual diet and that they are therefore regularly eaten at home. They are also frequently eaten at the homes of relatives and friends within the village. Hunting sea mammals is also a powerful indicator that some of the subsistence resources eaten recently by the respondent have been contributed by persons within the respondent's household and some by persons in other households (sharing).

Natives who are actively engaged in sea mammal hunting are also apt to speak their native language at home most of the time, to visit friends frequently during the week, to vote in city council and village corporation elections, and to feel that their social ties with persons in other communities are satisfactory.

Hunting a wide variety of sea mammals and land mammals on a frequent basis, fishing regularly for several species of fish, and relocating to camps away from the village on a regular basis are not necessary to predict with considerable accuracy that persons gain a large percentage of their diets from naturally occurring resources, frequently dine and snack with relatives in their relatives' homes, visit friends and relatives frequently, speak native languages at home most of the time, attend public meetings often, and exercise the political franchise during city and village corporation elections. If you know a person is a native, unemployed, unemployable or retired and earning less than $17,000 (household income) per year (in 1989-90 dollars) you will be correct more than 75% of the time, whether or not the person participates in subsistence extraction activities, predicting that the person practices all of the above.

There are definite differences between high and low income earners among natives. If the native is a high earner, the household is likely to be nuclear and larger than four persons. Households of low earners are likely to be any of several kinds of non-nuclear households (denuded, fragments, single-parent, composite, stem). The low earners are more apt to be receivers of resources (food, meals) than extractors and donors, particularly if the respondent is elderly or if it is a female-headed household. Respondents in high earner households, unless they are very elderly, are much more apt to engage in several subsistence activities, and much more apt to be donors of resources than are low earners. Thus, income and age influence native participation in subsistence extraction activities, but consumption and sharing of naturally occurring resources occurs among almost all natives.

There are differences between natives in large, heterogeneous villages and those in small, homogeneous ones. Age, sex, income, and length of residence influence native participation in various traditional customs in the large, heterogeneous villages. In general, natives in the largest

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complex, and heterogeneous.

[7]It is likely that commercial set-net fishermen kill seals and sea lions found eating fish trapped in the nets. It is not known how many seals may be killed annually by non-native and native fishermen in these situations.

villages are better educated, employed for more months of the year, and earn greater incomes than their counterparts in the small villages. They are less apt to have had subsistence food as parts of their meals the preceding two days, less apt to gain 75% of their sustenance from naturally occurring resources, less apt to dine and snack regularly with relatives, less apt to have received subsistence food from persons in households other than their own, and less apt to speak their native language at home most of the time than is the case for their congeners in the small, homogeneous villages.

Statements to the contrary notwithstanding, the best prediction for traditional custom cited above is that each one is engaged in by natives residing in *Mixed* (and *Hub* and *Comm Fish*) villages. Furthermore, natives in large villages are as likely to have attended public meetings, voted in village corporation and city elections, and visited with friends and relatives in the past week as are natives in small villages.

The differences between **natives** and **non-natives** in the large *Mixed* villages is much greater than the differences between natives in *Mixed* and *Native* villages, or between natives in *Comm Fish* and *Noncomm Fish* villages. Finally, as income increases, natives in complex villages increase their participation in subsistence extraction activities and the consumption and sharing activities that accompany them.

CHANGE AS INFERRED FROM PRETEST-POSTTEST COMPARISONS AND COMPARISONS OF WAVES OF THE PANEL

The posttest demonstrates a definite economic downturn from the pretest that is confirmed by the first and third waves of the panel. In the total panel, as well as in the *Mixed* and *Native* panel contrasts, there is an increase in the percentage of unemployed, unemployable and retired persons in the posttest and third wave responses. The similarities with the pretest/posttest results hold, even though the panel has (undoubtedly) selected for respondents with stable employment over the past four years. There is a drop in private sector employment and a decrease in long-term residence in both sets of comparisons, suggesting economically induced migration.

It is suggested that during a short period — two to three years in this instance — public sector employment is more stable than private sector. In Alaskan villages following the first research wave, the public sector provided a greater proportion of employment and accounted for higher average incomes than the private sector.

The evidence is not solid, but it appears that declining income influenced single persons (living alone), conjugal pairs, and nuclear families among non-natives and natives to relocate following the pretest, while also causing formation of several non-nuclear households among natives.

A cluster of strongly related traits occur in *Mixed* villages in the posttest, but not the pretest, including high income, satisfaction with income, the attitude that game are more plentiful now than five years earlier, voting in city council elections, and frequent attendance at public meetings. This change appears to reflect the shift to dominance of high earners in the public sector over high earners in the private sector in the posttest sample. We surmise that more public than private sector earners participate in village affairs and also reside in villages year around.

In *Mixed* villages as well, native households with high incomes increased their extraction rates (activities and days given to them), and elders benefitted from the sharing of resources most likely harvested by these high earners. These are probably indicators of the activation of native ethics in response to economic exigencies. Earning more to harvest more so as to give it away is not a Western, Protestant ethic practice. The increase in participation in extraction activities and income was sufficient to separate the several 'traditional subsistence' variables from the variables comprising 'intense extraction' in configurations for the third wave of the panel (not shown), and for the *Mixed* and *Native* subsamples (Figures 2-4 are provided) of the posttest.

A greater proportion of non-natives participated in land mammal and fish extraction in the posttest than the pretest. This change may be a function of the loss of single persons and conjugal pairs as the private sector continued to plunge on the one hand, and the persistence of families employed in the public sector on the other. The larger, higher earning non-native households whose respondents are employed in the public sector, and households with mixed non-native-native marriages, were the most active extractors of naturally occurring resources among non-natives in the posttest.

HOPE BASIN SUBSISTENCE OVERVIEW

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A consideration of subsistence was one of the chapters of the Hope Basin Socioeconomic Baseline study (Kevin Waring Associates 1992). The study focused on Kotzebue Sound comprising essentially the NANA Region of the Northwest Arctic Borough.

Burch (1980) has cautioned against a static view of human ecological adjustment in northwest Alaska:

> "Most of us think in terms of a 'traditional' or a 'contact' or an 'aboriginal' state of affairs as having been somehow immutable until massive European interference suddenly changed everything. This is a tendency we must resist. Life seems always to have been in a state of flux in Northwest Alaska, particularly at the individual society level."

A basic source of variability in subsistence practice is the uneven geographic distribution of subsistence resources. Many variables affect the location, timing and concentration of subsistence resources. Periodic (short-term) regional and local surpluses and shortages must be allowed for in a subsistence stratagem. Failure in the harvest of one or more resources can occur and may be anticipated and compensated for by shifting emphasis to alternate, perhaps less desirable, resources. Another compensating mechanism is exchange. For example, based on the geographically widespread occurrence of obsidian (a volcanic glass used in the manufacture of sharp-edged tools) in archaeological sites, trade networks may be inferred to have been in place for over 8,000 years in northwest Alaska.

Dunbar (1968) suggested that arctic ecosystems are less mature than temperate or tropical ecosystems and are characterized by high environmental oscillations in long-term cycles and few species with large populations. Minc (1986), using tree-ring data to graph temperature and moisture regimes in northwest Alaska, identified long-term climatic cycles of warmer, drier conditions followed by colder and wetter conditions. She hypothesizes that these fluctuations prompt shifts between coastal and interior subsistence orientations. Pielou (1991, Figure 1) provides a useful backdrop for considerations of subsistence and graphs climatic variations during the last 20,000 years, (a data set more familiar to geologists, palynologists and archaeologists than to subsistence researchers). Pielou's figure helps illustrate the cyclic (long-term) fluctuations of resources. Cyclic variations in the earth's orbit have affected the amount of solar radiation reaching the earth and were a major, if not primary, factor in controlling the climate. Pielou's speculative reconstruction of actual temperature variation (solid line) shows comparatively warm intervals alternating with comparatively cold intervals, this alteration caused by cyclical variations in the sun's output. The warm hypsithermal interval, occurring roughly between 8,500 and 5,000 years ago, was the culmination of a rapid warming period that ended the last, or Wisconsin, glaciation. We are now in a neo-glacial period but the cooling trend has not been continuous. The timing of the Little Climatic Optimum differs somewhat from place to place but peaked at roughly 200 A.D. Following the Little Climatic Optimum, a cooling trend culminated in the Little Ice Age of 1350 to 1870 A.D. We are currently in a warming trend. Climatic oscillations are reflected in floral and faunal communities and human subsistence stratagems must respond accordingly. Two brief examples will show the kinds of change provided by a historical view of environmental change and subsistence resource availability.

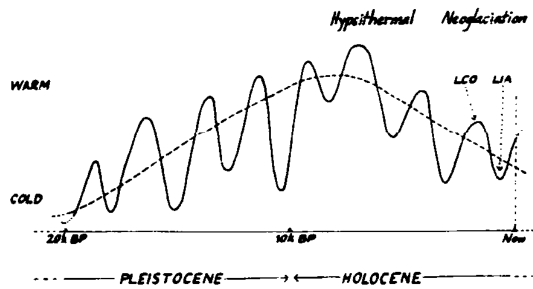

Figure 1. Climatic variations during the last 20,000 years. The dashed curve shows how solar radiation reaching the earth at 65°N latitude varied because of cyclical variations in the earth's orbit (the Milankovitch cycle). The solid line is a speculative reconstruction of actual temperature variation. LCO = Little Climatic Optimum; LIA = Little Ice Age (Pielou 1991).

In the last 40 years spruce has greatly expanded its foothold on the Baldwin Peninsula (upon which Kotzebue is located) (Hopkins p.c.). However, two 'forest horizons' are evidenced by plant macro-fossils in lacustrine sediments on the peninsula; the younger horizon "contains wood of spruce, birch, poplar, and alder that is commonly beaver-gnawed, has a radiocarbon age of 10-8.3 ka (10,000 to 8,300 years ago) and is assigned to the early Holocene" (Hamilton and Brigham-Grette 1991). As recently as 9,000 years ago, then, the Baldwin Peninsula presented a very different environment to subsistence foragers.

Such environmental changes do not necessarily require millennia. Residents of Noatak village attest to the very recent appearance of moose and beaver in the Noatak valley. However, at the site of Kangiguksuk, just downstream of the Noatak Canyon, the faunal elements associated with a solitary winter house excavated by Hall include the remains of one adult moose and three beaver (Hall 1971). Tree-ring dating indicates that the Kangiguksuk house was constructed sometime around A.D. 1578. Hall's reconstruction suggests the site was occupied just under four years and that sometime after the site was abandoned, probably due to environmental conditions, moose and beaver were so unavailable in the Noatak valley as to appear as recent migrants to residents and biologists today. The Kangiguksuk data suggest a long cycle of variation of subsistence resources, a cycle whose period (interval between successive events) is longer than the time depth of personal experience and far beyond written biological records. Oral traditions, especially, and archaeology possibly may eventually provide important information for resources whose oscillation period is longer than the lifetime of the informants.

Subsistence users are very cognizant of the fluctuations in resource availability: "Those subsistence people who were and are on the scene have just as dramatically adapted their use, methods, and means of taking and preserving methods as...animals have risen in importance or faded to insignificance" (Uhl and Uhl 1977).

The subsistence chapter in the Hope Basin Socioeconomic Baseline Study was limited to existing sources; no new field data could be elicited. In this study subsistence users in northwest Alaska were viewed as modern exemplars of the thousand-year-old Arctic Woodland subsistence pattern. Organization of the data was developed on the premise that newer sociocultural adaptations or adjustments are founded in preexisting sociocultural states and thus are amenable to historical analysis. Contemporary subsistence was viewed as the culmination of cultural and historical developments which were divided into six periods: the prehistoric period known from archaeological sources only; the traditional period known primarily through ethnographic reconstruction and ending in mid-nineteenth century; the transitional period initiated by protracted contacts with Euroamericans and further subdivided into early (1850), intermediate (1890-1940s) and recent (1940s-1970) transitional periods; and the post-ANCSA period.

Using the available literature, each period was characterized in terms of resource supply, social organization, settlement and population, economic processes, and social integration. The flexibility and adaptability of the subsistence food procurement system in the face of chronic fluctuations of resource availability was emphasized.

For this discussion, I shall only touch upon the social and economic arrangements for averaging out harvest failures over geographic areas for two of these periods: the traditional and the post-ANCSA.

TRADITIONAL PERIOD

Traditional nineteenth century societies in northwest Alaska occupied well-defined territories and these societies practiced distinct seasonal cycles and spoke a subdialect of Inupiaq. These societies were approximately 80 percent endogamous. Thirty-three kinship roles were named during the Traditional period. The Traditional societies were segmental. The basic unit was the domestic or nuclear family though the operative unit politically and economically was the 'local family' (Burch 1975). The local family was a lineal (related by direct descent), collaterally (related by non-lineal descent, as cousins) and affinally (related by marriage) extended family. This prototypical local family was composed of thirty individuals belonging to four domestic units (Figure 2). Unit 1 is comprised of siblings of both sexes, spouses and offspring. Unit 3 is comprised of male siblings, spouses and offspring, and is affinally linked to Unit 1. Unit 2 is comprised of male siblings and a female cousin, with spouses and offspring, and is collaterally linked to Unit 3 and affinally to Unit 1. Unit 4 is an extended family that is lineally linked to Unit 2, collaterally related to Unit 3, and affinally related to Unit 1. Each local family was linked to numerous other such families by both consanguineal and affinal ties. During the Traditional period, each society comprised a network in which the nodes were local (extended) families, and the lines between the families were less active or temporarily inactive kinship ties of various kinds. The societies were linked by bonds (of intermarriage, co-marriage and partnerships) which over time extended to their domestic families. Such a system provides a safety-valve, allowing for the radical reconstitution of face-to-face groups at multiple levels in case of social or ecological crises. When resource surpluses or shortages occur, the constituent domestic families would move and activate kin relations in another local family elsewhere within the societal territory or even in the territory of another society (Burch 1980). Demographic trends (population reduction and dislocation) stemming from Western contacts and the decline of the Western Arctic Caribou herd between 1850 and 1860 contributed to the disintegration of the societies of the Traditional period.

POST-ANCSA PERIOD

One of the most striking features of the social organization of the Northwest Arctic Borough, or NANA region today is the all-pervasive orientation to kinship. Ironically, the geographic extent of today's kin relations stems from the dislocations that caused the demise of the Traditional societies. Far-flung kinship relations are still cultivated, indicating their enduring relevance to modern social interaction. "Formal kinship remains a central organizational principle that shapes customary patterns of mutual aid and subjective sentiments. Kinship principles are still used to discover, create, or allege social ties that, if present, justify affiliations between people." (McNabb

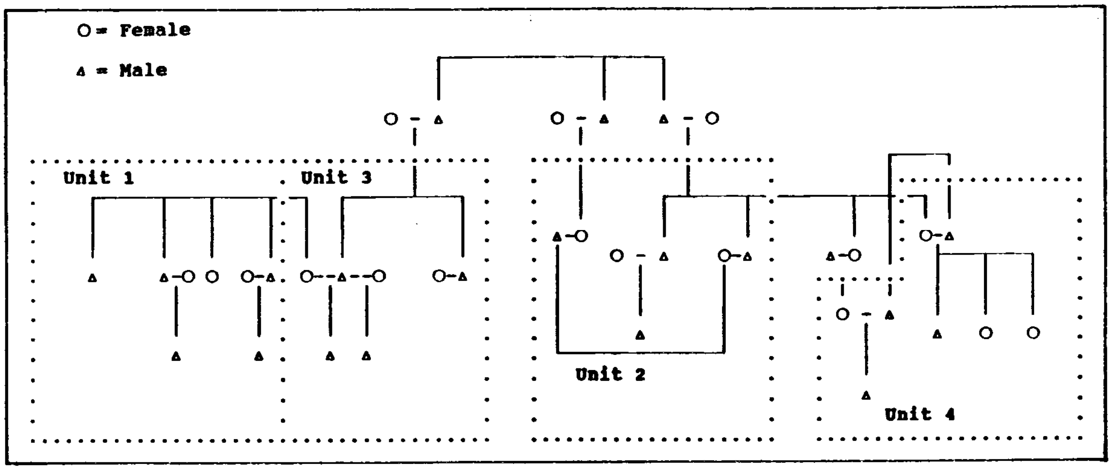

Figure 2. Diagram of Nuatarmiut local family with residential units, ca. 1885.

1990). The physical occupation of Native allotments reflects, though palely, the local families of the Traditional period. Partnerships defined and named traditionally also occur but remain unstudied and are supplemented by a proliferation of Western sodalities such as Church groups, Lions, etc.

Although the villages now are permanent, social ties to other villages and distant subsistence resource catchments are still important. Related domestic families, linked economically and socially, are scattered throughout the settlements of the region and beyond. Anderson and Anderson (1977) report that

> "The relatively high number of marriages between Selawik and [sea] mammal hunting coastal residents is socially and economically important. Socially they create kinship bonds and opportunities for closer interaction which can lead to further marriage alliances. Economically, they provide the families involved better opportunities to acquire coastal products. Such marriages also provide social networks in the coastal villages to facilitate moves to the coast, should they desire. Likewise, the marriages between Selawik and Kobuk River residents afford the families in each area the possibilities to exchange products not found in the other area."

Numerous anecdotes in the literature describe the movement of subsistence goods along far-flung social networks. Mail, modern travel and communications have largely replaced the pattern of the Traditional period: physical relocation of domestic families to form alignments with new local families in new territory. Uhl and Uhl (1979) report that for Noatak in 1978 it is "Through the unique system of visiting and sharing at different seasons of the subsistence-oriented year, any one of several thousand people who have relatives, friends or casual acquaintances among Noatak River resource harvesters may share in the fruits of the harvest."

Unfortunately, for the NANA Region and Northwest Arctic Borough, studies of the structure and operation of this system at the village or regional level or of the amounts and kinds of resources so distributed have not been completed. Measures of the economic and social importance of transactions involving locally produced foods and their significance in the overall economy of the region need to be developed if we hope to assess the impacts of modern activities on the long-established subsistence lifestyle of northwest Alaska.

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NORTH SLOPE SUBSISTENCE STUDY (WAINWRIGHT AND BARROW)

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with

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For the past 15 years, Stephen Braund has been principal of Stephen R. Braund & Associates, an anthropological consulting firm specializing in socioeconomic and subsistence research in Alaska and Japan.

This study had two objectives: First, to collect, analyze, and report generalizable subsistence harvest data by species for Barrow and Wainwright; and second, to provide accurate mapped harvest location information for these communities. The study was conducted for three years in Barrow and two years in Wainwright, and an annual report for each community was written at the end of each study year. This summary presents findings from Years One, Two and Three of the study in Barrow (April 1, 1987 through March 31, 1990), and Years One and Two of the study in Wainwright (April 1, 1988 through March 31, 1990).

The study team conducted periodic harvest discussions throughout all three years with 101 Barrow households (a disproportionate stratified probability sample) to obtain the date, location, and amount of each harvest by species. The data from this sample were weighted to represent the entire community (based on a 1985 population of 3,017 residents in 937 households). The data indicate that Barrow residents collectively harvested an average of approximately 702,660 pounds of usable resource product per year, equal to 750 pounds per household or 233 pounds per capita.

Overlapping with the last two years of study in Barrow, the study team collected identical subsistence harvest data for two years in Wainwright. Due to the relatively small population in Wainwright, participation of every household in the community was sought. Ultimately, 100 households participated in the study for the full two years. The data show that Wainwright residents collectively harvested an average of 304,047 pounds of usable resource product per year, averaging 2,624 pounds per household or 638 pounds per capita.

SUMMARY OF FINDINGS

Study findings are presented in the annual reports in several ways. The species harvested are organized by major resource category (e.g., marine mammals) and discussed both at that level and at the level of individual species. Monthly totals are presented by species in both pounds (of usable resource product) and number of animals harvested, along with pounds per household and per capita. Percentage of households participating in the harvest of each species and the percentage each species contributed to the total pounds harvested are included in the annual reports along with an analysis of harvests and household characteristics by harvester level. Dr. Sam Stoker provided an analysis of the harvest levels in terms of major species' population status and sustainable yield. Harvest locations were entered in a Geographic Information System and appear in the annual reports as maps showing where study participants harvested resources. The following information summarizes only a portion of the data generated from this study.

BARROW HARVEST AMOUNTS

Barrow residents harvested at least 52 species of mammals, fish, birds, and other resources during the three years of study. In terms of usable pounds harvested, bowhead whale and caribou contributed the most subsistence food to local households. Barrow landed seven whales in Year One, 11 whales in Year Two and 10 whales in Year Three, amounting to an estimated average of 265,196 usable pounds per year or 38% of the average yearly harvest. During the study, Barrow residents harvested an average of 1,595 caribou, or 186,575 usable pounds, constituting 27% of the total harvest.

Walrus was the third most important resource by weight during this study, with an average of 81 walrus yielding 63,285 usable pounds, 9% of the entire harvest. The fourth most heavily harvested species by weight during the study were whitefish (spp.) averaging 61,149 pounds or 8.7% of the overall Barrow harvest.

The above four species combined contributed an average of 83% by weight of the annual Barrow subsistence harvest during the study. The remaining 17% consisted of (in order of importance by weight): bearded seal, moose, ringed seal, geese (spp.), polar bear, eiders (spp.) and less than 1% each of Dall sheep, brown bear, porcupine, ground squirrel, and various other fish and bird species. Barrow residents also harvested wolverine, red fox, and arctic fox for their furs. (Because these species are not eaten, weights were not calculated for their harvests).

BARROW SEASONAL HARVEST PATTERNS

An average of 93% of the annual harvests by weight occurred during the seven month period from April to October. Bowhead whale harvests dominated the months of April, May and June. Whalers harvested occasional seals, birds, and polar bears from whaling camps while some families went inland to spring camps to harvest geese, caribou and some fish. May yielded the highest average harvest of spring bowheads by weight and the highest average annual bird harvests. Bowhead whale harvests declined and fish harvests increased after May. Typically, July was characterized by walrus and seal hunting, as weather and sea ice conditions were favorable for hunting by boat. (However, in Year Two, ice conditions were unfavorable in July and most walrus and bearded seal were harvested in August). July was also an important month for caribou harvests, as were August, September and October. Caribou was the main species harvested in August, supplemented by large harvests of walrus, bearded seal and fish. Walrus and bearded seal harvests subsided in September, while fall whaling provided the main September harvest in addition to caribou, fish and moose. October was the month in which the peak bowhead whale, caribou and fish harvests occurred as whalers hunted bowheads and families went to fall camps to stock up on caribou and fish. Consequently, October averaged out to be the peak harvest month for subsistence harvests overall. The remaining five months (November through March) were lean harvest months during which the most active hunters traveled onto the pack ice for seals and inland for caribou and furbearers.

BARROW HARVEST LOCATIONS

During the study, sample households traveled along the coast in either direction from Barrow, harvesting resources as far west as Peard Bay and as far east as the Colville River. Marine mammals were harvested over 25 miles offshore. Rivers provided summer travel routes inland, and harvest locations tended to be concentrated along the main waterways: the Inaru, Meade, Usuktuk, Topagoruk, Chipp, and Ikpikpuk rivers.

WAINWRIGHT HARVEST AMOUNTS

Wainwright residents also harvested at least 46 species of mammals, fish, birds, and other resources between April 1, 1988 and March 31, 1990. Marine mammal harvests dominated the Wainwright harvest, providing 70% of the usable pounds harvested, followed by terrestrial mammals (24%). Fish and birds provided only 4% and 2% (respectively) to the overall harvest.

As in Barrow, bowhead whale contributed the most usable pounds (105,274 pounds per year averaged over the two years). Wainwright landed four bowheads in Year One and two in Year Two. Bowhead whales produced 35% of the total subsistence harvest, while walrus contributed 27% (81,708 pounds) and caribou contributed 23% (71,141 pounds) of the total harvest. With bearded seal (5%), these four species combined yielded 90% of the total harvest. The remaining 10% consisted of (in order of importance by weight): least cisco, polar bear, rainbow smelt, ringed seals, and less than 1% each of arctic grayling, brant, beluga whale, spotted seal, moose, brown bear, ground squirrel and various bird and fish species. Berries, coal and ice were also collected by Wainwright residents, and fox, ermine, wolf and wolverine were harvested for their furs.

WAINWRIGHT SEASONAL HARVEST PATTERNS

Eighty-seven percent of the year's harvests by weight occurred in the six month period from April through September. In contrast to Barrow, Wainwright whalers landed bowheads only in the spring: April and May, with May being the peak month for bowhead harvests and for subsistence harvests overall. Whalers also harvested seals and geese from their camps on the ice during April, May and June. Families traveled inland in May and June to hunt geese, ptarmigan and a few caribou from their spring camps. Walrus and bearded seal were harvested June through September, though predominantly in July. The most intensive caribou hunting occurred from July through October when 76% of the year's caribou were taken. Ringed and spotted seal harvests occurred throughout the year, peaking in the summer months (June and July). Most of the fish were harvested in August, September and October. Harvests during the quiet months from November through March included caribou, polar bears, a few ringed seals, fish caught under the ice, and furbearers (sought in deep winter when their coats are thickest).

WAINWRIGHT HARVEST LOCATIONS

Marine mammal harvests were concentrated within a 15 mile radius offshore from Wainwright, with additional harvests extending northeast to Peard Bay and southwest to Icy Cape. Terrestrial mammal harvests were widespread, occurring along the coast southwest to Cape Sabine and northeast almost to Barrow, as well as inland to the Brooks Range. Fish harvests occurred principally along the Kuk River system which extends far inland from Wainwright, while bird harvest areas were split between this river system and the coastal areas near Wainwright.

CONCLUSION

This study is one of the most comprehensive, long term subsistence harvest studies conducted in Alaska and provides valuable baseline data, both numeric and mapped, for assessment of development impacts and for other future studies. Reports from this study can be obtained from the U.S. Department of Interior, Minerals Management Service, Alaska Outer Continental Shelf Region, 949 E. 36th, Anchorage, AK 99508.

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QUESTIONS AND DISCUSSION

CALEB PUNGOWIYI: This is actually something my wife brought out, and that is on the percentage of harvest, on numbers of marine mammals, perhaps there should be some clarification that this is percentage of weight by utilization rather than-- it makes it look like on the marine mammals that bowheads are 69 percent of the harvest when it's by weight, not by numbers of -- Okay?

STEPHEN BRAUND: Which table?

CALEB PUNGOWIYI: Figure ten.

STEPHEN BRAUND: By weight, yes. Okay.

TOM NEWBURY: I'd like to ask Joe Jorgensen about something. I had the impression from your graphs that if somebody moves from a subsistence lifestyle to a cash economy, and then loses their job, that they don't move back to a subsistence lifestyle. But at the end, you said, if they're non-native, they move out. If they're native, they do tend to move back to a subsistence lifestyle, or they move back, I guess, to an extended home.

Well, at any rate, I wanted you to clarify that. If somebody who has moved from a subsistence lifestyle to a cash economy, a job, and then loses that job, what do they shift back to?

JOSEPH JORGENSEN: One of the striking things about the research among natives is that so few in our sample moved away from the harvesting of wild resources whether they lived in Kotzebue but were from Noatak originally, or whether they lived in Unalakleet but came, say, from Shishmaref. That they had defined places to hunt and to gather resources if they were gainfully employed full-time and they did so.

We have very few natives who did not engage in resource extraction. It works this way: that the more a person made, the more likely that they contributed more to subsistence harvest. Not necessarily their own harvest, but perhaps to the harvest of their kinspersons and family. It's quite evident that in our sample, persons would regulate their vacation time with visiting relatives in villages from which they came and doing so in harvest season so that they could participate in harvest.

We have very little evidence that people gave it up completely. We have huge evidence that in the post-test as well as in our panels, after 1988, that persons harvested more resources than they had previously. So they went back from apparently preferred species to many species that they harvested.

So that makes it clearer to you? When persons are gainfully employed, they have less time to pursue subsistence resource harvests. When they do so, they usually go after preferred species. They contribute to the harvest in which their families engage, often putting out the grubstake for them. When they lose their jobs, people begin harvesting resources that they hadn't done perhaps five years or for two years or for ten years.

So that makes it clear. What you could see in that, if you could follow those three-dimensional solutions, in the posttest, in the mixed villages, the villages took the form again almost of the native villages. People who extracted lots of resources were grouped together, and those that engaged in traditional activities, and if you really extracted lots of resources and put a lot of effort into it, you're also giving much to people who could not do so.

But everybody increased their resource extraction by our measures in both the panels and in the mixed and native villages in 1989 and 1990 over what they had done in 1987 and 1988, in the mixed villages. The native villages kept right on doing what they'd been doing.

CHUCK DEGNAN: I'm really concerned about how these studies are going to be utilized and interpreted in the regulatory process to small communities and Alaskan natives. The definition from local natives will be completely different than the definitions done by the studies. And you have to make sure that it's culturally relevant to local natives who live in the regions that you're studying.

It would be perhaps helpful if Minerals Management Service and maybe the State of Alaska and some local governments do a study on how governments impact and try to change the local people to conform to the dominant society's definition of how they should be gainfully employed. What is a job? The sense I get is that governments do not really want to hire local people to do things. So the local people that live in the villages have to employ themselves and therefore, their activities are not considered a job. But when you sift all these biases out, these people are working very hard to survive. And that needs to be the tie-in in making sure that the people's rights are protected from the local perspective.

PANEL DISCUSSION

Social and Economic Studies in the Northern and Northwest Arctic: Assessing Methodological Approaches, Strengths in the Knowledge Base, and Information Needs

Thursday, January 21, 1993

PANEL DISCUSSION

Social and Economic Studies in the Northern and Northwest Arctic: Assessing Methodological Approaches, Strengths in the Knowledge Base, and Information Needs

Moderator: Tracy Andrews, MMS

Panel Members:
Robert Harcharek, North Slope Borough
Kurt Jacobsen, North Slope Borough
Walter Russell, Northwest Arctic Borough
David Case, Northwest Arctic Borough
Joseph Ballot, Northwest Arctic Borough
Sverre Pedersen, Alaska Department of Fish and Game
Larry Merculieff, City of St. Paul
Steve Colt, Institute for Social and Economic Research
Don Callaway, National Park Service

Introduction — Tracy Andrews, Moderator

I would like to provide a brief description of how and why this session was developed, as well as to remind everyone of how the presentations and discussion will be organized.

The participants are seated from your left to right generally in the order that they are listed on your program. Also, because of prior commitments, Don Callaway, the final presenter on this panel, will arrive towards the middle of the session. Hence, the empty seat at the end of the table. Generally, each participant will give about a 15 minute presentation. In order to assure that everyone has their full opportunity to speak, it is my responsibility to actively remind the participants when their talks need to end.

If there are any critical questions about individual presentations that are required to clarify information, we'll take these immediately. But 30 to 45 minutes has been set aside after all the panel members have had the opportunity to speak, specifically for discussion among the presenters and for questions from the audience. At that time, the microphones here at the front and on the floor will be operative. And I will ask for comments and questions.

As to the reason this panel was organized, we had three general questions in mind as a list of possible participants was developed. First, from both the local and regional perspective, what are information needs and priorities for future research related to social, cultural, and economic issues? Second, what kinds of studies are necessary to obtain this information? For example, are more general, subsistence surveys needed, and what are the benefits of this approach? And what kinds of critically important information is being missed? For example, how can the knowledge of long-time local residents be better documented and integrated into social, cultural, and economic studies? Finally, how can cooperation and coordination among local communities and regional governments and state and Federal programs be improved in order to obtain the best quality of information possible?

This final question encompasses several critical issues. The first of which is what Federal programs call "burden hours" placed on individuals and communities that are the focus of research efforts. Overlapping research efforts may not only burden the participants, but may also result in a duplication of some information while other critical issues are overlooked.

Finally, in a time of scarce economic resources, the priorities for scarce research funds is a constant issue. One of the panel members aptly observed that Alaska's very size often is an impediment to communication among the people and programs concerned about and responsible for conducting social and economic studies in this State.

To summarize the goal of this session, it is to provide the opportunity for communication of information and knowledge among some key individuals, institutions, and programs. We realize that many other organizations besides those participating in today's panel are involved in and concerned about social and economic studies in the Arctic, and I regret not being able to include all of them. But perhaps a similar panel can be convened again at next year's Information Transfer Meeting and others will have the opportunity to give presentations.

Again, there will be an open discussion session after all the panelists have presented, and at this time general comments and questions are encouraged. This session is not designed as a forum for critiquing specific studies sponsored by the Minerals Management Service or any other individual or program, because there are many other opportunities available for expressing such concerns.

And while research priorities, methods, and goals can sometimes seem a purely academic and esoteric concern, critically important policy and resource management decisions are based at least to some extent on information from social, cultural, and economic studies. It is the improvement of the basic social, cultural and economic knowledge base currently available for the Northern and Northwest Arctic that is the focus of this panel.

We have two speakers from the North Slope Borough today. In organizing the panel, I did not usually invite a specific individual or assign specific topics to be presented by the panel members. Generally, the focus of the panel was presented to a contact person and I asked that the program or organization itself decide who they wanted to represent them and, given a specified length of time to speak, to establish their priorities for the information they wanted to present. Topics relevant to each program or individual's background were suggested, and generally, these fit well with the participants' own priorities.

Dr. Bob Harcharek is presently the Economic Planner for the North Slope Borough. He has worked for many years with projects relating to social, cultural, and economic impacts of actual and potential development activities in the Arctic. He's going to present an overview of and recommendations concerning on-going and proposed social and economic research.

ROBERT HARCHAREK: Thank you, Tracy. I'll apologize at the beginning for my voice. If it gives out on me, I'm sorry, but I've come down with a bug of some sort and that sort of has curtailed it.

Over the past ten to fifteen years, there has been a wealth of social, cultural and economic studies focusing on the North Slope Borough and its residents, who are predominantly Inupiat Eskimo. These studies and research efforts have been funded by numerous state and Federal agencies. The studies themselves have usually been conducted by academic researchers and academic research centers, industry consultants, private professional research firms or combinations of the three. Individual researchers and academicians have utilized their research experiences and increased knowledge base gained from participating in these research efforts to produce professional publications which are insightful, thought-provoking and seminal (Jorgensen 1990; Kruse 1992).

These studies have usually focused on separate but interrelated topics relating to development activities and the residents of the North Slope Borough. Some were descriptive and historical compilations (Worl Associates 1978; Kruse, Baring-Gould, Gross and Knapp

1983; Alaska Consultants 1984). Others focused on socioeconomic and sociocultural descriptions (Knapp 1983; Alaska Consultants 1984; Kruse 1991); the North Slope Borough government [Morehouse & Leask] 1980; McBeath 1981); energy development and its impacts on the Inupiat (Kruse 1982; 1984); and employment (Knapp 1985). Still others focused on subsistence activities and harvests (Steve Braund and Associates 1990; 1991) and migration patterns of individuals and families to and within the North Slope (Marshall 1991).

All of these studies, including the early studies of the North Slope conducted in the late 1970s and early 1980s, are to be applauded for **potentially contributing** to increasing the body of retrievable and usable knowledge relating to the modern-day Inupiat; their cultural, subsistence and environmental indigenous knowledge; the land they live on; their unique but sophisticated government; as well as their social, educational and economic aspirations and problems.

Not withstanding how extensive these studies may be or how many of them have been done, there are still a number of ingredients missing for this body of knowledge to take on a unified quality. Almost all of these studies, when taken together, still only give you bits and pieces of information. Most have been conducted within the realm of only one discipline. Multi-disciplinary approaches focusing on the same concept or problem are basically non-existent. Only relatively recently, or so it seems, have the published research reports of the Minerals Management Service demonstrated that the researchers and the sponsoring agency have **actively incorporated** data and research techniques from previously conducted studies (Jorgensen 1992) or with a multi-disciplinary perspective and approach (Impact Assessment, Inc. 1988). The academic researcher, however, seems to incorporate previous studies, data and research techniques in publishing research findings, as a normal practice.

For the most part, I know of very few practitioners, researchers, policy makers or government bureaucrats who have attempted to read through these voluminous reports once they are published. In order to utilize the data or findings, one must wade through page after page seeking bits and pieces on information that can be utilized in decision making or planning processes. Usually the only time that the Inupiat have an opportunity to have any input whatsoever in the research process is after the research has been conducted and the report is written.

It seems as if many, if not most of these studies are contracted out to satisfy some legislative requirement, similar to the requirements to conduct "public hearings" before lease sales or development activities take place. As with the "public hearings," the same things are said over and over again, but it does not seem to make one bit of a difference. The Inupiat have become disenchanted and even disgusted with the process. They continuously provide input and are the subjects of countless studies, but they never see any positive results coming from this input or these studies.

A number of colleagues and I have identified some of the reasons for this. First, consultation with the Inupiat or the North Slope Borough prior to designing, contracting and conducting a research study rarely, if ever, happens. From our point of view, **research studies must be designed, planned and conducted in cooperation with the residents of the North Slope Borough communities.** This cooperation must not be "after the fact" or co-optive, but must have mechanisms in place for the active input and genuine participation of the residents in the design and conduct of the studies.

Second, the studies must be designed so that each study builds on previous research and that the findings of all related studies have the capability of being combined into a complete and easily accessible knowledge base. In order to do this, the studies must be comparable with reference to definitions, reliability, validity, standardization of instruments, the format of reporting and the capability of being replicated.

Third, the framework for these studies involves community control, or at least input that is accepted and utilized, with an emphasis on community values, perspectives, social/cultural context and "indigenous knowledge." This requires research methods that the Inupiat feel comfortable using and that represent their viewpoints effectively. The research must incorporate a regional and historical view with a development approach.

It is obvious from the areas identified for potential lease sales on the map accompanying this Information Transfer Meeting announcement, that the Inupiat of the North Slope are the ones who will be impacted the most by this development. The intimate link between people and the environment in the Arctic on one hand, and the role of the Arctic for the economy of the entire nation implies that these issues in the Arctic have an impact that reaches far beyond the level of the North Slope Borough.

If the current and proposed research efforts of the Minerals Management Service are going to have any meaningful long-range benefits to the Inupiat of the North Slope Borough, we believe that it is necessary for the Minerals Management Service, academia, industry, and the North Slope Borough to create a mechanism for active dialogue to consider prioritizing their research agendas to include the following objectives: (1) To assess the impacts of energy resource development on the residents of the North Slope Borough communities; (2) To establish a framework to facilitate Inupiat participation in the design and conduct of research; (3) To establish a mechanism to collect, record and consolidate the knowledge base regarding the social, cultural, economic, subsistence and environmental data concerning the North Slope and its residents (for example, the Geographic Information System of the North Slope Borough). This would facilitate the dissemination of research results to the communities, governments and private sector interests; (4) To enable the residents to develop their priorities and strategies for dealing with energy development impact issues; and (5) To examine the planning aspects of energy development activities that can be nurtured to accentuate the positive impacts of energy development and to limit the potential negative impacts.

Thank you.

TRACY ANDREWS: The second speaker from the North Slope Borough is Kurt Jacobsen. He's also with the Planning Department and specifically, he has been the GIS Manager since the program moved from Anchorage to Barrow last year. He will discuss the North Slope Borough's goal of developing an internal program that will allow them to gather and document subsistence information useable in long-term planning efforts.

KURT JACOBSEN: Thank you very much.

What I'm going to do is talk about one of the tools that the North Slope Borough is using in addressing the problems of access and the problems of comparing different types of studies from different disciplines in the planning process.

Of course, the first step that the North Slope Borough needs to achieve is to develop policy that will enable the exchange of information and the cooperative work on conducting studies on the North Slope. The second step, which I'm going to be talking about, is the creation of an interdisciplinary tool that can be used by both researchers and the decision makers and residents of the North Slope.

The North Slope Borough (NSB) has had a sophisticated GIS facility since the early 1980s. This facility has very highly trained personnel and the most sophisticated equipment available for doing spatial analysis and also information collection and display.

Some of the goals that we're trying to achieve using this technology are:

The first is to establish good communications between private and public agencies and individuals doing subsistence and related biological research on the North Slope. Again, this is more of a policy issue. We're working on preparing memorandums of understanding between the different entities on the North Slope, including the regional corporations and the different native entities. And then the other side of it is to establish sort of an open door policy with the Federal and state agencies and private agencies that are doing work up there to allow the free exchange of data, and also the uses of the GIS tool.

The second goal is to work directly with the researchers to establish the best format in which to record information so that it may be integrated into an NSB-wide database. This is one of the problems that Bob was discussing. A lot of the information that has been gathered is in forms that are hard to compare, or hard to consider it together. This makes it very difficult for decision makers to sit down and be able to think about all the different implications of their decisions.

What we would like to do is to work with the different researchers and set up a format in which the information could be analyzed and store it together and allow access. Some of the examples of this that have happened in the past, which is as far back as the early 1980s with Sverre Pedersen's work on subsistence in the North Slope, and then more recently was the Steve Braund work that the North Slope Borough GIS helped in part.

We'd like to push this a lot further and get people to start talking to us in order to get this information out into the hands of the users. That's really the most important thing we're trying to do here, getting the information out to the people that are going to be affected.

The other issue is to establish a GIS facility as the central data storage place for subsistence information. As I was saying earlier, we have a really sophisticated setup that allows a vast amount of spatial and tabular information to be stored and compared. There's also the capability to put this information out in a really easy to understand form that would be a very valuable tool for all the people that are involved in establishing policy in the Borough.

Another really important effort that we've already started is to integrate empirical and traditional knowledge into one data structure. At the GIS Division, we have an Inupiaq interpreter that is actually holding oral interviews and we also have recordings and video tapes from as far back as the early 1970s and late 1960s that have a whole lot of information in them that is not being used right now in the planning process. These could be things such as traditional hunting sites. These could be things related to places of significant cultural value, like mythological places and those sort of things.

The reason that a lot of this information isn't considered is because of the time factor in when lease sales come up. A lot of times, there's very little time to go out and gather the information needed to make a good decision. The result of this is that a lot of a things aren't considered. And the implications of not considering these things are going to get us in the end.

The other thing that we're working on is gathering historic information on subsistence use and automate and integrate the database on a priority basis. There are rooms full of books both at the state and Federal level and in the Borough that are collecting dust. And there is a lot of really good work in there. Right now, very few people have access to those documents, and most people wouldn't understand half of the scientific lingo and technology that was used in the studies.

So what we want to do is, starting on a priority basis, concentrate on areas that are most susceptible to development. We're going to go back and gather this information using bibliographies that have already been prepared by many of the studies that have been done and integrate that into a spatial database.

As I was saying earlier, one of the most important things that we want to do is to put this information into the hands of the residents and decision makers of the North Slope Borough. The way that we're going to achieve this is by making the information easy to understand and in one context, in one form. This will be done by, again, working on historical studies and also working with researchers that are currently doing work in the Borough.

Right now, for instance, we're doing a project with Sverre Pedersen in Anaktuvuk Pass starting from not quite the beginning of the study, but in the middle of the study, and we will be providing a method for Sverre to store information on caribou in Anaktuvuk Pass. And this information, because he's directly working with us, will be immediately accessible by the Borough, and will also be in a format that fits in with the rest of the information that we have.

Another example of the way we're going to try to achieve this kind of democracy of knowledge is starting at the end of this year, we're going to be placing computers in all of the villages. They will have menu-driven, both in Inupiaq and English, information systems that they can directly access this information. It will be prepared in a way that most people can understand. For example, one use of this might be if a teacher in, say, Point Lay, wanted to know about historical subsistence activities for a class, he would be able to use this system and directly access the information related to that.

Another example might be if there was to be a lease sale north of Anaktuvuk Pass — you know, there are no big lines out there that have the boundaries of the lease sale, so most people in the villages are mostly responding with emotion and gut feelings about why there shouldn't be a lease sale, why there shouldn't be particular kinds of development in a certain area. But it's hard for them to put into words or use a lot of the language and fortitude that a lot of the people that are pushing for this kind of development use.

What we're going to do is, for instance, send out just a simple disk that will have the information on the boundaries of the lease sale, and they will be able to immediately be able to see other information related to the geographical area. The created map can then be used for public discussions in the villages, and also as a tool for the North Slope Borough or the individual villages to exemplify a point.

Another advantage to this would be that people would be able to look at studies and kind of criticize them and use their own traditional knowledge and their own feel for the land, and look at the studies and put in input on what they feel is the value of the results and of the methodology used.

This is a really huge project and we're using a lot of extensive technology. But the most important thing, like Bob described, is that it's really difficult for anybody to really know what's going on a Slope-wide scale with subsistence activities related to development potential.

This is what we're trying to do. The Borough is making a commitment of both funds and resources to help achieve the goal of responsible planning practices in regards to both native and Federal and state needs.

TRACY ANDREWS: There are three panel members today representing the Northwest Arctic Borough. Sitting next to Kurt Jacobsen is Walter Russell, who is Director of Planning for the Northwest Arctic Borough and a life-long resident of the region. Next to Mr. Russell is David Case, the Northwest Arctic Borough's attorney. And next to Mr. Case is Joseph Ballot, a consultant to the Borough's planning department, a life-long resident of the region, and the person responsible for conducting local hearings about the Borough's recently completed comprehensive plan, including discussions about subsistence issues and information. Each of these people will present briefly, although I understand that Mr. Ballot will be the main presenter.

Again, the presenters were chosen by the representatives of the Northwest Arctic Borough and in agreement with representatives from NANA who chose to provide their time slot to the Borough rather than to give a separate presentation. The general topic will be comprehensive planning in the Northwest Arctic Borough.

WALTER RUSSELL: I want to say that I hated to come down to another Minerals Management Service meeting to listen to all these so-called experts on the bowhead whale and the land that we live in. And I'm very glad and very proud that the North Slope Borough, our sister borough to the north, is getting the recognition that it so widely deserves and the people are starting to be heard. I'm very proud of the North Slope Borough.

When we originally started out with the thought of a comprehensive plan and a zoning ordinance for the Northwest Arctic Borough, we wanted to do it right. We asked ourself how do we do it? The way that it's going to work for everybody else that comes into the North and Northwest is that you go to the people first, then you ask them what is important to you and how do you perceive the plan should be. And then we take it from there.

I want to say that we worked hand in hand with our attorneys. They said, "Well, you can't do this." And I said, "Okay, then figure out another way that we can do it then. If we can't, then that's fine."

One of the questions that Tracy had asked, and maybe some of you might ask, is why are we so disgruntled about some of the studies that have been made in the North and Northwest? We are probably the most studied indigenous people in Alaska, and we're getting tired of that. The reason is because when we do get studied, none of the studies ever go back to the people. And you ask them, this is what we came up with, is this right? And if it's not right, how can we make it right? None of this is happening. And this is some of the animosity that you feel or that you see when you go out to do studies in the North and Northwest.

I would like to go ahead and shut my portion of the speech off. We allotted most of the time for Joseph Ballot who has taken the comments of the people to heart and ran with the plan and to have gone so far as we have. If you look over to the wall on this side, we have a map of the zoning districts of the Northwest Arctic Borough. We did model the plan after the zoning ordinance of the North Slope Borough. We changed it to fit our purposes, and this is what we come up with and Joseph will discuss most of the plan with you. Thank you.

DAVID CASE: Well, I'm the lawyer for the Northwest Borough, and I don't know what a lawyer is doing talking to a bunch of sociologists and economists. We have been involved, as Walter mentioned, as the Borough's lawyers in the development of the zoning ordinance. But the Borough is required by state law and its own charter to manage the lands within the Borough and to develop land use plans and land regulatory mechanisms. Sometimes I've had the impression that in the press the zoning ordinance of the Borough is portrayed as some kind of wild-eyed radical idea. In fact, it's something that is required of the Borough by its charter and state statute, and is the product of at least three years of continuous effort.

The zoning ordinance itself is based on the Comprehensive Plan. And the Comprehensive Plan is the product of information derived from a number of sources, including some studies of the effect of offshore oil development on subsistence and subsistence baseline studies done by MMS, as well as studies done by the Alaska Department of Fish and Game, and one or two other baseline studies that over the years have been developed by the Borough or other institutions in the Borough.

There is a sense among the planners who developed the Comprehensive Plan and the consultants who advised the Borough that there is still a definite and increased need for more intense studies at the local, village level of subsistence uses and needs. And I think, by that, we mean also, as has been mentioned several times here, not just studies in which somebody goes out and puts people under a microscope or does a quick survey through the village, but studies that actually involve people in the village on perhaps an extended basis in the gathering of the data, its analysis, and its interpretation.

One of the key elements and the key sources of information in developing the Plan and finally the zoning ordinance, was the extended trips that the Planning Department, sometimes with us along, made to the villages to first ask the people what they thought the subsistence zones should look like, where they should be, what were the interests that the people had and held most important.

Not surprisingly, the most important interest the people in the villages expressed was what we might categorize as subsistence, which in fact means a lot of other things associated with hunting and gathering from the land, including the culture and identity of the people themselves. Subsistence, it's fair to say, is the key to this plan. It is the key focus of the Northwest Arctic Borough's Comprehensive Plan, and it is the purpose for which its land use regulations are directed. And that may be — I think it is — unique, not only in Alaska, but in the country.

That pretty much concludes what I had to say regarding the studies that were available to the Borough and the kinds of information that we think need to be obtained in the future, and that needs to be obtained in the course of analyzing the feasibility of Outer Continental Shelf development.

As has been emphasized several times here, but let me just say it one more time, it's very important, it's vital that the people at the village level — the village level — be involved directly. Not only just as the subjects of information that is gathered, but as the individuals who reflect on that information, tell you if you got it right and interpret it.

Now, that concludes my portion of this panel. I'll turn it over to Joe. Oh, by the way, we do have a few copies of the Comprehensive Plan here on the table. If you want more, they are available at Ridgeway's downtown at cost. But there are free copies here.

JOSEPH BALLOT: Thank you very much. I'm very proud as a Inupiat to be able to be here to share some information about our people, about how much effort we have put in together, about trying to compile information about our people and about our villages, about the time.

But before I do that, I'd certainly like to introduce the mayor of Northwest Arctic Borough, Chuck Green, sitting in the back. Chuck, the mayor, has played a real important part in getting a lot of the work done and in putting together the Comprehensive Plan.

When we started off trying to compile information, we were interested in achieving a whole bunch of objectives that we recognized we wanted to put in the Comprehensive Plan, that in everything that we put together that we wanted to maintain our Inupiat culture. It was very important. We wanted to promote subsistence and the traditional way of life. We wanted to write this into our Comprehensive Plan.

We wanted to protect the environment. Being environmentalists in our own way is very important, so that we can protect the land off which we subsist. We want to protect the resources that we gather in order to feed our people. We want to keep the villages strong, that we want to promote local control. That we put all of these together and did a lot of traveling in order to compile the information. We have 12 villages that exist within the boundary of Northwest Arctic Borough.

When we looked basically at the land mass that is inside our Borough, there's approximately 15 million acres. Out of this 15 million acres, our regional corporation, which was formed under the Alaska Native Claims Settlement Act (ANCSA) owns approximately 1.2 million acres. The remaining approximately 13.8 million belongs to either the State or Federal government.

When we started putting this program together, we were interested, we talked and we looked at what kind of information was available. Just taking a look at it, we realized that the State of Alaska has done extensive studies throughout not only our village, but our people, and throughout the land. The National Park Service, which is a major land owner, has done extensive studies on their part. The U.S. Fish and Wildlife Service has done extensive studies within our area. And also the Bureau of Land Management.

We started looking at their documents and trying to study and look at how much information was available there that we can take a look at. We started finding out that there are a lot of differences in the studies that were made by different agencies that concern our people. The economic need, the social need, the subsistence need all vary. And it all depended on who did the studies. In some cases, we put up maps that were made by some of these agencies during our village travel, and some of the people would go to the map and said, "Who drew this up?" You know, it was quite embarrassing to go around through the villages, to meet with our people, to tell them that we're putting together a Comprehensive Plan that it required a lot of work. It required a lot of input from the villages. It was quite common for a lot of our village residents to echo the same frustration that was common throughout the villages. "We've been providing input. We've been providing input. That whenever they wanted input, we've been giving out information. We've been doing all this. We don't know what comes back."

A lot of the frustration that they're going through was echoed a little bit by my boss, Walter Russell. A lot of times regulations would come back, and these regulations would be taken to the villages, and our people would be told this is how you can use the land. These are your restrictions. These are your limitations. You can't do this. You can't cook. You can't travel on it. You can't camp on it. You know, and we share all of this frustration.

So when we started putting together the effort to put together the Comprehensive Plan, we wanted to do it in detail. It required us to go back to some of the villages as much as four or five times. We averaged anywhere from two to four and a half hour meetings. And something that was very critical is that when you're out there compiling information that you need people that can translate. It's very important that some of the critical information that you end up gathering, that you need, comes from the elders, and these elders can only speak in the Inupiaq language. So it's very important that you need to take time to study these people.

There have been a couple of points that were brought up yesterday that I listened to about people that were gathering information in our villages, that when you go out, when you're going to compile information, that you need to do it over an extensive period of time. You cannot go in, spend two weeks in a village, and then go back and produce a document and say this is the lifestyle of the people of these villages. You just can't do that.

And when you compile information, like Kathy Frost brought up yesterday, you need to involve the people. You need to involve the villages from the start to the end, until the document is done. When you go in and do an information, then take it back and put it into your own words, by the time the thing comes back, it almost contradicts the lifestyle that we have.

If you look at me, you would say, now, there's a guy wearing a white shirt and a tie, and he's a native guy. You wouldn't be able to find out that my Eskimo name is Amianiq. You wouldn't be able to find out that I am a Niliġmiu by my father's side. You would not be able to find out that I am a Milugiaġmiu from my mother's side. That you would not find out that I also am a Kuuŋmiu from my father's side. That you would not know that I am a Siilviŋmiu. All of these are critical information, that we take very much pride in who we are, where we're from. The Eskimo name that I was given came from my grandmother, that I'm very, very proud of it.

These are a lot of things that we have to discuss. A lot of times it's really critical that you make contact with our people, normally in Kotzebue, you're going to take information because you're talking about NANA Regional Corporation is a major entity there at Kotzebue. Maniilaq Association, which is a nonprofit organization, is a good place to gather information. We have the Northwest Arctic Borough School District, which is another place where you can gather information. We have the Northwest Inupiat Housing Authority, which is a good place to gather information. And on top of that, we also have the regional elders.

So when you want to gather information, you have to take into consideration that there are a bunch of entities and agencies that have to co-exist, that we gather information for our purposes, and yet at the same time, some of the information that we gather, that we say is, in bare fact, a true reflection of what our people are, may not suit the needs of someone else.

When we started putting together the zoning districts that we wanted to use within our boundary, this was a plan that came from the people within Northwest Arctic Borough. They expressed the needs of what they wanted to see in the future and how they wanted to see the land being taken care of, how we needed to regulate the land so that our people can continue to subsist and to maintain their traditional way of life.

When we produced this map, it didn't take very long for the state agencies to come to us and say, you're in violation of our plan. We have made a plan that has basically said this is what you can do, what you can't do. It didn't take very long for the Federal agencies to write letters and say we cannot comply with what you want.

So we have a document that has come from the people that have said this is the way that we would like to see our future. We would like to see the protection made so that we can subsist and to maintain our traditional way of life. And yet, at the end, when we produced that, it didn't take very long for everybody else to start coming back and say that is unusable. That does not comply with what we have produced for you.

So you start seeing the conflicts right away because we have put in the effort to produce something that is in the best interest of not only our people but the future of our people. And then for other agencies to come back and to tell us that won't work. It's very critical in the transfer of information. It's very critical in the gathering of information that you involve the native people to the furthest extent that you can in order to do your studies. When information needs to be gathered, especially information that is going to go into Federal regulations, into Federal plans, you need to involve us. We need to be involved almost from the start until you've completed the document so that the best information can be put together so that you involve not only us, but our villages.

I know that we don't have very much time to talk about a lot of things that are required in order for us to do this. We traveled in our villages for approximately seven months in order to compile that information. A lot of times we had to go back. You need to take into consideration that summer time, especially, is a bad time to try to gather information because our people are out trying to work. Our people are out subsisting. Our people are out camping. The people that you need to gather the information from normally are gone. We were at one small community and they were sharing with me and they said the best time for you to come is to come when the fall storms hit that village. They said sometimes you don't get an airplane for six or seven days. People have absolutely nothing to do. They can't go camp. They can't fish. They can't hunt because of the extremely high winds and the cold weather. People end up staying home. And that's the best time to go and gather the information because the people are available.

So you can pass that information on to your agencies that if you have people interested in going, especially to Northwest Arctic Borough, now is the best time because the villages are having as much as -40°, -50°, -60° weather. As a matter of fact, because of the extreme cold weather we've declared a state of emergency for one of our villages. This is the best time to go. This is the best time to go and to see our people and to fully realize how we have to survive in the extreme temperatures that we have to live in.

Don't come during the summer because it's warm. Don't come in the summer because you want to go fish, because Walter is going to require that you have a permit that you qualify before you can go fish within our zones anyway.

(LAUGHTER)

And I thank you for the time.

TRACY ANDREWS: Joseph, would it help you to know that I'm going to Kivalina in four days?

(LAUGHTER)

The next speaker that we have today is from the Alaska Department of Fish and Game. Sverre Pedersen has been with the Division of Subsistence since 1979 and he is the Division's principal investigator for North Slope area studies. He will present information on the quantitative and descriptive subsistence harvester base and community baseline studies being conducted by the Division of Subsistence.

SVERRE PEDERSEN: Thank you very much, Tracy. Good afternoon. It's nice to be here. Lots of interesting ideas and very good ideas that I've heard so far. I'll try to contribute a few things here as well and also participate as much as I can in the ensuing discussion. And may I give you a little bit of background information on our Division and we'll develop the theme as we go along here.

The Subsistence Division is part of the Department of Fish and Game. It was created by the Alaska Legislature in 1978. The Division's mission is research, primarily social science research. The Division has no direct regulatory management or enforcement authority. Our duties pretty much are to gather information on the role of subsistence hunting and fishing in the lives of Alaskans, to assess the reliance of Alaskans on food and materials acquired through subsistence hunting and fishing, to assist the boards of fisheries and game in their decisions about subsistence uses and harvests, to provide information and recommendations to the boards and the Department on matters related to subsistence, and to make research data available to the public, government agencies, and other organizations.

Division staff includes social scientists, biologists, and local resource experts. We have offices in many rural areas and urban communities in the State. And Alaska, by the way, is the first state in the nation to have this type of applied anthropological research unit in the Department of Fish and Game, so we're a pretty unique operation.

Information gathered by the Division includes Community Profile Studies. These are studies of all community households that are asked to provide information on household sex, age composition, amount of resources harvested, sharing, income, land use. There are also, at the other extreme, issue-driven studies where we, for instance, take a selected group of key respondents in a community or an area and ask them to provide us information on specific topics.

Completed studies are published in a Division of Subsistence Technical Paper Series, which at this time numbers in the order of about 250 separate community or issue reports. However, not all information collected by the Division is published in this series. There are scores of Board of Game and Board of Fish reports, briefing documents, maps, and other descriptive and quantitative reports which are also produced each year. And generally, this information is cataloged and it is available in the Division's regional offices.

The Division is divided into six regions: the Southeast, South Central, Southwest, Western, Interior, and the Arctic. And since we're mainly talking about the Arctic here today, I will restrict the rest of my comments to this particular region. What we classify or use as the Arctic region are the boundaries which are formed by the Norton Sound communities with Stebbins-St. Michael as the farthest south community. It includes the Seward Peninsula, the Kotzebue Sound communities, and all of the communities of the North Slope Borough, and stretches east-ward over to the Canadian border.

There are three regional centers in the region: Nome, Kotzebue and Barrow, and there are a score of smaller communities served by these centers. The Division, at times, had offices in each one of these centers. At this particular time, we have only one office in the region and that is in Kotzebue. Our administrative center presently is in Fairbanks, and that serves actually three regions, among them being the Arctic. Division studies in the Kotzebue-Norton Sound area are carried out from the Kotzebue office, whereas the North Slope studies are fielded from Fairbanks. Staffing in the Arctic region is thin at this time. There are really only two full-time research positions. One located in Fairbanks and the other one in Kotzebue. And we also have a technician position in the Kotzebue office.

To date, the Arctic region staff has produced over 17 detailed community studies for nine communities in the region, and there have been over 44 separate Technical Paper Series reports issued on various subsistence topics from the region.

That subsistence harvesting is an important social, cultural and economic activity which produces large quantities of locally harvested resources in the region is well established by now and the documentation is quite clear and concise. Some general information that might be interesting here is that, for instance, the per capita harvest in the region is very high. It ranges from between 400 to 1000 pounds per person, and the sharing of a harvest between households and between communities in the region is widespread, and the diversity of resources relied upon varies considerably between communities. Also community areas used for harvesting resources tend to be large.

I don't have any descriptive material or overheads to show you this at this time. We have lots of reports and I have some of that material with me here. I left a batch of reports and sort of overview materials at the back table. I don't know if there are any left. If you didn't get some of this material, let me know and I'll make sure you get sent some.

Presently our staff is deployed pretty much as follows: the North Slope staff, which is me, is deployed in a couple of studies on the North Slope. They're pretty much monitoring studies aimed at developing a long-term database on a particular key resource. In this case, it's caribou, and we're doing work in Anaktuvuk and in Kaktovik. And we've been doing work in Anaktuvuk for about two years, and in Kaktovik for about ten years.

We have some issue-oriented studies going on pertaining to the fishery in Unalakleet and Elim. And we have several community baseline studies, some that are ongoing, some that are going to happen shortly. And we have a baseline study in Kotzebue. One in Kivalina and one in Kaktovik. The Kotzebue study is just about complete. The data analysis is taking place now. Kivalina, that study is beginning pretty much today or tomorrow. And the study in Kaktovik will commence in June when the weather is real good but nobody can leave the island because it's iced in. So we pick good times to go to communities generally. So everybody sits around and talks about how nice it's going to be when the ice goes and they can leave and not have to answer all these questions we have.

We also have one more study planned for the region and that will be either in Wainwright or in Nuiqsut. That will also be a community study. And what I've outlined here and that will pretty well occupy our staff through our fiscal year 1994.

A couple of other things that we should talk about here is in an effort to make information readily available to people. We understand very well the problems that several speakers have pointed out here. Reports can become very thick. They can contain a lot of interesting stuff that is hard to find, and reports do not necessarily have a wide distribution. The Division recognized this in the mid-1980s and entered into a series of efforts to try and crystallize information from our studies. One effort that has been very successful is the creation of what we call the Community Profile Database. This is a series of binders, like this one, containing crystallized information from our community studies across the state. This one is for the Arctic Region. It contains the 17 studies that I mentioned to you.

We have in here information on demography of the community, income in the community, all the quantitative aspects of the information that we collect, such as harvests by species, both in terms of total number of pounds taken in the community as well as the per capita harvest in the community. There are other elements as well that I'm not going to get into here right now.

This is available to people in two forms, either in this binder form or in a computer form that is on a disk. If a community or a governmental entity is interested in accessing this information in an automated way and has the computer program required to look at this information, they can easily look up data on just about any variable that we've collected for a particular community in their area.

The other effort that we have on-going is an attempt to put together all the mapped information that we have for the Arctic region, and in fact, for the whole state, into a catalogue. Now, that's a little more difficult to do. Because the technology keeps changing on us and evolving pretty rapidly actually, we haven't come up with a medium for providing this information. So maybe treading water is the best way to put it right now. We're waiting to see if this GIS effort that the North Slope Borough and other entities have gotten involved in, is a good medium to put this information into.

In terms of evaluating methodologies that are being employed right now, I would like to say this: that the Division of Subsistence has worked very hard to establish, particularly in the community studies that we do, pretty much a standard format, a standard questionnaire that has been used now for many, many years upon which this database is built, that we feel very good about. It has withstood acid tests throughout the State. We encourage other people who are interested in doing community level studies in the Arctic region to consult with us and look at how we have designed our instrument, and to work with us so that this database that we now are building up and trying to disseminate can include their work. And the same thing really applies to mapped information, although we haven't gotten as far.

When it comes to social, cultural studies, we haven't made much progress in systematizing that yet. It's a pretty difficult area. And besides, the Division really is a very applied operation. In fact, very often regulatory activities sort of derail our research activities and modify our schedules quite a bit. So anyway, the efforts that we've gotten into so far is making sure that we have a good system for collecting community level information.

Where do we go from here? Well, clearly, in this setting here, we're interested in having deeper information in some of the communities that we've studied. That is, have more years' worth of information on them. In some communities, we only have one year's worth of information. And that pretty much gives you one point in the graph and you can't tell anything from that. So we'd like to see additional community studies being done and are happy that the MMS has decided to go ahead and fund several of these in the Arctic Region. I think they will be very helpful.

I have one other product. It's an abstract of the studies that we've done within the Division. We don't have a lot of copies of this, but again, if someone would like a copy of it, give me your name and I'll make sure that it gets sent to you.

TRACY ANDREWS: Our next speaker is Larry Merculieff, who is currently the Manager for the City of St. Paul in the Pribilof Islands, where he was born and raised. He is the founder and coordinator of the Bering Sea Coalition, which focuses on the health of the Bering Sea ecosystem and the sustainability of traditional ways of life. He is also a founding member of the Indigenous People's Council on Marine Mammals, the Pribilof Aleut Fur Seal Commission, and co-founder of the Amiq Institute, which involved in developing linkages between Western science and traditional ways of knowing.

Mr. Merculieff was one of the few panel members I contacted with the request that he specifically participate. And I asked him to focus particularly on how the knowledge and perspectives of Alaskan natives can be better documented and integrated into social, cultural and economic studies. Fortunately, he has agreed to my request.

LARRY MERCULIEFF: *Aungulkingux̂ Kufuthax̂*. The closest I can come to an interpretation is: "The afternoon tastes good."

Mr. Ballot, I really enjoyed your presentation. I think it had a lot of good points to ponder. And like he said, we would encourage researchers to come out to the Pribilofs and Aleutians during the winter time. I think in the last ten years we had one group much to Fish and Game's Subsistence Division credit, they came out here this last week to the Pribilofs. We only get winds in the winter time from 40 miles per hour and frequently up to 80 miles per hour, so, bring lead weights for your shoes.

Also, Mr. Russell pointed out that the area is the most studied area in Alaska. I guess we'll lay claim to the second most studied area. We've stacked up, just for the information of researchers, all the studies done out there in the Pribilofs that relates to the Pribilofs, and the dimensions of these studies as we stacked them up is five feet high, three feet deep, and 20 feet long, covering a ten-year period. So it's a little bit humbling to researchers when they come out and they want to talk with us and we show them this room, and they take very little of our time afterwards.

(LAUGHTER)

The title of my presentation today is "Pickled Seal Flipper (*Lusta* in the Aleut language) and Western Science." And no, it is not about an inebriated pinniped appendage — for those requiring further definition of my topic. However, that is my topic — what is and is not definable in language, why, and the implications to cooperation and collaboration between Alaska natives and the scientific research and resource management establishments, as well as our search for answers to growing environmental problems worldwide.

Over the past two decades, Pribilof Aleuts have been at the forefront of efforts trying to explain the importance of the connection between culture, language, self-esteem and the environment. This has involved us in scientific research, effective resource management, subsistence and economic issues before Congress, the general public, scientists and resource managers. Much of our effort has been the result of the Pribilof Northern Fur Seals being considered a public resource and therefore of particular interest to animal rights groups who seek either elimination of Aleut subsistence rights or substantial control over how seals are taken and what parts are used in subsistence. I have taken a cold, hard look at how effective or ineffective our educational efforts have been in advocating our right to take traditional Aleut food. In doing so, I have realized that we have been only marginally successful in contributing to any meaningful education of the hundreds, perhaps thousands, of people with whom we have met in endless and highly varied public forums.

I began a methodical analysis of our efforts in an attempt to understand why we have not been as successful as we hoped. My analysis began with general questions and gradually became more and more specific. Our goal has always been to communicate the importance of fur seals to the Aleut people and why our right to take seals for food should be upheld and unhampered by unnecessary and demeaning scrutiny. To achieve this goal, we have attempted to define what our culture is, to define the meaning of fur seals to the Aleut culture, and to define the way we ensure that waste does not occur in the taking of seals for food. I was puzzled by our limited success in being fully understood on these points. I tried to bring my analysis to the most basic terms. I began with defining what a seal flipper is and why it is important to us. But, after many attempts at defining the importance of seal flippers to Aleuts, I gave up. Hmm, I thought to myself: I am reasonably articulate and able to communicate on most levels; why then can't I define something as simple as a seal flipper and its meaning to my people? And, if I cannot define something as elementary as a seal flipper, how can I possibly define Aleut culture and the meaning of Fur Seals to our culture?! Now wait a minute, I thought to myself, we are able to define most things either by quantifying, by describing physical properties and/or describing function in its context. We did all that, even added some heartfelt emotion, and yet we failed to communicate the true meanings. Why? The answer was suddenly in front of me: I was using the English language to define something Aleut and I was attempting to define things which I, an Aleut, found indefinable.

Intuitively and intellectually I have always known that culture and language are inseparable, but I have now recognized (re-cognized) that much can be lost in the translation between languages — and most importantly, that there is no comparable translation beyond the literal word for some aspects of the Aleut culture. When I say *Lusta*, the Aleut word for pickled seal flipper, to a non-Aleut it has no meaning; however, when I say *Lusta* to an Aleut, there are a host of emotions, experiences and memories automatically attached. *Lusta* is recollection of the times the person went out hunting with family members and friends to get a seal; *Lusta* is recollection of comical or otherwise memorable events which occurred while hunting or preparing the food; *Lusta* is remembering the voices of loved ones around the dinner table speaking in the rhythmic and melodic patterns of the Aleut language; *Lusta* is a unique smell and taste; *Lusta* means humor and it means dignity in times of hardship; *Lusta* is pride in the knowledge and experience it takes to get and properly prepare seal flipper; *Lusta* is a necessary part of a particular meal prepared when the time feels right or when there is a medicinal need for it; *Lusta* is the knowledge of our spiritual and physical link to the seal and all that sustains the seal and the Aleut people; *Lusta* is history physically manifest; *Lusta* is uniquely Aleut. *Lusta* can mean all these things to a person all at once or it can mean some of these things — it all depends on the time, place and circumstances. *Lusta* is not a thing — it is an essence; it is not something that is physically or emotionally definable. It is an essence, and the proper place for its definition is within one's heart; it cannot come from one's mouth.

So, *Lusta* is not something that survives translation after all, and it is only one aspect linked into an entire cultural universe. As a link, it is inseparable from the whole. It is the whole and yet it is not. Given this kind of complexity, one can understand the character of the Aleut language and even how we use the English language: we do not define. Definition diminishes the essence of what we attempt to define. I now fully understand the great wisdom in what my grandfather once told me: "When you see a sunset, do not try to tell others how beautiful it is, just be quiet." In those few words my grandfather explained the basis of ten thousand years of Aleut life.

Herein lies the salient point I am pondering: perhaps one of the reasons native people with successful sustained interaction with their immediate environment for generations are successful (emphasis added) is because they do not define everything. The act of defining fragments our understanding of the world we live in and requires us to become more and more specialized. This, in turn, translates into specialized professions; and, all ways of organizing, understanding and dealing with environmental issues become structured to accommodate this way of looking at the world. This is fine as long as this way does not stifle our creativity and imagination in our search for solutions by placing other ways of looking at the world in the margins. With the daunting and ever growing environmental problems humans are facing, we need creativity and imagination.

I wonder how much of our need to define things telescopes our ability to think critically about the human role in the environment, allowing us to miss simple but innovative solutions to environmental problems. For example, it is said that theoretical physics and quantum mechanics (in the frontier of scientific inquiry) are now bordering on art. If that is the case, is there a role for artists in scientific research and inquiry? I think so. Let me read an artist's statement written by Susanne Swibold who is an artist and research associate with the Arctic Institute of North America in Canada:

> "The artist is willing and not uncomfortable in exploring the unknown, the untried. The artist's process is to bring unity within diversity: to establish a dynamic equilibrium which is a harmony of diverse parts. This is beauty. In the process, the artist looks deeply into the institutional group and organizational forms, and finds a way to release the spirit within. When set free, the possible is realized and set in motion.
>
> To the artist, our world is alive, creative and diversified because there is a unity of its parts which are inseparable and exist in a dynamic equilibrium-seeking process. It contains elements of unpredictability in constant motion. There are no solutions to this movement. Man can respond to this through the process of creative looking, listening, and thinking that requires a sense of adventure and courage. Humankind's place in that unpredictability must be one of humility, as one element among many in the dynamic forces of nature. When we seek to understand how nature's systems behave, we may realize the inherent value of living in a world that moves beyond our control. This dynamic, living, complex world that continually seeks equilibrium in mysterious ways to ensure life, enriches and stimulates our curiosity, awe, and wonder, and nourishes our spirits in wisdom and grace."

What a wonderful and creative dimension the artist can bring to the process of scientific inquiry. Ms. Swibold's interpretation of art strikingly articulates some of the native world view of themselves and their role in nature. And yet, the artist has little stature in our society and no role in scientific research and management. Are we losing something in our search for solutions to human problems because of this? And, is this because of our need to define? How many other perspectives, which could benefit our search for answers, are we not even considering because we have developed a definition driven mindset?

Perhaps we need a new paradigm in dealing with environmental and cultural issues: that we must not define everything and that we must be careful in what we seek to define lest we lose something in the process.

I suggest that one of the first steps we can take to minimize the atmosphere of confrontation, polarization and suspicion between scientists, researchers, resource managers and policy-makers and Alaska natives is for everyone, Alaska natives included, to accept this paradigm and act accordingly. We have nothing to lose by doing this, and potentially we have everything to gain. The possibilities are exciting. At the very least, I would like for you to remember the pickled seal flipper (*Lusta*) as it applies to how we use our minds in our work, western science, and in our everyday lives.

If we take this mental leap, we can then move on to constructive approaches to relationships between natives and non-natives which could include: 1) development of regular annual forums between Alaska natives, scientists, managers and policy-makers to examine the issue of cross-cultural communication and collaboration in research and management; 2) joint work at pilot and demonstration projects which pioneer use of native and western science on an equal footing in research, management and policy-making; 3) developing support for native efforts to expand their capacity to institutionalize native ways of knowing; and, 4) joint development of the means to link native ways of knowing and western science so that information can be used by either the Alaska native or western science systems without suspicion or question of credibility.

Thank you.

TRACY ANDREWS: The next speaker is Steve Colt, who is a research economist at the Institute of Social and Economic Research of the University of Alaska Anchorage. While the Institute has conducted a wide range of social-cultural studies over the years, I requested that their representative focus on assessing economic information available for the Arctic. Mr. Colt will draw on his own doctoral dissertation research that addresses the comparative economic performance of the ANCSA regional corporations as well as integrating comments from other economists working with the Institute of Social and Economic Research.

STEVE COLT: Thank you, Tracy.

After listening to Larry's wonderful talk, I wish we could just go for my 15 minutes and watch the sunset from Point Warenzof and I would happily be quiet.

During the past ten years, research sponsors such as MMS have spent millions of dollars on social and economic studies in the Arctic. I argue that sponsors have purchased too much economic analysis and not enough economic data.

We still know very little about some basic economic processes in rural Alaska. In the labor market, these include shifting employment patterns, labor force participation, and migration. In the fishing industry, it seems impossible to find definitive data on how many people fish, who they are, where they live, and where they spend their money. We also know very little about important economic institutions such as the Native Regional and Village Corporations.

As a result of the lack of resources devoted to primary data collection, socioeconomic studies are often forced to recapitulate existing economic data over and over again. This sometimes results in lengthy — but ultimately futile — mental gymnastics as analysts try mightily to reconcile conflicting numbers and to patch together a useable time series.

The lack of high quality basic economic data can be easily explained by the economic theory of public goods. Basic economic data are like weather observations. They are very costly and tedious to collect, especially when one is setting up the collection system for the first time. Once collected, however, they can be shared at very low cost. Thus, while the *total* benefits of baseline data to *everyone* may be tremendous, the *marginal* benefits of primary data collection to any *single* research project are often less than the marginal cost of that data collection. Under these circumstances, rational proposers cannot afford to offer primary data collection as part of a project bid unless the Request for Proposal (RFP) specifically requests data collection as the only work product. But rational research sponsors acting in isolation will not waste their budgets on data collection that will (mostly) benefit others.

I suggest, further, that this problem is especially acute when the existing primary data base is generally poor. In economic research, we face the following curious situation: *If you start out surrounded by shoddy data, a small amount of additional high-quality data may be worthless.* This problem stems from the multiplicative nature of economic models. If the result is $Z = X \times Y \times W$ and the uncertainty of both X and Y is plus or minus 50%, it doesn't pay to go out and narrow the range for W. However, as the quality and quantity of the available baseline data grows, it becomes worthwhile for a single study to go out and collect additional high-quality data. That is, if accurate data for X and Y are available, the marginal benefits of pinning down W are quite high. This is potentially good news: if we can get over some critical hump in the average quality of economic data, it will be rational for smaller and smaller research efforts to add primary data collection to their agendas!

In economic theory, the public good problem is solved by collective action. We have the National Weather Service, Bureau of Labor Statistics, and the Census as examples of decent data collection programs at the national level. We need a research program devoted solely to economic data collection and maintenance, under which both program managers and competitive bidders are rewarded for providing high-quality and consistent data. The budget for this program need not be overwhelming. There are a number of relatively modest things we could do which — *if kept up over time* — would pay great dividends of knowledge about the economic structure of the Arctic. Some pressing information needs include:

(1) Wage and salary employment data at the census subarea level;

(2) Ongoing employment surveys of ANCSA Village and Regional Corporations and collection of annual reports;

(3) Collection of data on proprietorships, to augment wage and salary employment data and provide a better picture of the fishing industry; and

(4) Continuation of migration and labor force studies via an ongoing panel sample.

My colleagues and I have been pleading for more primary economic data collection for years, with little success. Furthermore, the halcyon days of big budgets for social and economic research in Alaska are probably over. Still, I am cautiously optimistic that research sponsors are realizing that, while basic economic data is costly and tedious to collect, the alternative is more costly and tedious studies without it.

TRACY ANDREWS: Our final speaker today is Dr. Don Callaway, who is an anthropologist currently working for the National Park Service's Subsistence Research Division. Some of you may recognize Dr. Callaway as a presenter and the chair of social and economic study sessions in previous Information Transfer Meetings.

This past summer, Don finished a seven-year tenure with the Minerals Management Service, initially as a socioeconomic specialist, and then for several years as a supervisory chief of the Social and Economics Study section. He was instrumental in developing many important studies for the Minerals Management Service. And while we might prefer he was not participating as the representative of a different agency, we are pleased he could arrange to discuss the subsistence research efforts being designed by the National Parks Service.

DON CALLAWAY: Thank you, Tracy.

As a former MMS employee, I would be completely surprised if Steve found the word "impact" in any of our titles since it was *verboten*. I assume that it was because of management's association with things dental.

(LAUGHTER)

The Alaska Native Interest Land Claims Act (ANILCA) established four parks in the Arctic regions: Noatak, Kobuk, Cape Krusenstern; and Gates of the Arctic. ANILCA also established a mandate for the Park Service to protect and preserve park resources and at the same time, make these resources available for use.

Current research that — and I'll come back to this mandate a little later — the Subsistence Division of the National Park Service is conducting is a project in the community of Wiseman. The intent of this research is to try to understand how increasing population in a community affects resource use.

There's another project ongoing in Yukon Charlie that is analogous to much of the work that Sverre and ADF&G have done with respect to collection of subsistence harvest data, but also has a particular emphasis on trapping.

Another study that is ongoing with the Park Service is in the Lake Clark area. This is a detailed investigation of plant use within the Park and Preserve boundaries, and at some point I hope that this data set can be linked with the ADF&G data set also.

The Park Service is also contracted through its Cooperative Park Studies' Unit at the University of Washington to analyze ADF&G's permit data and to look at a data set collected by ADF&G in 1987 that was related to communities around the Wrangel-St. Elias Park.

Finally, one current ongoing research effort is a cooperative agreement with the Copper River Native Association (CRNA) to look into some aspect of customary and traditional use of park resources. This cooperative agreement is yet to be fleshed out. We hope to work closely with the CRNA to develop the intent, goals, and project personnel of this research, and that will be on-going in the next several months.

The Subsistence Division plans to conduct research in the next two years in several areas. One, we plan to do a cooperative management study in the Northwest Arctic Borough region.

A second study is the use of cabins in Denali Park.

Another study will be a detailed research project in the Katmai region involving the communities of Levelock, Igiugig, and Kokhanok. This project, as it's now envisioned, will be multi-method. We hope to use a memorandum of understanding with ADF&G to collect subsistence harvest data. In addition, we hope that the principal investigators will collect detailed information on some issues and subjects that the ADF&G questionnaire doesn't cover, such as the passing on of subsistence traditions, reciprocity of resources, and any number of other topics. We hope to link both these survey efforts into one combined data set. Over-arching both these survey research efforts will be a detailed ethnographic and ethno-historical analysis and description of the three communities. And finally, we hope to collect some biographies of elders and others within these communities, and make that part of the products.

Finally, our last envisioned research for the next couple of fiscal years will be research in the Bering Land Bridge area, specifically, we hope, in the communities of Wales, Shishmaref, and Deering.

That's kind of an overview of potential and on-going research for the Subsistence Division. I'd like to talk about a couple of issues related to this research.

One thing that came to mind when I was thinking this over was my attendance at the ITM last year where a biologist stood up and said — and this is etched in my memory — "We really have no idea what's going on in the Donut Hole region." Furthermore, he said, "We don't even know what variables to measure to find out what's going on." And then he capped that off by saying, "Even if we knew what variable to measure, we wouldn't know how to measure them."

I link that with Mr. Merculieff's paper at a previous conference that he attended, where he talked about the relationship between what he called western linear thinking and the cyclical thinking that he termed the native participants in the environment engage in. And it occurred to me that some of the panel members, Mr. Merculieff talked about it, several hundred cubic feet of data that has been of no use, and Steve talked about there not being enough data, and that seemed to be a strong contradiction to me.

It occurs to me that data or objective facts really don't exist. And I think one thing we've found with the MMS experience is that objective facts don't exist. That really what exists are social facts. And I don't mean facts about social behaviors, but social facts in the sense that people agree that they have participated in a research project in terms of its goals and aims, that they have agreed to the methods in which information will be collected. They've agreed to the personnel that will collect this information, and they have some trust in the personnel that will analyze the results. So, by social facts, I mean a sense of legitimacy to the information that is collected and is used.

The Park Service, as I mentioned, has one cooperative agreement with CRNA. But it's difficult and part of what I like to say is to underline the difficulties in the conduct of cooperative research. There are a number of difficulties just in the structures and the number of entities that are engaged in research in the Arctic. We've had meetings where we've had representatives of all the Federal agencies, and within Federal agencies there's often some tension between those people that live and exist in the local communities versus the regional office in terms of what the goals of research or the data collected should be. So there are some difficulties in just coordinating and getting agreement among Federal agencies. Then you have state agencies that also have a vested interest in what's going on. And that adds to the level of coordination and time needed to reach a consensus.

And finally, beyond that you have the local, regional and community interests. And I think it's important that Federal agencies and other agencies doing research spend the time up front in working in terms of these cooperative agreements with these local communities to develop some kind of method whereby they can be part of the research design, participate in the research itself, and then use the research products when they're through.

It's not an easy process as we've found out in the *Social Indicators* effort. For example, many key personnel on the *Social Indicators* effort from local communities or from the regions were extremely skilled and talented in their participation, but it was very difficult to sustain them in terms of employment full year since most of the data gathering was done on a seasonal basis. Secondly, these very talented individuals have huge demands on their time from the region, from entities within the region, and from their own professional and other development. So it's difficult to establish continuity.

Other difficulties occur in the way research is funded. It's difficult to obtain any continuity since research budgets are often the first object of budget cutters' attention. And in point of fact, the Park Service has experienced in my brief stay there one such light severing of research resources.

I think I'll leave it at that. With a final summation to say that it's my hope, somewhat dim through practical experience, that all the entities that are involved in a research project, both in the Arctic and throughout Alaska, on subsistence and other issues, spend the time and the effort to work together to develop some sense of commitment to the process. And I think only then will the products really have a utility and meaning for everyone.

Thank you.

TRACY ANDREWS: We're going to turn on the microphones here at the front table for the panel participants. Also, the microphones in the audience are being turned on.

I would like to start with our participants, and ask if anybody has particular comments or questions for each other, now that all the presentations have been completed. Please speak into the microphone; we are recording this panel presentation and considering trying to publish the proceedings.

ROBERT HARCHAREK: I'd just like to make a comment here. Though it may seem to the contrary, we did not have a planning session among the panelists prior to this, even though we did seem to come to a consensus on seven to nine panelists of identifying some similar problems.

TRACY ANDREWS: Anybody else on the panel have anything at this point they want to reiterate, or raise as a question for the other panel members?

LARRY MERCULIEFF: Also by way of reiteration, I've traveled all over the State over the past couple of decades on a lot of these issues and what I've seen described in the North Slope Borough, Northwest Arctic Borough, everywhere else, is the sense by native peoples about research management, I feel, to be incredibly similar in terms of what the sense is. And because of that sense, real or not, whatever these perceptions are, there's growing disenfranchisement, polarization, and atmosphere of confrontation that keeps ratcheting upwards and upwards and upwards. Somehow, we've got to bring the two together because there's so much to be benefitted of by the different groups that are involved.

But no one is paying attention to that issue. And the more we talk about it, the deafer ears we find. And so we need to establish some forums, I think, to begin seriously examining what's happening.

TRACY ANDREWS: Sverre?

SVERRE PEDERSEN: To some extent, it is really disconcerting for a researcher to hear these sort of things. On the other hand, we should probably expect them. And based on my experience on the North Slope, we have been involved in a lengthy effort to produce information in a variety of settings and on a variety of issues, and some of them are community based. This meeting is real good and I'm beginning to get a grip on this, I've noticed that even though our Division works very, very closely with the communities, we don't do this study in the community without there being concurrence in the community to do the study. In fact, many of the studies we do, the communities ask us to do the studies. So we take care of the protocol before we do any study. We review the information practically as we collect it with people in the communities. We review the analysis with people. We review conclusions with people, and we don't issue a report unless the community agrees with our findings and our conclusions.

So now we've done a project, we've done something meaningful in the community. People are happy about it, and there's no problem with us coming back and doing more work. However, there is a condition where this begins to fall apart. And that is if there is a pressure put on the community to protect particular interest they have that is outside, let's say, the realm of the Department of Fish and Game, let's say it's a land management issue, they have this stack of information that has been alluded to here. It may be 20 feet high by 40 feet long. The problem is that a request for information to a community is never in the format in which the information was provided to the community.

So somebody in the community has to sit down and digest the information now. And that's a real problem. And I am seeing it more and more. And I think it is clearly a communication problem. It's frustrating for me to be in a community where I see that they have an issue that they — I have produced information for them on the particular issue but they don't have the means to put the information together to feed it back to whatever agency it is that needs this information from them.

And I'm not in the position to do the writing for them. So what I'm concluding from this is that there is a need for better communications between the researchers and the individuals in the communities. I also think that there is a great need to better equip people at the local level to use the information that is being produced for them. And I'm not seeing, particularly on the North Slope where I'm intimately familiar, I do not see an effort directed toward that. And that concerns me quite a bit. And I don't know what can be done about it.

But I know that we're going to continue keeping information on people and the problem is probably going to become worse rather than better as time goes by here because it becomes more critical for them to have this vast information.

The other thing that happens, of course, is that when people find that they cannot use the information that's been provided to them, they feel that what has been produced is useless. And so you get caught in a paradox. And we need to get out of that.

LARRY MERCULIEFF: I do appreciate that perspective. I have to disagree, I think, on that entire point. I think there's a more fundamental issue here. You know, it's becoming a new accepted paradigm that cultural diversity is just as important as biologic and genetic diversity to survivability of the human race and the integrity of the environment. And also that cultural erosion is a precursor to environmental degradation. And the United Nations is now just beginning to accept that as a paradigm to apply to South America.

I think the fundamental point is that it's what scientists or native people do or don't do that contributes to further erosion and disruption within the community, or in a destructive pattern that contributes to destruction of culture. For example, when punitive laws or regulations are applied into a community from the outside, it replaces the traditional authority figures in the community, be they elders or shamans or whoever, with the force of outside law, and thus does not give them credence in the eyes of the young people whose lives are they see defined by these laws. Therefore, the focus and interest is not there. They start to shifting to the western system. There begins the process of cultural erosion.

And by the same token, when researchers come to the community and we're flooded with this information, we spend our entire time reacting and responding to that information rather than looking within ourselves about what we want to do. And that, unfortunately, is where Alaskan native leaders are today. They're just bouncing from one thing to the next, reacting to one thing and another, and no creative pro-active thinking is taking place anymore.

DAVID CASE: I'm just listening to this and reflecting on a couple of things. And I'm perhaps not the best person to talk about this, but I'll tell you in working on the zoning ordinances, it's on the map there and (inaudible) was planned. There comes a time in the consideration of any ordinance where it goes through a political process and part of the process goes to the Northwest Arctic Borough Planning Commission for its review of the ordinance.

And, of course, the Planning Commission has to decide to recommend the ordinance to the Assembly for its adoption or not. And it really made an impression upon me when the time came to make a motion there was a long pause. Nobody quite knew what was going to happen. One of the planning commission members, with a great deal of emotion in his voice, moved to adopt the ordinance and said, "All these years, people have been making these plans for us. Now we are making a plan for ourselves."

When Joe was talking here today about this zoning ordinance being enacted and the agencies saying it wasn't going to work, this would be exactly what people in the villages hear all the time. I mean, as plans come out and they say this won't work. Well, the tables get turned here.

And what's happening, I think, in the Northwest Arctic Borough is people, the Inupiat people, are taking control of the process themselves by asking Congress that it would be interpreted through their own cultural values in a way that is more useful, less destructive, and perhaps constructive, more constructive, than previous plans.

TRACY ANDREWS: Are there any questions from the audience at this point?

TOM NEWBURY: I have one comment.

Several comments have been made about things that would help resolve "the problems": deaf ears, lack of communication, etc. There is something that I want to add; that is to consider very carefully the decision that might be influenced. For example, whether it's the type of research that will be done, the area that might be leased, or will there be exploration. Each one of those decisions carries different implications.

With a lease sale, there is a definite decision — a decision to lease land under certain conditions. But that doesn't necessarily mean that it will be explored. It may simply be leased and the tracts relinquished. The decision to explore carries a bigger implication, but it, too, can be, I think, relatively ephemeral. I think the exploration in the Chukchi Sea is an example of that; rigs come, the holes are drilled, and the rigs go.

I think that development decisions carry much longer range implications; and for that reason, it's important to focus on the development prospects: Endicott, Niakuk, and the Colville River Delta. Kuvlum is another recent announcement. Those projects, I think, carry long range implications. And I think that it's worthwhile, especially with an information intensive system like the GIS, to focus it on those long-term projects.

TRACY ANDREWS: Anyone else? Go ahead.

ROBERT HARCHAREK: I'd like to comment. I agree with you on the statement you just made. It has been a matter of a few years when the North Slope Borough has actually become pro-active in reference to some development, and it's because of the information base that has been developed through GIS that we were able to do that. And my pleadings for more intense community participation in the research is to, I guess, merge in partnership even further. And so that development, if and when it does take place, the detrimental impacts will be minimized. But I totally agree with what you said.

LARRY MERCULIEFF: I also would like to agree. I think that there needs to be more emphasis on process orientation rather than goal orientation in conducting research, management, or even economic development. And therein lies the key to I think what I would like to recommend that we begin exploring, is what is that process.

For example, the environment is constantly in a state of flux. It is dynamic. It's organic. It moves and changes all the time. That we have to plan for chaos because that is one of the underlying premises of the way the environment operates. And by definition, indigenous cultures with any integrity adapt to these environmental mandates, and consequently are also affected by this. And that if we have a goal oriented system of planning and management, we totally lose some avenues to seek some answers to the challenges that we face.

TRACY ANDREWS: I have one question. I believe it was Mr. Case who said he thought that more intensive studies were needed at the local level. And I understand the main issue is the involvement of local villagers. But I want to ask about the kinds of information that is needed at this point; information that you did not find when you were trying to do the Comprehensive Plan. Are there are specific types of information needed, and to what kinds of local level studies are you referring?

DAVID CASE: Well, we didn't have a complete list. In preparing this panel we looked at that question. And as Bob Harcharek said, we didn't get together, but we have some remarkable sort of synchrony up here.

The need to analyze and gather data concerning the effects of migration on people associated with development has been mentioned several times. And that's one of the issues in the Northwest Arctic Borough. One of the surprising effects, it appears, of the Red Dog Mine is that people who have obtained jobs there move to Anchorage, even though they are from the region. And they then hop on the jet at Red Dog and fly direct to Anchorage and other locations. And that was a surprising result.

So I've heard migration mentioned several times, and I'm not sure if that's the kind of migration people had in mind, but that's the kind of migration that we're concerned about in the Northwest Arctic Borough. I don't know if it's good or bad. It may not be bad. It's hard to say. What is the effect of that? What's causing that would be one source of inquiries. What is the effect of it? Does it really mean that people leave the region and don't come back? Or are they able to maintain ties such as immigrants from a foreign country maintain ties with their home roots sending money and goods and visiting, eventually moving back to their home community, but then living someplace else for a while?

There are probably other factors, like housing, associated with the quality of life in the region that caused people to leave. Those things would be important to understand because if you have OCS development, you're going to have the same thing. They're going to have jobs in the region and they're going to do the same thing. We should understand that before it happens.

Another question we kicked around was what's how do you attract people to entry level jobs, because the entry level job pay level may not be sufficient to offset what they give up in terms of their present income and family relationships, subsistence activities, way of life, and to get the entry level jobs, which may be beneficial, they may not be able to give up those other things that are important to them.

So what do you need to do to deal with that? How do you support, provide support for people who are getting these sorts of entry level jobs at the same time allow them to maintain their identities with their ways of life?

On the subsistence front, I guess what I heard several times on this panel was — and I think we all alluded to it a bit here too — when you go to a village to gather data, the ability, that's only part of it. And you need to design the study with the village. Then do it with the village, and then go back and vet it with the village. And then you get to the place, maybe, where the information becomes useful to them, to people in the village.

But I'm also wondering if you don't have to go even further and say probably none of this will really become useful to the people until they actually do it themselves. Until the people in the regions are doing the work that they want to do and analyzing the issues and the questions, and the problems that they want to analyze, rather than have, inevitably, have folks from the outside come in and give it to them or do it for them, as was said a couple of times.

It seems to me that it's got to be something that's relevant to the people there and they've got to feel an ownership about it to pursue it. And you know, that's not a criticism. That's a goal.

TRACY ANDREWS: Thank you.

LARRY MERCULIEFF: I would like to say, it is commendable to get consultation with native peoples and for the most part, most of the people who have done that who were non-natives are very sincere in their effort to try to understand what's going on. But frequently we don't think critically about the implications of this.

If we accept, even by default, which appears to be the case today, that native peoples cannot be co-managers or co-researchers, then we go to consultation forms which are advisory boards, public hearings, presentations before forums like this. What does that do? What does that do, for example, if by not going to co-research where the researcher comes into a community from the outside and the young people see this, that their way of knowing is not validated, and therefore that encourages them to drift off and not take into serious account what their world view is as it applies to the way research and management affects their lives in their communities today. In other words, these forms of consultation are actually making us enablers of cultural erosion.

Then the next question becomes if there is cultural erosion, so what? In other words, why should we even care? And then you get into a whole other string of questions.

So I guess in evaluating this in all of my work in this area, I'm beginning to conclude that this consultative process is one of the host of elements that are contributing to destruction of culture.

UNIDENTIFIED SPEAKER: How do we overcome that?

LARRY MERCULIEFF: The question was how do we overcome that. Thank you.

First of all, I think that what we need are some basic tools for what was referred to as cross-cultural communications. We need to sit down, both native and non-native peoples need tools for cross-cultural communication. That becomes the beginning point then to start forums. I mean, right now here I've heard people say, well, why don't we get native peoples and scientists and research together and let's just have a forum to discuss our perspective. That isn't good enough from my experience in working with many groups around the world on this issue.

We have to lower our cultural blinders and our systemic blinders like I mentioned in the presentation about a definition driven mindset — how are our minds being affected in the way that we perceive things — before we can lower barriers sufficient enough to explore constructive solutions.

And there are constructive solutions. For example, we can have forums between native and non-native; but unless there's communication occurring, it's no good. And unless we're all made aware of how our mindset is preventing that communication, never the twain shall meet. And we can do demonstration projects after that. We can do pilot projects after that. We can help to institutionalize native ways of knowing. But we can't do it until we get to that first initial point of each of us dealing with this whole thing of communication.

CLEVE COWLES: A lot of the discussion has got my mind spinning in many directions. Mr. Merculieff's comments about language and communication and understanding bring to mind my own background. I understand that there are many people in this room that would not have the same appreciation for certain foods that were part of my family's long experience. And I thought that perhaps the way that I could have you appreciate, for example, the plum puddings that my grandmother made right until when she was a 102 years old, would be for you to have sat at the family get-togethers that we had. And I know that's impossible and I know it's also impossible for me to understand subsistence in that same dimension.

And then I thought how might in the future there be some small way that resource users could better understand what they mean to different cultures. And in thinking about the Marine Mammal Protection Act, the way it's structured right now, it seems to me that it doesn't facilitate the cross-cultural use of abundant resources. And I realize that probably from one point of view, that is good and from another it is bad. But at the same time, if people from different cultural extractions could co-utilize, in the future, certain resources, we might then better understand the values of those and better develop the coalitions that are needed to implement different policies and different national management schemes.

So I guess I just offer that as a one small place to start would be to, as the Marine Mammal Protection Act is reviewed and revised, for all parties to think better about how abundant marine mammal resources could be utilized by not just one potential user group but by several.

TRACY ANDREWS: Well, it is about five o'clock, our adjournment time. I want to thank all the panel members, not just for being willing to participate, but for the enthusiasm that they brought to these issues and the concern and the commitment to identifying and discussing the problems. We very much appreciate their time.

The doors do not lock here at five o'clock. If you have questions and would like to come up and talk with some of the participants, and if they can stay around, please feel free to do so. Thank you.

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PHYSICAL ENVIRONMENT AND POLLUTANT TRANSPORT

Friday, January 22, 1993

A COUPLED ICE-OCEAN MODEL OF THE BEAUFORT AND CHUKCHI SEAS

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Dr. Kate Hedstrom has worked at Rutgers University for the past 2 years as Computer Services Manager in the Institute of Marine and Coastal Sciences. She learned ocean modeling from Professor Dale Haidvogel while working at the Institute for Naval Oceanography. Dr. Hedstrom received her B.A. in physics from the University of California at San Diego and her Ph.D. in oceanography from Scripps.

We are working on a wind and thermally driven coupled ice-ocean model of the Beaufort and Chukchi Seas. A curvilinear grid for the region of interest has been generated and is shown in Figure 1. This grid has 128 by 128 unevenly spaced nodes and has a grid spacing of 15-20 kilometers over most of the domain, with enhancement by the Alaskan coast. The ocean model also has Lagrangian drifters which trace the path taken by particles released at given locations. These drifters are being used to calculate the probable direction taken by a potential oil spill off the northern coast of Alaska.

The ocean model we are using is the Semi-Spectral Primitive Equation Model (SPEM) described in Haidvogel et al. (1991). The model can be used with a curvilinear, orthogonal grid such as the one shown in Figure 1. SPEM can also be directed to mask out land areas such as Wrangel Island and Alaska. In addition to the grid and mask information, the model must be provided with the bottom depth. We have decided to use a bathymetry which ranges in depth from 50 to 1000 meters with the water below 1000 meters assumed to be at rest. The cross-Arctic boundary is treated as a wall with a specified leakage to compensate for the Bering Strait inflow. This can be changed to an open boundary with a sponge if necessary.

Our strategy is to independently configure the ice and ocean models for the Arctic and to then couple the models. Once the coupled model is working we will execute the production run using thermal forcing and high-resolution winds from 1983. We will spin up the model for four years, reusing the same forcing fields and then run for a fifth year which will be used in the analysis. The velocity fields will be used to advect a large number of surface drifters so that the average drifter behavior can be ascertained.

We have successfully run the ocean model in this domain for two years. We used daily wind and thermal forcing from John Walsh, and a specified inflow of one Sverdrup at the Bering Strait. There was a specified barotropic outflow along the large open boundary to keep the mass balance. After a spin-up period of 90 days, the velocity field from the first year is almost identical to the second year velocity field. Figure 2 shows the velocity vectors at 40 meters depth after one year plus 90 days of simulation. The flow is dynamically consistent with the imposed wind stress forcing. However, in the absence of ice formation, there are some serious problems with this model:

1. The surface temperature reaches -10° Celsius, well below the freezing point of water.

2. Too much momentum is imparted to the oceanic surface layers. In the winter the ice is almost a solid mass and would reduce the wind-stress felt by the ocean.

We have the Owens' version of the Hibler (Hibler 1979) ice model which includes the extra terms for use on a curvilinear grid. This model comes with a one-dimensional mixed layer ocean beneath the ice. We have attempted to run this model in the Arctic domain with limited success. The model fails to converge after some tens of days in a way which seems to be inherent in the physics of the ice model. Carol Pease (personal communication) agrees that the ice rheology in the Hibler model is not appropriate on the spatial scales of the domain we are using, and is working on an ice model with an alternate rheology which may be more successful on our grid.

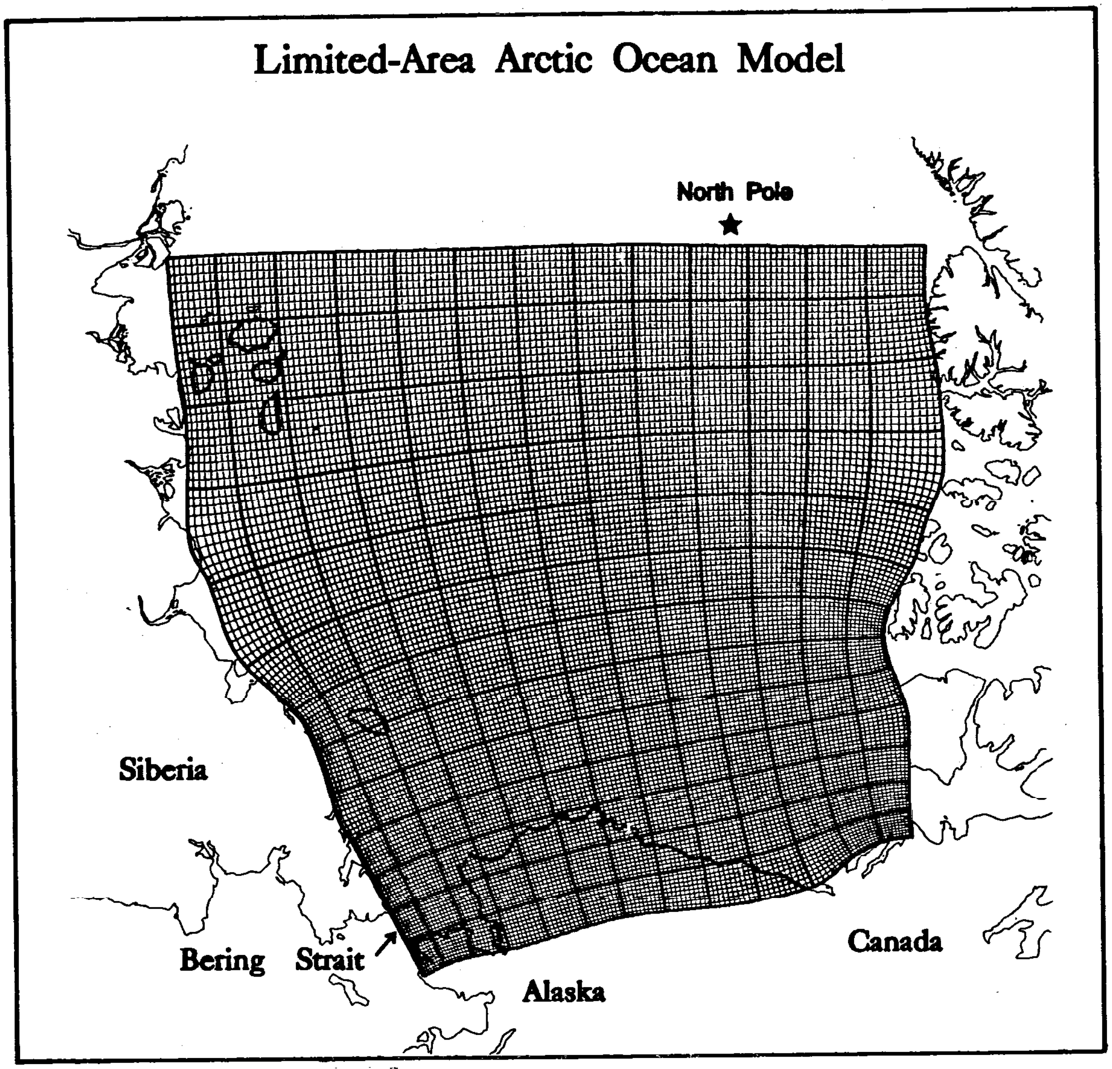

Figure 1. Limited-area Arctic Ocean model.

Once we find an ice model consistent with our needs we will be coupling it to the ocean model. This coupling involves a transfer of momentum and heat. In ice-covered regions there is a flux from the air to the ice to the ocean, while ice-free regions have a flux directly from the air to the water. The heat budget involves the melting and freezing of ice, which in turn alters the surface salinity of the ocean.

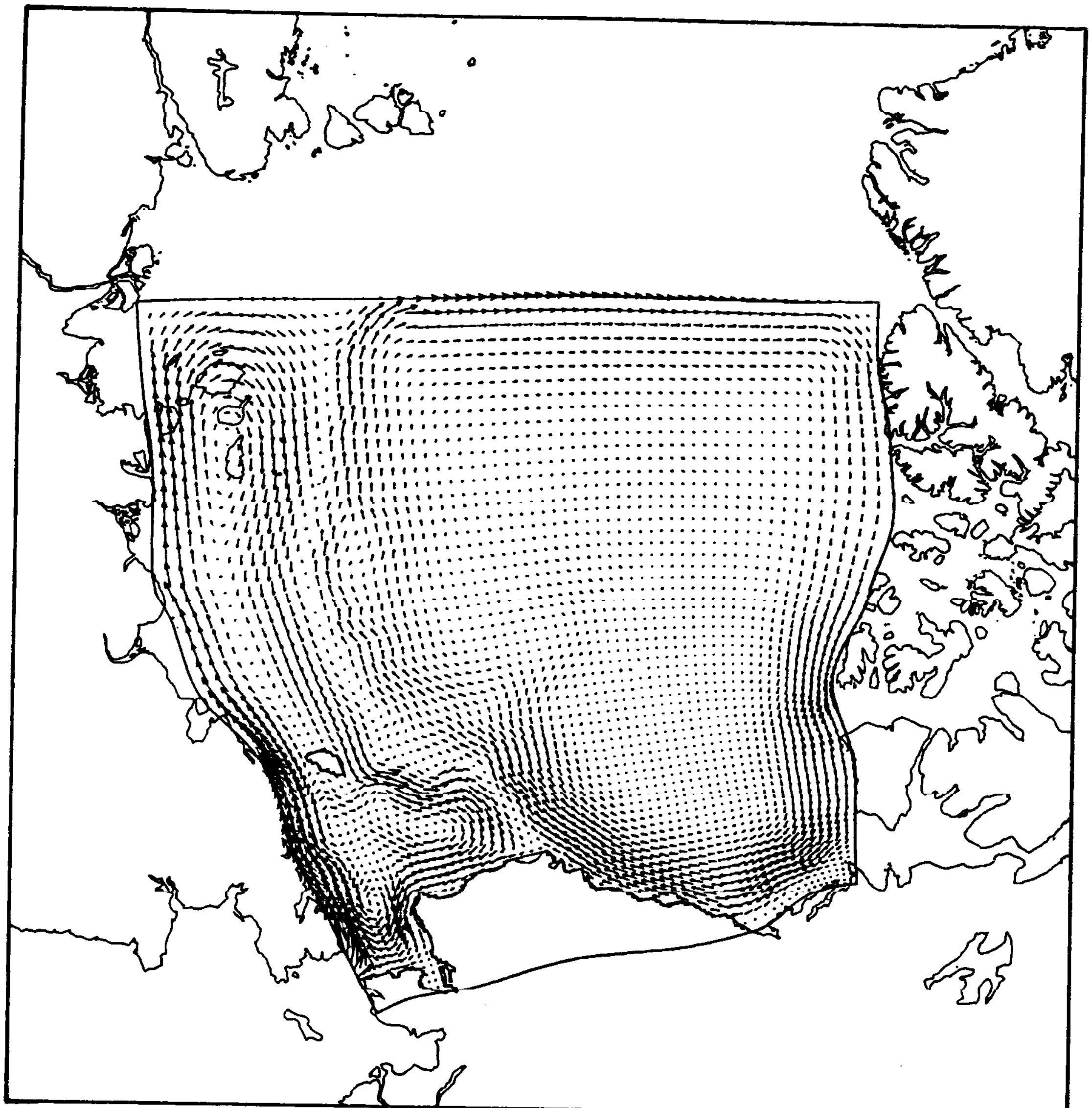

Figure 2. Velocity vectors from April 1 at 40 m.

Once the coupling is complete we will do some parameter studies to find the most realistic solution. The issues which need to be explored include values of viscosity and diffusion, open boundary conditions, and possible nudging towards a climatology. With the best parameters worked out, we will be ready to go ahead with the production run. The results from the production run will be compared with what little data we have for the Arctic in 1983. This includes weekly ice concentration data from the Joint Ice Center and also the trajectories of drifting buoys.

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QUESTIONS AND DISCUSSION

CALEB PUNGOWIYI: I came in late and I missed the first part of your presentation. But in looking at some of your ocean currents and the way that you predict some of the temperatures, etc., and then looking at the ice cover that's near Wrangel Island, and then at open areas over to the east and north of the Russian side, and then at open waters over to the northern coast of Alaska, something does not hit right there. Because, you see, the ice goes all the way down to Wrangel Island and stays there most of the year, and yet the currents are supposedly flowing some other way. So there must be something else that plays into that which keeps the ice within that area instead of moving north like ice in other parts of the Arctic.

And also, from our own traditional knowledge, we know in spring time it moves north. That's because of the vast amount of flow that comes into the Bering Sea from the rivers within the Alaskan and Siberian side. In the fall time, we know that it comes down. There is some flow from the Arctic Ocean into the Bering Sea, perhaps not the amount that is equivalent to the spring flow. But there is at least surface flow from the north side into the Bering Sea from the Arctic Ocean. And that's something that probably should be studied more and documented so that it becomes part of the history, you might say, to the scientific community.

KATE HEDSTROM: You're saying that ice flows this way through this Bering Sea, Bering Strait?

CALEB PUNGOWIYI: In the fall time, late October, early November. And in the old days, before the seasonal warming that we've gone through in the last 30 to 40 years, the multi-year ice also used to flow down into the Bering Sea. We don't see that happening anymore.

KATE HEDSTROM: Well, that will not be covered in the current, MMS-funded project, but perhaps once we get into this expanded domain we'll be able to look and see if we get ice coming through the Bering Strait.

TOM NEWBURY: You mentioned that you were basing your model on 1983. Nineteen eighty three, right along the Beaufort coast, was an unusual ice year. It was a very heavy ice year. That may have been just a local phenomenon, but it also could have been due to a change in the high or low pressure centers, which would influence, I think, your broad scale model.

KATE HEDSTROM: Well, we're using the wind forcing from 1983, which should either provide that forcing that's required, or not. The year 1983 was picked before I became involved with this project and that's just--

DICK PRENTKI: I can help Kate out on that one a little bit. Generally, 1983 was chosen because, for most of Alaska, it appeared to be a very typical year. It's not necessarily typical around Barrow.

OCEANOGRAPHIC EFFECTS OF BEAUFORT SEA CAUSEWAYS

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Dr. Jack Colonell has lived and worked in Alaska since 1976. For most of this time Dr. Colonell's professional endeavors have been focused on the oceanography of coastal and estuarine waters around the state. He has been involved in the assessment of environmental impacts on North Slope oilfield developments, and especially the physical and biological effects of causeways, since 1980. While Dr. Colonell's formal education is in civil engineering (B.S., University of Colorado; M.S., Washington State University; Ph.D., Stanford University), for the past 20 years he has worked primarily as a physical oceanographer, both as an academician and in private practice. Dr. Colonell is currently the manager of the Anchorage office of Woodward-Clyde Consultants.

INTRODUCTION

Two gravel-fill causeways have been constructed into the shallow nearshore Beaufort Sea on the north coast of Alaska for the development of petroleum reservoirs (Figure 1). Not unexpectedly, these long (4-8 km) causeways interact with coastal oceanographic processes and are thus capable of altering local circulation patterns. Resulting changes in distribution of water temperature and salinity concern regulatory agencies because of possibly unfavorable changes to the habitat of anadromous fish that inhabit the coastal waters during the three-month open-water season. Further, the possibility that the causeways might impede the movements of anadromous fish along the Beaufort coast, in combination with presumed habitat alterations, has prompted fear that continued existence of the affected anadromous species is threatened. Causeways are not considered to pose any environmental risk during winter. It is only during the short Arctic summer that the causeways are capable of altering the aquatic environment.

The fish populations of concern include several coregonids (ciscoes and white fish) and a species of char, all of which exhibit a special type of anadromous behavior. Unlike more familiar species such as Pacific salmon, which undertake long ocean migrations and then return to fresh water to spawn and die, these Arctic species migrate from the rivers into the estuarine-like coastal zone each summer for feeding and then return to the rivers to over-winter. Consequently, these fish must obtain most, if not all, of their annual energy requirements during the brief Arctic summer. Two requirements for the survival of these Arctic species provide the basis for concerns about the effects of causeways on their habitat and movements: (1) these fish have only a brief period available for finding food, and (2) they must be able to move freely along the coast to find that food.

West Dock Causeway

West Dock is a multiple-purpose, solid-fill gravel structure located northwest of Prudhoe Bay (Figure 2). The first "leg" of West Dock, constructed in the winter of 1974-75, extends 1200 m north-northeast from the shore to Dockhead 2. In late summer of 1975, supply barges became trapped in ice offshore of Dockhead 2, so emergency permits were granted for construction of the second leg to service the icebound barges. West Dock was thus extended 1600 m north-northwest in early 1976 to Dockhead 3, where the water depth is about 2.2 m. Since its construction, West Dock has served as a landing facility for heavy marine-borne cargo used in support of the development of oilfields in the Prudhoe Bay area.

In the summer of 1981, West Dock was extended another 1520 m, due north from Dockhead 3, to a water depth of 4.3 m. This extension provides all-weather access to a facility that treats and supplies seawater for a secondary oil recovery process known as "waterflooding." The third leg of West Dock, known as the Waterflood Extension, is connected to the original structure just north of Dockhead 3 by a bridge that spans a 15.8 m (50 ft) wide channel, or "breach," the purpose of which is to permit passage of fish through the causeway.

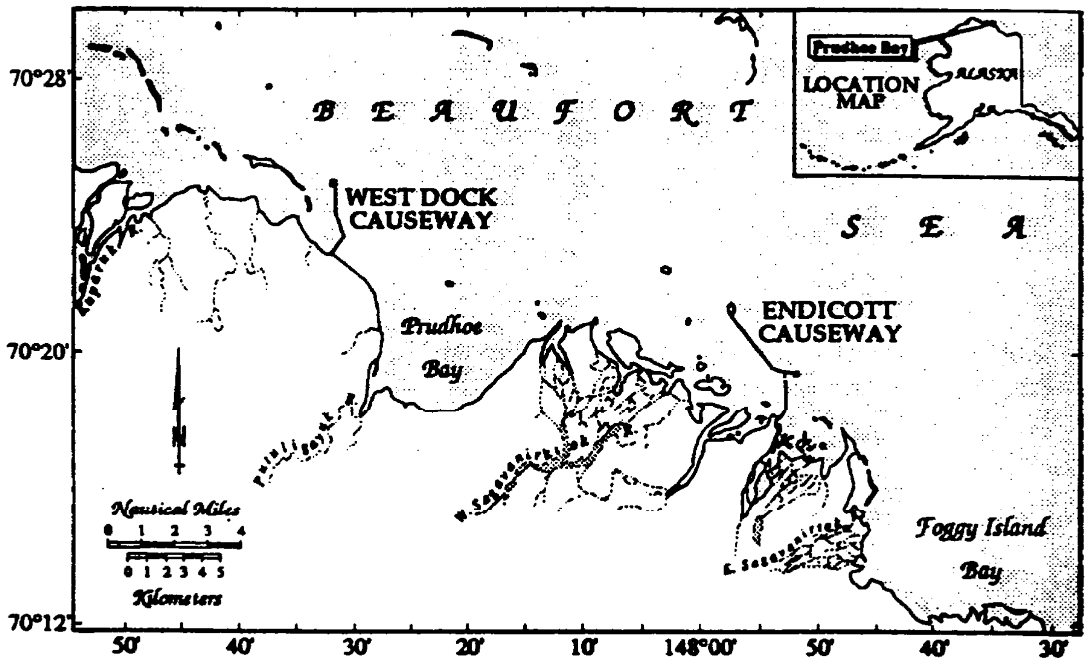

Figure 1. Prudhoe Bay and vicinity, showing locations of West Dock and Endicott causeways.

The Waterflood Project heightened agency concerns over potential impacts to coastal fish, so the construction permit stipulated that a comprehensive monitoring program be conducted. Extensive field studies of oceanographic conditions and anadromous fish use of the coastal zone near West Dock and in the Prudhoe Bay region were conducted annually during the period 1981-84, under auspices of the U.S. Army Corps of Engineers (USACE). The goals of these studies were (1) to evaluate the predictions of the Waterflood Project Environmental Impact Statement (USACE 1980) and (2) to determine the actual environmental effects of the causeway extension.

Endicott Causeway

The Endicott Development Project is an offshore facility for recovery of petroleum in the nearshore Beaufort Sea east of Prudhoe Bay. Constructed in 1985-86, the Endicott project includes two gravel drilling islands (Main Production Island [MPI] and a Satellite Drilling Island [SDI]), located seaward of the Sagavanirktok River delta just beyond the 2 m isobath (Figure 3). The MPI and SDI are connected by a gravel-fill inter-island causeway; a shore-access causeway connects the latter to the mainland. The shore-access causeway contains two breaches for fish passage: a 152 m (500 ft) breach nearshore and a 61 m (200 ft) breach near the intersection of the inter-island and shore-access causeways. The causeway system has a total length of about 8 km (5 mi).

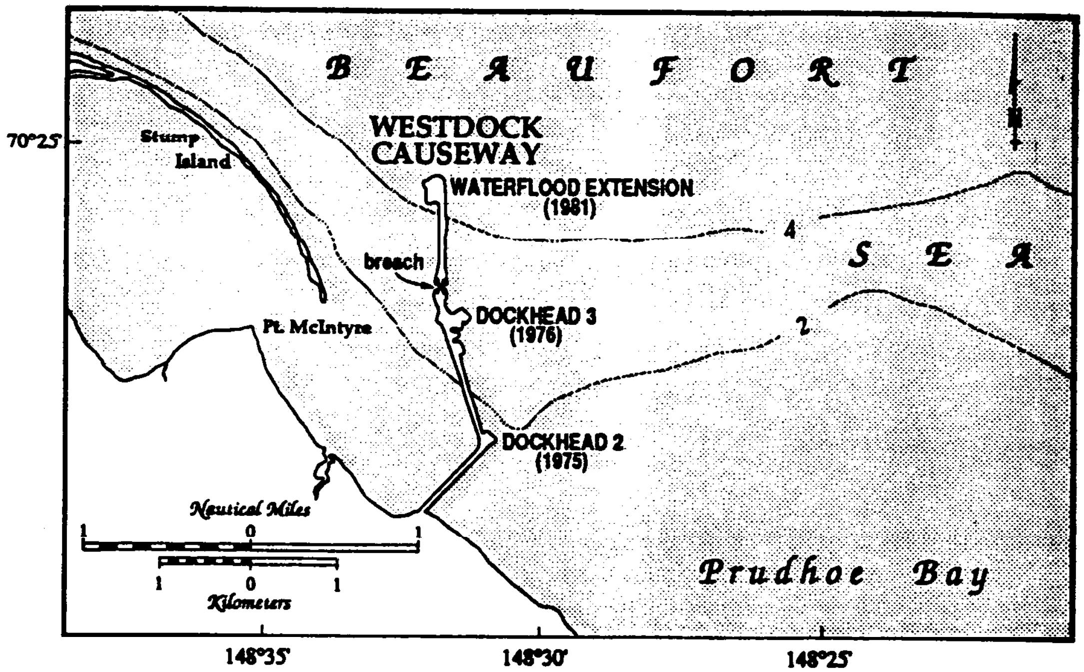

Figure 2. West Dock causeway, showing sequential extensions (depths in meters).

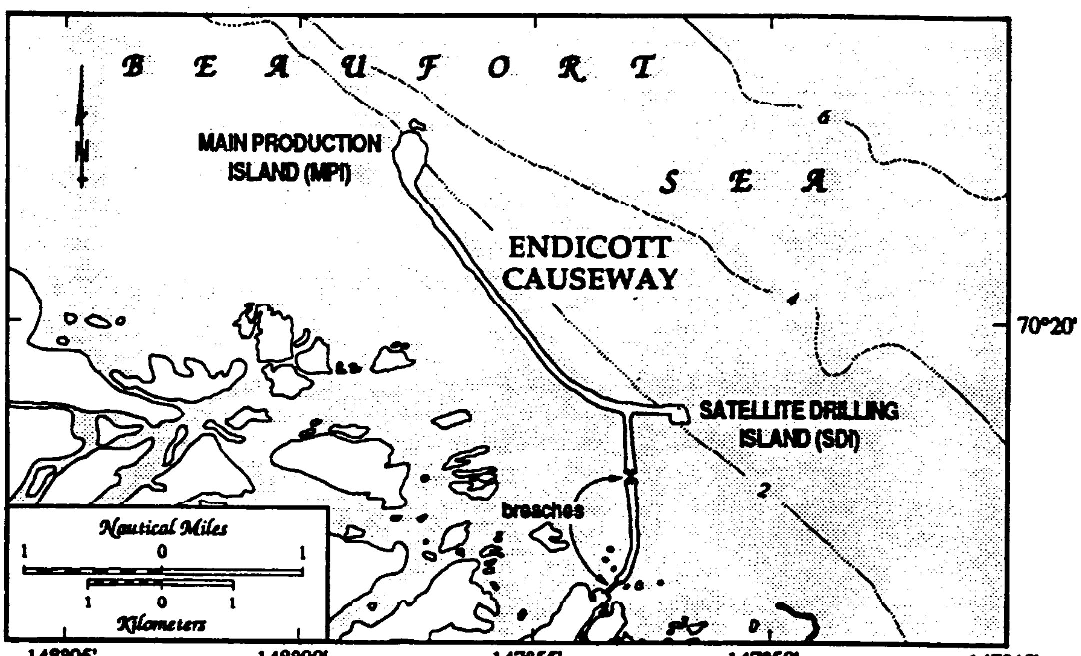

Figure 3. Endicott causeway (depths in meters).

Considerable controversy ensued as a result of the permitting and construction of the Endicott Development, due to lack of agreement over the Environmental Impact Statement (EIS) conclusions (USACE 1984). As a result, the USACE stipulated one of the largest environmental monitoring programs ever undertaken in North America. The marine components of this program, which began in 1985, included monitoring fish movements and oceanographic conditions along more than 40 km (25 mi) of the Beaufort Sea coastline. The stated objectives of these studies were (1) to "validate" the EIS predictions, (2) to document the actual environmental effects of the project, and (3) to evaluate effectiveness of the breaches.

During 1985-1987, a joint oceanographic and fish monitoring program was conducted under the auspices of the USACE. In March 1988, the USACE discontinued the fish study component, after three years of the planned seven-year study. The USACE's rationale for this action was that significant impacts to anadromous fish habitat had been identified and that mitigation of those effects was required. However, there was no consensus among resource agencies concerning the USACE's interpretation of the monitoring results to that date. The operator of the Endicott Development, BP Exploration (Alaska) Inc., elected to continue the anadromous fish studies, in part, because the North Slope Borough (NSB) permit for the project contains a fish monitoring requirement that would not be met in the absence of the USACE program.

During 1988-1990, separate oceanographic and fish monitoring programs were conducted for the USACE and NSB, respectively. The USACE oceanography program continued along the lines established by the 1985-1987 program. The NSB fish monitoring program of 1988-1990 established a fish sampling and experimental program designed to address specific questions needing resolution. The NSB impaneled an independent Science Advisory Committee to review and provide guidance to the program. Major emphasis was placed upon preparing technical papers on key questions for publication in refereed journals. In this way, a synthesis of various elements of research efforts could be based upon peer-reviewed literature. Since many of these questions were of an oceanographic nature, the fish monitoring program also included oceanographic analyses and assessments (separate from the USACE program) using available data. Both fish and oceanographic monitoring have continued in response to requirements of the NSB permit for the Endicott Development project.

These environmental monitoring programs, and others conducted over the past 17 years, have produced an unprecedented quantity of data with which to address environmental concerns. This paper focuses on conclusions reached with regard to physical oceanographic effects of the causeways and draws upon analyses presented in many summary reports and papers (e.g., Niedoroda and Colonell 1989; Colonell and Gallaway 1990; Niedoroda and Colonell 1990; Gallaway et al. 1991; Hachmeister et al. 1991).

THE SUMMER ARCTIC MARINE ENVIRONMENT

In summer the Beaufort coast enjoys nearly four months of continuous daylight, during which the sun does not set for 75 days and air temperatures occasionally exceed 70°F. During a few weeks in late May to early June, the rivers discharge their spring runoff and sediment load over the shorefast ice. The flood of fresh water brings sediments, nutrients, and terrigenic debris to the nearshore marine environment. By mid-July, the nearshore zone is usually ice-free, so the ocean is open from the shore to the edge of the pack ice. The boundary between open water and the permanent pack ice is indistinct, and is composed of scattered ice floes and breaks ("leads") in the ice. The pack ice occasionally retreats as far as 100 km offshore but, in some years, it will press its ragged edge close to shore for much of the "ice-free season," thereby restricting coastal navigation.

The peak discharge period for most rivers is short and occurs in late May to early June. Consequently, the salinity of nearshore waters increases gradually through the summer as river flow decreases. Frequent wind reversals drive cold marine water into and out of those coastal areas that are washed by the relatively warm and brackish waters of a nearby river, thus causing large fluctuations of salinity and temperature.

REGIONAL OCEANOGRAPHY

The nearshore area is within the "coastal boundary layer" (CBL), which is so named because of the profound influence of the shoreline on water mass dynamics (Csanady 1982). Along the Alaskan Beaufort Sea coast, the gentle seabed slope and the relatively large Coriolis acceleration serve to amplify CBL processes beyond what is familiar in lower latitudes. Niedoroda and Colonell (1989) presented scale arguments, based on dimensionless Ekman number and available hydrographic data, to show that the inner, friction-dominated portion of the CBL extends only to depths of 4-5 m. Within this inner zone, the effects of friction greatly exceed those of Coriolis acceleration (i.e., earth-rotation) and surface transport is aligned with the wind-stress direction. Further seaward, Coriolis effects become progressively more important in determining the response of water masses to wind stress and horizontal pressure gradients. The demarcation between the inner (friction-dominated) and outer (geostrophic) zones of the CBL, which occurs in water depths of only 4-7 m, is actually an indistinct transition where, under easterly winds, the *divergence* of shore-normal surface transport produces local *upwelling*. Conversely, under westerly winds, the *convergence* of shore-normal surface transport produces local *downwelling*.

These CBL processes occur on a regional scale, so they have important implications to the general circulation and distribution of water masses in the coastal Beaufort Sea. The scale, magnitude, and development rate of these upwelling/downwelling processes are controlled by the wind speed, wind direction (relative to the shoreline), and wind duration, as well as the water depth and thicknesses and densities of the water mass layers (Niedoroda and Colonell 1990). Coastal topographic features with length scales of 5-10 km (e.g., promontories, barrier islands, and causeways) are small relative to the length scales associated with CBL processes (> 100 km), and are thus unable to alter the regional dynamical oceanography.

Salinity and temperature in the nearshore zone are quite variable because the system responds rapidly to changes in wind speed and direction, and because large volumes of relatively warm and fresh water are contributed by the coastal rivers. Indeed, this *natural* variability is the main reason why oceanographic effects of the causeways have been difficult to determine. The fluctuations of nearshore temperatures and salinities are strongly linked to regional wind-driven upwelling and downwelling as well as changes in the discharge of coastal rivers. As the open-water season progresses, coastal waters become colder and saltier as solar heating and freshwater input both diminish. The season ends with the formation of a continuous ice sheet over the ocean surface in late September or early October.

CAUSEWAYS AND COASTAL OCEAN DYNAMICS

West Dock Causeway

For much of the summer, the waters in and around Prudhoe Bay are brackish (salinity <15 ppt), due to the large freshwater input of the Sagavanirktok River. Summer winds along this portion of the Beaufort coast are nearly always alongshore, with easterlies being about twice as frequent as westerlies. Regional oceanographic processes driven by easterly winds are effective in displacing higher salinity "bottom" water shoreward, a process referred to earlier as *upwelling*. Under easterly winds, West Dock is a barrier to the brackish longshore flow such that, by deflecting this flow, it creates an offshore-directed, low-salinity surface plume. Simultaneously, an eddy forms on the west (lee) side of the causeway.

Under these conditions, upwelled marine water appears as a thin (<1 m) bottom layer of high-salinity (>30 ppt) water in depths as shallow as 3-4 m. Since West Dock terminates in a water depth of 4.3 m, the eddy on its lee side intercepts the layer of marine water. The secondary (vertical) flow within the eddy then mixes the bottom water upward into the water column to form a "pool" of higher salinity water on the west side of the causeway. When the water column is stratified prior to the onset of westerly winds, a less extreme but similar condition occurs on the east side of West Dock.

Endicott Causeway

The effects of the Endicott causeway differ from those of West Dock because it is larger, of different shape, and located adjacent to different coastal features. The shore-access leg of the Endicott causeway divides nearly equally the discharge of the Sagavanirktok River. This reduces effects of the causeway because nearshore currents are mostly shore-parallel so half of the river discharge is always directly available for mixing into the nearshore water mass. The other half of the river discharge disperses in different ways, depending on the river flow and the wind. During low river flows, which are typical for most of the summer, mixing with coastal waters begins within, or at the mouths of, the river distributaries. The breaches in the mainland leg are effective in conducting much of the fresh to brackish flow to the downwind side.

During high-discharge events, which result from heavy rains in the foothills of the Brooks Range to the south, the river virtually overwhelms the nearshore marine water and displaces it seaward as much as 2 km. When this coincides with west winds, the river discharge turns to its right and flows eastward close to the shoreline. Some discharge from the west side flows around the seaward side of the causeway to the SDI, where it rejoins the nearshore flow. When a river discharge is deflected to its right in the northern hemisphere by the overall balance of forces, it is stable. Horizontal forces are balanced across the interface between the plume and the adjacent marine water; that is, the Coriolis acceleration and wind stress are in stable dynamic equilibrium. The plume is then held against the shoreline as it moves down-coast and mixes with the coastal water mass (Chao 1988).

When high river discharge occurs under east winds, the dynamical balance is not stable. Gravitational and Coriolis effects tend to propel the river discharge offshore and to its right. In shallow water, before the river water overflows marine water, the wind drives the flow westward toward Prudhoe Bay. The wind also drives the general nearshore ocean flow westward and this also serves to deflect the plume to its left.

Hydrographic data, satellite images, and analyses of plume dynamics show that the river water that ponds on the extensive shallow region in front of the delta during high-discharge events interacts with the marine water in two ways under east winds. A major part of the discharge flows westward toward Prudhoe Bay. At the same time, a strong front forms along the northern and eastern margin of the ponded river discharge. Gravitational flow occasionally drives some of the river water across this front as a thin (<1 m) and relatively narrow (<2 km) plume, separated by a strong density gradient from the underlying marine water. The strong density interface sharply reduces frictional coupling with the underlying flow. This combines with gravitational flow, the surrounding baroclinic pressure field, and possibly stratification-limited Ekman-layer wind-driven effects (Csanady 1982) to carry this plume several kilometers offshore. From this point, it curves generally westward, thickens, and eventually becomes entrained in the brackish nearshore flow. This feature was observed both before *and* after the causeway was constructed (Niedoroda and Colonell 1990).

During persistent easterly winds, a surface "pool" of high-salinity (>25 ppt) water has been observed to occur in the lee of the MPI (Figure 4). As this can be the result only of a secondary (vertical) flow phenomenon, it is reasonable to conclude that a local-scale hydrodynamic feature such as a wake-eddy is responsible. However, just as at West Dock, the surface expression of high-salinity bottom water will not occur unless the *regional* upwelling is developed to the extent that marine bottom water reaches the causeway.

CONCLUSIONS

Oceanographic effects of the causeways can be categorized as either *hydrodynamic* or *hydrographic*, where the former term refers to alterations of water motions such as waves, tides, surges, and currents, and the latter term refers to alterations of the distribution of water mass properties such as temperature and salinity. In the highly variable oceanographic climate of the nearshore Beaufort Sea, it is difficult to obtain data sets that delineate clearly the spatial and temporal extents of these effects. However, applications of coastal boundary layer theory and fluid mechanics principles, in conjunction with the available data, have enabled evaluations of oceanographic perturbations which can be attributed to the causeways.

Hydrodynamic Effects

- Regional processes are not affected by causeways.
- Some nearshore circulation patterns have been altered significantly, but only in immediate vicinity of causeways.

Hydrographic Effects

- Nearshore circulation alterations can result in occasionally significant redistributions of water properties such as temperature and salinity.
- Vertical flows associated with wake effects (flow separation and eddies), in conjunction with regional upwelling events, serve to create "pools" of colder, saltier water in lee of causeways.
- Small but detectable alterations of temperature and salinity patterns are observable at significant distances from the causeways.

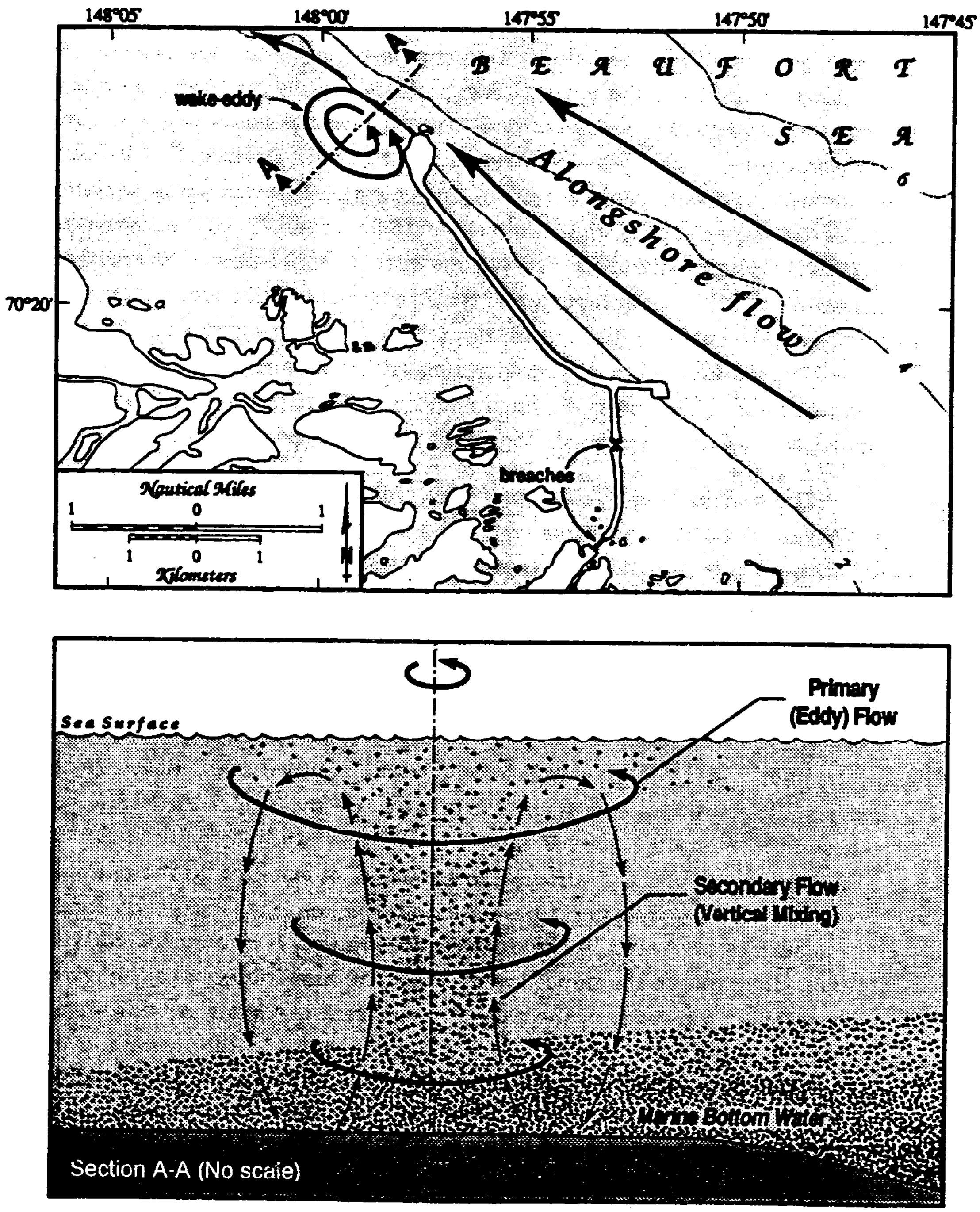

Figure 4. Schematic diagram of wake-eddy flow near MPI: Plan view (upper panel) and cross-section (lower panel).

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BENTHOS-ENVIRONMENTAL INTERACTIONS IN THE NORTHEASTERN CHUKCHI SEA

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Dr. Sathy Naidu has been a Professor in the Institute of Marine Science at the University of Alaska for the past 25 years. His areas of research interest are sedimentary and geochemical processes, and sediment-benthos interactions in the arctic. Dr. Naidu received his M.S. and Ph.D. in geology from the Andhra University, India.

In the northeastern Chukchi Sea most of the locally produced and advected particulate organic carbon (POC) is not consumed in the water column, because of the paucity of pelagic grazers. The POC, which eventually settles to the bottom, is then utilized by benthic organisms. Consequently, a predominantly benthic system has evolved in the northeastern Chukchi Sea. The results of a Minerals Management Service/National Oceanic and Atmospheric Administration funded investigation of the northeastern Chukchi Sea benthic system (Feder et al. 1989) are summarized here.

Multivariate analyses of benthic macrofaunal abundance data from 37 stations (Figure 1) delineated four cluster (station) groups (Figure 2). The most abundant organisms present in Group I were ampeliscid amphipods and juvenile barnacles; in Group II, the polychaete worm *Maldane glebifex* and small clam *Nucula tenuis*; in Group III, juvenile and adult barnacles and amphipods; and in Group IV, the sand dollar *Echinarachnius parma*. Stepwise multiple discriminant analysis indicates that the station groups are related to sediment type and substrate water content. This is best depicted in a ternary diagram (Figure 3). The relationships shown in this diagram are consistent with the known habitat requirements of the taxa within the station groups. For example, the predominance of the two subsurface deposit-feeding taxa, the tube-dwelling polychaete *M. sarsi* and the clam *N. tenuis*, in the highly fluidized mud within the region of offshore Group II, and the association inshore of adult suspension-feeding barnacles with the gravelly-sand of Group III. Additionally, taxa within offshore Groups I and II were associated with a water mass of high salinity ($\geq$32.5%) and low temperature ($\leq$4°), whereas taxa of inshore Groups III and IV were associated with relatively low salinity (<32.5%) and high temperature (>4°) water.

A broad delineation in the grouping between offshore subsurface deposit and inshore suspension-feeding taxa is consistent with the association of muddy substrate offshore and the high amount of suspended POC inshore. Faunal diversity between inshore and offshore regions were unrelated to sediment sorting, in contrast with the benthos in the northeastern Bering and southeastern Chukchi Seas. Regional differences in benthic diversity within the northeastern Chukchi Sea are related to greater environmental stresses (e.g., ice gouging, wave-current actions) inshore than offshore.

The shelf area north of 70°N latitude, which is characterized by a relatively low primary productivity, is characterized by high benthic biomass (Figure 4), with abundant populations of polychaete worms and amphipods inshore and clams offshore contributing to this high biomass. The presence of the high biomass is related to enhanced local flux of POC derived from the northern Bering and southern Chukchi Seas, which provides a persistent source of carbon to the benthos (Figures 5 and 6). That POC enrichment of the bottom in the high biomass region adjacent to Point Franklin must, in fact, persist on a long-term basis, is consistent with the continued return in summer of gray whales (Moore and Clarke 1986; Clarke et al. 1987), which feed primarily on amphipods (Nerini 1984; Highsmith and Coyle 1992), and walrus (Fay 1982; Phillips and Colgan 1987; J. Burns person. commun.). This study, therefore, demonstrates that there can be high standing stocks of benthos in arctic regions with low primary production if local carbon can be augmented by POC advected there from a highly productive area.

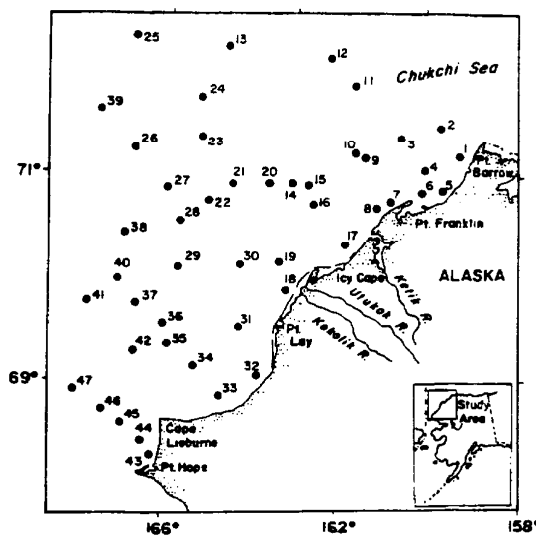

Figure 1. Map of northeastern Chukchi Sea showing locations where geological and benthic samples were collected.

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QUESTIONS AND DISCUSSION

CALEB PUNGOWIYI: Have you done any studies on these suspension feeders as to whether they are accumulating any toxins or pollutants or heavy metals because of the possible introduction of these from the different currents that might be transporting them?

SATHY NAIDU: Not in the Chukchi Sea. We have some projects in mind to initiate very soon.

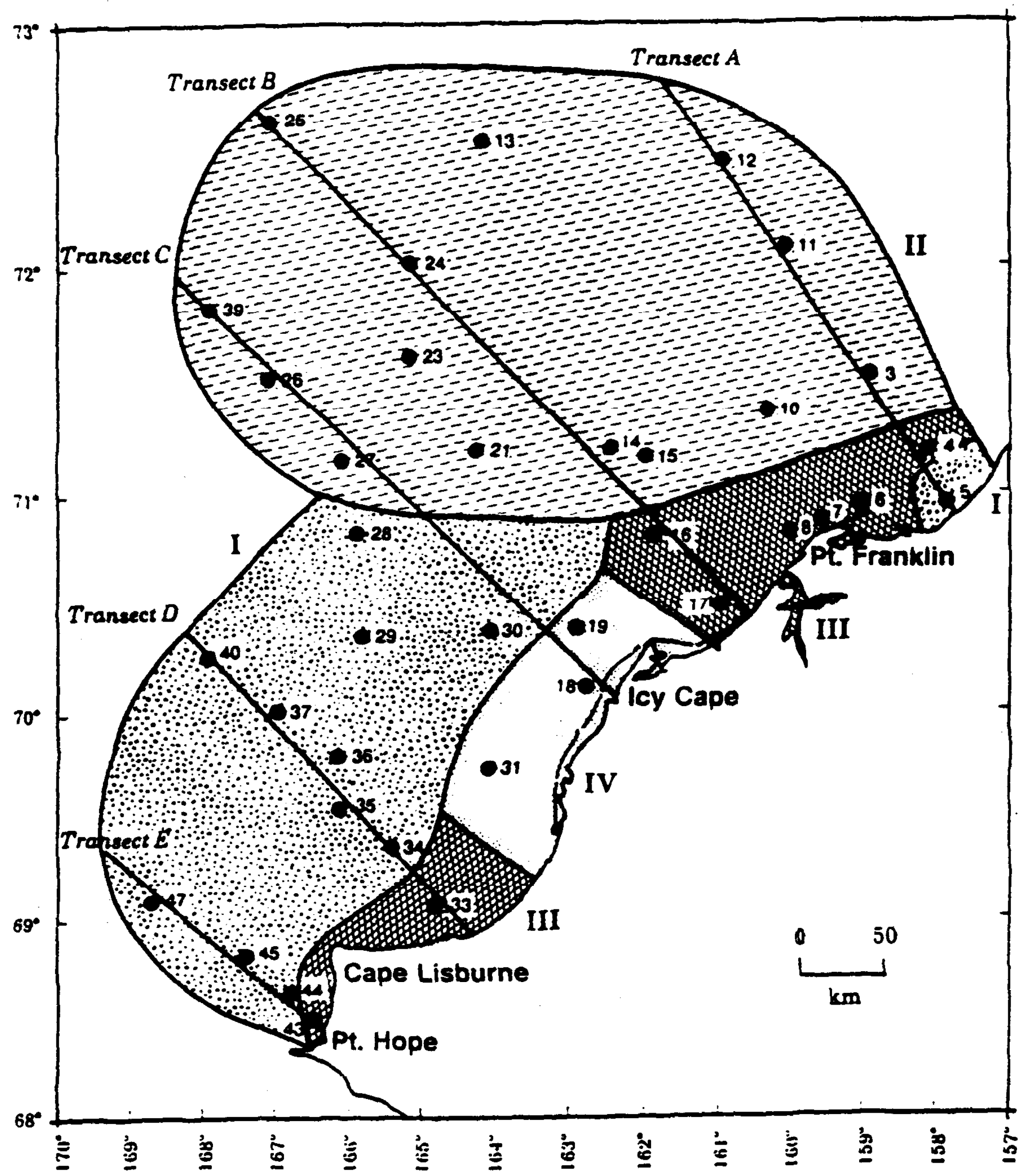

Figure 2. Distribution of the four benthic macrofaunal station groups in northeastern Chukchi Sea.

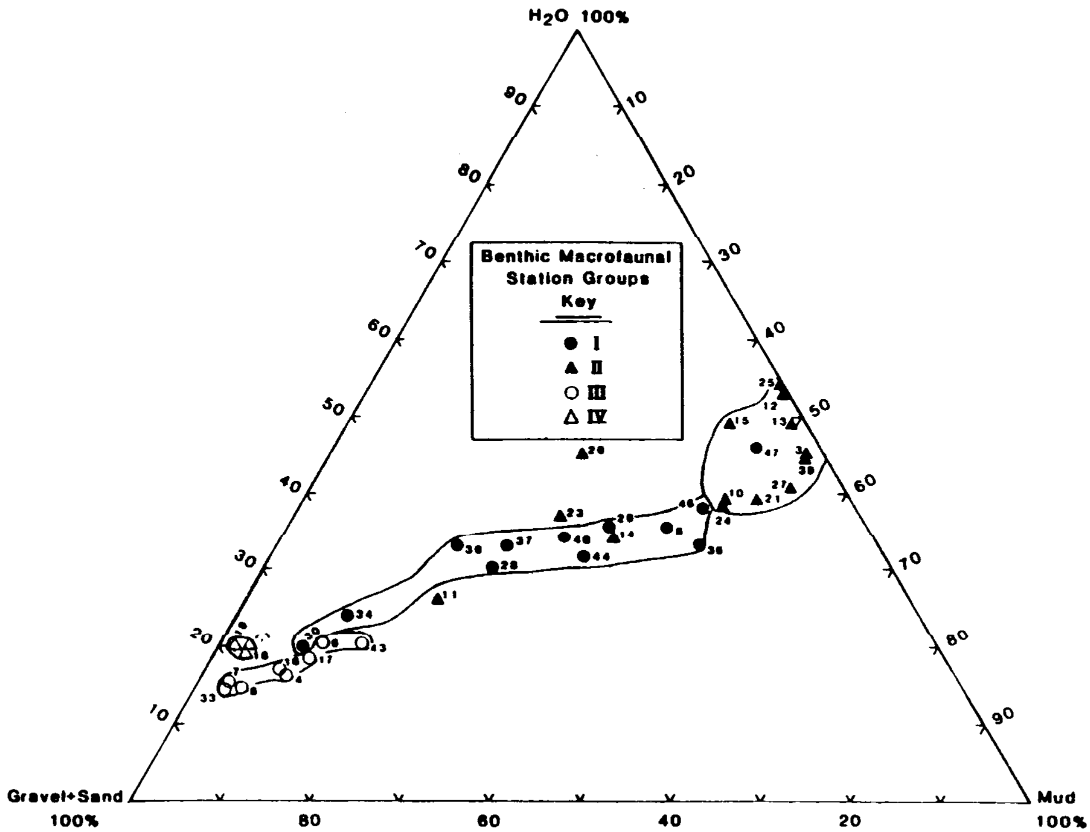

Figure 3. Ternary diagram relating stations to stations to station groups based on % water, gravel + sand, and mud in sediments.

CALEB PUNGOWIYI: In the presentation yesterday, different nitrate and chlorophyll levels in the Alaskan Current and Anadyr Current waters were described. Will there be some studies on the Anadyr Current as to the differences in the biomass that exists on the other side of the Chukchi Sea versus the Alaska side?

SATHY NAIDU: Tom Weingartner will speak on that later.

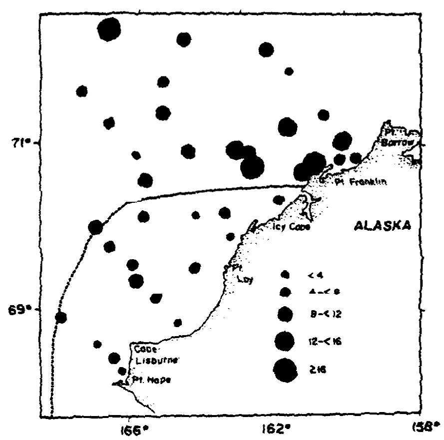

Figure 4. Distribution of benthic biomass (gC/m) in the northeastern Chukchi Sea. The frontal zone presumably separates the mixed Bering Shelf/Anadyr Water in the north and the Alaska Coastal Water in the south.

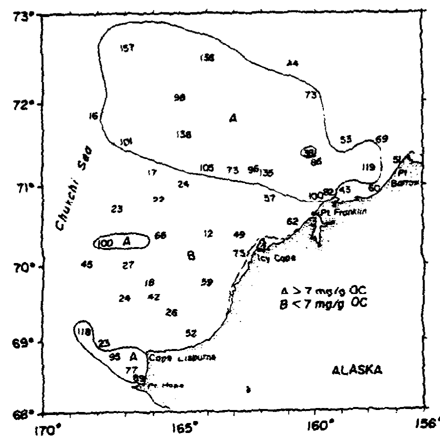

Figure 5. Organic carbon (mg/g x 10^{-1}) in surficial bottom sediments in the northeastern Chukchi Sea.

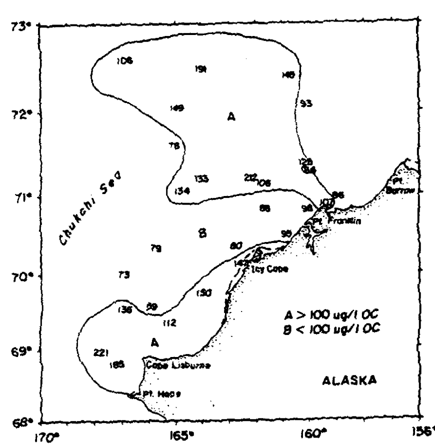

Figure 6. Organic carbon (µg/L) in suspended particles of near-bottom waters in the northeastern Chukchi Sea.

RESULTS FROM OIL-SPILL RESPONSE RESEARCH 1991-1992

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Edward Tennyson serves as the Program Manager for Oil Spill Response Research with the Technology Assessment and Research Branch of the Minerals Management Service (MMS). He holds an M.S. in marine biology and has completed additional graduate studies in oceanography. He is credited with being the chief architect of the MMS research program to increase response capabilities for marine oil spills. This program has made significant contributions to nonconventional response strategies including in situ burning, chemical treating agents and increased understanding of the fate of spilled oil in the marine environment. He recently received the Meritorious Service Award from the Department of the Interior for his efforts. He holds a patent for original research and is widely published.

INTRODUCTION

The Minerals Management Service (MMS) has made significant advances in oil spill response research, as a part of its programs during the past two years. This report has been prepared in an ongoing effort to keep responders and decision-makers informed on our recent findings. Results of the specific project areas are presented individually. Because of the broad scope of the MMS funded cooperative program on oil spill response research, only summary information is presented. In-depth descriptions of any of these project areas would exceed the guidelines of this publication. The reader is encouraged to seek additional information in the cited literature.

IN SITU BURNING

Research, funded by the MMS on *in situ* burning of spilled oil began in 1983 to determine the limitations of this innovative response strategy. Specific physical variables evaluated were slick thickness, degree of weathering (sparging), sea state, wind velocities, air and water temperatures, degrees of emulsification and degree of ice-coverage. All of the oils tested burned with 50-95% removal ratios as long as emulsification had not occurred. Slick thickness of 3 mm or thicker was required to sustain ignition, and extinguishment occurred when the slick reached approximately 1 mm thick.

The next phase of the research involved quantitative analysis of the pollutants created by *in situ* burning, including chemical composition of the parent oil, burn residue, and airborne constituents. The National Institute of Standards and Technology (NIST) conducted these studies with emphasis on particulate and gaseous components created by the burning process. Research efforts with a variety of crude oils over several years yielded data that indicated that aldehydes, keytones, dioxans, furans, and polyaromatic compounds (PAHs) were not formed in the burning process. The airborne pollutants reflected similar concentrations of these compounds that were present in the parent oil. Lighter molecular weight PAHs tended to be converted to higher molecular weight compounds. Predominant burn products released into the air were by weight: 75% carbon dioxide, 12% water vapor, 10% soot, 3% carbon monoxide, and 0.2% other products including those listed above. The residue was composed of the higher molecular weight compounds in the parent oil with minimal concentrations of the lighter molecular weight compounds present. These lighter weight compounds in the unburned oil are the major reason for the acute toxicity of spilled hydrocarbons. The burn residue tended to be consistently weathered throughout and did not contain relatively fresh oil in the center and weathered oil coverings, as typically found in naturally weathered tar balls.

Concern for the behavior of the airborne products of *in situ* burning resulted in an extensive effort to develop a model to predict the concentrations of pollutants including depositional patterns on the earth's surface. This sophisticated model is nearing completion at NIST. Verification of model using full-scale *in situ* burns (approximately 25,000 gallons) is required.

The third phase of research involved evaluation of the effects of scaling upon the extensive results obtained in the laboratory. In 1991, 14 mesoscale experiments were conducted to measure the burning characteristics of crude oil on salt water. These burns took place in a fire pit at the U.S. Coast Guard's (USCG) Fire and Safety Test Detachment in Mobile, Alabama. Fire sizes ranged from 5 meters square to 15 meters square with burn volumes ranging from 343 to 3,720 gallons. The amount of oil removed from the water surface in these experiments typically ranged from 90-99% with one burn yielding 75% removal for unknown reasons. The smoke plume was extensively sampled with emphasis on burn rate, radiation, and concentrations and behavior of particulate and gaseous burn products. Burns lasted from 5 to 25 minutes and the most usual burning time was 16 minutes. The burning rates indicated by the regression rate of the oil surface was 0.55^{+} 0.01 mm/sec. for pan fires with a diameter of 7 meters. Smoke particulate generation from fires larger than2 meters in diameter was approximately 13% of the oil burned on a mass basis (Evans et al. 1992). These rates of removal are significantly higher that those of conventional oil spill response strategies. Data from the mesoscale tests confirmed laboratory results. The effect of scaling from the laboratory to the 15 meter square fire has been quantified by investigation of the behavior of the plume resulting from mesoscale experiments.

Additional mesoscale investigations on burning a wide range of crude oils, refined products, and emulsions are needed. There is a critical need for comparisons of air quality impacts of spilled oil under the burn and no burn scenarios. These studies were initiated, at mesoscale, in the fall of 1992.

Acceptance of *in situ* burning as primary spill response technique will require full-scale field verification on the open ocean. The MMS, USCG, and private industry are attempting to obtain permits to conduct a series of intentional releases of oil at specific sites to conduct this full-scale field verification of *in situ* burning. The location and timing of the proposed efforts are being coordinated with state and local entities to minimize the potential impacts of these efforts on sensitive resources.

Field verification is necessary to quantify the effects of scaling on health and safety issues pertinent to the responder and nearby populace as well as to confirm the behavior model of the airborne plume at full scale. A series of burns of similar field scale (approximately 25,000 gal.) is needed.

Research indicates that burning of spilled oil offers removal rates significantly above those of conventional booms and skimmers. Preliminary data indicate that air quality impacts of burning compare favorably with the natural evaporation of the more toxic lighter molecular weight compounds that normally occur in the vicinity of a spill. Data from mesoscale experiments indicate that burn components reach levels which are considered safe within several kilometers of the burn site. The ultimate depositional concentrations of particulates and associated pollutants are several orders of magnitude below acutely toxic levels. These results must be verified in the field at full-scale.

AIRBORNE OIL THICKNESS SENSOR

A critical gap in responding to major oil spills is our present lack of capability to measure and map the thickness of oil on the water surface accurately. The MMS began in 1986, with

Environment Canada (EC) and Esso Resources Ltd. Canada, to evaluate the use of various sensors to produce dependable and repeatable signals indicating the presence and thickness of spilled oil on the surface of the water. Infrared and active microwave were judged to be inadequate. Passive microwave and laser thermal showed that only slight improvements in existing capabilities would be possible. Only the laser acoustic technology was considered worth pursuing with limited budgets.

The system designed as part of this study uses two lasers. The first stimulates a thermal pulse on the oil surface, imparting a series of sound waves that are reflected by the oil-water interface. The second laser detects the sound waves on the oil surface. The thickness of the oil is indicated by the time required for travel from the surface of the oil to the oil-water interface and back. Time of travel does not vary significantly with oil type. A slick thickness of one millimeter gives a delay of 1 to 4 microseconds. This delay should allow the sensor to discriminate all thicknesses of oil that are meaningful to the responder.

A system of three lasers is required for aircraft application to ensure that the water surface is planar to the instrument. The first low power laser is used to determine the reflection of the laser back to the aircraft. This triggering laser measures the time when maximum signal-to-noise ratio can be achieved and fires the thermal pulse laser. Then the laser to measure the acoustic impulse in the oil is triggered. An engineering breadboard has been fabricated for aircraft application, and the triggering laser has been successfully tested from aircraft during the spring and summer of 1992. Full system testing is expected in the fall of 1992. Laboratory evaluation has determined the present system to have a maximum altitude limitation of 60 meters because of the CO_2 laser capability. This laser operates at 10.6 microns wavelength in the thermal infrared range (Fingas, 1991a).

LASER FLUOROSENSOR

The laser fluorosensor project began in 1985, under joint funding with EC, the American Petroleum Institute (API) and the USCG. The project has developed a 64-channel airborne laser fluorosensor to detect oil on water, ice, and the shoreline and to eliminate false targets, which are a major problem with existing technologies. The sensor engineering breadboard was made flight compatible in 1991 and was flown over industrial areas during the spring of 1992 (Dick and Fingas 1992). This active system has been developed to give day-night capabilities. However, significant atmospheric moisture between the sensor and the target significantly reduces the system's capability. The system also is also expected to have limited capabilities to detect submerged oils.

This system is self-contained with a XeCl eximer laser, a 64-spectral-channel range gated receiver, and a data logger and requires one trained operator. The package was designed to be compatible with smaller aircraft possessing a standard 10-inch camera hatch. The Laser Environmental Airborne Fluorosensor (LEAF) design is based upon experience of over 20,000 line- kilometers of oil exploration flight with an earlier commercial unit.

The LEAF was installed in a twin-engine Aero-Commander aircraft and tested during flights over Lakes Ontario and Erie in late 1991 and early 1992. In 1992 the system flew over contaminated and clean water ponds at the Nanticoke refinery on Lake Erie and at an area specifically constructed near Ottawa, Ontario. A total of 33 flights were flown over holding ponds filled with clean and oiled water. Of these flights, 22 were flown over one test area and 15 covered all test locations. The Ottawa site contained a series of 20x50 or 40x50 foot ponds separated by berms. The smaller ponds contained water, broken ice, gravel, gambion rock, and sand. These materials were coated with Alberta Sweet Mixed Blend (ASMB) crude oil. The larger ponds contained the same materials without the oil. Surface samples of the materials in the ponds provided ground truth.

The LEAF flights over the oil-contaminated ponds at the Nanticoke refinery yielded distinct, reproducible signatures from the fresh floating oil, the aged material along the shore of the pond, nearby roadway, the clean snow and ice on adjacent ponds.

Results from the Ottawa flights yielded clear, reproducible signals for each of the materials in both their clean and contaminated forms. The ASMB crude was used to treat the materials in contaminated tanks at an average rate of 320 ml/m² for a target oil thickness of 0.3 mm; however, oil thickness varied greatly with the different types of materials. For clean materials, the fluorescence was 10 to 30 times weaker than the contaminated materials. For contaminated materials, the fluorescence was sufficiently different between fresh and weathered oils to be readily detected by the sensor package.

The next phase of this project is to develop a scanning capability 15° from perpendicular and improve data logging, manipulation, and display capabilities. This effort was begun in the summer of 1992.

CHEMICAL TREATING AGENT DEVELOPMENT AND TESTING

The MMS initiated a major cooperative project with EC in 1986 to address five areas including the study of dispersant action mechanisms; development of a laboratory test procedure, which would yield reproducible results, for evaluating the effectiveness of dispersants; investigations into new, more effective dispersant formulations; development of test protocols for non-dispersant chemical treating agents; and testing of existing and new chemical treating agents.

Using the "Swirling Flask" method developed in this project, over 15,000 laboratory evaluations of dispersant effectiveness have been completed with commercial and experimental chemical agents (Fingas and Tennyson 1991a). This method was adopted by the Environmental Protection Agency (EPA) for use in testing for product inclusion in the revised National Contingency Plan.

The mechanism of dispersant action was determined under this project (Fingas and Tennyson 1991b). Surface active agents or surfactants are the active ingredients in dispersants. Surfactants show varying actions on oil and water solubilities. The hydrophilic - lipophilic balance (HLB) is commonly used to characterize surfactants. Those with an HLB of 1 to 8 promote water-in-oil emulsion formation while surfactants with an HLB of 12 to 20 promote oil-in-water emulsions. An HLB of 9 to 10 is required for dispersant effectiveness.

The program evaluated the importance of mixing energy indicating that although each oil-dispersant combination shows a unique onset of dispersion, the effects of dispersants increase linearly with energy increases (Fingas et al. 1992).

New test methods for evaluating gelling agents, surface washing agents, and emulsion breakers (demoussifiers) were developed as part of this project, and selected treating agents were tested (Fingas, 1991b). Test results for solidifiers were repeatedly within 5%. Two emulsion breakers, Dasic Slickgone, and Demoussifier indicated good performance in these tests.

Evaluations indicate that efficient surface washing agents show poor capabilities as dispersants. This relationship is beneficial to responders, as effective surface washing agents do not actively promote dispersion of removed oil, thus allowing recovery after the adhering oil has been removed. A number of products that showed poor capabilities as a surface washing agent or a dispersant were tested.

FATE AND BEHAVIOR OF SPILLED OILS

The MMS began a cooperative research effort with EC in 1987 to quantify the effects of various weathering phenomenon on the fate of spilled oil. Primary emphasis was placed upon crude oils produced in North America, including the Outer Continental Shelf, and those crudes and refined products shipped in large quantities through North American waters.

Initial studies emphasized submergence and overwashing of weathered oils. Several oils from recent spills were located as tar mats on the bottom or as suspended droplets in the water column. This phenomenon was observed with oils of densities over 0.95 and increases with sea energy. The size of oil droplets overwashed varied directly with the square of the wave length and inversely with the square root of the wave amplitude.

The depth of the submerged oil was related to the exponential of the inverse of the specific gravity difference between the weathered oil and water times the size of the oil droplet (Fingas 1991c). Because of the common presence of pycnoclines in the top 5 to 10 meters, most submerged oil is found initially in this depth range. Once oil has submerged, the rate of weathering markedly decreases with little increase in density over several weeks.

The formation of emulsions was studied because of their extreme importance to spill responders. Conclusions from these studies emphasized that asphaltenes and resins are effective emulsification agents either in combination or singly. Weathering of the oil affects the physical state of these agents. They are most effective in sustaining stable emulsions when they are in finely divided submicron particles. Waxes in this condition also aid in the formation of stable emulsions; however, oils with waxes alone did not form emulsions. Addition of small concentrations of asphaltenes to waxy oils led to the formation of stable emulsions (Bobra et al. 1992). The degree to which oils can be expected to emulsify, therefore, depends in part on the degree of weathering. Emulsification tendencies of selected oils are reported in the 1992 Oil Properties Catalogue published by EC.

Several intensive efforts to summarize the effects of various weathering processes are being compiled as part of this project. The first effort addresses the behavior and fate of spilled oil in ice (Dickins 1992). This report combines a thorough literature search with recent research and should serve as a standard reference document. Further compilations will address evaporation and photoxidation.

SHORELINE CLEANUP

The MMS initiated with EC a cooperative effort that has identified knowledge gaps in the application of clean-up techniques to the beaches characteristic of the Pacific coastline from southern California to the Aleutian chain. This project will evaluate the effectiveness of minimizing biological damage of spilled oil to such beaches and will attempt to establish a correlation between clean-up effectiveness and environmental damage caused by various clean-up techniques. The results of this program will allow spill response personnel to choose shoreline clean-up strategies that will minimize the ecological effects of the spill and increase recovery potential of the affected ecological community (Sergy and Harper 1991).

Planning work continues for the SCOPE Project (Shoreline Cleanup Options: Performance and Effects). Screening and aerial reconnaissance conducted in British Columbia, Canada, in November 1991 identified a large number of promising areas between Prince Rupert and Queen Charlotte Strait. Winter weather and unsuitable tidal windows prohibited the conduct of ground surveys until summer 1992. In January 1992, a recap was conducted on the objectives and strategy for the experiment; the legal issues remaining to be addressed; communications with Federal, province, and local officials; and the site selection and final experimental design of the experiment. (Dickins et al. 1991).

In May 1992, the project was deferred at the Federal level until the regulatory approval mechanisms at the Federal and provincial levels in Canada were clarified.

In August 1992, the promising shoreline sites in northern British Columbia were surveyed. These ground-truthing surveys were completed and a location south of Prince Rupert was found to be suitable for the experiment. However, until the legal questions regarding this experiment are clarified, this project is on hold.

Environment Canada is working with the Canadian Coast Guard and the Canadian Department of the Fisheries to develop a regulation that would allow experimental oil spills under the Canadian Fisheries Act. This issue is being pursued at the Federal level in Canada.

OHMSETT

The MMS, with financial support from USCG and EC, began in 1990 to refurbish the deactivated spill response testing facility at Leonardo, New Jersey. Ohmsett is an above-ground concrete tank, 667 feet long, 65 feet wide, and 11 feet deep. The facility has the capability of producing repeatable regular and confused wave conditions while towing equipment up to 6.0 knots and laying oil in front of equipment being tested. Prior to facility closing in 1988, Ohmsett was used to generate approximately 95% of all oil spill response equipment data.

Ohmsett became operational in July 1992 after an extensive ($1.4 million) renovation process. All major systems including the towing carriages, wave generators, beach, oil dispersing and piping systems, and tank integrity have been refurbished. Data acquisition has been automated to a large degree. Testing began in August 1992 with sufficient research and performance evaluation efforts identified to occupy the facility for the first 12 months.

During the first year of operation, users of the tank will be charged $7,200 per day of operations. This user fee will be adjusted after the first year of operation to cover operational and testing costs. Results of equipment performance evaluations will be used by the MMS and USCG for reviewing oil spill contingency plans. Potential users are encouraged to contact the MMS. Priorities for Ohmsett activities are established by the Ohmsett Interagency Technical Committee (OITC) composed of the facility's sponsors.

STANDARD RESPONSE EQUIPMENT TEST PROTOCOLS

The MMS, with EC and USCG, began in 1986 to develop procedures whereby offshore oil containment booms and skimmers could be evaluated by standard test methods. These evaluations would result in the development of a performance database that would allow direct comparisons of equipment for the first time. These test methods have been completed (Chapman 1992 a and b) and testing began at Ohmsett in August 1992. The Marine Spill Response Cooperation used the boom protocol for testing selected booms at sea, in the fall of 1991. The protocols require performance evaluations of booms and skimmers as a function of tow speed, wave characteristics, oil characteristics and oil slick thickness in a test facility. These protocols also require performance measurements of sea keeping in a range of wave heights and periods, without oil, in the open ocean.

PORTABLE OIL ANALYSIS KIT FOR RESPONDERS

The MMS and EC joined in a cooperative effort to develop a field kit to measure those physical properties of spilled oil that most affect capabilities of spill responders. Specifically, these properties are density, viscosity, water content, flashpoint, and the effectiveness of various dispersants upon the condition and type of oil spilled. Spill responders must understand these properties before determining safe and efficient countermeasures for the spill at hand. Many countermeasures rapidly lose effectiveness when the spilled oil becomes highly viscous and increases in density through the weathering process.

The kit has been developed after extensive evaluation of portable test apparatus and comparisons of their evaluations with standard laboratory test procedures. Two kits have been completed and containerized. They will be field tested with personnel who have not been involved in its development to ensure user compatibility and also to evaluate its ruggedness. (Lambert et al. 1991).

SORBENT TESTING

The MMS and EC are cooperating with the Canadian General Standards Board (CGSB) in the development of a certification and listing program for oil sorbents. An ongoing testing program is being developed whereby manufacturers will have the opportunity to have their products evaluated and classified. An attempt will be made to produce a common standard through CGSB and the American Standards for Testing and Materials (ASTM). The test results will be reported in a sorbent database being developed by the U.S. Coast Guard. The database will provide responders with information during a spill situation.

ACKNOWLEDGEMENTS

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DISCLAIMER

Mention of specific trade or brand names does not constitute an endorsement on the part of MMS, other Federal agencies, or the author.

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QUESTIONS AND DISCUSSION

CALEB PUNGOWIYI: Two quick comments and then a question. On the burn that was done with the ice in the water, are those fresh water slabs? They looked real clean, real straight. Or are they salt water?

EDWARD TENNYSON: The water was salt, the ice was fresh simply because we wanted to repeat the ice concentrations time after time. I recognize that was a non-standard ice field. But basically it was fresh ice.

CALEB PUNGOWIYI: Ice made from salt water is more porous and oil can mix into it more than into fresh water ice, which is more solid. The other comment is if there is a spill in ice infested waters most likely it will be located near a structure, either a drilling well or a ship. At what point is a decision made to burn the oil? In terms of trying to protect a man-made structure versus trying to prevent the spread of the oil spill?

EDWARD TENNYSON: Let me answer that in two ways. One, if it is in ice, you can wait quite a while because the ice itself retards the spreading of the oil below the 3mm thickness to start off with. So you can burn after a fair amount of weathering. That is precisely what we did the first year was to weather the oil as heavily as we could, then try to burn it in ice. In terms of man-made structures, if you can be assured that two things don't occur; one, you get explosive mixtures of VOCs coming off the platform or off the spill vessel, that is gaseous, not oil, but gaseous clouds and you don't have a flashback. That is one safety consideration. The other is that if you have a blow out where you have a long term persistent release, you can, in fact, stage your containment equipment, downstream at a safe distance. Let that oil build up and burn it off intermittently or keep it burning continuously depending on your flow rates. When Alan A. Allen did it in Prince William Sound, there was concern because nobody really knew a lot about burning. They wanted him to take a bite sized chunk, about 15,000 gallons out and tow it off to a safe distance, several miles away from the major slick and burn it. I think that was probably unnecessary with today's understanding of the situation, but a very valid call in 1989 with the understanding we had. Burning is not the only tool. We are looking to improve all response strategies by putting some real world terms under them. There are some constraints certainly for burning just as there are for using booms, skimmers, or dispersants. We like to work very closely with the State of Alaska and the Regional Response Team to flesh those out. A lot of information exists now. We are still in the publication cycle and a lot of it isn't out in the open. It should be in the next 18 months.

PAM MILLER: I am a chemophobic. I was just curious to know a little bit more about the limitations of the use of dispersants. You talked a little bit about how they are virtually rendered ineffective if the oil is emulsified. So what kind of sea states are you talking about where a burn would not be effective. It seems like they are only effective really under fairly calm conditions. The second question is could you say a little bit more about the toxicity of this new generation of five dispersants that you mentioned? You were talking about the approximation of C_{12} to C_{20} and that affects cell membranes?

EDWARD TENNYSON: The first question is burning and the second question is dispersants, right? Okay. We don't know what the upper limits, quite candidly, of sea states and winds are for burning. We haven't had the opportunity to do that. We have been trying since 1990 to get a permit to burn in the Gulf of Mexico, with Coast Guard support. We have not had the opportunity to get that permit. One of the reasons why we are working so heavily and we have also been trying since 1989 to get a burn off Newfoundland. The Russian activity is something more recent. We are trying to look at those upper limits in a practical mode.

We have no information at this point on the effect of large waves on burning. The Norwegians have said that they can burn emulsions, which is something we have not seen in smaller scale, they can burn in larger scale. There is a wave limitation yet to be defined for emulsions. Certainly there will be some limitations on burning. I suspect at this point it has more to do with the ability of the containment boom to hold the oil than it will be for the fire to propagate. We have actually burned in 52 kt winds at Ohmsett and still managed to keep a flame going. The flame would not propagate upwind at that point.

In terms of dispersants, the reasons for dispersant's ineffectiveness, if I can use that term, is we've never figured out how to test them in the open world. People are always looking at the surface slick. We know by Eckman spiral, surface dynamics and subsurface oceanography that the subsurface slick doesn't go the same direction as the surface slick. In every case of 107 times that people have tried to use dispersants and measure the effectiveness in the open ocean, only three and those were the very first three, came back with any numbers whatsoever. Using the thickness sensor and laser fluorosensor we can get a very good mass balance of what is on the surface before, during and after the dispersant application. In terms of C_1 through C_{12}, dispersants differentially weather.

By the way all of this information, in terms of dispersants, is available from the Alaska office. Numerous articles have been published in the last several years on the specific actions of dispersants, the pros and cons of using them by this program.

C_1 through C_{12}, normal alkanes, are the ones that flash off quickly anyway. Basically what you are doing is aiding and abetting or increasing that weathering rate of the C_1 through C_{12}. Those are the most acutely toxic compounds in the oil. Those are the ones that normally weather off very quickly. The old axiom is that you never use dispersants when the viscosity of the oil starts going above 2,000 centipoise that is the point where the C_1 through C_{12} are flashed off. Or may be it would start higher than that, but for most lighter crudes the viscosity changes very quickly when the C_1 through C_{12}s are gone. And those usually go in the first 8 to 24 hrs, 24 hrs in the Arctic and 8 in the warmer waters. But if it takes you three days to get permission to use dispersants on a slick in warmer waters or even in the Arctic, the commercially available dispersants tend to be somewhat ineffective.

We had published the best numbers we saw for fresh Prudhoe Bay crude in 1987, two years before the spill, which was 17% with Corexit 9527. That is, with the maximum dosage according to the manufacturer and under the best conditions, you can get 17% of the oil to disperse. When you start looking at the lighter ends of that oil, it comes out to about 20%. The C_{12} through C_{24} are likely to be around in order of days or weeks depending on the temperature. Those are the ones that wash up on the beaches. Those are the ones that stick to birds, primarily. The acute toxicity is considerably less than in the C_1 through C_{12}, but the persistence is much higher and therefore the threat itself tends to be higher. In terms of using dispersants that break down the C_{12} to C_{30} chain, again that is the base for mucosal membranes and cell membranes, and we feel we can reformulate those dispersants in years to come up with something that has a fairly low toxicity rate or an acceptable toxicity rate but a very high effectiveness rate. Right now on the product schedule, as it stands, EPA's product schedule, there are a number of products out there with zero effectiveness by anybody's measurement that are more toxic than PCBs. We have worked with EPA in the past and they are going to adopt the standard Canadian approach. In other words, you are looking at a 40 to 50% effectiveness ratio as a cut-off point and then you start looking at toxicity. But dispersants that don't have 40 to 50% effectiveness to start off with won't make the cut and that makes a lot of sense. So if you have a fairly effective dispersant with a fairly high toxicity rate, you are still better off than if you have one with a high toxicity rate and zero effectiveness or low effectiveness.

PAM MILLER: Yes, but I was curious about these five new ones more specifically.

EDWARD TENNYSON: They are proprietary formulas at this point. They are experimental and they are still in the lab being tested.

GLADYS PUNGOWIYI: My question is when you burn in other parts of the world, the lower 48, off California coast or off of Mexico, how far does the smoke travel?

EDWARD TENNYSON: That is something we need to look at in full scale. With the 4,000 gallon burns in a 50 X 50 ft pits that we have had down in Mobile, we track the visible smoke down as far as 15 km, at which point it became indistinguishable from atmospheric haze. We do know that in considerably less distance than that, even though you can still see the particulates, you no longer can measure them. There is no known measurable levels of VOCs or anything else in that plume itself.

GLADYS PUNGOWIYI: Just a comment, that we see a change in our environment back home. It is just like a haze. I don't know if it is from forest fires or what but it is different.

EDWARD TENNYSON: One thing that I would like to bring forward is the scale of what we are dealing with. We are talking about burning tens of thousands of gallons over a period of an hour or less at a point source. And one other issue I didn't bring up, we know that birds and mammals don't always avoid surface slicks of oil. What you saw in the burn is pretty good intuitive evidence that they would avoid those burns. So there are bioavoidance mechanisms available in the burn process that aren't available if you have the slick just sitting and evaporating on the surface of the ocean. I don't know what is causing the haze up there. It could be photo-oxidation, it could be dust from Mt. Pinatubo, we blame everything else on Mt. Pinatubo, we might as well blame that.

PAM MILLER: I was just curious to know, I know that oil spill response for the last spill in the Shetlands was considerably hampered because of weather. But I know that dispersants were being considered and I wondered what dispersants were considered since that was a fairly light oil. And secondly, was a burn ever considered as a response measure for that spill?

EDWARD TENNYSON: A burn was very definitely considered on the Shetland oil spill, unfortunately the winds dropped down to about 50 kt one day. Other than that, it was kind of nasty out there. They had hurricane force winds for some four straight days. The concern for burning, obviously we were looking at 20 ft waves breaking over the vessel right on the shoreline. It was not a good place to burn. I don't know how you would even get an igniter in to the oil itself to start it to burn. I would not have attempted that simply because of the aerodynamics of the oil itself. The oil was being blown off the surface and being carried inland in liquid droplets. I don't know how you would have burned it. It was well beyond the capabilities.

For dispersants, the United Kingdom is the only entity in the world today that uses dispersants as their first and only spill response. Their first response is to use dispersants in the Channel and in the open ocean. They have a quasi-military, ex-Royal Navy captain in charge. It is military in terms of the way it operates. He gets a phone call that says there is a spill. He asks where and what is it and he starts off. The next call is to get his pilots and aircraft in the air with dispersants on board. No other country in the world has that aggressive a dispersant approach to life in general. The use of dispersants is limited not by the energy of the ocean surface, because the best cleaner-upper there is is a Beaufort scale 7 wind, unless it be a Beaufort 8 or 9, but the ability to get the dispersant on the surface of the ocean from an aircraft or a ship. That is usually limited to 30 or 40 kt winds. You cannot spray the dispersant from the back of an aircraft and have it reach the surface of the ocean. The other thing is that if it is a very light oil, it should have dispersed very easily with the existing dispersants, the Corexit 9527 or its European counterparts. But it is operationally extremely limited in terms of wind speeds. You have to fly at about 150 ft, hurricane winds over coastline it not a place that I would like to fly an aircraft either, riding or flying. So weather is a very major consideration.

UPDATE OF COASTAL OIL SPILL SENSITIVITY INDEX FOR BP ARCTIC OPERATION AREAS

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INTRODUCTION

In the summer of 1991, BP Exploration (Alaska), Inc. (BPX) updated oil spill contingency plans for the BPX North Slope operating areas in response to passage of State of Alaska House Bill 567 (HB 567). At that time, the most current environmental, biological, and cultural resource information available for the North Slope of Alaska was in the *Alaska Clean Seas ABSORB Contingency Planning Manual* published in 1984. Final regulations pursuant to HB 567 (18 AAC 75) were adopted by the Alaska Department of Environmental Conservation (ADEC) in May, 1992 As a function of updating the BPX 1991 spill contingency plans to meet 18 AAC 75 regulatory requirements, BPX made a decision to replace the Alaska Clean Seas sensitivity information by developing a set of Contingency Field Maps incorporating environmental sensitivity and land use information collected throughout BPX's years of operation on the North Slope of Alaska.

DEVELOPMENT OF BPX FIELD CONTINGENCY MAPS

BPX has a computerized topographic map base of the Alaska North Slope for Kuparek to Point Brower. It was determined that this map base would be used to display the sensitivity and land use data for use during spill response operations. Information to be displayed on the Contingency Field Maps included land ownership/use, facility infrastructure, surface drainage, potential oil flow routes, potential spill response options, and environmental sensitivities. With the exception of environmental sensitivities, all of the above information was already incorporated into the BPX map data base for the BPX areas of operation. Environmental sensitivity information to be incorporated into the Contingency Field Maps was obtained from existing published information, BPX field studies conducted in conjunction with BPX's North Slope operations, and BPX Endicott Causeway studies. Table 1 provides a list of data sources for information incorporated into the Contingency Field Maps. Table 2 indicates the number and type of environmental studies conducted by BPX, the results of which were incorporated into the Field Contingency Maps.

SUMMARY

This effort resulted in a set of Contingency Field Maps containing two base maps covering the entire BPX North Slope operating area, a series of 47 individual field maps for various sites throughout the operating area, an index for the individual field maps, and a common legend for the map series. These Contingency Field Maps have subsequently been incorporated into Oil Discharge Prevention and Contingency Plans for BPX's Prudhoe Bay and Endicott operating areas for use during spill response activities.

Table 1. BPX Sensitivity Map Data Sources.

Data	Source
Native Allotments	U.S. Dept. of Interior, Bureau of Land Management Master Title Plats
Military Sites	U.S. Dept. of Interior, Bureau of Land Management Original Survey Plats
Traditional Land Use/ Subsistence Land Use Sites	North Slope Borough, GIS Division, Planning Dept. document "Exhibit B - Confidential GIS Project Report"
Historical and Archaeological Sites	State of Alaska Office of History and Archaeology, "Exhibit A, Beechey Point Sites - BP Alaska Confidential Information," July, 1992
3-meter Bathymetric Contour	1:50204 NOAA charts 16046 of 12/15/90; 16061 of 2/25/89; and 16062 of 3/12/83
Fox Den Locations	"Status Report, Arctic Fox Investigations in the North Slope Oilfields in 1991," ABR, Inc.
Brant Brood/Staging Group Observations	"Tundra Swan and Brant Surveys on the Arctic Coastal Plain, Colville River to Stains River" (1989-1991), ABR, Inc.
Brant Nest Site Data	"Tundra Swan and Brant Surveys on the Arctic Coastal Plain, Colville River to Stains River" (1989-1991), ABR, Inc.
Tundra Swan Brood Observations	"Tundra Swan and Brant Surveys on the Arctic Coastal Plain, Colville River to Stains River" (1989-1991), ABR, Inc.
Tundra Swan Nest Sites	"Tundra Swan and Brant Surveys on the Arctic Coastal Plain, Colville River to Stains River" (1989-1991), ABR, Inc.
Snow Goose Brood Rearing Areas	Final Report for the Endicott Environmental Monitoring Program: (1985-1987); Envirosphere. Draft Reports for the Endicott Environmental Monitoring Program (1988-1989), ABR, Inc.

Table 2. BPX Environmental Studies.

Type of Study	1989	1990	1991	1992
Population Monitoring	2	4	6	7
Abandonment/Restoration	6	5	7	6
Permit Required Programs	9	11	11	8

QUESTIONS AND DISCUSSION

CALEB PUNGOWIYI: One thing I see missing on your sensitivity map is the offshore waters. Also, something that I have been harping on to the scientific community that needs to be studied is to see the ice as a life supporter that is used by fish and other species for shelter, for production, and for creating life. I wish that the oil companies or MMS or somebody could do some studies and document this information and identify critical habitat areas where ice is used for biological production rather than seeing it as something that deters life.

MARY COCKLAN-VENDL: The primary reason these maps are set up this way is because our operating areas, for the most part, are onshore and we aren't doing any offshore exploration or production right at the moment. Endicott is an area that is considered on the shoreline or offshore and we tried to take in to account as many of the sensitivities as we actually have data for and putting the data that we have on there. So these areas are intended to cover the areas that we currently operate in. We try to get as much data as we can to put on them.

FISH

Friday, January 22, 1993

FISHERIES OCEANOGRAPHY OF THE NORTHEASTERN CHUKCHI SEA

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Nora Foster is the Coordinator of the Aquatic Collection at the University of Alaska Museum. Her areas of research interests are the biology of benthic invertebrates, and the systematics and biogeography of marine mollusks. Ms. Foster received her B.S. in biology from the University of Alaska in 1969 and her M.S. in biological oceanography from the University of Alaska in 1979.

The purpose of this study was to determine (1) the distribution and abundance of fishes and mollusks in the northeastern Chukchi Sea, (2) the biology of three major fish species, and (3) relate their distribution and biology to oceanographic conditions. Fish and epifaunal mollusks were sampled with an otter trawl during the autumn of 1990 and 1991. Station locations and dates may be found in Smith et al. (in press). Infaunal mollusks were sampled with van Veen grab during 1986 (Feder et al. 1990).

Preliminary sampling with a trynet in 1989 and sampling in 1990 and 1991 resulted in 61 species of fishes representing 13 families captured (Table 1). Of the 52 species collected systematically in 1990 and 1991 five made up 95% of the total abundance and 88% of the total biomass collected (Table 2). The Shannon-Weiner diversity index indicated that the diversity was highest (>0.9) in a narrow band along shore from Pt. Hope to Pt. Franklin (Figure 1), intermediate (0.89-0.4) offshore nortwestward of this band south of the Pt. Lay area, and a low diversity (<0.39) north of the latter area. The biology of Arctic cod, Arctic staghorn sculpin, and Bering flounder were examined. Arctic cod was the most abundant fish captured with the highest abundance occurring in the Pt. Hope area. The highest estimated abundance was 120,000/km^2 and largest biomass estimate was 1,800 kg/km^2 but there was considerable interannual variability in abundance and biomass. The maximum estimated age of arctic cod was 8 years. The gonads of males were beginning to mature indicating that they were preparing to spawn sometime during the winter. Bering flounder was the most common flatfish captured and demonstrated extreme interannual variability in abundance and biomass (Figures 2 and 3). Overall estimated mean biomass reflected this variability; it was 17.2 kg/km^2 in 1990 and 0.8 kg/km^2 in 1991. Maximum estimated age of Bering flounder was 8 years. Historical data on abundance and age structure indicates extreme variability in recruitment and abundance. The arctic staghorn sculpin was the most abundant sculpin in the study area with an overall mean estimated biomass of 8.4 kg/km^2 in 1990 and 4.7 kg/km^2 in 1991. The highest abundances occurred inshore and south of Icy Cape. The oldest female was 9 and male 8 years of age. In 1990, 42% of the population was $\geq$ 4 yrs old, but in 1991 only 9% was $\geq$ 4 yrs old with the 1987 year class virtually missing

(Figure 4). There were generally fewer snow crab and lower biomass inshore than offshore and in the northern than in the southern area. From observations of the three dominant fish species it is suggested that the physical environment has considerable influence on the fishes of the northeastern Chukchi Sea.

Because infauna and epifaunal samples were collected by different gear types and often at different stations, it was not possible to pool and analyze all mollusk abundance and biomass data jointly. Infauna and epifauna were analyzed separately, then data from both groups were integrated to evaluate overall patterns of the distribution and abundance of mollusks in the study area. Cluster and ordination techniques of multivariate analysis were used to examine groupings of infaunal and epifaunal species in terms of their abundance at stations. Then, stepwise multiple discriminant analysis was applied to interpret the cluster analysis in terms of environmental variables.

The two investigations resulted in a fairly comprehensive collection of the area's mollusks. The northeastern Chukchi Sea has an abundant and diverse molluscan fauna. Taxa collected included forty-four bivalves, sixty-five gastropods, two chitons, and one cephalopod.

Multivariate analysis of infaunal abundance data present resulted in six station groups, with three nearshore groups (groups IV, V and VI), and three offshore group (groups I, II, and III) (Figure 5; Table 3). Abundance of varied from $42/m^2$ in inshore group VI to $388/m^2$ in group I; and biomass from $20gC/m^2$ in nearshore group IV to $147gC/m^2$ in group I.

Table 1. Families of fishes and number of species in each captured in the northeastern Chukchi Sea.

Families of Fishes	Number of Species
Cottidae (Sculpin)	19
Pleuronectidae (Flounders)	9
Zoarcidae (Eelpouts)	7
Agonidae (Poachers)	5
Stichaeidae (Pricklebacks)	5
Gadidae (Cod)	4
Cycloptaridae (Lumpsuckers)	3
Liparidae (Snailfish)	3
Osmeridae (Smelts)	2
Hexagrammidae (Greenlings)	1
Clupeidae (Herring)	1
Ammodytidae (Sandlances)	1
Anarhichadidae (Wolffishes)	1
TOTAL SPECIES	61

Table 2. Dominant (mean abundance and biomass) fish species captured in the northeastern Chukchi Sea during the 1990 cruise.

Species	$\#/km^2$	(%)	kg/km^2	(%)
Arctic Cod	19,451	(76.1)	301.0	(61.3)
Myoxocephalus verrucosus	1,812	(7.1)	61.9	(12.6)
Saffron Cod	1,643	(6.4)	38.8	(8.4)
Arctic Staghorn	782	(3.1)	9.1	(1.8)
Bering Flounder	486	(1.9)	17.4	(3.5)
		(94.6)		(87.6)

A discriminant analysis explained the station groupings in terms of differences in percentage of sand present and secondarily by bottom salinity.

A similar analysis of the epifaunal stations resulted in five groups (Figure 6; Table 4). The groups are not as well separated as the infaunal groups. The discriminant analysis showed that the groups are separated by percent of gravel and by bottom temperature. Abundance of mollusks varied from $765/km^2$ in group III to $18,993/km^2$ in group V. Biomass varied from 24 kg/km^2 in group IV to 292 kg/km^2 in group V.

Mean infaunal molluscan biomass at stations north and west of the oceanic front between Bering Sea Water and Alaska Coastal Water which extends from Point Franklin, is significantly

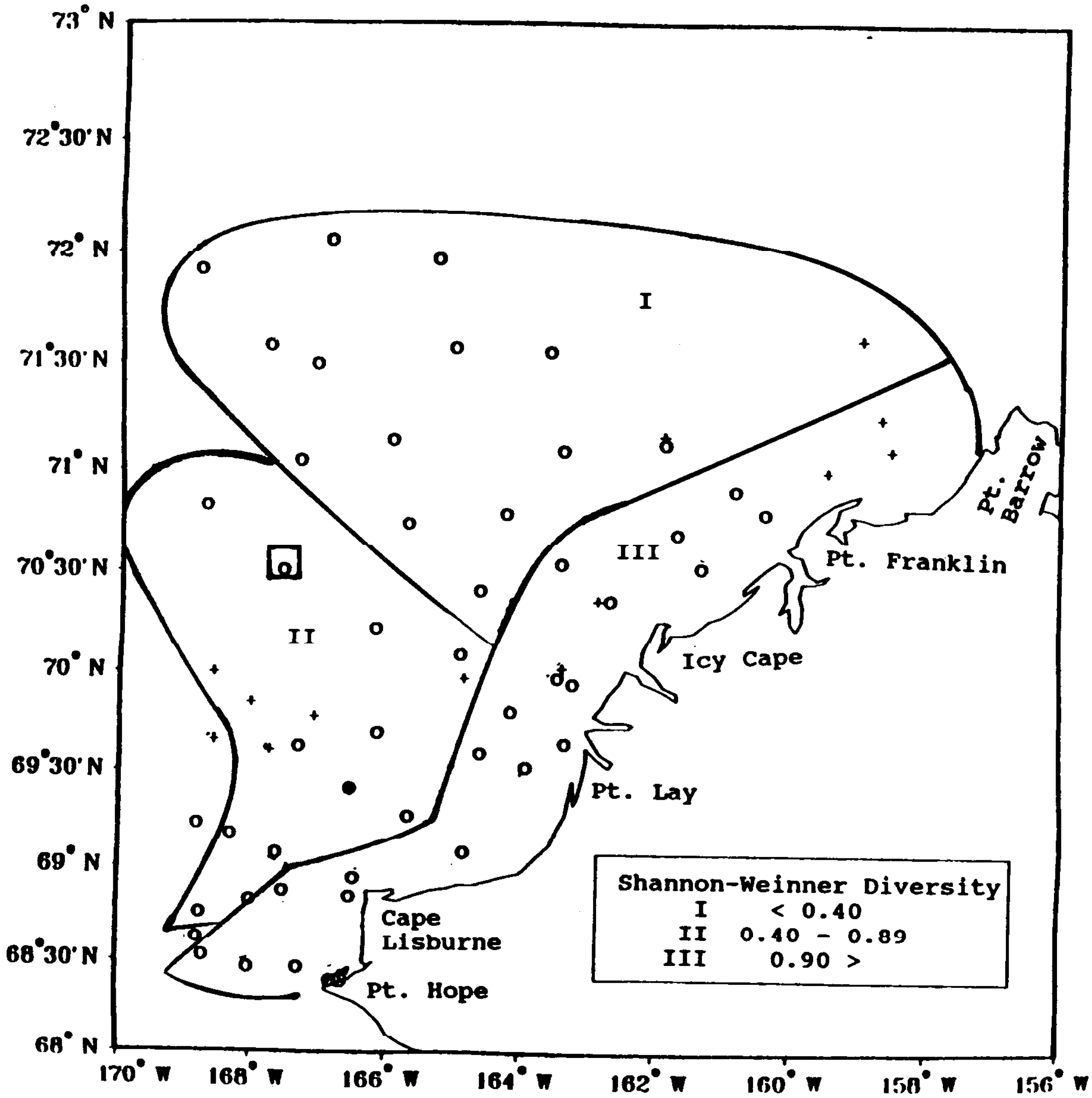

Figure 1. Station groupings for three levels of species diversity indices of fishes captured in the northeast Chukchi Sea. Circles are stations sampled in 1990 and pluses are those sampled in 1991. The square in group II is a station with a species diversity index of 1.09.

higher than the biomass values for the southern stations. This north-south biomass difference was noted for total infauna by Feder et al. (1990) (Figure 7).

The increase in general abundance and biomass of benthic fauna adjacent to and north of the oceanic front separating Alaska Coastal Water from Bering Shelf Water and Resident Chukchi Water, indicates a flux of carbon to the bottom. A variety of factors may be responsible for this enhancement. However, an increase in the abundance of mollusks as well as other infauna just north of Cape Lisburne, is probably the result of a small gyre which may concentrate the particulate organic carbon on the bottom.

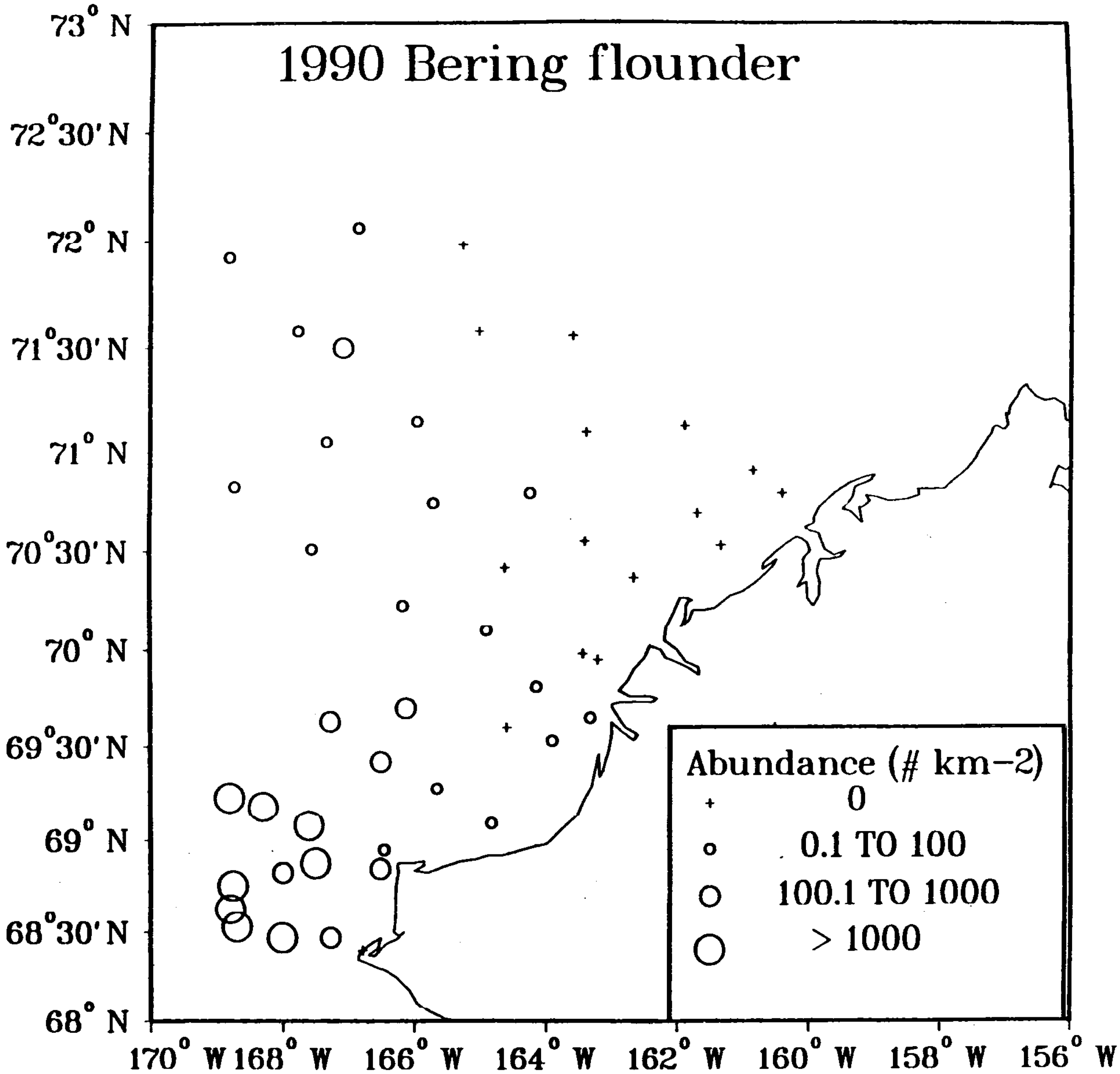

Figure 2. Relative abundance of Bering flounder captured in the northeastern Chukchi Sea during 1990.

The abundance and distribution of dominant bivalve taxa can to some extent be related to particulate organic carbon (POC) in the sediments or in suspended particles near the bottom.

Deposit feeding bivalves dominate the molluscan infauna. Protobranchs, primarily *Nucula tenuis* and the heterodont *Macoma calcarea* were most abundant in the offshore stations in the northern part of the study area, where fluidized mud with a high concentration of particulate organic carbon provided suitable habitat.

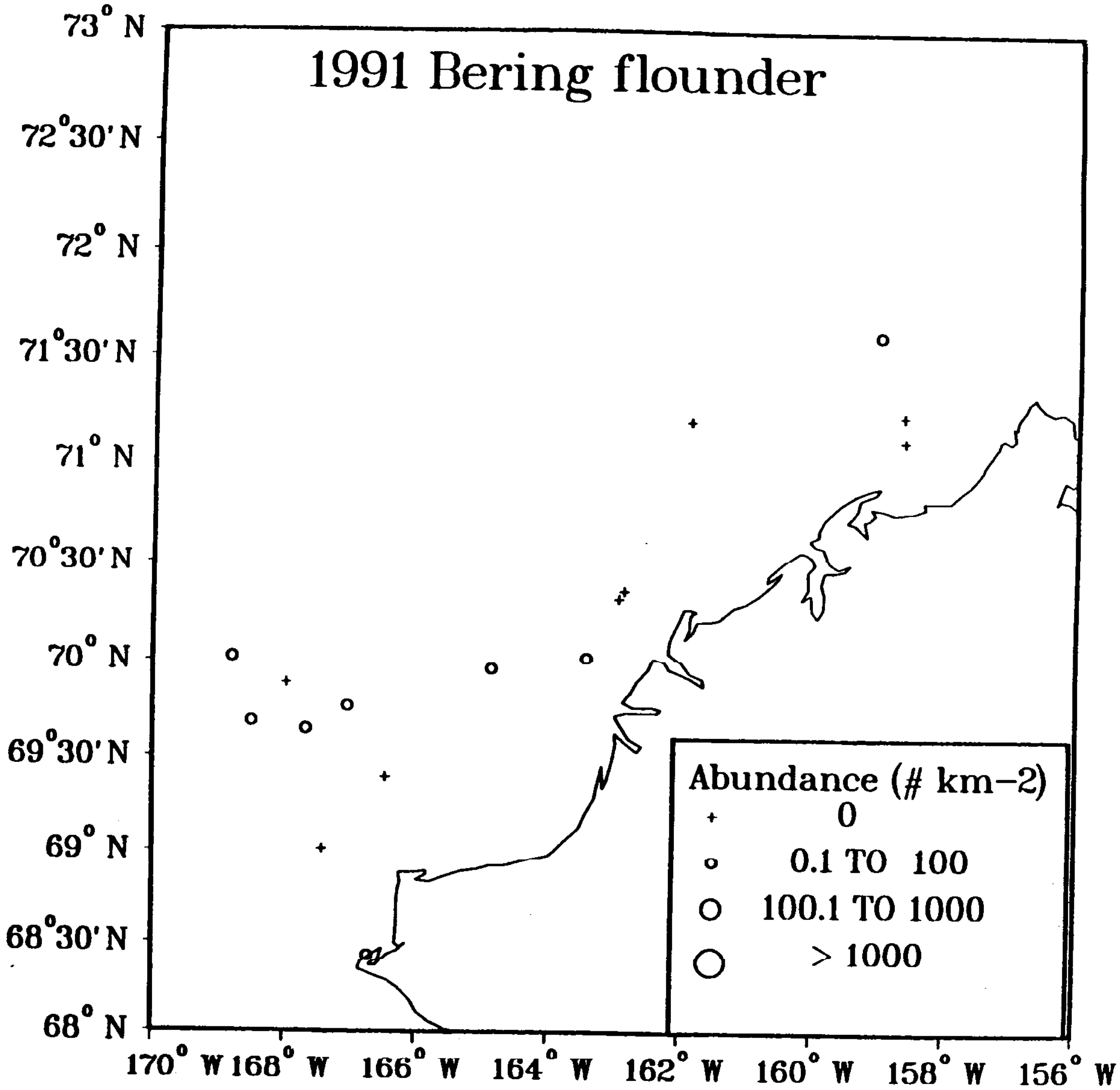

Figure 3. Relative abundance of Bering flounder captured in the northeastern Chukchi Sea during 1991.

The surface deposit feeder, *Thyasira gouldi*, was found in great numbers off Point Hope, along with the *Chlamys*, a suspension feeder. High concentrations of suspended carbon and nitrogen were found in the same area by Feder et al. (1990). Presumably the same source of POC also supports the large population of scallops north of Cape Lisburne where a small gyre concentrates the POC and allows it to flux to the bottom. The scallop was also present at similar abundance levels just north of Point Franklin in an area where high levels of POC also supply large populations of ampeliscid amphipods utilized by gray whales.

The high abundance and broad distribution of the epifaunal neptunid and buccinid gastropods can be attributed to their high mobility and opportunistic feeding behavior.

Mollusks are an important component of the benthic system of the northeastern Chukchi Sea and many of them represent a trophic link with benthic predators. Large snails are occasionally used by marine mammals, but gastropods are mainly preyed upon when small. Thus it is the small infaunal and epifaunal species that form this link. Predators in the study area include some hermit and spider crabs, at least 10 seastar species and serpent stars. They are also a minor component of the diet of arctic flounder and staghorn sculpin. Although the large neptunids and buccinids are abundant and widely distributed in the northeastern Chukchi Sea, they are mainly preyed upon when they are small. And, since they are relatively long-lived, it appears that they represent a carbon sink that mainly contributes carbon to the system after they die.

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Feder, H.M., A.S. Naidu, M.J. Hameedi, S.C. Jewett, and W.R. Johnson. 1990. The Chukchi Sea continental shelf: Benthos-environmental interactions. U.S. Dept. of Commerce. NOAA. OCSEAP Final Report 68:25-311.

Smith, R.L., J. Gillispie, W.E. Barber, and A. Ritchie. In press. Biology of *Gymnocanthus tricuspis*, the Arctic staghorn sculpin, from the northeastern Chukchi Sea. Symposium on Fish Ecology in Arctic North America. American Fisheries Society.

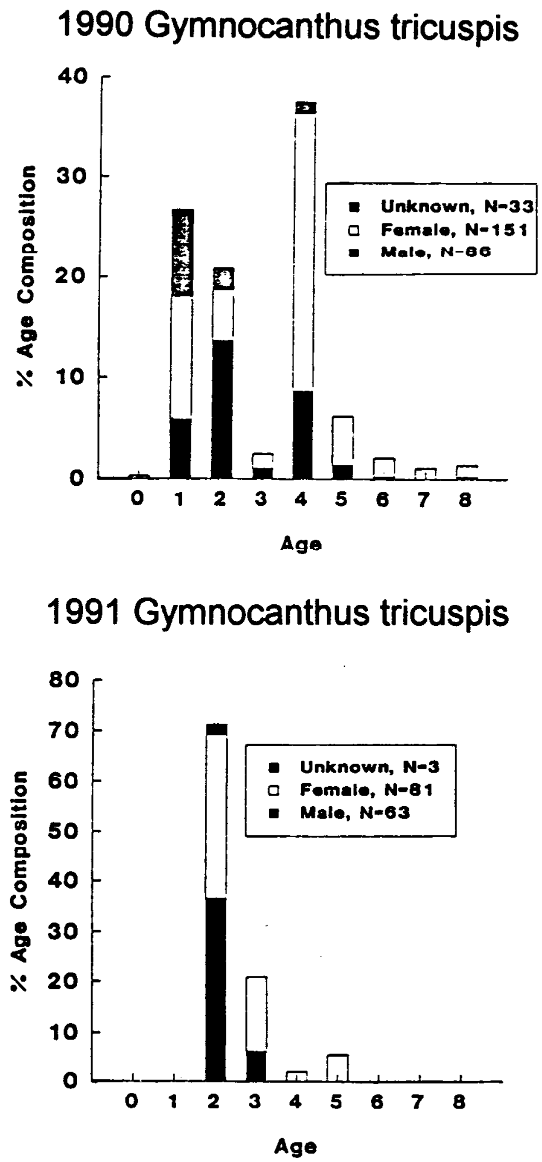

Figure 4. Age composition of the arctic staghorn sculpin (*Gymnocanthus tricuspis*) captured in the northeastern Chukchi Sea during 1990 and 1991. Unknown are those fish of unknown sex and n = sample size.

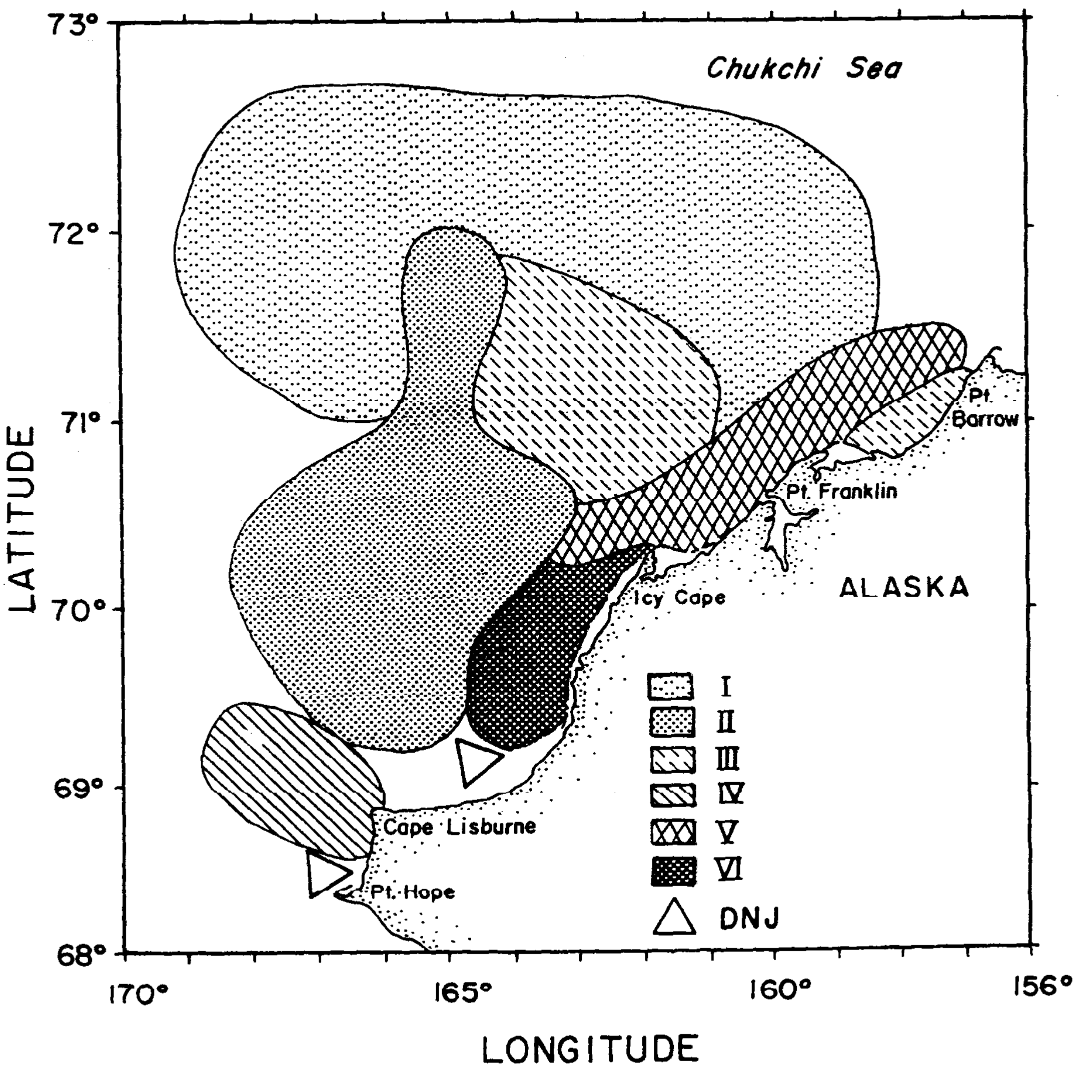

Figure 5. Infaunal molluscan assemblages in the northeast Chukchi Sea.

Table 3. Infaunal molluscan abundance dominants within six stations groups and two stations not classified. Taxa occurred at 50% or more of the stations within a station group. DNJ = Did not join a station group.

Station Group	Stations in Group	Taxa	Abundance (ind.km ^{2})	% Occurence in Group
I	3 10 11	*Nucula tenuis*	196	100
	12 13 24	*Macoma calcarea*	88	100
	25 26 27	*Thyasira gouldi*	17	90
	39	*Yoldia hyperborea*	14	80
		Nuculana radiata	14	50
		Retusa obtusa	11	90
		Mysella sp.	8	60
		Cylichna alba	8	70
II	23 28 29	*Nucula tenuis*	98	100
	30 34 35	*Thyasira gouldi*	14	89
	36 37 40	*Macoma calcarea*	6	56
		Tachyrhynchus erosus	5	89
		Solariella varicosa	4	78
		Cylichna alba	4	56
III	5 14 15	*Nucula tenuis*	70	100
	16 21	*Astarte montaqui*	16	100
		Cyclocardia ovata	10	100
		Astarte borealis	9	80
		Solariella obscura	6	100
		Cylichna alba	5	80
		Oenopota sp.	5	100
		Propebela sp.	5	60
IV	44 45 47	*Thyasira gouldi*	105	67
		Nucula tenuis	65	100
		Nuculana radiata	57	100
		Retusa obtusa	8	67
		Tachyrhynchus erosus	3	67
		Polinices pallidus	3	100
V	4 6 7 8	*Cyclocardia ovata*	123	83
	17 19	*Astarte montaqui*	29	100
		Liocyma viridis	25	83
		Yoldia myalis	14	50
		Mysella sp.	13	83
		Axinopsida serricata	8	50
		Musculus spp.	7	100
		Hiatella arctica	5	50
		Polinices pallidus	4	100
VI	18 31	*Yoldia scissurata*	12	100
		Thyasira gouldi	5	50
		Macoma calcarea	4	100
		Clinocardium ciliatum	4	100
		Liocyma viridis	3	50
		Liocyma fluctuosa	2	50
		Natica clausa	2	50
		Tellina lutea	2	50
		Cylichna alba	2	100
DNJ	33	*Musculus spp.*	26	
		Cylichna alba	4	
		Nucula tenuis	2	
		Yoldia myalis	2	
		Oenopota spp.	2	
	43	*Musculus spp.*	10	
		Hiatella arctica	6	

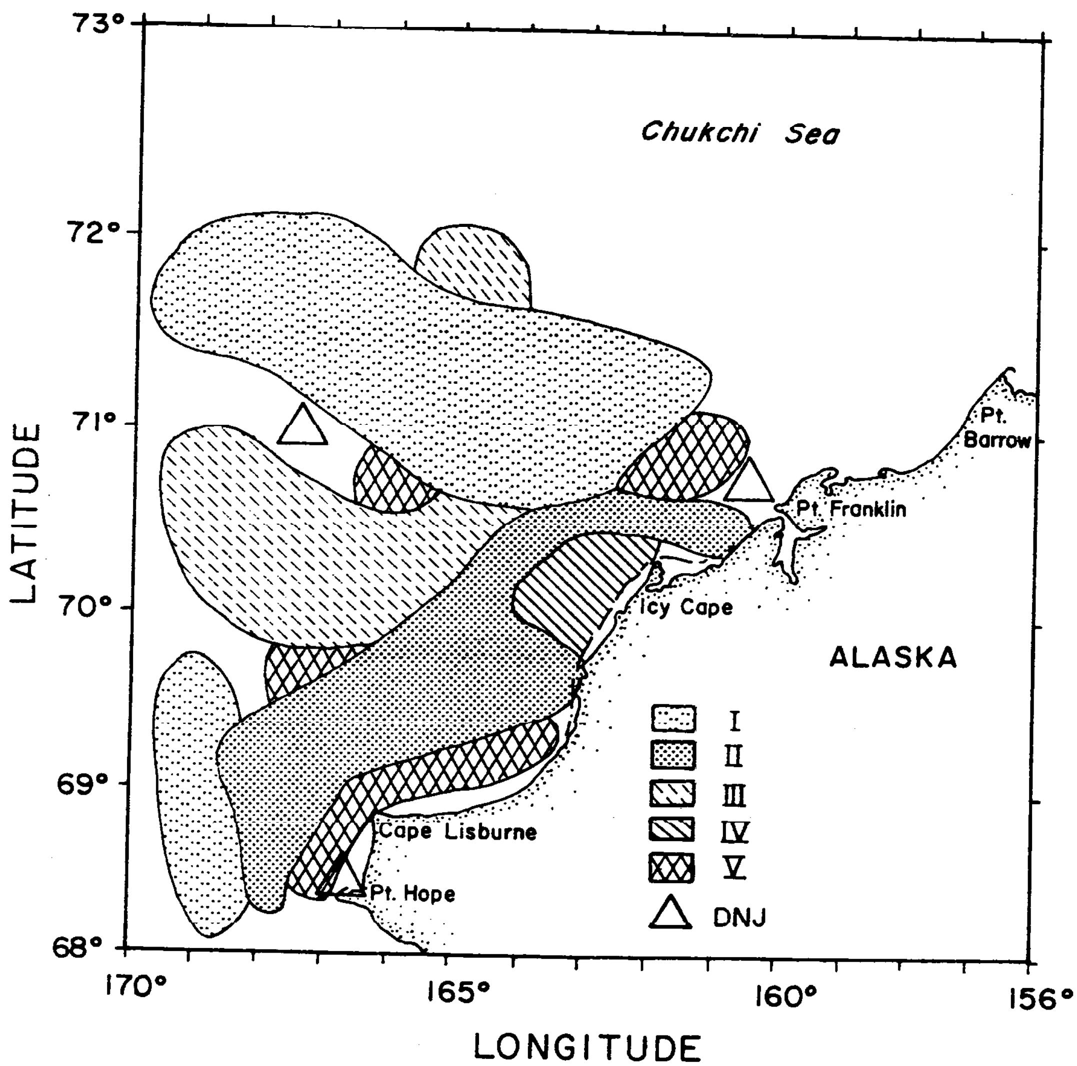

Figure 6. Epifaunal molluscan assemblages in the northeast Chukchi Sea.

Table 4. Epifaunal molluscan abundance dominants within five station groups. Taxa occurred at 50% or more of stations within a station group. DNJ = Did not join a Group.

Station Group	Stations in Group	Taxa	Abundance (ind.km^2)	% Occurence in Group
I	1 2 3 4 5 9	*Neptunea heros*	1 021	100
	10 11 18 27	*Buccinum polare*	390	100
	28 30 31 32	*Neptunea borealis*	236	100
		Buccinum scalariforme	128	100
		Volutopsius fragilis	126	50
		Natica aleutica	97	86
		Polinices pallidus	87	86
		Clinopegma magna	81	93
		Onchidiopsis sp.	76	100
II	8 12 13 16	*Neptunea heros*	4 256	100
	17 20 21 24	*Neptunea ventricosa*	668	60
	34 43 44 45	*Buccinum scalariforme*	506	93
	46 47 48	*Neptunea borealis*	436	100
		Buccinum angulosum	147	93
		Onchidiopsis sp.	72	67
		Beringius beringi	54	73
		Volutopsius fragilis	33	60
		Serripes groenlandicus	31	67
III	29 37 40 42	*Neptunea heros*	442	100
	41	*Neptunea borealis*	72	100
		Buccinum scalariforme	71	100
		Buccinum polare	51	80
		Neptunea ventricosa	37	60
		Plicifusus kroyeri	17	60
IV	23 35 36	*Neptunea heros*	752	100
		Buccinum tenellum	98	100
		Buccinum polare	91	67
		Buccinum angulosum	85	67
		Natica aleutica	57	67
		Neptunea borealis	56	100
		Polinices pallidus	28	67
		Neptunea ventricosa	28	100
		Bulbus fragilis	3	67
		Buccinum sp.	6	67
V	7 14 15 19	*Chlamys behringiana*	3 971	100
	22 26 33 38	*Neptunea heros*	2 363	100
		Neptunea ventricosa	1 814	100
		Buccinum angulosum	1 471	88
		Trichotropis bicarinata	1 457	63
		Amicula vestita	1 168	100
		Margarites costalis	821	50
		Onchidiopsis sp.	794	100
		Plicifusus kroyeri	748	100
		Buccinum scalariforme	477	75
		Cyclocardia crassidens	419	88
		Volutopsius difformis	391	62
		Beringius stimpsoni	431	50
		Volutopsius stefansoni	341	62
		Buccinum polare	293	50
		Beringiuw beringi	258	88
		Boreotrophon clathratus	204	63
		Colus spitzbergensis	167	3
		Neptunea borealis	136	50
		Buccinum glaciale	127	75

Table 4. (Cont.)

Station Group	Stations in Group	*Taxa*	Abundance (ind.km²)	% Occurence in Group
		Seripes groenlandicus	61	63
		Clinocardium ciliatum	57	75
		Crepidula grandis	35	62
		Musculus discors	32	50
DNJ	25	*Neptunea heros*	3 177	
		Neptunea ventricosa	498	
		Volutopsius difformis	453	
		Buccinum plectrum	199	
		Buccinum glaciale	199	
		Chlamys behringiana	199	
		Beringius beringi	54	
		Beringius stimpsoni	54	
		Buccinum polare	54	
DNJ	39	*Chamys behringiana*	160	
		Neptunea heros	114	
		Buccinum anguloeum	46	
		Plicifusus kroyeri	23	
		Neptunea ventricosa	23	
		Buccinum polare	23	
		Clinopegma magna	23	
DNJ	6	*Neptunea ventricosa*	410	
		Clinocardium californiense	155	
		Neptunea heros	114	
		Musculus discors	68	
		Serripes groenlandicus	46	
		Beringius beringi	33	
		Clinopegma magna	22	

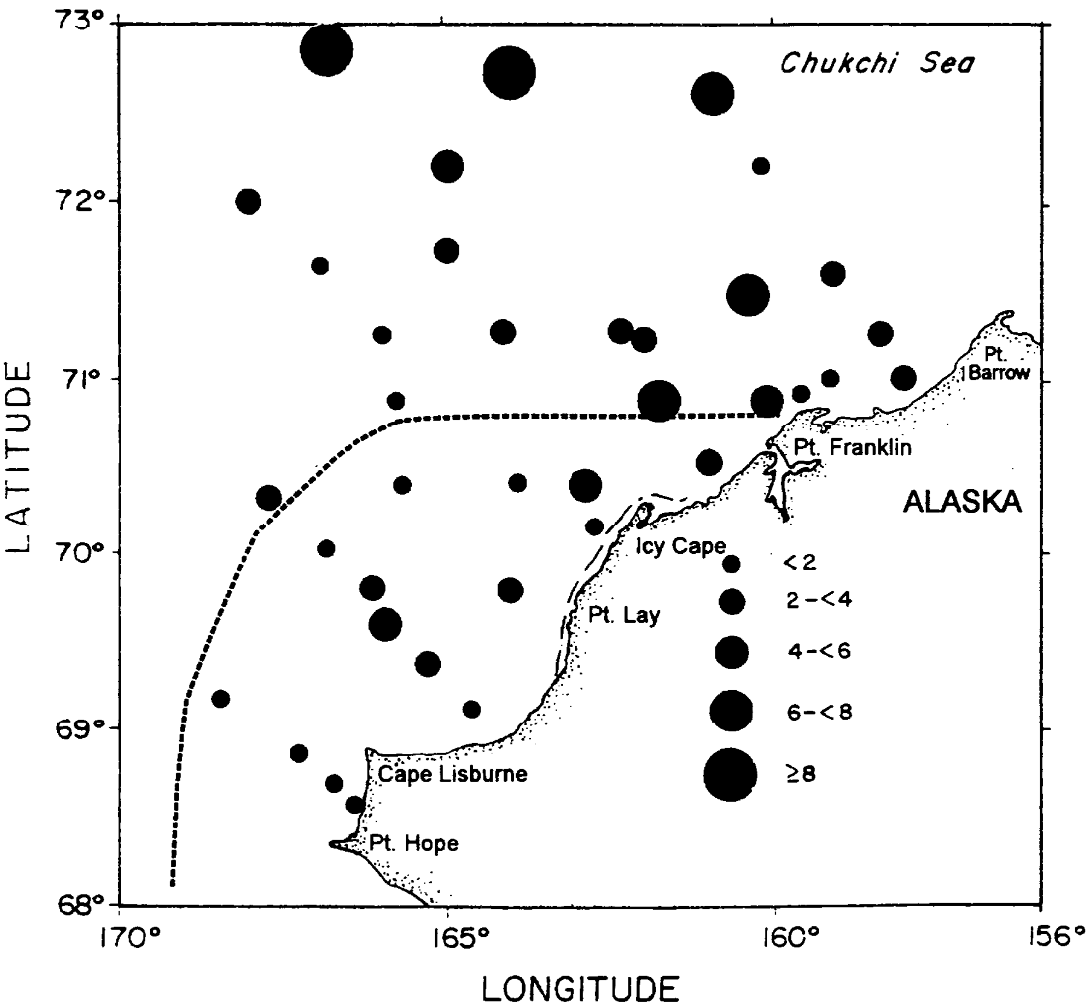

Figure 7. Abundance (numbers/m²) of infaunal mollusks in the northeast Chukchi Sea.

THE PHYSICAL OCEANOGRAPHY OF THE NORTHEAST CHUKCHI SEA

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INTRODUCTION

In this talk I will review aspects of the circulation and hydrography of the Chukchi Sea which are important to its biological communities and discuss pertinent interannual variations in oceanographic conditions. This review is based upon both historical data as well as a subset of hydrographic and current meter data collected in the fall of 1992. Figure 1 shows a bathymetric map of the Chukchi Sea as well as the 1992 CTD station locations and the positions of the current meters for the period October 1991 through September 1992.

Oceanographic conditions in the Chukchi Sea are strongly influenced by the northward flow of waters through Bering Strait which affects the heat and salt balance and which is a major source of nutrients, and particulate organic carbon (Walsh et al. 1989) for this arctic shelf sea. This northward flow consists of Alaska Coastal Water (ACW) flowing through the eastern side of Bering Strait and Bering Shelf Water (BSW) flowing primarily through the western side of the strait. A front separates these two water masses and extends northward from Bering Strait to north of Pt. Hope. According to the classification scheme of Coachman, Aagaard and Tripp (hereafter abbreviated as CAT, 1975), ACW water mass properties vary broadly, with temperatures ranging from 2-13°C and salinities less than 32.2 practical salinity units (psu). Bering Shelf Water is colder (0-3°C) and more saline (32.5-33 psu) and has much higher concentrations of dissolved nutrients and chlorophyll than ACW (Walsh et al. 1989). The flow bifurcates offshore of Pt. Hope; one branch flows to the northwest and the other continues along the northeast coast of Alaska as the Alaska Coastal Current (ACC). Bottom waters on the northernmost portion of the shelf are characterized by the low temperatures (<1°C) and relatively high salinities (32-33 psu) of Resident Chukchi Water (RCW). This water mass is either advected onto the shelf from the upper layers of the Arctic Ocean or is shelf water remnant from the previous winter. Resident Chukchi Water occurs throughout the Chukchi basin at the beginning of summer and is gradually displaced northward by inflowing BSW and ACW throughout the summer and fall.

SHELF CIRCULATION DYNAMICS AND KINEMATICS

The most important forces affecting circulation on the Chukchi shelf are:

1) the pressure gradient arising from cross-shelf density differences. This force, which can vary on time scales of days to years, is greatest in the late summer and fall when density gradients between the warm, dilute ACW and cold, salty BSW and RCW are largest.

2) the large-scale pressure gradient between the Pacific and Arctic Oceans which varies on time scales of decades to centuries and which is responsible for the mean northward flow through Bering Strait and the Chukchi Sea.

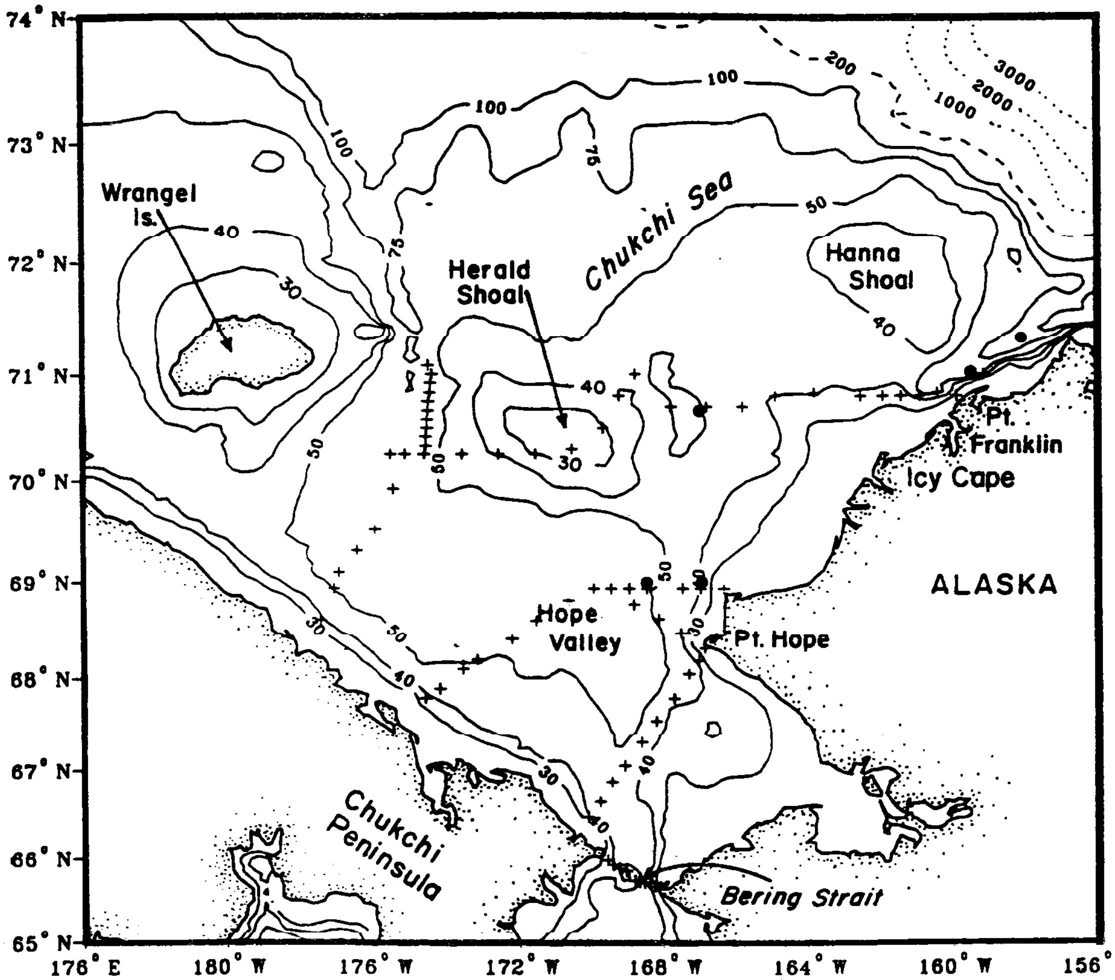

Figure 1. Bathymetry of Chukchi Sea indicating positions of the September-October 1992 CTD stations ("+") and locations of the current meter moorings (solid circles) deployed from September 1991 to October 1992.

3) the wind stress acting on the surface of the ocean. Winds are northerly on average and vary on time scales of days to years.

Coachman and Aagaard (1988) showed that Bering Strait transport fluctuations are coherent with wind stress fluctuations on a daily time scale. Figure 2 shows their estimates of the annual and mean monthly transport through Bering Strait. Minimum northward transport occurs in winter when north winds are maximum and maximum northward transport occurs in summer when winds are weak and more variable.

In the northeast Chukchi Sea, current meter data from 1991 and 1992 show that Barrow wind stress fluctuations are coherent with current fluctuations at periods longer than about 6 days (Figure 3a). The phase relation implies that northeast winds decelerate (and occasionally reverse) the northeasterly flow of the ACC. Furthermore, Johnson's (1989) results show that, adjacent to

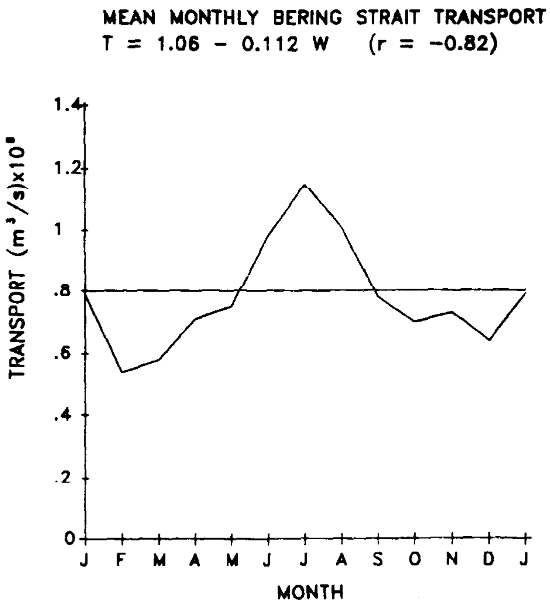

Figure 2. Mean monthly transport through Bering Strait. Horizontal line indicates value for the mean annual transport. Regression equation relates mean daily transport (T) to mean daily estimate of wind along 192°T. (Adapted from Coachman and Aagaard, 1988).

the coast, northeast winds lead to coastal upwelling with ACW being replaced by RCW.

The current meter data also show that, for time scales between 3 and 40 days, the current fluctuations are coherent and in-phase over spatial scales of at least 400 km (Figure 3b). On seasonal time scales (which are poorly resolved with this data set), winds over the Chukchi Sea are coherent with those over Bering Strait. Hence, on these time scales, current fluctuations are probably coherent over the whole Chukchi Sea. The last point is particularly important because it implies that the replacement of RCW by ACW and BSW on the Chukchi shelf is dependent upon the regional wind field.

Table 1 lists the mean vectors and axes of principal variance estimated from current meters deployed at the head of Barrow Canyon, to the east of Herald Shoal and to the west of Cape Lisburne. At Barrow Canyon the net flow is northeastward, and at the other mooring locations it is northward. The net flows reflect forcing by the large-scale pressure gradient between the Pacific and Arctic oceans. Bathymetric steering of the

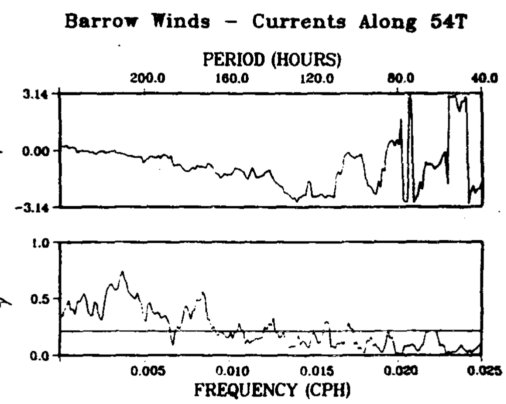

Figure 3a. Coherence squared and phase between Barrow winds and Barrow Canyon currents. The calculation is based upon wind and current components resolved along 54°.

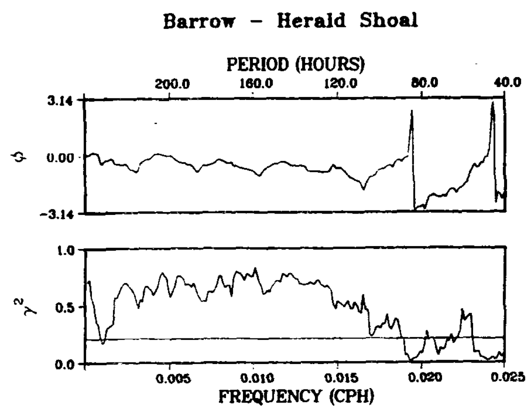

Figure 3b. Coherence squared and phase between Barrow Canyon and Herald Shoal current components resolved along their axes of principal variance. Horizontal line in both the coherence squared plots indicates the lower limit of the 90% confidence level based upon 22 degrees of freedom.

Table 1. Net velocity and axis of principal variance (Θ) for 1991-1992 Chukchi Sea moorings.

Mooring Descriptor	Latitude (N°)	Longitude (W°)	Time Period	Water Depth	Meter Depth	Net cm/s	Velocity (T°)	Θ (T°)	% Variance Explained
Barrow Canyon	71.05	159.55	10/1/91-9/4/92	79	76	21	(60)	54	96
Herald Shoal	70.66	167.03	10/2/91-9/27/92	50	47	8	(350)	355	76
Cape Lisburne	69.01	166.96	9/30/91-9/22/92	43	40	5	(345)	355	77

flow is indicated by the fact that the principal axes of variance lie approximately parallel to the local isobath orientation. Of particular interest, is the observed mean northward flow at the Herald Shoal site where, previously, CAT inferred that flow was southward. The significance of this northward flow is implied in Figure 4 which shows the cross-section profile of fluorescence obtained along a CTD transect extending from Pt. Franklin to Herald Valley. (Fluorescence is proportional to living and detrital phytoplankton biomass and can be considered a proxy variable for a portion of the particulate organic carbon concentration). Maximum values of fluorescence are observed in Herald Valley and in the bottom depression east of Herald Shoal - at the same location as the Herald Shoal current meter mooring. Taken together, the current meter and fluorescence observations suggests that this site might be an important route for the flux of particulate organic carbon onto shelf north of 71°N. Furthermore, ocean dynamics argue that, north of this latitude, the near-bottom waters will flow eastward and parallel to the isobaths. If so, then the carbon flux through Herald Valley is also potentially available to the benthic community of the northeast Chukchi Sea.

HYDROGRAPHY

The current meter data summarized above indicate that flows are strongly influenced by the bathymetry. Synoptic current measurements obtained by Johnson (1989) in August of 1986 show that the main core of the ACC parallels the 30 and 40 m between Cape Lisburne and Barrow Canyon. Hydrographic data obtained from the same cruise indicates that the ACC's core coincides with a bottom temperature front (Figure 5a) whose intensity varies in proportion to the magnitude of the bathymetric gradient. Hence bottom temperature gradients and currents are greatest in the vicinity of Icy Cape and Pt. Franklin. The latter is indicated in Table 1 which shows that the maximum net velocity and variance is observed at the Barrow Canyon mooring (northeast of Pt. Franklin) where bottom slopes are substantially larger than those of the other mooring sites. North of the front, RCW is observed, while to the west of the front a mixture of BSW and ACW is observed. This bottom front was also observed in 1982 by Aagaard (1984) and in 1990 during the fishery surveys conducted by W. Barber (Figure 5b). Although station spacing during the 1991 fishery survey was too sparse to prepare maps similar to those shown in Figure 5(a,b), it appears that the flux of ACW into the northeast Chukchi Sea was greatly reduced in this year in comparison to 1990. This is illustrated in Figure 6 which shows vertical profiles of temperature and salinity collected in 1990 and 1991 from two stations located between Cape Lisburne and Pt. Franklin. In 1990, warm, dilute ACW is observed throughout the water column, whereas in 1991 the upper 15 m consists of meltwater from sea-ice and the deeper waters consists of cold, salty RCW. Similarly there is no evidence of a bottom front observed in Aagaard's (1984) data for 1981. In the next section, I will offer an hypothesis to explain these differences. In general, however, I believe that the bottom temperature front is a seasonally (summer through fall) recurring feature of the northeast Chukchi Sea. Additional evidence in support of this is Feder et al.'s (in prep.) observed geographical differences in benthic community structure which are delineated by the front.

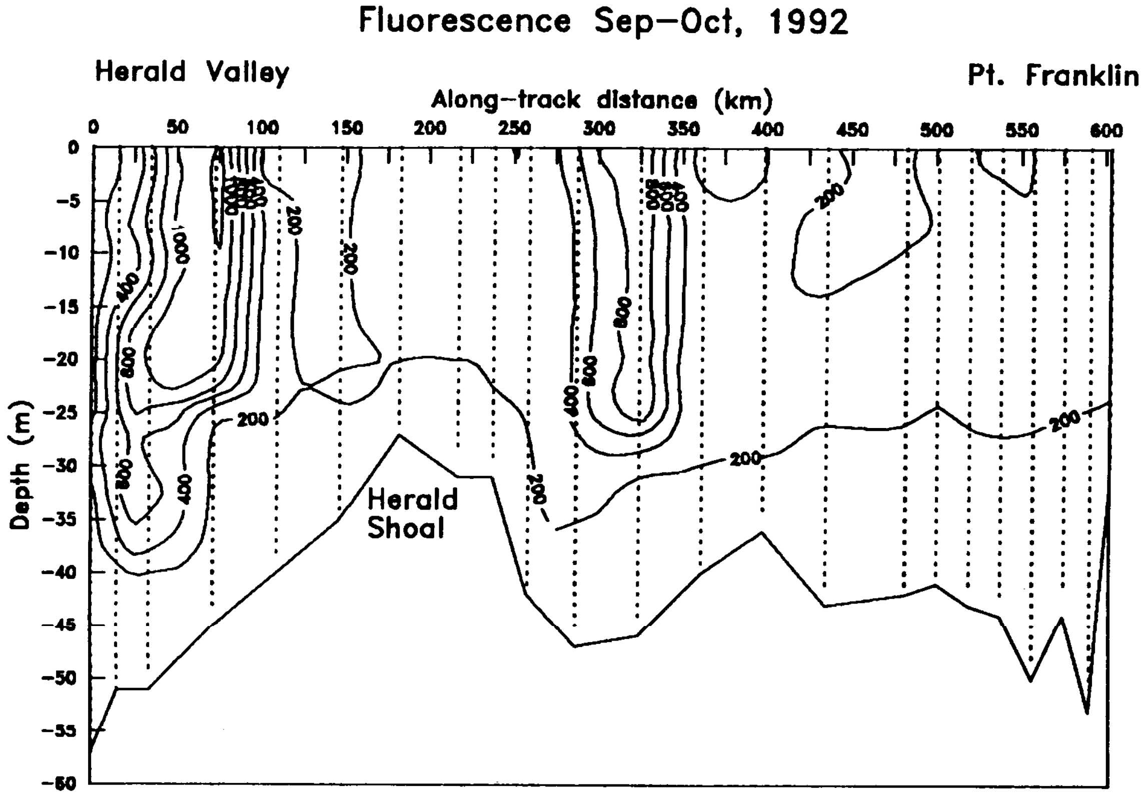

Figure 4. Cross-section profile of fluorescence (mvolts) measured along the CTD transect between Herald Valley and Pt. Franklin.

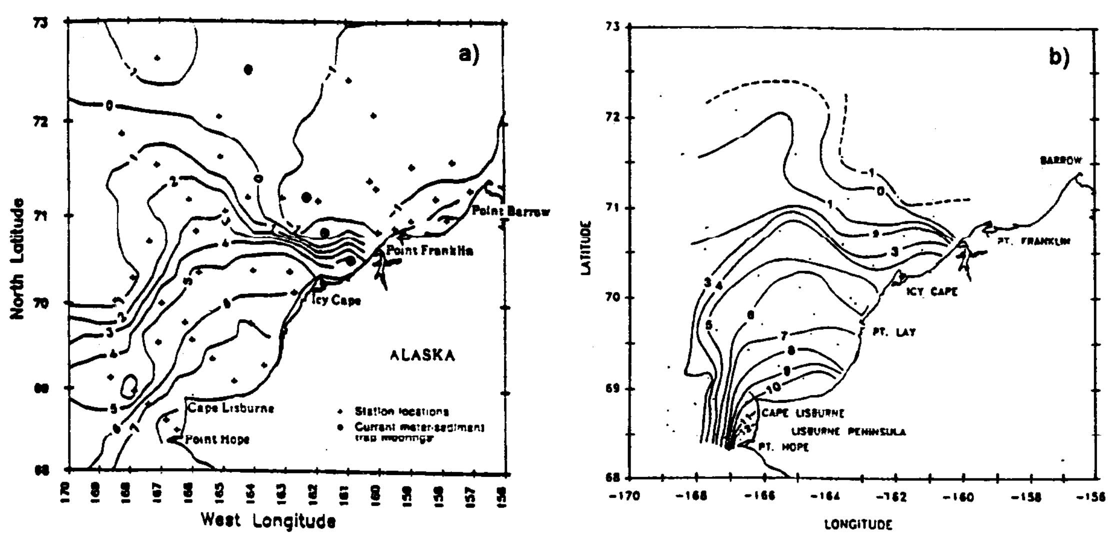

Figure 5. Contour maps of bottom temperature from a) 1986, and b) 1990. The 1986 figure is reproduced from Johnson (1989).

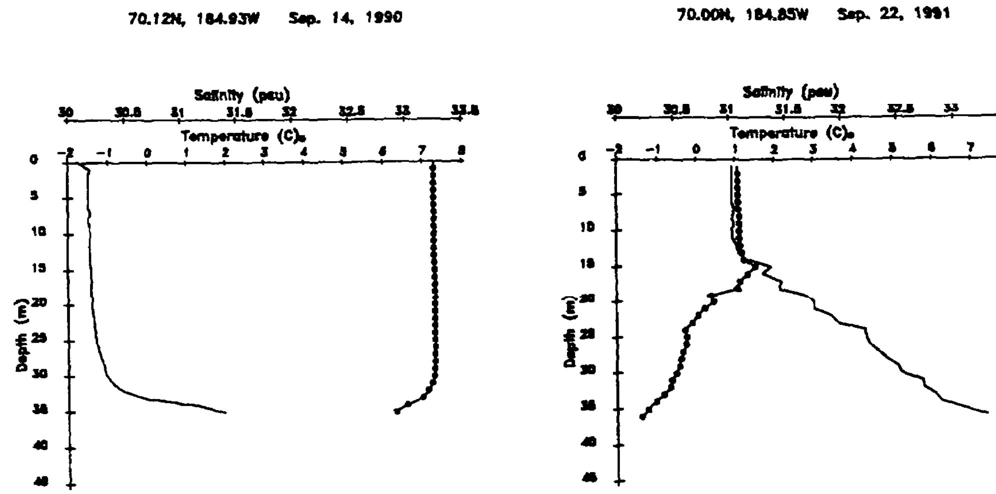

Figure 6. Vertical profiles of temperature (dotted line) and salinity (solid line) obtained in 1990 (left panel) and 1991 (right panel) at about 70°N, 165°W.

INTERANNUAL VARIABILITY

The dependence of circulation on wind stress and the observed interannual variations in hydrography suggest that the two are related. Figure 7 shows monthly anomalies of the north component of the gradient wind computed at 67.5°N, 167.5°W from sea-level pressure fields compiled by the U.S. Navy's Fleet Numerical Oceanography Center. The figure shows that winds were anomalously southward in summer of 1981 and 1991; years characterized by the absence of the bottom temperature front and a relatively small volume of ACW on the northeast shelf. In contrast, winds were anomalously northward in summer of 1986 and 1990, which were years characterized by the presence of the bottom front and relatively large volumes of ACW on the northeast shelf. To further illustrate the effect of winds on the arrival times of BSW and ACW on the northeast shelf, consider Figure 8 which shows temperature time series from the 1991/92 current meter data. In 1991, warm water appears off Cape Lisburne and Barrow in early October, whereas in 1992 warm water is observed at these locations one to two months earlier. While the foregoing is suggestive of the role of the regional wind field, other factors are most certainly involved. For example, interannual variations in temperature and salinity properties of the Bering Strait throughflow are probably substantial.

SUMMARY

The preceding analyses indicates that:

1) A bottom temperature front and the core of the Alaska Coastal Current parallel the 30 to 40 m isobaths in the northeast Chukchi Sea. Frontal strength and current speeds vary in proportion to the bathymetric relief. The front is a seasonally recurring phenomenon which appears in most years.

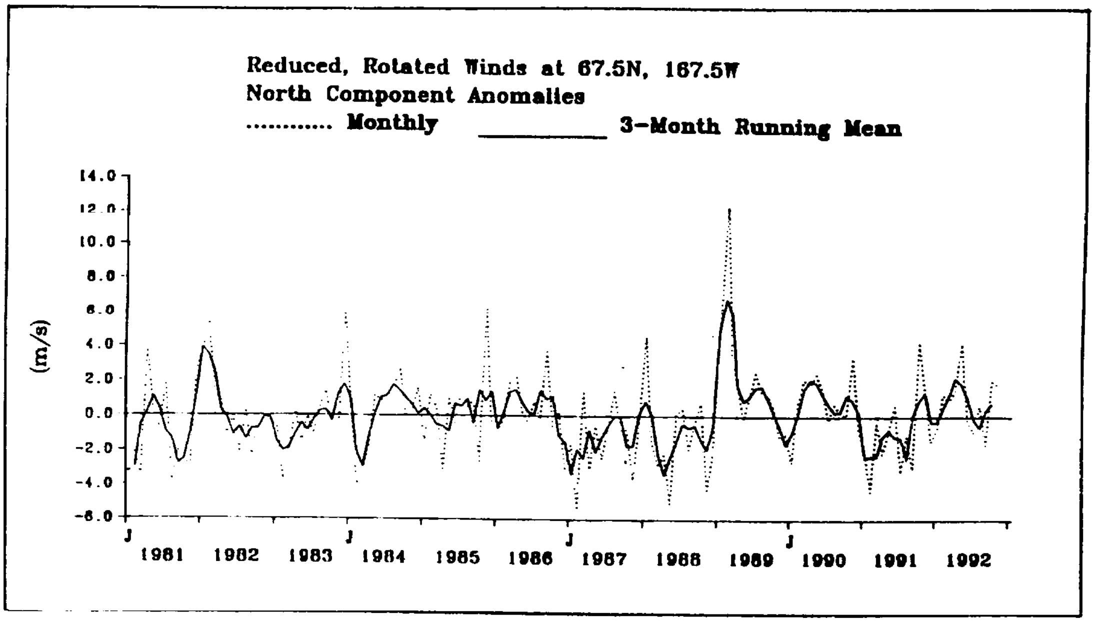

Figure 7. Time series plot of the monthly (dotted line) anomaly of the meridional component of the gradient wind estimated for the period from January 1981 to November 1992 at 67.5N, 167.5W. Solid line is the three-month running mean of these anomalies. Negative values imply above average southward wind speeds and positive values imply below average southward wind speeds.

2) interannual variations in summer winds over the northern Bering and Chukchi Seas are large and affect the flushing time on the northeast shelf and the formation of the bottom front. The data suggest that persistent, northerly wind anomalies delay flushing and impede frontal formation.

3) northward flow to the east of Herald Shoal appears to be an important route for the flux of particulate organic carbon onto the northeast shelf.

Several topics that require additional research include:

1) investigating circulation on the outer shelf (north of 71°N).

2) obtaining a better understanding of the spatial coherence between fluctuations in the regional wind field, Bering Strait transport, and circulation in the Chukchi Sea.

3) interannual variations in the flux of temperature, salinity, nutrients and carbon through Bering Strait and on the Chukchi shelf.

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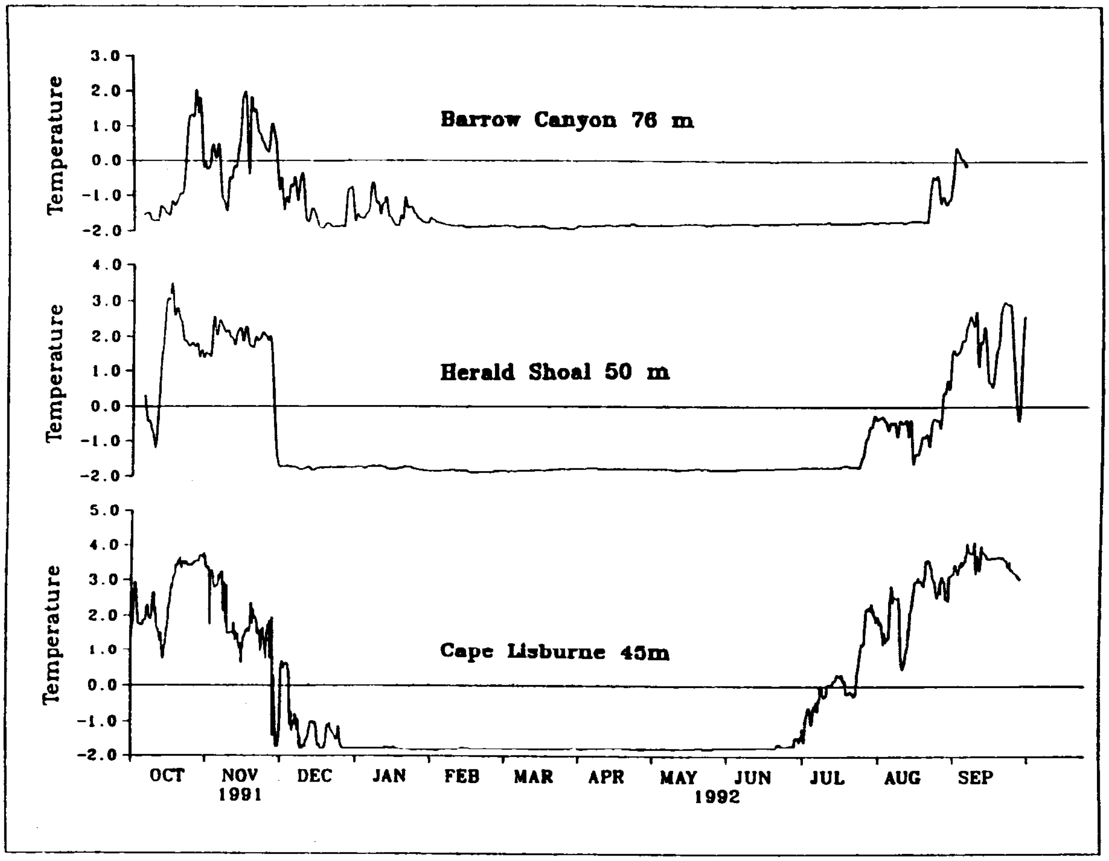

Figure 8. Time series plot of temperatures at (from top to bottom) Barrow Canyon, Herald Shoal, and Cape Lisburne from October 1991 through September 1992.

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HABITAT USE BY DOLLY VARDEN CHAR AND ARCTIC CISCO IN BEAUFORT SEA COASTAL WATERS: SHORT-TERM MOVEMENTS AND TEMPERATURE OCCUPANCY

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INTRODUCTION

The availability, quantity, and quality of summer feeding habitat are among the most significant factors limiting the growth of fish populations in the arctic (Gallaway 1990). When food resources in freshwater habitats are limited, many arctic fishes adopt an amphidromous life history pattern that includes annual feeding migrations to marine waters (Craig 1989). The primary foraging area of a large portion of the salmonid populations residing in the North Slope region of Alaska and the Yukon is the Beaufort Sea (Craig 1984). The advent of large-scale oil and gas development activity in the coastal region of the North Slope has raised concerns about its effects on fish habitats and fish movements and prompted numerous studies (see, e.g., Ross 1988, Hale et al. 1989, Gallaway et al. 1991). In 1988 we initiated a fish habitat use study in Beaufort Sea coastal waters that was intended to complement the intensive ongoing work along the immediate shoreline. Our working hypothesis was that amphidromous salmonids occupy the entirety of the relatively warm, brackish water mass present along the coast during summer, but make relatively little use of adjacent cold, saline marine waters. This paper focuses on one element of the study--the use of ultrasonic telemetry and concurrent oceanographic observations to obtain information on habitat use by large Dolly Varden (*Salvelinus malma*) and Arctic cisco (*Coregonus autumnalis*).

STUDY AREA AND METHODS

The telemetry investigation was conducted in Camden Bay, Alaska, during the summers of 1990 and 1991. Camden Bay is a potential site for oil production and transport facilities. It also lies in the center of the most marine-like section of the Beaufort Sea coast (Gallaway et al. 1991). These conditions result from a combination of an absence of large local freshwater sources, lack of barrier islands, and comparatively deep water near shore, which facilitates intrusions of marine water and pack ice as well as vertical and lateral mixing.

Most of our telemetry observations were made from the 11-m vessel *1273*. However, we also used a skiff when tracking fish in shallow water. A global positioning system receiver was the primary positioning device; it was supplemented with radar during periods of intermittent satellite coverage and when tracking fish from the skiff. Vessel positions were recorded every five minutes. The telemetry system's onboard components consisted of a portable receiver/data storage unit and directional hydrophone. Individual transmitter calibration data loaded into the unit converted received signals to engineering units, which were stored with time data supplied by an internal clock. In 1990 we used a 5 min recording interval, while in 1991 a 1 min interval was used. Temperature transmitters or miniature pingers were attached externally to the fish. Pingers provide only location information. An internally recording salinity-temperature-depth (STD) instrument was used to measure the thermohaline structure of the water column at each fish release location and periodically during tracking. The data from the telemetry receiver and STD were periodically downloaded into a laptop computer.

The fish we used for the study were captured at the east end of Simpson Cove. Large individuals were selected to minimize tag effects on behavior and movements. Most fish were released 2-3 km offshore; however, during 1991 encroaching pack ice caused us to release three fish in Simpson Cove proper. We attempted to maintain close contact with the fish while tracking in order to minimize the effects of varying fish-vessel relationships on movement rate calculations and usually followed a fish as long as possible. Most tracks terminated when the fish reached the shoreline and acoustic contact was lost or water depths became too shallow for safe navigation. Tracking activities are summarized in Table 1.

Table 1. Summary of fish tracking in 1990 and 1991.

Fish No.	Species	Total Length (cm)	Transmitter Type	Start Date	Duration of Track (min)
1	Dolly Varden	53.1	Temperature	7/30/90	166
2	"	54.0	"	7/31/90	935
3	"	48.5	"	8/01/90	292
4	"	56.9	"	8/03/90	1260
5	"	54.2	"	8/10/90	140
6	"	53.5	"	8/11/90	545
7	Arctic cisco	42.9	"	8/12/90	261
8	"	43.7	"	8/10/91	577
9	"	43.7	Pinger	8/12/91	465
11	"	32.9	"	8/14/91	45
12	"	44.1	Temperature	8/16/91	274
13	"	45.6	"	8/18/91	330
14		45.6	"	8/20/91	343

Ground speed was the primary variable used to evaluate fish movement rates. It is the vector sum of a fish's swimming speed and ambient currents and includes error terms due to the variable spatial relationship of the fish and tracking vessel and navigation inaccuracies. The gross ground speed of a fish is its speed made good over an entire track. Net movement rate was defined as the speed made good over the shortest water path between starting and ending points of track. Net movement direction was determined from the starting and ending points of a track. The ratio of net movement rate to gross ground speed provided an index of the directedness of movement of a fish, with 0 indicating no directed movement and 1 completely directed movement.

Raw ground speed data were standardized to total body lengths/second (L/s) and screened for excessively high values (>3.3 L/s). Position data bounding high values were examined and in most cases it was possible to identify erroneous positions, which were deleted. Speeds were then recalculated over the longer interval. Remaining errors were reduced by calculating averages over either 1 h (1990) or 0.5 h (1991) segments of tracks, interpolating when segment ends did not coincide with observed positions. The averaged data were then screened for serial dependence with a runs test prior to statistical testing. We used only nonparametric statistical tests due to the small sizes and prevalent non-normality and heteroscedasticity of the data sets. Circular statistics were used for tests of randomness of net movement directions of each species. Temperature time-series data were screened for outliers, any data gaps filled by interpolation, and then the data were examined for autocorrelation before statistical testing.

RESULTS AND DISCUSSION

Markedly differing oceanographic conditions prevailed during the two years of our study. In 1990 strong and persistent easterly winds drove the pack ice far offshore. Relatively fast currents, weak vertical stratification, inshore upwelling, and marine waters typified the local oceanographic regime. In the uppermost 4 m, temperatures and salinities averaged 3.2°C and 29.9 ppt, respectively. In 1991 comparatively weak and inconsistent east winds occurred and the pack ice remained close to shore all summer. The water column was stratified, with temperature and salinity in the uppermost 4 m averaging 1.8°C and 19.0 ppt, respectively. During both years little of the relatively warm, brackish water thought to be the prime feeding habitat of amphidromous salmonids was present in Camden Bay during mid-summer; it occurred mainly in the vicinity of creek and river mouths.

Six Dolly Varden and seven Arctic cisco were tracked over distances totaling 112 km and 63 km, respectively (Table 2). The average gross ground speed of the char was 55.8 cm/sec (range 48.8-74.2 cm/s), or 1.06 L/s (range 0.96-1.37 L/s). The standardized ground speeds of the three Dolly Varden tracked for the longest distances were not significantly different. Net movement rates of Dolly Varden ranged from 9.5 to 64.3 cm/s. The average gross ground speed of the Arctic cisco was 45.9 cm/s (range 30.1-71.1 cm/s), or 1.04 L/s (range 0.69-1.61 L/s). Differences were evident in the standardized gross ground speeds of individual Arctic cisco. Fishes 12 and 14 swam significantly faster than Fishes 8, 9, and 13, while the intermediate speed of Fish 7 was not significantly different from either of those two groups. There was no significant difference in the speeds of the Arctic cisco equipped with a miniature pinger and several others equipped with larger transmitters. The net movement rates of the Arctic cisco ranged from 12.0 to 44.1 cm/s. Gross ground speeds of individual Dolly Varden and cisco varied by as much as 55 cm/s along a given track. We were able to make estimates of swimming speeds of two Dolly Varden. Each was very similar to its gross ground speed, suggesting that at least for the longer tracks, the latter also may be good estimates of swimming speeds.

The standardized ground speeds of the Dolly Varden and Arctic cisco were higher than those observed for steelhead (*Oncorhynchus mykiss*) and cutthroat trout (*O. clarki clarki*), and about as fast as those of sockeye salmon (*O. nerka*) (Table 3). The group mean net movement rates of our fish were less than the highest reported movement rates of tagged char and Arctic cisco that had traveled long distances in the Beaufort Sea. They may typify movement rates of adult fish returning to fresh water, as the return migration of large fish is underway by early August.

The directedness of movement varied among fish; however, all but a few were observed to return to the shoreline after being released offshore. The mean direction of the Dolly Vardens' net movements as a group was 116°T and random, whereas that of the Arctic cisco was 253°T and non-random. The apparent shoreline affiliation of both species is consistent with the relatively

Table 2. Summary of movements of Dolly Varden and Arctic cisco.

Fish No.	Movement Gross (km)	Movement Net (km)	Net/gross ratio *	Gross ground speed (cm/s)	Gross ground speed (L/s) **	Net ground speed (cm/s)	Compass bearing (°T.) ***
				Dolly Varden			
1	6.9	6.3	0.9	69.7	1.31	63.2	329.0
2	31.0	12.0	0.4	55.3	1.02	21.4	88.0
3	11.5	3.1	0.3	65.5	1.35	17.7	236.0
4	36.9	7.2	0.2	48.8	0.96	9.5	152.0
5	6.2	5.4	0.9	74.2	1.37	64.3	174.0
6	19.3	5.2	0.3	59.0	1.10	15.9	125.0
	-	-	-	55.8 ****	1.06 ****	19.6 ****	116.0 *****
				Arctic cisco			
7	7.7	7.0	0.9	48.9	1.14	44.1	231.0
8	10.4	4.2	0.4	30.1	0.69	12.0	256.0
9	11.5	5.4	0.5	41.1	0.94	19.2	268.0
11	0.9	0.4	0.5	34.4	1.04	15.9	120.0
12	11.7	4.2	0.4	71.1	1.61	25.7	272.0
13	8.3	3.3	0.4	41.9	0.92	16.7	248.0
14	12.6	7.2	0.6	61.5	1.35	34.7	278.0
	-	-	-	45.9 ****	1.04 ****	23.0 ****	253.0 *****

* This ratio is an index of directedness of movement with 0 equaling no directed movement and 1 equaling unidirectional movement.
** Total body lengths per second.
*** Degrees true; based on starting and ending points of track.
**** Grand mean; total gross movement divided by total time tracked.
***** Unweighted mean.

heavy use of shoreline habitat observed by others in Simpson Lagoon (Craig et al. 1985) and in Camden Bay, where the largest gill-net catches of both char and Arctic cisco have been at stations nearest shore (Fruge et al. 1989, Palmer and Dugan 1990).

Association with shorelines is a frequent, but not consistent, behavior of amphidromous salmonids elsewhere in North America. It appears to be commonplace among Dolly Varden and cutthroat trout in southeastern Alaska (Armstrong and Reed 1971, Jones 1976), as well as among cutthroat trout in Puget Sound, Washington (Washington 1977). Conversely, cutthroat trout have been captured as far as 46 km off the Washington-Oregon coast in the Columbia River plume (Pearcy et al. 1990) and Dolly Varden have recently been shown to make extensive oceanic migrations in the northern Bering Sea-Chukchi Sea region, including movements between the freshwaters of western Alaska and Russia (DeCicco 1992).

The mean temperature of waters occupied by Dolly Varden was 3.6°C (range -0.5-6.5°C, N = 587). Despite much different oceanographic conditions in 1991, the mean temperature occupied by Arctic cisco also was 3.6°C (range 1-7.5°C), N = 1,562). The Dolly Varden appeared to use the entire observed range of temperatures in the study area, whereas Arctic cisco did not occupy waters colder than 1°C. However, avoidance of waters colder than 1°C by Arctic cisco may be more apparent than real — an artifact produced by the existing oceanographic conditions. The Dolly Varden and Arctic cisco we tracked were surface-oriented, which is

Table 3. Gross ground speeds of salmonids.

Species (N)	Total length (cm)	Group average speed (cm/s)	Group average speed (L/s) *	Individual average speed (cm/s)	Individual average speed (L/s)	Reference
Dolly Varden (6)	48.5-56.9	55.8 **	1.06	48.8-74.2	0.96-1.37	This study
Dolly Varden (1)	-	-	-	30.8	-	Armstrong and Reed (1971)
Cutthroat trout *** (14)	31.0-40.0	33.6 **	0.86	6.8-44.9	0.20-1.31	McCleave and LaBar (1972)
Steelhead trout (6)	72.0-89.0	57.4 **	0.74	38.9-69.4	0.54-0.96	Ruggerone et al. (1990)
Sockeye salmon (13)	-	61.0	0.99	-	-	Blair and Quinn (1991)
Sockeye salmon (25)	60.6-73.1	64.7 66.8 ****	- 1.0 ****	- 31.9-108.0 ****	- 0.48-1.66 ****	Quinn (1988)
Pink salmon ***** (37)	41.0-60.0	48.3 ******	-	-	-	Martin et al. (1990)
Arctic cisco (7)	32.9-45.6	45.4	1.04	30.1-71.1	0.69-1.61	This study

* Total body lengths per second.
** Weighted average; summed track lengths/summed times.
*** Entire track. Tracks 1-4, 6-9, 14, 17, 19, 21, 23, 25.
**** Swimming speed; currents removed from ground speeds.
***** Three control groups; sustained swimming toward stream.
****** Grand mean of means weighted by numbers of fish in each control group.

consistent with gillnet catch patterns in Camden Bay. In 1991 the prevailing stratification did not present the Arctic cisco opportunities to encounter the coldest waters, which were below the depths the fish used. Dolly Varden tagged with temperature transmitters did not avoid cold surface waters resulting from upwelling.

CONCLUSION

Camden Bay offered little in the way of warm, brackish water habitat during the summers of 1990 and 1991, yet both Dolly Varden and Arctic cisco were present there. Their presence can be interpreted as a mix of obligate and elective habitat uses. In 1990 many young-of-the-year Arctic cisco were carried there by currents, while in both years spawning imperatives would have driven unknown numbers of adults of both species into the area. Dolly Varden and Arctic cisco may also have been electively using Camden Bay in order to optimize the joint conduct of their life processes (sensu Neill 1979). Harsh thermohaline conditions may be tolerated when the net benefit to the animals is greater than that offered where preferred conditions occur (see, e.g., Magnuson et al. 1979, Johnson 1980, Quinn and Leggett 1987). Larval and juvenile Arctic cod (*Boreogadus saida*) and larval liparids were very abundant in Camden Bay area during 1990

(Thorsteinson et al. 1991), so perhaps some Dolly Varden and Arctic cisco were attracted there then by abundant prey. We have no definitive information on prey availability during 1991.

Amphidromous Arctic char and Dolly Varden have seasonally varying osmoregulatory abilities (Johnson and Heifetz 1988, Arneson et al. 1992) that appear to be linked to photoperiod (Arneson et al. 1992). In late summer, day length is rapidly decreasing, so perhaps the shoreline affinity of many of the fish we tracked represents a behavioral adaption to declining osmoregulatory abilities. When brackish water is discontinuous or absent, close association with shorelines may promote survival by maximizing opportunities to encounter all available freshwater refugia, even small or transient ones such as creeks and their plumes.

Finally, the mean swimming speeds of Dolly Varden and Arctic cisco that we observed approximate the theoretical optimal cruising speed of fish in the presence of currents (Trump and Leggett 1980). Swimming at that speed presumably would be advantageous to fish attempting to assimilate and retain energy reserves while making long feeding dispersals or spawning migrations.

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QUESTIONS AND DISCUSSION

CALEB PUNGOWIYI: Why was the decision made to catch and then release these fish rather than following natural or where they travel on their own rather than releasing them out in the bay?

LAURIE JARVELA: Well, as I said, part of the reasoning was that our vessel required a water depth of approximately 2 m to operate safely. So that is one reason we released them in the bay. We did look at the oceanographic conditions in both sites and there was about a 2° temperature difference between Simpson Cove where they were captured and the outer bay. Salinity was essentially the same in both areas every time we looked at it.

THE ENDICOTT FISH MONITORING PROGRAM: IMPACT ASSESSMENT AND ISSUE RESOLUTION

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INTRODUCTION

Oil and gas exploration and development have been ongoing in northern Alaska since the 1960s. Impacts of development activities have been monitored since the discovery of the Prudhoe Bay field in 1968. Accompanying the development of hydrocarbon resources has been the construction of nearshore solid-fill causeways in the central Alaskan Beaufort Sea and environmental concerns have been expressed over their impacts on nearshore hydrography and fish populations.

Two causeways have been developed in the region to date (Figure 1): West Dock and the Endicott Causeway. West Dock was constructed in 1974-75 to provide deep water access to barges delivering supplies and equipment to develop the Prudhoe Bay oil field. The dock was lengthened during early 1976 to provide access to barges trapped in nearshore ice, and in 1981 was lengthened again for the installation of a water intake facility. The second and third segments were separated by the placement of a 15 m breach, located 2800 m offshore. The total length of West Dock is approximately 4300 m.

The Endicott oil field is located about 16 km northeast of Prudhoe Bay adjacent to the Sagavanirktok River delta. The field contains oil reserves of approximately one billion barrels, about 350 million of which are recoverable. Development of the field required a 16 km-long gravel access road and an 8 km causeway connecting two manmade islands which support the oil production complex. The causeway was constructed in 1985 and includes two breaches in the mainland-to-interisland segment totaling 230 m. Concerns have been raised over the potential effects of causeways on regional fish populations.

Impact assessment research and long-term monitoring of effects of these two causeways on the nearshore environment have been more or less continuous since 1981. Under permit from the U.S. Army Corps of Engineers and the North Slope Borough, environmental monitoring has been specifically mandated to include habitat and fish population studies. Various studies have been completed, but continued long-term monitoring of the Endicott Causeway has been required by the Borough because of their concerns over potential effects of the Endicott Causeway on fish populations important to local residents.

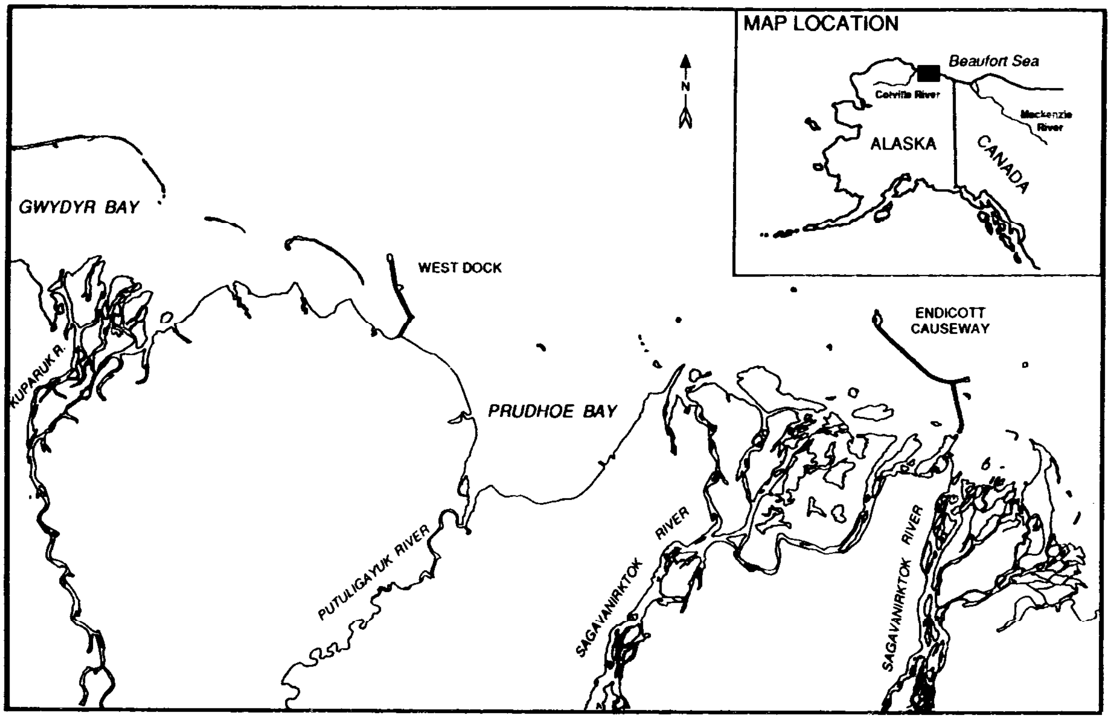

Figure 1. Causeways in the Prudhoe Bay region, Alaska.

METHODS AND RESULTS

This paper describes the marine environmental monitoring program in the Prudhoe Bay region, and specifically reviews the major issues associated with causeway impacts on fish populations in the central Alaska Beaufort Sea. These issues are:

(1) What are the effects of the causeways and/or causeway-induced changes in circulation and hydrography on the migration of young-of-the-year Arctic cisco (*Coregonus autumnalis*) from Canada to the Colville River of Alaska?

(2) What are the effects of the causeways and/or causeway-induced changes in circulation and hydrography on the nearshore migration corridor (from the shore to the 2 m isobath) used by most species and size groups of anadromous fish?

(3) How are the temperature/salinity characteristics of the nearshore habitat altered by the circulation and hydrographic effects resulting from the causeways, and what ramifications do these changes have on the fish populations in the Sagavanirktok River region?

(4) What are the impacts on Sagavanirktok River broad whitefish (*Coregonus nasus*) population levels and on the Colville River Arctic and least cisco fisheries?

These major issues of concern are restricted to the question of effects of coastal modification on physical and biological processes. The major issues are well documented, having been articulated in the early 1980s based upon comments presented in a series of public forums and resource agency meetings while the project was being planned. These issues provided the focus for the project environmental impact statement (EIS) and the subsequent monitoring program.

This paper introduces each of these issues and describes the process being used to assess impacts of causeway development on fish of the nearshore Beaufort Sea. It introduces a series of four papers that follow, each of which describes the status of the resolution of the four issues.

SUMMARY

To date, the results of fish monitoring efforts suggest that marine causeway development in the Alaskan Arctic has not resulted in significant degradation in fish habitat nor has it caused reductions in the fish populations inhabiting this region. Because of a recent decision reached by industry and Federal regulatory agencies to increase breach length in the causeways to mitigate perceived impacts on fish, an important policy decision has been made by government and industry that may influence other mitigation actions in the future.

QUESTIONS AND DISCUSSION

TOM NEWBURY: I just hope at some point we will talk about the broad whitefish population in the Sag.

BILL WILSON: Yes, you will hear a lot about the broad whitefish population here shortly.

EFFECT OF WIND ON THE RECRUITMENT OF YOUNG-OF-THE-YEAR CANADIAN ARCTIC CISCO (*COREGONUS AUTUMNALIS*) INTO THE CENTRAL ALASKA BEAUFORT SEA

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INTRODUCTION

When Gallaway et al. (1983) first speculated that the Mackenzie River in Canada was the source of Arctic cisco in the central Alaska Beaufort Sea, they also theorized that wind-driven coastal currents could provide a mechanism for the dispersal of young-of-the-year fish. The idea proposed was that the "migration" of young-of-the-year from Canada to Alaska was largely a passive drift process governed by wind speed and direction. If this assertion is true, it would have a profound impact on assessing causeway effects on the dispersal process. The effects would be a direct function of the degree to which the structures modify circulation in a manner that would either enhance "drop-out" of fish prior to reaching the Colville River (eddies, current reductions, etc.) or increase offshore transport such that the fish would be exposed to colder marine conditions. If the dispersal is largely a passive drift phenomenon, the focus of the assessment would shift from biology to meteorology and oceanography.

If wind speed and direction govern the movements of young-of-the-year Arctic cisco into Alaska from Canada, then there should be strong association between catch per unit effort (CPUE) of young-of-the-year and wind speed and direction; this hypothesis is tested below.

This paper provides an analysis of meteorological and fyke net catch data to determine the degree of association between the strength of the yearly recruitment of young-of-the-year Arctic cisco and summer wind patterns. The analysis presented below is an extension of that utilized by Fechhelm and Griffiths (1990).

METHODS

The principal difference between the data used in this analysis and that published by Fechhelm and Griffiths (1990) is the source of the wind data. Fechhelm and Griffiths (1990) used wind data collected from the National Weather Service (NWS/NOAA) meteorological station located at Barter Island, Alaska; however, the Barter Island station ceased operations during the winter of 1989. As an alternate data source, we used meteorological data collected at the Deadhorse Airport, Deadhorse, Alaska. Wind vectors were converted from polar (x, Ø), to rectangular (x, y) coordinates, with a wind vector, or the resultant average of many wind vectors,

[1]Presentation given by William Griffiths, LGL, Ltd.

represented by a single point. The ordinate (x) and abscissa (y) of the wind vector in question thus represent the east/west and north/south wind components, respectively (see Fechhelm et al. 1989).

For each of the ten study years, average wind vectors were calculated for the period 1 July-15 August. The period of July-August encompasses most of the open water season during which movement of age 0+ Arctic cisco from the Mackenzie River to Alaska take place (Fawcett et al. 1986, Bond and Erickson 1987, Cannon et al. 1987, Moulton 1989). The months of June and September were excluded from the analysis because it was felt that variable yearly ice cover during these months could bias the results—ice cover could negate the effect of wind on current. The July-August period of analysis was further truncated to 1 July-15 August. The reason for deleting the last two weeks of August is that during good recruitment years, young-of-the-year arrive in the Prudhoe Bay area around mid-August. Wind conditions occurring after their mid-August arrival could distort the wind/recruitment relationship (Fechhelm and Griffiths 1990).

Recruitment strength for the years 1982 to 1991 was quantified based upon fyke net catches of young-of-the-year fish in terms of fish caught per net per 24 hrs of operation. Because young-of-the-year cisco are absent from the Prudhoe Bay area during the first half of the summer, catch rates were not calculated until the arrival of new recruits. This was defined as the first day in which any single fyke net caught more than two age 0+ Arctic cisco for two consecutive days followed by a continuous and marked increase in catch throughout the study area. Size cohorts were identified and abundance levels calculated using the methods described by Fechhelm and Griffiths (1990) and LGL (1990).

RESULTS AND DISCUSSION

Table 1 illustrates the relative recruitment strength in terms of catch-per-unit-effort (CPUE). CPUE ranged from a high of 340 fish/net/day in 1990 to complete absence of catch in 1982, 1984, and 1991. When Ln (CPUE+1) was plotted against average east/west wind speed, there was a marked segregation of data (Figure 1). The five years characterized by the highest CPUE of young-of-the-year Arctic cisco (1983, 1985, 1986, 1987, 1990) were also years in which there was a strong net easterly wind component in excess of 9.9 km/h (strong transport). In contrast, the five poorest catches (1982, 1984, 1988, 1989, 1991) were recorded in years characterized by weak east winds less than 4.1 km/h (weak transport). There was a highly significant difference ($P<0.001$) in $\log_e$ (CPUE +1) for the five strong wind years versus the five weak wind years (t-test, Sokal and Rolfe 1989).

Table 1. Arrival date in Prudhoe Bay area and subsequent catch rates for age 0+ Arctic cisco by year.

Year	Arrival Date	Total Catch	CPUE (fish/net/day)
1982	na	0	0.0
1983	27-Aug	2,968	24.2
1984	na	0	0.0
1985	16-Aug	81,000 *	144.0
1986	10-Aug	115,000 *	153.6
1987	13-Aug	31,000 *	67.3
1988	3-Sep	180	1.1
1989	30-Aug	591	1.9
1990	5-Aug	58,000 *	340.0
1991	na	0	0.0

* Estimated (see Fechhelm and Griffiths 1990 for method)

SUMMARY

Analysis of yearly catch-per-unit-effort and wind data from 1982 to 1991 for the period 1 July-15 August of each year revealed that the five years (1983, 1985, 1986, 1987, 1990) with the

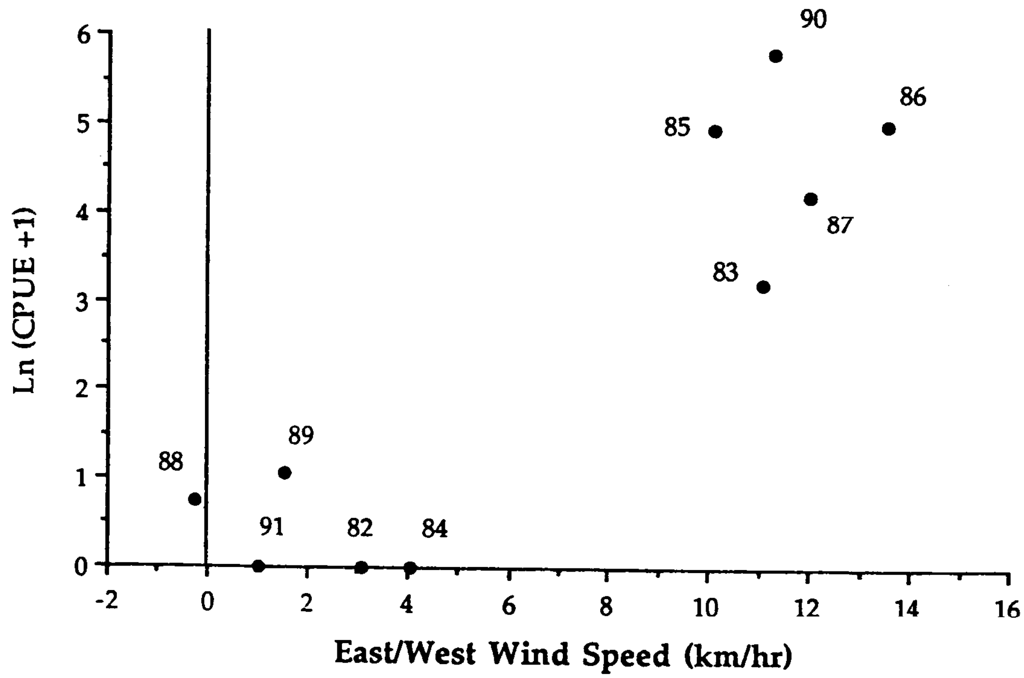

Figure 1. Ln of catch-per-unit-effort (fish/net/24 hr) of young-of-the-year Arctic cisco as a function of net east (positive)/west (negative) wind speed covering the period 1 July-15 August.

highest catch-per-unit-effort (strong recruitment) of young-of-the-year Arctic cisco were also characterized by average east winds in excess of 9.9 km/h. Conversely, the five years (1982, 1984, 1988, 1989, 1991) with the lowest catch-per-unit-effort (weak recruitment) were characterized by weak east winds $\leq$4.1 km/h. (Net winds for 1988 were actually out of the west.) Comparison of Ln (CPUE +1) revealed significantly ($P< 0.001$) higher catch-per-unit-effort during the five strong east wind years.

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QUESTIONS AND DISCUSSION

GAIL IRVINE: How did you determine the start date? I noticed that this one looked like a different start date. You said the last one was the first of July?

WILLIAM GRIFFITHS: This is the arrival date, the date they arrived in Prudhoe Bay rather than the start date.

GAIL IRVINE: They started the 20th of June?

WILLIAM GRIFFITHS: No, this is the arrival date in Prudhoe Bay. The other date, the start date was the 1st of July starting in the Mackenzie Delta. So it took them about a month and a week to get there.

GAIL IRVINE: Was the start date on the 1st of July determined by ice break-up times or do you have some shifting of patterns?

WILLIAM GRIFFITHS: No, that is one of the things that causes certain of the years not to work very well. We don't know the exact date each year of the release out of the Mackenzie. This was just basically an exercise to show, although winds won't exactly predict every year, they are one of the most dominant things that control the movement of the fish.

JAY BRUEGGEMAN: What effect have you seen with the pack ice relative to recruitment, years that we have had heavy ice?

WILLIAM GRIFFITHS: 1991 was such a year. We had very heavy pack ice in 1991 and we had a very low recruitment. We would have thought it would have been bigger than it had been. But I think it dampens the movement across coast currents.

EFFECTS OF PRUDHOE BAY CAUSEWAYS ON THE ALONGSHORE MOVEMENT OF LEAST CISCO (*COREGONUS SARDINELLA*)

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INTRODUCTION

During the early 1980s the primary focus of environmental studies in the Prudhoe Bay area was on the West Dock Causeway. Of the six major studies conducted from 1981 to 1984, four centered on West Dock (Griffiths and Gallaway 1982; Critchlow 1983; Biosonics 1984; Moulton et al. 1986), one served as a baseline study for the proposed Lisburne Causeway (Woodward-Clyde Consultants 1983), and one served as the baseline study for the Endicott Development Project (Griffiths et al. 1983). The Waterflood studies ended with the 1984 study which employed 26 fyke nets arrayed east and west of West Dock (Moulton et al. 1986). From 1985 to 1991, attention shifted to the newly constructed Endicott Causeway located in the middle of the Sagavanirktok Delta. The 1985 to 1991 Endicott studies have been of sufficient scope to include sampling in the West Dock Causeway region (Cannon et al. 1987; Glass et al. 1990; Reub et al. 1991; LGL 1990, 1991, 1992a, 1992b).

A key issue has been whether the West Dock Causeway blocked the alongshore movement of anadromous fish. This has been one of the issues that drew a consensus opinion of yes; however, the ecological effects on the fish remained moot.

The fact that West Dock blocks or delays alongshore fish movement has been documented in numerous reports and publications (e.g., Cannon and Hachmeister 1987; Fechhelm et al. 1989; Gallaway et al. 1991; Hachmeister et al. 1991; Robertson 1991; LGL 1992a, 1992b). Briefly, under east winds, current patterns modified by West Dock cause a wake eddy to form in the structure's lee. This wake eddy contributes to the development of a cell of cold, saline water between Stump Island and the West Dock Causeway. This marine intrusion appears to prevent some size groups of fish from entering the area, particularly from the west. The nearshore band is effectively "closed" during these periods.

While there was a general consensus that the blockage event can occur, debate continued over its ecological relevance. For example, apparent blockage is most clearly seen with small least cisco, primarily because this species is absent from Prudhoe Bay in early summer and only moves into the area from the Colville River during July (Griffiths and Gallaway 1982; Critchlow 1983; Griffiths et al. 1983; Moulton et al. 1986; Cannon et al. 1987; Glass et al. 1990; LGL 1990,

[1]Presentation given by William Griffiths, LGL, Ltd.

1991, 1992a, 1992b; Reub et al. 1991). It has also been suggested that the number of small least cisco that move into the Prudhoe Bay area during summer represents only a small portion of the total Colville River stock, so that the net effect of blockage to the least cisco population would be negligible (Moulton et al. 1986; Cannon and Hachmeister 1987). In addition, Moulton et al. (1986) suggest that voluntary feeding behavior could delay least cisco in the area west of West Dock because of high prey concentrations caused by the wake-eddy effect of West Dock.

METHODS

In this paper we use the fyke net data from 1985 to 1991 to investigate the blockage of small least cisco (<180 mm fork length) by West Dock and use the presence of sharp discontinuities in the alongshore distribution of these fish as an indicator of blockage.

RESULTS AND DISCUSSION

Catch-per-unit-effort (CPUE) of small least cisco in the study area of West Dock show a marked difference based upon year. From 1985-1987, catch rate data indicate that few small fish arrived in the study area from the Colville River: seasonal CPUE west of the causeway ranged from 0.4 to 1.5 fish/net/24 hr (Table 1). The absence of fish was also reflected in catch levels east of West Dock (0.3 fish/net/24 hr) and from the study area as a whole (0.3-0.7 fish/net/24 hr). Winds during July of all three years were predominantly from the east which may have prevented very small (<120 mm) least cisco from moving eastward through Simpson Lagoon and into the study area. In contrast, CPUE levels west of West Dock from 1988 to 1991 were 1-2 orders of magnitude higher than the 1985 to 1987 period, ranging from 27.5 to 50.9 fish/net/24 hr (Table 1). The low catch in 1985-1987 precludes analysis.

Table 1. CPUE (fish/net/24 hr) for least cisco from 1985 to 1991.

	CPUE			
	Total	West of West Dock	East of West Dock	Ratio East/West
		<180 mm (Cohort I)		
1985	0.7	1.9	0.3	-
1986	0.3	0.4	0.3	-
1987	0.4	1.5	0.3	-
1988	6.7	27.5	2.2	0.08
1989	7.7	28.8	1.1	0.04
1990	37.0	50.9	31.3	0.61
1991	20.5	39.0	16.8	0.43
		≥180 mm (Cohort II)		
1985	11.6	13.2	11.0	0.83
1986	6.1	9.2	5.3	0.58
1987	12.3	47.4	9.0	0.19
1988	29.9	60.8	23.1	0.38
1989	12.6	25.7	8.8	0.34
1990	109.2	224.7	62.3	0.28
1991	43.3	95.3	32.8	0.34

For the remaining four years, 1988-1991, there were sharp discontinuities in the coastal distribution of small least cisco (Table 1; Figure 1). Seasonal mean CPUE ranged from a high of 27.5 fish/net/24 hr west of West Dock to 2.2 fish/net/24 hr at stations east of the structure in 1988, and from 28.8 to 1.1 fish/net/24 hr in 1989. A Wilcoxon signed rank test was used to compare daily CPUE west and east of West Dock for both years. Data in this analysis were limited to the time when fish first arrived in the area, and to the time when the average CPUE dropped to below 5 fish/net/24 hr in the whole study region which was assumed to reflect the point at which most small least cisco had left the study area. The resultant time periods for the analysis were 16 July-11 September in 1988 and 15 July-18 August in 1989. Mean CPUE west of West Dock was significantly ($P < 0.01$) higher than mean CPUE east of West Dock in both years. We took the analysis one step further and repeated the comparison using only the most productive location (Station 208) east of the causeway. Again, mean CPUE west of West Dock was significantly ($P < 0.01$) higher than at the most productive net east of West Dock in both

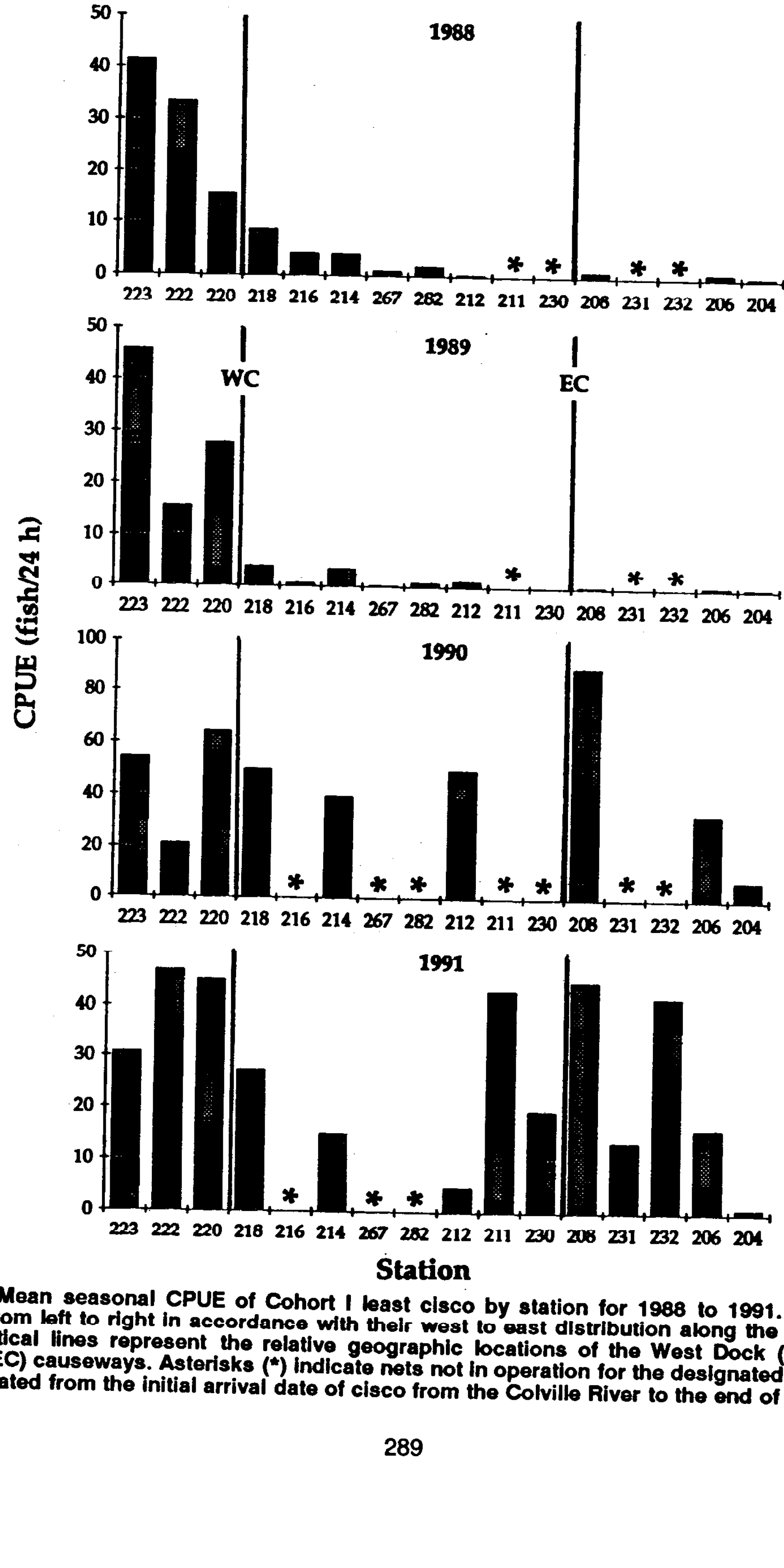

Figure 1. Mean seasonal CPUE of Cohort I least cisco by station for 1988 to 1991. Stations are oriented from left to right in accordance with their west to east distribution along the Beaufort Sea coast. Vertical lines represent the relative geographic locations of the West Dock (WC) and the Endicott (EC) causeways. Asterisks (*) indicate nets not in operation for the designated years. CPUE was calculated from the initial arrival date of cisco from the Colville River to the end of the sampling season.

years. These data indicate that while small least cisco were able to move into the eastern end of Simpson Lagoon, few bypassed the West Dock Causeway, suggesting blockage.

In contrast to 1988 and 1989, the coastal distribution of small least cisco in 1990 and 1991 was more homogeneous, with no sharp discontinuities in distribution at either the West Dock or Endicott causeways (Table 1; Figure 1). A Wilcoxon signed rank test comparing daily mean CPUE (16 July-15 August in 1990; 14 July-22 August in 1991) revealed no significant ($P > 0.05$) difference in CPUE on either side of West Dock. These results indicate that, unlike 1988 and 1989, fish were able to bypass West Dock in substantial numbers in 1990 and 1991.

The coastal distribution of large least cisco rarely shows a sharp discontinuity at West Dock (Figure 2). In fact, Station 208, located on the seaward face of the inter-island segment of the Endicott Causeway, is typically one of the most productive locations in the entire study area, suggesting that large fish often move around the causeway during their dispersal from the Colville River. A Wilcoxon signed rank test comparing daily catch data on both sides of West Dock revealed a significant ($P < 0.05$) difference in only one of the eight years analyzed (1987) from 1985-1991.

SUMMARY

The presence of sharp discontinuities at West Dock in the alongshore distribution of small least cisco in two of the four years for which data were available indicates that West Dock can delay or block the passage of these fish. Abundances of small least cisco were significantly higher on the west side of the causeway in 1988 and 1989. However, there were no significant differences in side-of-causeway catches in 1990 and 1991. These results indicated that blockage does occur in some years, but not in others. Therefore, the effects of the blockage on the Colville River population of least cisco is thought not to be biologically significant. In some years small least cisco do not even reach as far east as the West Dock Causeway, indicating that the area east of West Dock may not be a critical habitat for these fish.

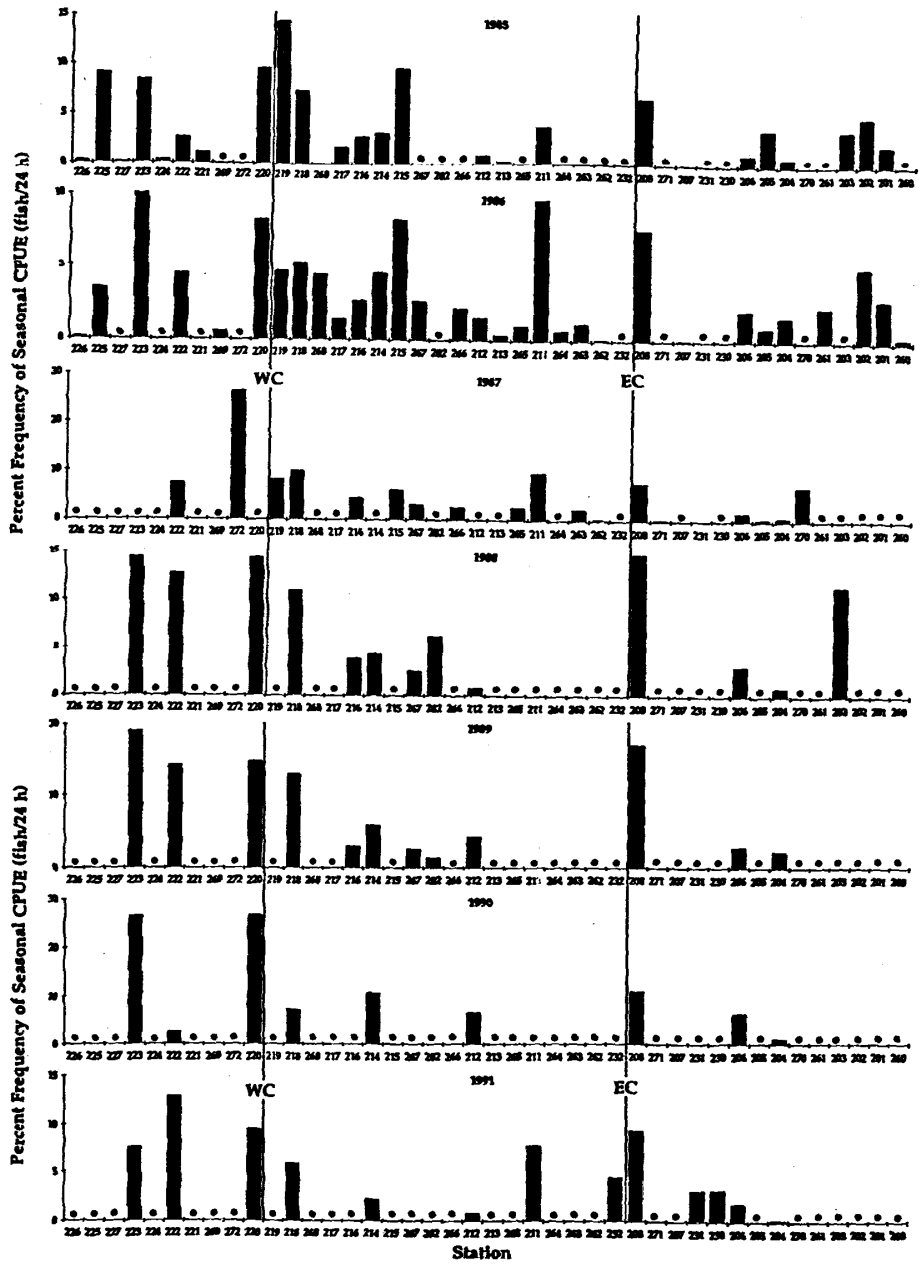

Figure 2. Percent frequency of mean seasonal CPUE of Cohort II least cisco by station for 1985 to 1991. Stations are oriented from left to right in accordance with their west to east distribution along the Beaufort Sea coast. Vertical lines represent the relative geographic locations of the West Dock (WC) and the Endicott (EC) causeways. Dots (•) indicate nets not in operation for the designated years. CPUE was calculated from the initial arrival date of cisco from the Colville River to the end of the sampling season.

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QUESTIONS AND DISCUSSION

TOM NEWBURY: So you are saying that even though the small fish, moving back west, sometimes are pushed offshore...

WILLIAM GRIFFITHS: No, I didn't say that. I did not say they were pushed offshore. I said they moved along the north shore of Stump Island and through the Egg Island entrance.

TOM NEWBURY: All right. Then what do you think is the fate of those fish?

WILLIAM GRIFFITHS: Well, once they go into Egg Island entrance they are in Simpson Lagoon and they go back to the Colville.

TOM NEWBURY: Why do you object to my saying "pushed offshore?"

WILLIAM GRIFFITHS: Well, because they weren't pushed offshore. Tom, to me, pushed offshore means they go off here, this is offshore. This is alongshore.

TOM NEWBURY: Okay, I'm sorry. They end up on the outside of the barrier islands.

WILLIAM GRIFFITHS: They are on the outside of the barrier island, but they are not offshore.

GAIL IRVINE: Another question about the estimate that you were just making from Larry Moulton's study in 1985 or 1986.

WILLIAM GRIFFITHS: It was from the Waterflood Study of 1984.

GAIL IRVINE: Based on some of the figures you were showing that very few fish came over as far as the causeway in those earlier years, do you think that estimate might be an underestimate of the percentage of population at later...?

WILLIAM GRIFFITHS: 1984 was a good year for them to come over. Those early years 1985, 1986, and 1987 weren't good years. But 1984 was like a west wind year which would have pushed the fish over. So in some years, none come over. In other years, 10 or 20%. But most of the small fish, ...on this slide, this is the catch in Prudhoe Bay and the blue in the background is the catch in the Colville. What we see here is when we have nets in the Colville and these catches go down then we see the fish showing up in the Colville. But one thing to remember is that when these nets are in the Colville that the small fish are already there. There are a lot of the small fish that don't come over at all. They just spend their entire life in Harrison Bay.

PAM MILLER: I was just curious to know about the fish returning to the Colville, have there been any studies to show how those fish fare? Whether they might exceed what the habitat has to offer there because of the additional fish returning?

WILLIAM GRIFFITHS: What we know about the least cisco and the Arctic cisco in the Colville is mainly from the commercial fishery and the subsistence fishery data, another portion of the study. That is how they are monitored. We monitor those two fisheries to see how the fisheries are going. So that over a period of years we get to see if there have been any effects. We have not seen any decreases in the population numbers.

PAM MILLER: That reminds me of another question if there is time. I was also curious to know since there is a fairly substantial subsistence fishery there and a commercial fishing operation, have you made any attempt to incorporate indigenous knowledge into your work and historical knowledge?

WILLIAM GRIFFITHS: Yes, all of that is incorporated into the aspect of the study that is being run by Larry Moulton which is the commercial and subsistence fishery study.

BILL WILSON: Pam, just a quick corollary to that. LGL hires residents from the North Slope Borough for our fish crews in the summer, but Larry Moulton employs two or three people from the village of Nuiqsut in his studies there every fall. He monitors there from October to late November.

TOM NEWBURY: What are the factors that influence whether the least cisco make it to West Dock? Are there any oceanographic factors?

WILLIAM GRIFFITHS: For the small fish, we think it is the wind. In this case it is the reverse pattern of the Arctic cisco, that if you get strong northwest winds, they will move the currents to the east and bring a lot of those smaller fish over. If we have strong northeast winds, those fish would have to swim against the current and tend not to come over. So in the three years of the Endicott study, where we didn't see any of those fish, those were all three strong northeast wind years and we didn't see any of the small fish even arrive in the area to be affected.

MARK MOREHEAD: I just did a quick calculation on Laurie's numbers of fish swimming about a fish length per second. It ends up they swim about 400 km in the 45 days. How far is it from the Mackenzie to the Sag?

WILLIAM GRIFFITHS: It is about 600 km.

MARK MOREHEAD: So if they were swimming at that level they can't make it just on their own?

WILLIAM GRIFFITHS: Yes.

GROWTH AND CONDITION OF ARCTIC CISCO AND BROAD WHITEFISH AS INDICATORS OF CAUSEWAY-INDUCED EFFECTS IN THE PRUDHOE BAY REGION, ALASKA

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INTRODUCTION

The shallow ($\leq$2 m) coastal environment of the central Alaskan Beaufort Sea provides important summer feeding habitat for several anadromous and amphidromous coregonines of subsistence and commercial importance (Arctic cisco, *Coregonus autumnalis*; least cisco, *C. sardinella*; broad whitefish, *C. nasus*) (Craig 1989). For these fish almost all feeding occurs during the brief arctic summer when they complete most of their yearly growth and accumulate the energy reserves needed to survive the winter (Craig 1984). During summer, the ability of fish to assimilate the required energy is affected by such abiotic factors as temperature and salinity (Fechhelm et al. 1992).

Coastal zone petroleum development has relied on the use of solid-fill causeways, raising concerns because these structures alter local water circulation (Niedoroda and Colonell 1990), potentially reducing temperatures and increasing salinities.

This paper examines growth and condition patterns of age 1 and 2 Arctic cisco and broad whitefish resident in the Prudhoe Bay region based on the 1985 to 1989 Endicott Causeway Monitoring Program data. The goal was to determine the association between growth and condition and temperature and salinity for broad whitefish and Arctic cisco, and to attempt to quantify the effects of the Endicott Causeway on growth.

The study area, delineating habitats for both age 1 and 2 broad whitefish and Arctic cisco, is shown in Figure 1. The two area causeways, West Dock and Endicott, and the stations sampled between 1985 and 1989 are also shown.

METHODS

Growth Analyses

Growth was based on age 1 and 2 broad whitefish and Arctic cisco. Growth of these age groups is generally more rapid and thus more responsive than for older fish. Also, age 1 and 2 fish can be estimated accurately from length data.

For each year, surface temperature and salinity recorded at each station were plotted by habitat type and date. Major shifts in the daily temperature regimes were used to delimit 14 growth periods during the five summers. In all cases, the growth periods were defined independently of the growth data. We regressed daily mean length against time within each growth period which resulted in 14 regression slopes that could be correlated against

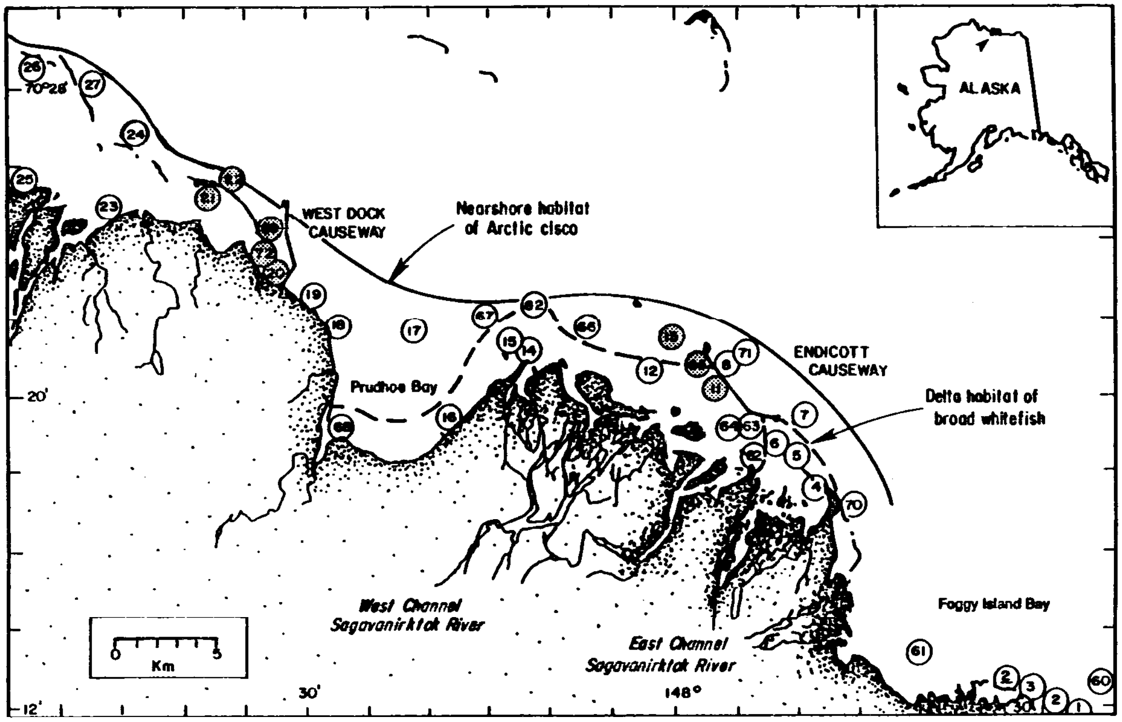

Figure 1. Map of the study area showing fyke net locations sampled between 1985 and 1989.

corresponding temperature and salinity levels.

Condition Analyses

We regressed log (mass) on log (fork length) using least squares regression for Arctic cisco for fish between 125 and 370 mm fork length, and for broad whitefish were calculated for fish in the 100-410 mm length range, size ranges common to each of the five years.

Mean temperature-salinity levels by habitat and year were the basis for orthogonal contrasts designed to test the associations of annual condition levels with the temperature and salinity.

Analyses of causeway effects

First, we quantified the temperature effect using the Before-After Control-Impact (BACI) model (Stewart-Oaten et al. 1986). The simultaneous daily measurements were averaged to provide a single observation for each ice-free season (1 July-15 September) in the Before and After periods and in each area (Impact and Control).

Next we determined if broad whitefish or Arctic cisco avoided the causeway-imposed hydrographic effects outside the wake area, using CPUE data transformed to $\log_e$ (CPUE =1) and the same BACI design. If fish were not avoiding the impacted area, then there should be no differences for age 1 and 2 broad whitefish and Arctic cisco.

Finally, we translated the observed causeway-induced temperature changes into effects on growth, using the temperature-growth model developed below, by using the results of BACI analysis to raise the daily temperature levels at the impact stations by the magnitude of the causeway effect.

RESULTS AND DISCUSSION

Growth versus Temperature and Salinity

The hydrographic plots suggested that the data from both habitats could be divided into two to four growth periods within each year, based on their temperature characteristics (e.g., Figure 2). Fourteen growth periods were delineated over the five years.

Kendall's tau correlations of growth against adjusted mean temperature for the 14 individual growth periods showed significant relationships between growth and temperature for ages 1 and 2 Arctic cisco and broad whitefish. The relationship between growth and mean adjusted salinity was negative in all cases, and significant for age 1 Arctic cisco and ages 1 and 2 broad whitefish. The weighted linear regressions showed temperature to be the main growth-regulating factor, as it explained from 77 to 92% of the variation; salinity explained only 23 to 50%. The negative correlation of salinity and growth may be spurious because there was also an inverse relationship between water temperature and salinity at about the same level as for growth and salinity.

Fechhelm et al. (1993) reported that age 1 Arctic cisco, maintained at constant temperature, showed no significant differences in growth or weight gain across five salinity levels (6, 12, 18, 24, 30 ppt).

Condition

Analysis of covariance showed significant differences in slope among years for broad whitefish but not for Arctic cisco. Significant differences in mass (condition) were evident among years for Arctic cisco. Orthogonal analysis showed that 1989 Arctic cisco (much higher than average temperature and higher salinity) were significantly heavier ($\underline{P}=0.05$) at a given length than the average of the fish collected during 1985-1988. Within the latter group, condition in years of relatively high salinity and low temperature (1985-1986) was not significantly different than condition in years having lower salinity and higher temperature (1987-1988). Condition of Arctic cisco appeared to be relatively constant over a wide range of temperature and salinity.

Because the slopes differed significantly, the orthogonal analysis for broad whitefish condition could not be computed. Comparison of the annual broad whitefish slopes against mean temperature and salinity values suggests that the steepest slopes (poorest condition) were associated with the lowest salinity. Fisher's Multiple Range Test showed two homogeneous sets of slopes (1985-1989 and 1987-1988) and one intermediate value (1986).

In the first group (higher salinity conditions), broad whitefish condition in 1985 (lower temperature) was similar to that in 1989 (higher temperature). In the second group (lower salinity conditions), the 1987 fish (higher temperature) were significantly (2%) heavier than the fish collected in 1988 (lower temperature). Thus, there were no consistent patterns in condition with temperature among the years.

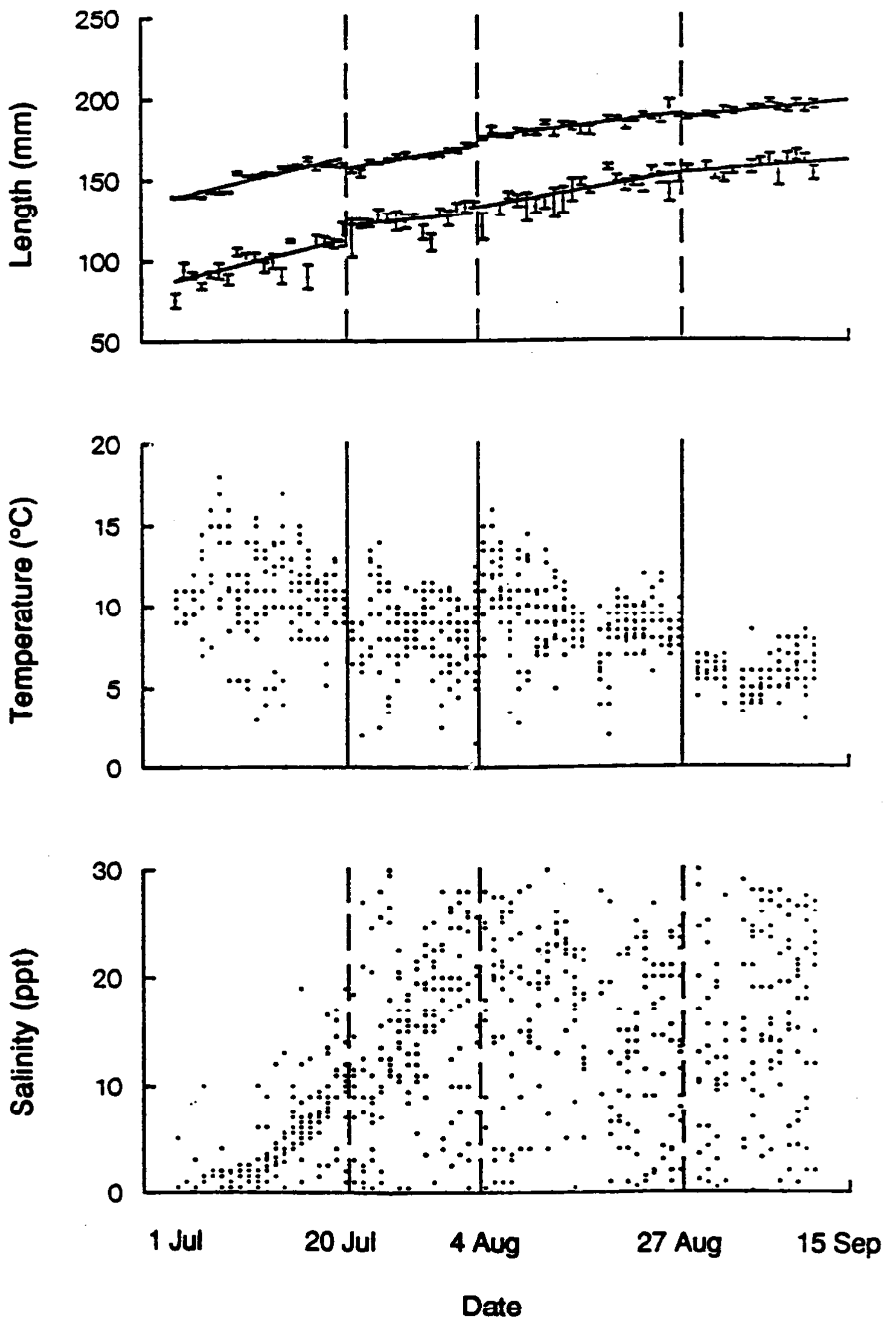

Figure 2. Example of the daily temperature plots used to define growth periods (solid lines). Corresponding divisions for daily salinities and size of age 1 and 2 Arctic cisco against time shown by dashed lines. Data shown are for nearshore habitat 1989.

Years with the steepest slopes (1987 and 1988) had the lowest salinity levels in the delta habitat. All the broad whitefish regression lines with different slopes cross near the upper end of the length range, indicating that small broad whitefish condition must have been poorer during years of low compared to high salinity. Conversely, large broad whitefish had better condition in low compared to high salinity years. Body weight for fish at 110 and 410 mm FL for each year using the annual regressions was plotted against the corresponding mean annual salinity level. Small fish (110 mm) were positively correlated with the corresponding mean salinity in 4 of 5 years, while the inverse was true in 4 of 5 years for the large (410 mm) fish.

Analysis of Causeway Effects

The effects analyses included assessments of 1) the causeway effects on temperature in habitats adjacent to the causeway wake, and 2) the predicted effects of the observed temperature change on fish growth, assuming the fish were unable to avoid the causeway-induced gradients.

The BACI analysis showed that temperature reductions have occurred in the post-causeway environment.

The BACI analysis of CPUE for broad whitefish showed the overall evidence for avoidance was inconclusive. Thus, we assume that all age 1 and 2 broad whitefish were exposed to the temperature changes resulting from the causeway (worst-case). No changes in mean relative abundance of Arctic cisco were suggested by the BACI analysis. Thus, both age 1 and 2 Arctic cisco were also assumed to be exposed to the subtle causeway-induced temperature changes.

Effects of Temperature Change on Growth. The annual mean adjusted temperature in the delta habitat averaged 0.2°C (range: 0.3°C in 1986 and 1989; 0.0°C in 1987), less than would have been the case in the absence of the causeway (e.g., Figure 3). Based on the temperature-growth model, this would have resulted in about a 5 to 6% decrease in growth for age 1 and age 2 broad whitefish (range: 9% in 1985 and 1986; 0% in 1987).

In the nearshore habitat, the annual adjusted mean temperature ranged from 1.1 to 4.4°C. The post-causeway temperatures averaged about 0.1°C (range: 0.2°C in 1986 and 1988; 0.0°C in 1989), less than the pre-causeway scenario. The average resultant reduction in growth for Arctic cisco was about 4% (range: 8% in 1986; 0% in 1989) for age 1 fish, and 5% (range: 10% in 1985; 0% in 1989) for age 2 fish.

SUMMARY

Growth

Growth holds considerable promise as a measure of sublethal impacts from causeway-induced changes on younger ages of broad whitefish and Arctic cisco. Growth varied directly with temperature, and accounted for 77 to 82% of the variance in Arctic cisco and 82 to 92% in broad whitefish. While growth of age 1 and 2 broad whitefish and age 1 Arctic cisco exhibited a significant inverse relationship with salinity, these regressions accounted for only 23 to 50% of the variation for Arctic cisco and 30 to 35% for broad whitefish. Temperature and salinity were also inversely correlated at a similar level, indicating a spurious relationship.

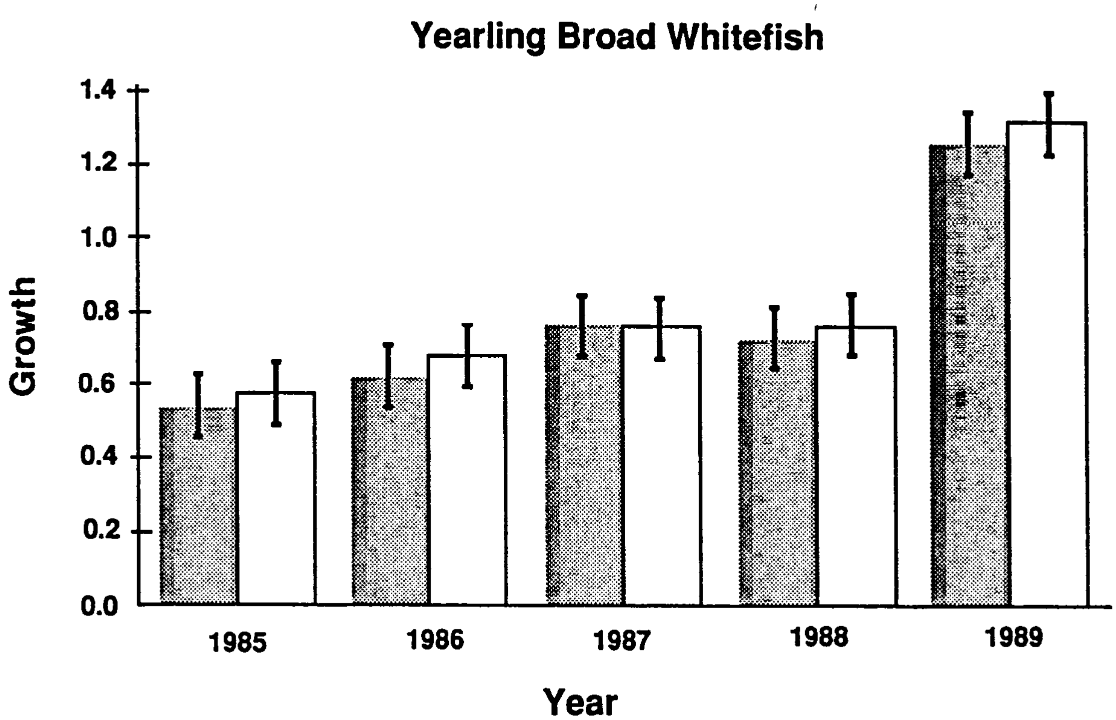

Figure 3. Comparison of growth of yearling broad whitefish for situations with (shaded bars) and without (open bars) the causeways for the years 1985-1989. Also shown are 95% CI.

Condition

Sex and state-of-maturity were not factors affecting the length-weight determinations for either species. All Arctic cisco specimens (mostly ages 1 to 7) were subadults as were most broad whitefish within the length range included in the analysis.

Condition as estimated by length-weight regressions was not a sensitive index of habitat quality. Condition of Arctic cisco and broad whitefish at given lengths remained constant over a wide range of environmental conditions. There were also different responses of large and small specimens that confounded interpretation.

Assessment of Effects

We have assumed that fish avoid the areas directly impacted by the wake, but not the areas adjacent to the wakes where the gradients in temperature are less pronounced. The observed changes in CPUE suggest that while some fish may avoid affected areas, most would be exposed to causeway-induced temperature change.

The study suggests that causeway-induced temperature changes have resulted in only small changes in growth over the period 1985 to 1989. A major weakness in our assessment is that in the Endicott region, the main area of concern, there is only one year of baseline temperature data, and only five years of post-causeway data that can be used in the analyses. However, at each step of our analyses, we have intentionally erred on the conservative side to produce a worst-case scenario for causeway-induced effects. Thus, we believe that the effects on growth from causeway-induced changes in temperature are probably less than we have estimated.

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QUESTIONS AND DISCUSSION

RAY EMERSON: When you say growth rate is an indicator of health of the fish, would rapid growth be healthy or the other way around?

WILLIAM GRIFFITHS: For instance in 1989 we had very rapid growth with these fish. They also gained weight and maintained condition. They maintained the rapid rate of growth throughout the entire growing season.

RAY EMERSON: Then is a more rapid rate of growth an indicator of a more healthy fish or population?

WILLIAM GRIFFITHS: No, what we were doing when we developed the equation was to determine the relationship between temperature and growth. Then we could measure the temperature and predict the growth for these fish. When the prediction fails to match the observed growth, we could then investigate the reasons for the differences. For instance, in 1991, the temperature of the water predicted that the Arctic cisco would have grown at a certain rate; well, they didn't grow at that rate. So that gave us an indication that there was a problem and this was confirmed with the lipid content analysis which showed a reduction of lipid levels during the open water season.

POPULATION DYNAMICS OF BROAD WHITEFISH AS RELATED TO CAUSEWAY DEVELOPMENT IN THE CENTRAL ALASKAN BEAUFORT SEA

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Dr. Benny Gallaway is a senior ecologist and President of LGL Alaska Research Associates, Inc. Dr. Gallaway's diverse scientific experience includes assessments of ecological impacts on fish, shrimp, and oyster populations; studies of deep sea and coastal benthic communities; analyses of commercial and subsistence fisheries in the Gulf of Mexico, Alaska, and Canada; genetic studies of fish, marine mammal, bird and terrestrial mammal stocks; and investigations of ecological community structure and their responses to environmental perturbations. The vast majority of these efforts have been in conjunction with oil and gas development in the Gulf of Mexico and northern Alaska. Dr. Gallaway has authored over 100 scientific publications and technical papers.

The Sagavanirktok River, located about 80 km east of the Colville River, harbors a disjunct spawning population of broad whitefish (*Coregonus nasus*) (McCart et al. 1972, Bendock 1979). There are no deep, freshwater lake systems around its delta, and freshwater overwintering habitat is restricted to the relatively few deep pools in the delta and upstream river channels. Craig (1989) has estimated that the amount of freshwater habitat available to fish in the winter in the Sagavanirktok and similar rivers may be as little as 1 to 5% of the amount available during the summer. Undoubtedly, overwintering habitat provides a severe constraint on the fish population.

Additionally, the absence of freshwater lakes suitable to provide summer feeding habitat could provide another constraint on the broad whitefish population in the Sagavanirktok River. In this area, the fish must use the low-salinity zone around the mount of the river for rearing. Juvenile broad whitefish cannot tolerate salinity levels above 15 to 20 ppt for long periods of time (deMarch 1989). While the area characterized by low salinity levels is larger earlier in the summer as compared to later, suitable rearing habitat is not extensive on either a temporal or spatial basis.

For over a decade, the Sagavanirktok River broad whitefish population, which is not exploited by any fishery, has been under environmental scrutiny because of its proximity to the causeways associated with offshore oil and gas development around Prudhoe Bay. These causeways can, at times, alter coastal hydrography causing nearshore waters to become colder and more saline due to a wake effect at their tips (Niedoroda and Colonell 1990, Gallaway et al. 1991). Depending upon the extent and severity of the hydrographic effects, causeways could further reduce the amount of summer rearing habitat which could potentially result in reductions in the local population of broad whitefish.

METHODS AND RESULTS

Broad whitefish have been censused in the Prudhoe Bay region since 1982 using standard mark-recapture techniques. Fyke nets were the principal sampling apparatus with nets serviced daily throughout each open water season. Fish were measured and subsamples aged.

Abundance was indexed using catch-per-unit-effort (CPUE) in each of several regions within the study area. In each subregion, total catch of broad whitefish within each 20 mm size interval represented across the entire length range were accumulated each summer, and divided by the

[1]Presentation given by William J. Wilson, LGL.

total effort associated with the catch to yield catch per net per 24 hr for each size interval. These were then summed to provide the total CPUE for the whole length range for each year.

The population level of broad whitefish with the Sagavanirktok River region was high during 1982-1984 but exhibited a precipitous decline in 1985, coincident with construction of the Endicott Causeway (Figure 1). Population levels remained low in 1986 and 1987. However, after 1987 the population increased rapidly reaching pre-Endicott Causeway levels in 1990 and 1991.

The length-frequency distribution for broad whitefish collected in the region of the Sagavanirktok Delta (Figure 2) was bimodal in 1982 with both modes falling in the juvenile size range (<250 mm).

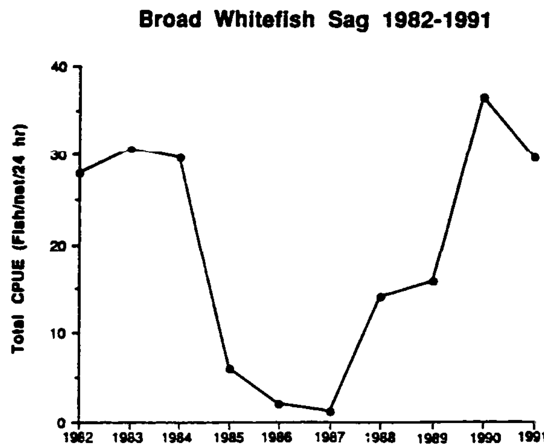

Figure 1. Abundance trends of broad whitefish in the Sagavanirktok River delta region during summer, 1982-1991.

A marked change in size structure was coincident with the pronounced decline in population size that occurred in the delta region in 1985. From 1985 to 1987, the population was dominated by early-age juveniles and sub-adults of the 1979 year class as evidenced by the bimodal distribution. The pronounced absence of fish between the two widely separated size groups suggested poor survival beyond the early juvenile stage during these years.

In 1990, a particularly strong year class in the 1-year-old size range entered the population, greatly elevating the size of the population. These fish, which represented the 1989 year class, remained abundant in 1991 when a second good recruitment of fish in the 1-year-old size range appeared. The population size structure in 1991 appears remarkably similar to that observed in 1982, only one year removed. A 10-year cycle is suggested.

A key question that emerges from the studies is what happened to the population between 1984 and 1985. September 1984 was unusual from all other years sampled in that, after the fish had moved into the river in mid-August, a large pulse of broad whitefish moved back into the coastal zone in early September. They traveled around the shoreline of Prudhoe Bay to the west, ultimately reaching as far as the east base of West Dock. A marine intrusion occurred beginning around 14 September, inundating the bay with salinity above the lethal limits (15 to 20 ppt) for small broad whitefish (deMarch 1989).

The observation suggests that older fish did not leave the winter refugium, and the inference is that they may have exhibited dominance behavior displacing smaller fish under crowded conditions. Mass mortality of the small fish would be expected under the observed conditions, resulting in a small population having a high proportion of sub-adults in 1985. Thus, high density during 1982-1984 was followed by a step decline in the population size. After the decline, the population was characterized by a high proportion of sub-adults. This size structure was maintained until 1988 when the sub-adults entered the spawning stock which is spatially associated with river channel habitat.

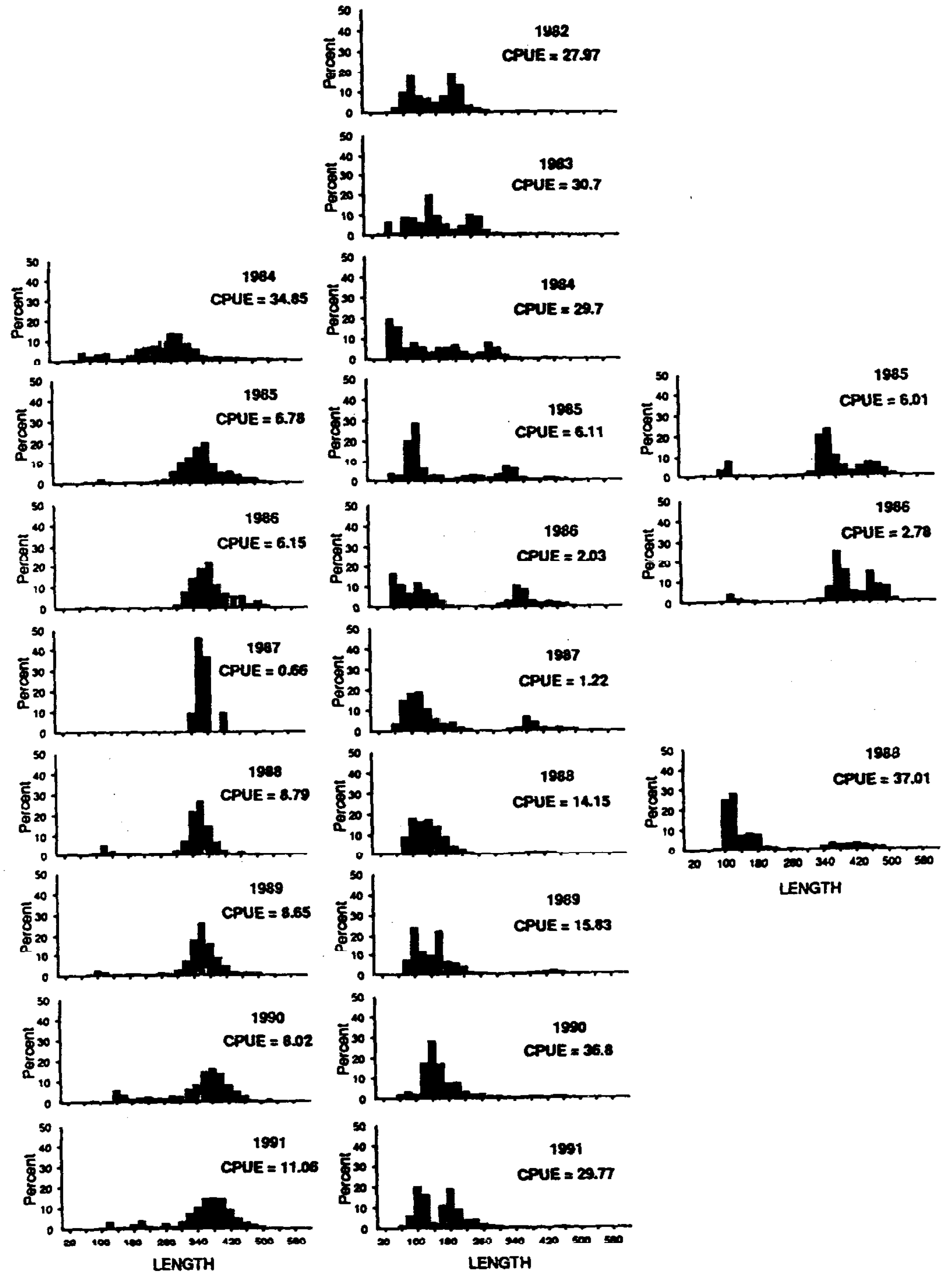

Figure 2. Length frequency patterns exhibited in the three subregions of the study area-west of West Dock (left panels), Sagavanirktok River delta (center panels), and Foggy Island Bay (right panels) during 1982-1991. Annual CPUE levels (fish/net/24 hr) are shown for each year.

Our conceptual model derived from these data is that, once established, sub-adult fish govern the recruitment of yearlings to juveniles and juveniles to sub-adults. We suggest that density in winter habitat, which is occupied for some nine months of the year (fall to spring), is the critical factor, and that larger fish exhibit dominance over smaller fish when density is high.

SUMMARY

There have been changes in the abundance and age/size structure of the Sagavanirktok River broad whitefish population based upon comparisons of these response variables during 1982 to 1984 to those observed during 1985-1991. However, the observed changes are not attributable to the Endicott or West Dock Causeways, but rather the result of density dependent population dynamics. Carrying capacity of winter habitat is probably the most critical factor governing the size of the population and, because of this constraint, summer habitat (affected by the causeway) is probably not filled to capacity.

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QUESTIONS AND DISCUSSION

TOM NEWBURY: Regarding your idea about the density dependence, if it was density dependent I think you would see middle-sized fish that were being displaced in all years when there was a relatively high population. In other words in 1982, 1983, 1984, and also in 1991; that it wouldn't happen in just one year. I want to suggest an alternative hypothesis and that is that there was a condition of the habitat before the causeway was built; there was a condition after the causeway was built. Neither of those conditions was bad. in the sense that the fish can't adapt to them. But what is difficult is change. The population responded to a change and now it is stable; it is adapted to the new situation. The fish have found new microhabitats in the delta to use. But then again it was the change that somehow affected the population and not the density dependence aspect.

BILL WILSON: Well, the specific mechanisms of how a population responds to changes in temperature, salinity conditions, or whether it is a physical obstruction to movement or not, we don't believe that. We see a lot of evidence for fish moving around and through breaches, etc. That aside, we are finding it hard to argue with empirical evidence, though, that shows that there was a significant displacement of very small fish out into that environment between 1984 and 1985. In fact, this displacement of fish occurred in the fall of 1984, well before there were any causeway activities ongoing out there. The causeway was actually constructed on or through winter ice, after the marine environment froze up. So the displacement of fish and a lot of that activity actually happened before the causeway. Whether there is conditioning involved, that has got to be true with any fish population. They are somewhat plastic animals. They are going to adapt to their environment as long as we don't encroach on the sublethal extremes of parameters that affect their overall health. We have looked at cross-causeway temperatures and salinities, etc. which I believe Mark will address here shortly. Some of these changes are pretty small, if you look at the overall range that these animals are living in and you look at the highly variable marine environment that they are present in all throughout the coast. I view these structures as having minor significance in the context of the whole central Alaskan Beaufort Sea region. Colonell tried to get at that this morning by comparing a lot of other promontories and islands along the coast. The hydrographic variability is pretty minor given the overall regional fluctuation, daily, hourly. We see dramatic changes in temperature and salinity conditions throughout that environment in all locations. I don't know that I would embrace your hypothesis real, real closely. But I can hear what you are thinking.

GAIL IRVINE: I am having a little difficulty with the density dependent hypothesis also. But some of it is falling out of information in my own head about the dynamics of this particular fish species. When they leave to go up a spawn, what happens to them then? Do they come back to those overwintering areas below?

BILL WILSON: There is very, very little overwintering work that has been done anywhere up there. So we really don't know. There has been some underwater work. Our staff actually dove under the ice in the delta of the Sag quite a number of years ago. There is some video tape footage. I don't believe, Bill (Griffiths), you might have to correct me if I am wrong, but I don't believe there were large adults in that overwintering habitat. They were all small to medium to subadult sizes of fish. We don't know where the spawning grounds are though we assume that they are upriver.

WILLIAM GRIFFITHS: One thing that we are doing right now is testing the hypothesis. We are now starting the first year of the second cycle. If we now see this same cycle repeat itself that will give us some confidence in the hypothesis.

GAIL IRVINE: It can actually be seen on that one graph where you had all that time series of the age-frequency distributions that a couple of years ago, to me it appeared, a somewhat smaller but similar pattern where you had the broad, almost double...

BILL WILSON: Like a bimodal..

GAIL IRVINE: But again no increase in the abundance of larger sizes.

BILL WILSON: What we are interested to see now, Gail, is that bimodal length frequency histogram that we have for 1992 to see if there is over a couple of years then a growing out of large fish and then a development of a size gap again.

GAIL IRVINE: I am a little bit like Tom, I don't understand why you weren't seeing that almost immediately upon the departure of that other large size class.

BILL WILSON: Well, it takes a little bit of time for fish to grow and to build body size and to mature into the size range where they are going to move into a spawning pool. All of the mechanisms that interact here are probably fairly complex. Obviously, we have greatly simplified this. I think our whole objective in trying to put forward hypotheses like these is to try to look at a linkage between a human structure, the causeway structure, and what we see are changes in a fish population that look like they are linked together. But we are proposing that they are, in fact, not linked, and that there also is background noise going on. But I suppose that remains to be proven decades from now.

GAIL IRVINE: I think that is one of the major difficulties of interpreting a lot of these data. A structured examination of population biology and what limits it has not been done. It has been much more of a site-specific investigation and so it makes it difficult to generalize to these other factors.

BILL WILSON: But we do also have the luxury of a reasonably well-funded study for a long period of time so at least we do have a dataset that is reasonably comprehensive to allow us to sort of infer some of these things. I think we would have been in worse shape if we had not monitored after 1987.

RAY EMERSON: You did say initially that this sort of density dependent mechanism was in the literature?

BILL WILSON: Well, I have seen classical density dependence explained for salmon populations and various other populations of fish around the world. There is a regulating aspect of density in the environment. There is only so much food to go around, there is only so much swimming space. These fish have got to have elbow room, there is competition...

RAY EMERSON: You do see the same type of size class gap; a paper that you are citing as a reference?

BILL WILSON: I don't know about very, very specifics. I am just talking about the overall hypothesis of density dependence regulating population abundance. Now the very specifics of length frequency, classes of fish and specifics... That is a good question. I would have to look at that more closely.

ASSESSMENT OF OCEANOGRAPHIC EFFECTS OF THE ENDICOTT CAUSEWAY: ENDICOTT OCEANOGRAPHIC MONITORING PROGRAM RESULTS

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Mark Morehead has worked for Science Applications International Corporation for the past five years, spending most of his time on the Endicott project. Mr. Morehead presently serves as Technical Director of the Endicott Oceanographic Monitoring Program. His areas of research interest are coastal physical processes, arctic and antarctic physical oceanography. Mr. Morehead received his B.S. in oceanography and his M.S. in physical oceanography from the University of Washington.

INTRODUCTION

This report summarizes the results of an ongoing multi-year (1985-present) oceanographic monitoring program. The Endicott Oceanographic Monitoring Program was designed to assess the effects of the Endicott Causeway on the oceanographic environment, specifically on the temperature and salinity distributions and the current field. In 1985 the eight kilometer long Endicott Causeway was constructed in the Beaufort Sea, east of Prudhoe Bay (Figure 1). Permit stipulations imposed by the U.S. Army Corps of Engineers (USACE) and the North Slope Borough (NSB) require the monitoring program to: 1) evaluate the Environmental Impact Statement (EIS) predictions; 2) determine the actual effect of the causeway on the environment; 3) supply oceanographic, meteorological and river information for the Endicott Fish Monitoring Program; and 4) measure the changes in the oceanographic environment due to the proposed construction of new breaches in the Endicott and West Dock causeways. The USACE (1985-1990) and NSB (1991-present) direct the monitoring efforts and select the contractors. The Endicott Unit Owners operated by British Petroleum Exploration (Alaska) Incorporated (BPX) funds the project.

METHODS

The study area is a very shallow (one to six meters) coastal estuary. The Endicott Causeway was built in the middle of the distributary for the Sagavanirktok (Sag) River and therefore has fresh water inputs on both sides. The Endicott Causeway has two sections (Figure 1). The first section connects two drilling islands (called the inter-island causeway) and runs parallel to the coastline about two kilometers offshore in about two meters of water. The second section (the mainland causeway) is perpendicular to the coastline and connects the inter-island causeway to shore, forming a T-shaped structure. The study area extends for about 40 km along the coast, and from the coastline out approximately 10 km, to the six meter isobath.

The Endicott Oceanographic Monitoring Program is a large and comprehensive program consisting of: hydrographic surveys; temperature, salinity, water level and current meter moorings; Sag River stage (discharge) and temperature monitoring; and meteorological measurements. The area is ice-covered for most of the year. The study is conducted from mid-July to early September, during the brief open water period.

Specific details of the monitoring program have changed from year to year as new questions have been addressed. In general, moorings have been placed around both the Endicott and West Dock causeways to measure the cross-causeway temperature and salinity differences. Reference moorings have been kept throughout the program to compare inter-annual variability. Hydrographic surveys were conducted from 1985 to 1990. These surveys had transect lines one

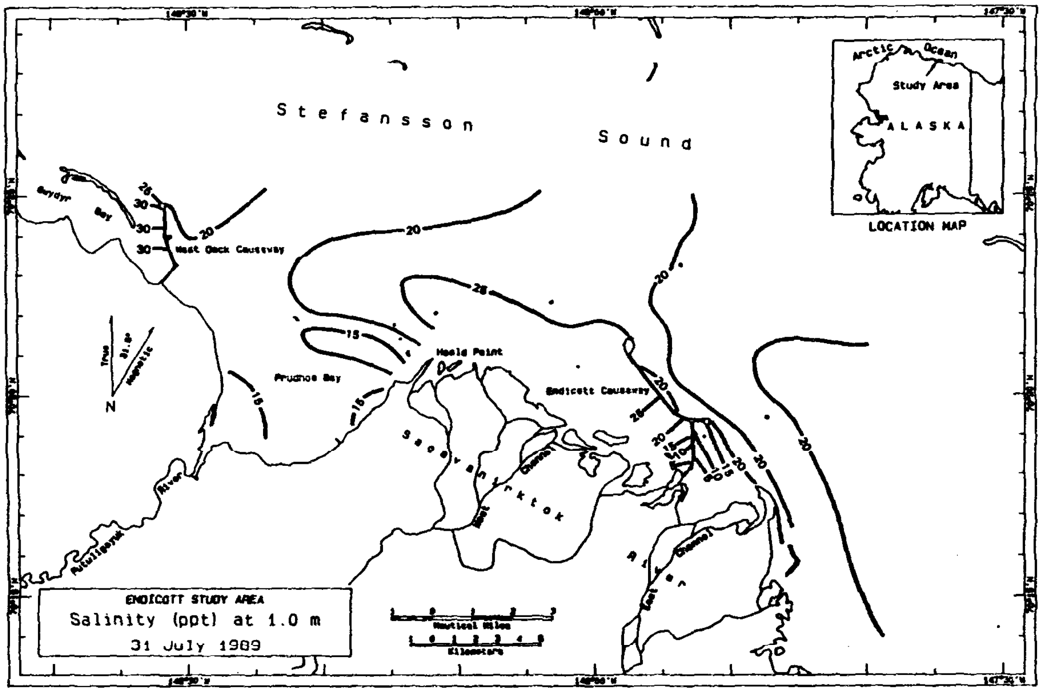

Figure 1. The Endicott study area.

to five kilometers apart along the coastline, and stations along the transects were separated by one-half to one kilometer. Hydrographic surveys including approximately 100 stations would be conducted in a day to measure the three-dimensional structure of the temperature and salinity fields.

RESULTS AND DISCUSSION

One objective of the Endicott Oceanography program is to assess the EIS predictions. The EIS made predictions based on limited observations and a 2-dimensional numerical model. The predictions were seasonal averages, therefore the comparisons are to seasonally averaged data. The EIS made predictions concerning the area over which the Endicott Causeway would affect the temperature (by 1°C) and salinity fields (by 2 ppt). Predictions were also made regarding the cross-causeway temperature and salinity differences.

Table 1 compares the observations with the EIS predictions. The areas of influence were calculated from the hydrographic survey data. Using pre-causeway data and knowledge of the natural gradients, the area over which the measured gradients deviated from the natural gradients was estimated for each survey. Then the areas of influence were averaged using 60 hydrographic surveys conducted over six years. These surveys are presumed to be representative of the natural conditions. The average area influenced by the causeway was significantly less than (at the 95% confidence interval) the EIS predicted area for both temperature and salinity.

Table 1. Comparison of observations with EIS predictions.

EIS Prediction	Observations Used to Access	Effects Observed	Comparison to EIS Values * Less	Same	Greater
Salinity changes > 2 ppt over 45 km^2	60 Hydrographic surveys (1985-1990)	average of surveys 20 ± 2.7 km^2 (> 2 ppt)	X		
Temperature changes $>1°C$ over 22 km^2	60 Hydrographic surveys (1985-1990)	average of surveys 16 ± 2.1 km^2 ($> 1°C$)	X		
T differences across inter-island causeway $\Delta T \approx 2.5 - 3.0°C$ (+4/-1) **	2 mooring pairs (1991-1992)	maximum seasonal mean $\Delta T = -1.26 \pm 0.39°C$		X	
S differences across inter-island causeway $\Delta S \approx 10 - 11$ ppt (+9/-6) **	2 mooring pairs (1991-1992)	maximum seasonal mean $\Delta S = 8.84 \pm 1.20$ ppt		X	
T differences across mainland causeway $\Delta T \approx 1.5°C$ (+4/-1) **	6 mooring pairs (1985, 1988-1992)	maximum seasonal mean $\Delta T = -0.68 \pm 0.27°C$		X	
S differences across mainland causeway $\Delta S \approx 6.5 - 7.0$ ppt (+9/-6) **	2 mooring pairs (1991-1992)	maximum seasonal mean $\Delta S = 1.68 \pm x$ ppt		X	

* Tested against the level of significance at the 95% c.i.
** Values in parentheses are the confidence limits for the EIS predictions.

Table 1 also shows the seasonally averaged cross-causeway temperature and salinity differences for both the inter-island causeway and the mainland causeway. During the first six years of the program, the hydrographic survey data were used to assess the cross-causeway temperature and salinity differences. This analysis provided a limited number of data points each year and therefore the confidence intervals were large. In 1991 and 1992, moorings have been placed across the causeways to measure the temperature and salinity differences. The moorings record every 10 minutes, yielding a large number of points each season and tightening the confidence limits considerably. The 95% confidence intervals (c.i.) were calculated by the bootstrap method using the number of independent observations calculated from the auto-correlation.

All of the cross-causeway temperature and salinity differences are less than the EIS predictions, but not significantly less (at the 95% c.i.). One reason for this is the EIS predictions had very large confidence intervals placed on them. These intervals cover most naturally occurring circumstances for the study area. The mainland cross-causeway differences are naturally low because the Sag River has channels on each side of the causeway, reducing temperature and salinity gradients. The largest natural gradients are perpendicular to the shoreline. The large differences across the inter-island causeway are partly due to the large natural gradients in this direction, and partly due to an intensification of the gradients across the causeway. The Endicott Causeway prevents mixing across the inter-island causeway.

One effect of the causeway that was not predicted by the EIS is localized upwelling. The 2-D model used for the EIS was not able to predict this phenomena because it is a 3-D mechanism. The localized upwelling is important because of the potential to affect fish habitat. In this area there are two types of upwelling. The first type is the classical coastal upwelling which is a result of Ekman dynamics and the Coriolis force (Niedoroda and Colonell, 1990). The second type is localized upwelling which occurs near the end of the causeways, at headlands and behind islands. The coastal upwelling is a regional scale phenomenon and is not affected by the Endicott or West Dock causeways. The localized upwelling is caused by a wake-eddy mechanism that occurs near the tip of causeways and natural flow obstructions (Wolanski and Hammer 1988, Deleersnijder et al. 1992). The hydrographic surveys have shown both types of upwelling to occur in the Endicott study area. The coastal upwelling manifests during the prevailing NE winds. It consists of a band of cold, saline water which extends along the entire study area and rises toward the sea surface. The band of cold saline water may outcrop into the fresher and warmer brackish coastal water. The localized upwelling occurs over a limited area just down-current from the end of the Endicott and West Dock causeways. The localized upwelling also brings cold saline bottom water up to the surface.

The localized upwelling only occurs under certain oceanographic and meteorological conditions. The winds need to be from the NE with sufficient strength and duration to drive coastal upwelling, 5 to 10 m/s, lasting for three or more days. The coastal upwelling is necessary to raise the pycnocline up far enough so that it intersects the end of one of the causeways. When the pycnocline intersects the causeway, the wake-eddy mechanism drives a secondary circulation pattern that transports the cold saline bottom water up toward the sea-surface. If the winds are strong enough and of sufficient duration, the upwelled water will be transported downstream from the causeway in a plume. Figure 1 shows an example of a plume which extends downstream from the Endicott Causeway. Figure 1 also indicates localized upwelling occurring at the West Dock Causeway.

The upwelling events were categorized by the area affected. Weak events were categorized as vertical salinity and temperature displacements occurring directly adjacent to the end of the causeway, but being limited to less than 2 km from the causeway. Strong events were categorized as having a measurable signal at least 5 km downstream from the causeway. Weak events do not affect a large area and are similar to natural variations in the system. Strong events occurred during 9% of 90 surveys conducted around the Endicott Causeway, and during 14% of 63 surveys conducted around the West Dock Causeway. This indicates that approximately twice a year at Endicott (three times at West Dock) a localized upwelling event occurs and may last for two or three days.

SUMMARY

The Endicott Oceanographic Monitoring Program is an intensive multi-disciplinary study to determine the effects of the Endicott Causeway on the oceanographic environment. The collected data have been compared to the EIS predictions. The Endicott Causeway's influence on the temperature and salinity fields is significantly less than the areas of influence predicted by the EIS. The cross-causeway differences are slightly less than, but not significantly different from, the EIS predictions. Localized upwelling of cold saline water occurs downwind of the Endicott and West Dock causeways. This upwelling is responsible for a large amount of the area being influenced by the two causeways. However, the upwelling only occurs during a couple of two- to three-day episodes each year when the hydrographic and meteorological conditions are favorable. The oceanographic monitoring has revealed that the effects of the two causeways on the oceanographic environment have been localized and are not regional.

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QUESTIONS AND DISCUSSION

CALEB PUNGOWIYI: If I were a broad whitefish I would probably know which one of you guys to call a liar. I can't help but feel that there is some effect by the causeway on the fish in the Beaufort Sea. Also the presentation that was given by Jack Colonell this morning that there are some significant changes in temperature and also salinity in the area that had to affect the fish population that goes through that area.

MARK MOREHEAD: [Refers question to Bill Wilson.]

BILL WILSON: No comment.

TOM NEWBURY: Were you looking at the change which might occur with the increased size of the breach that is being put in?

MARK MOREHEAD: We have a monitoring program to assess that underway. Basically we are looking at the differences across the causeway now and we want to look at the differences across the causeway once it is put in. We are going to try to do some areal estimates by having moorings further away from the causeway.

TOM NEWBURY: Can you give a rough prediction of how much of a change will occur when the large breach is put in?

MARK MOREHEAD: That is a real difficult question. We haven't done any modeling or anything like that to answer that question. As far as the localized upwelling that is occurring, it is still going to occur because you still have a significant flow blockage of the area. The breach that is going to be put in the West Dock may provide a freshwater passage that goes all the way along the coast and may alleviate the effects of the causeway. It is hard to say at this point without doing some significant modeling. We have thought about it but we haven't done enough work to say anything.

TOM NEWBURY: Part of the reason I brought it up is that it relates to the last comment I made about the habitat. The pre-causeway habitat wasn't bad and the post-causeway habitat wasn't bad. The change is difficult for the fish to adjust to. Well, this again may be a time when there may be a change that the fish have to adjust to. The condition isn't bad now but there is going to be a change in the habitat, smaller than when the causeway was built. It would be interesting to see if there is a change in fish population.

MARK MOREHEAD: I won't comment on the fish populations *per se*. It is clear that natural changes have occurred in the past. The river discharge at one point used to come out on the east side of Point Brower; it is now all on the west side. You can see the earlier delta. So there are large changes that do occur to the habitat on a natural basis.

PAM MILLER: I was interested to know if there has been any research on changes in benthic communities in the area?

MARK MOREHEAD: There is a study a little bit further off of the causeway in an area called the Boulder Patch. I did not do any of that work. I do not believe that there have been any changes due to the causeway on the Boulder Patch area. The nearshore environment for the Endicott Causeway is in the middle of the river delta and so there is a lot of silt and mud being put into the area on a continuous basis every year. Whenever a storm comes by, it mixes up the mud and redeposits it. So there is a big natural change in the bottom sediments in the area. They have tried to do sedimentation studies but they don't work very well. You put out a sediment trap and it traps a lot of sediment because it is all being resuspended every year. No real work has been done looking at the benthic populations.

DICK PRENTKI: I have attended several of these meetings over the years, being at MMS for over ten years. I recall some old discussion that came up in terms of whether the causeways were affecting the date of the local freeze up and the date of local melt out. There was some concern at the time that this would affect the oxygen levels at some of these overwintering areas. The claim was made at that time, I don't recall by who, that there was no evidence that the overwintering areas were limiting. Now today we hear today that perhaps there is some limitation in overwintering habitat.

BILL WILSON: Run that by me again. You said somebody has said that there is no evidence that overwintering habitat is limiting fish population?

DICK PRENTKI: That overwintering habitat was not limiting.

BILL WILSON: Oh, that is absolutely absurd. I have never heard that by anybody.

DICK PRENTKI: I have heard that.

BILL WILSON: Well, maybe you can give me a reference for that, because that would be a significant contribution...

DICK PRENTKI: One of our past MMS meetings, I don't recall which one. Okay, so overwintering habitat may be limiting. So that if you are having an earlier freeze up and a later thaw of the ice around these causeway areas in the delta, may you not have a problem...

MARK MOREHEAD: We have done a significant amount of studies on the ice break up milestone dates. The causeway can affect the ice in a very local area. It protects part of the area from waves and so locally you can have some ice forming a little earlier in the fall. In the spring it can also block some of the water motion and keep some of the ice around for a little bit longer. But the general ice break up and freeze up is controlled by regional scale processes. A lot of it is due to snow melt in the mountains, initiating the rivers breaking up which then initiates the coastal ocean breaking up. None of that is affected by the causeway because it is a regional scale event. So the basic ice milestones have not changed due to the causeway. But local effects have occurred.

DICK PRENTKI: How local are the overwintering areas?

MARK MOREHEAD: The overwintering areas are up the river and the causeway would have no effect at all on the overwintering areas of the fish.

BILL WILSON: You have to remember too, that overwintering habitat is in the river primarily, in the delta environment. Calculations have been made by Peter Craig a number of years ago that probably 3 to 5% of the habitat that was available during the summer months is still available to the fish during the winter months. It is extremely compressed in space and areal extent. If you look at the fish populations in the Arctic Refuge throughout the summer months and then look at the data that Fish and Wildlife Service and GS have gathered on overwintering, they can't even find water during the winter. It is quite scarce and from every bit of evidence that we know of, it does in fact limit population size. Certainly to some extent. There just isn't space for huge numbers of fish to live throughout the winter months in these few large rivers that do have sufficient pockets of water either in the delta or in the main channels to overwinter. Remember we are not talking about Dolly Varden char, either, that move well up river into spring areas where there are some areas for overwintering. The Sag happens to be one of the few river systems. There are some in the eastern part of the Arctic, where there is sufficient spring activity. One final point, the overwintering aspects of fish biology in arctic Alaska or probably any where in the world, is probably the least understood facet, but yet probably one of the largest periods of time in which fish must inhabit there. We just do not know a lot about that particular facet and probably never will, at least with some of our classical tools available to us right now.

APPENDIX A

AGENDA

ALASKA OCS REGION
MINERALS MANAGEMENT SERVICE

FIFTH INFORMATION TRANSFER MEETING
January 20-22, 1993, Sheraton Anchorage Hotel

AGENDA

WEDNESDAY, JANUARY 20, 1993

8:30 AM REGISTRATION AND COFFEE

WELCOME AND INTRODUCTION - Joy Geiselman, Chair

8:45 AM	Welcome - *Alan D. Powers, Regional Director, MMS*
8:50 AM	Decision-Making Under the Area Evaluation and Decision Process - *Robert Brock, Regional Supervisor, MMS*
8:55 AM	The Environmental Studies Program: Current Status and Research Priorities; and Update on the NRC/NAS Review of the Adequacy of Information Available on the Beaufort and Chukchi Seas and the Navarin Basin - *Jerry Imm, Chief, Environmental Studies, MMS*
9:05 AM	Resource Evaluation and Petroleum Potential of the Beaufort and Chukchi Seas and Hope Basin - *Larry Cooke, Resource Evaluation, MMS*
9:25 AM	Leasing History, Exploration, and Production Activities in the Beaufort and Chukchi Seas and Hope Basin - *Jeff Walker, Field Operations, MMS*
9:40 AM	International Arctic Monitoring and Assessment Program - *Elizabeth Leighton, Dept. of State/University of Alaska, Fairbanks*

10:00-10:20 AM BREAK

OPERATIONAL ISSUES AND REQUIREMENTS - Jeff Walker, Chair

10:20 AM	MMS Post-Lease Regulatory Requirements and Experiences with Floating Drilling Units in the Arctic - *Jim Regg, Field Operations, MMS*
10:50 AM	Oil Spill Response Preparedness - *Tom Murrell, Field Operations, MMS*
11:05 AM	Oil and Gas Extraction Point Source Category Offshore Subcategory Effluent Limitation Guidelines and New Source Performance Standards - *Cindy Gilder, EPA*
11:25 PM	EPA's Outer Continental Shelf Air Regulations - *Alison Bird, EPA*

11:45-1:30 PM LUNCH

MARINE MAMMALS - Cleve Cowles, Chair

1:30 PM	Marine Mammal Management Systems - *Jack Lentfer, Marine Mammal Commission* The Expanding Role of Alaska's Indigenous Peoples in Marine Mammals Management and Research - *Lisa Rotterman, Indigenous Council for Marine Mammals*
2:10 PM	Seasonal Movements and Distributional Patterns of Polar Bears in the Bering/Chukchi Seas - *Gerald Garner, US Fish and Wildlife Service*
2:30 PM	Handbook for Oil and Gas Operations in Polar Bear Habitats - *Joe Truett, LGL*

2:50-3:10 PM BREAK

3:10 PM	Distribution and Abundance of Beluga Whales and Spotted Seals in the Chukchi Sea, Including Recent Findings at Kasegaluk Lagoon - *Kathy Frost, Alaska Dept. of Fish & Game*
3:30 PM	Fall Distribution and Relative Abundance of Bowhead, Gray, and Beluga Whales in the Alaskan Chukchi Sea, 1982-91 - *Sue Moore, SAIC*
3:50 PM	Marine Mammal Surveys and Subsistence Coordination Associated with Industrial Activities in the Beaufort Sea - *Bob Griffeth, ARCO*

4:10 PM Reactions of Migrating Bowhead and Beluga Whales to Noise from Simulated Industrial Activities in Ice Leads during Spring - *John Richardson, LGL*

4:30 PM ADJOURN

THURSDAY, JANUARY 21, 1993

8:30 AM REGISTRATION AND COFFEE

MARINE MAMMALS CONTINUED - Cleve Cowles, Chair

8:45 AM Movements and Dive Habits of Bowhead Whales from Satellite-Monitored Radio Tags - *Bruce Mate, Oregon State University*

9:05 AM Aerial Surveys of Endangered Whales in the Beaufort Sea, Fall 1992: Preliminary Findings - *Steve Treacy, Environmental Studies, MMS*

9:25 AM Monitoring Marine Mammals in the Chukchi Sea during Industrial Activities Using Ice-Management Techniques - *Jay Brueggeman, EBASCO Environmental*

9:45-10:00 AM BREAK

BIRDS - Joel Hubbard, Chair

10:00 AM Use of Kasegaluk Lagoon, Chukchi Sea, Alaska, by Marine Birds - *Steve Johnson, LGL*

10:20 AM Design and Testing of a Monitoring Protocol for Beaufort Sea Waterfowl and Marine Birds - *Steve Johnson, LGL*

10:40 AM Population and Productivity Monitoring of Seabirds at Little Diomede Island - *Ada Fowler, US Fish and Wildlife Service*

11:00 AM Physical and Biological Structure of Seabird Food Webs on the Northern Bering and Chukchi Sea Shelf - *John Piatt, US Fish and Wildlife Service*

11:20 AM Satellite Tracking and Staging Ecology of Wrangel Island Lesser Snow Geese - *Craig Ely, US Fish and Wildlife Service*

11:40-1:00 PM LUNCH

SOCIAL AND ECONOMIC STUDIES - Tracy Andrews, Chair

1:00 PM Social Indicators of Traditional and Western Customs in Coastal Alaska - *Joseph Jorgensen, University of California, Irvine*

1:30 PM Hope Basin Subsistence Overview - *Bob Gal, National Park Service*

1:45 PM North Slope Subsistence Study (Wainwright and Barrow) - *Steve Braund, S. Braund & Assoc.*

2:00-2:15 PM BREAK

2:15 PM **Panel Discussion: Social and Economic Studies in the Northern and Northwest Arctic: Assessing Methodological Approaches, Strengths in the Knowledge Base, and Information Needs.** *Tracy Andrews, MMS - Moderator*

1. *R.C. Harcharek, North Slope Borough* — Overview of Ongoing and Proposed Social and Economic Research
2. *Kurt Jacobsen, North Slope Borough* — NSB GIS Subsistence Program
3. *Walter Russell, Joseph Ballot, David Case, North West Arctic Borough* — Comprehensive Planning in the North West Arctic Borough
4. *Sverre Pedersen, Alaska Dept. of Fish & Game* — Subsistence Studies and Community Profile Database Information for the Division's Arctic Region, 1993
5. *Larry Merculieff* — Pickled Seal Flipper (Lusta) and Western Science
6. *Steve Colt, Inst. for Social and Economic Research* — Basic Economic Data for the

Arctic: Are we getting what we need?

7. *Don Callaway, National Park Service*: NPS Subsistence Program in the Arctic

5:00 PM ADJOURN

FRIDAY, JANUARY 22, 1993

8:30 AM REGISTRATION AND COFFEE

PHYSICAL ENVIRONMENT AND POLLUTANT TRANSPORT - Dick Prentki, Chair

8:45 AM A Coupled Ice-Ocean Model of the Beaufort and Chukchi Seas - *Kate Hedstrom, Rutgers University*

9:05 AM Oceanographic Effects of Beaufort Sea Causeways - *Jack Colonell, Woodward Clyde*

9:25 AM Benthos-Environmental Interactions in the Northeastern Chukchi Sea - *Sathy Naidu, University of Alaska, Fairbanks*

10:05-10:20 AM BREAK

10:20 AM Results from Oil Spill Response Research, 1991-1992 - *Edward Tennyson, TARP/MMS*

10:50 AM Update of Coastal Oil Spill Sensitivity Index for BP Arctic Operating Areas - *Mary Cocklan-Vendl, BP Exploration*

FISH - Robert Meyer, Chair

11:10 AM Fisheries Oceanography in the Northeastern Chukchi Sea - *Will Barber, Nora Foster, University of Alaska, Fairbanks*

11:40 AM The Physical Oceanography of the Northeastern Chukchi Sea - *Thomas Weingartner, University of Alaska, Fairbanks*

12:00-1:30 PM LUNCH

1:30 PM Habitat Use by Dolly Varden Char and Arctic Cisco in Beaufort Sea Coastal Waters: Short-Term Movements and Temperature Occupancy - *Laurie Jarvela, Environmental Studies, MMS*

1:50 PM The Endicott Fish Monitoring Program: Impact Assessment and Issue Resolution - *William J. Wilson, LGL*

2:10 PM Effect of Wind on the Recruitment of Canadian Arctic Cisco (*Coregonus autumnalis*) into the Central Alaskan Beaufort Sea - *Robert G. Fechhelm, LGL*

2:30 PM Effects of Prudhoe Bay Causeways on the Along-Shore Movement of Least Cisco (*Coregonus sardinella*) - *Robert Fechhelm, LGL*

2:50-3:10 PM BREAK

3:10 PM Growth and Condition of Arctic Cisco and Broad Whitefish as Indicators of Causeway-Induced Effects in the Prudhoe Bay Region, Alaska - *William B. Griffiths, LGL*

3:30 PM Population Dynamics of Broad Whitefish as Related to Causeway Development in the Central Alaska Beaufort Sea - *Benny J. Gallaway, LGL*

3:50 PM Assessment of Oceanographic Effects of the Endicott Causeway: Endicott Oceanographic Monitoring Program Results - *Mark Morehead, SAIC*

4:10 PM ADJOURN/REFRESHMENTS

APPENDIX B

LIST OF ATTENDEES

MINERALS MANAGEMENT SERVICE
ALASKA OCS REGION
INFORMATION TRANSFER MEETING

ATTENDEE LIST

*** = speaker**

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As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interest of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in Island Territories under U.S. Administration.