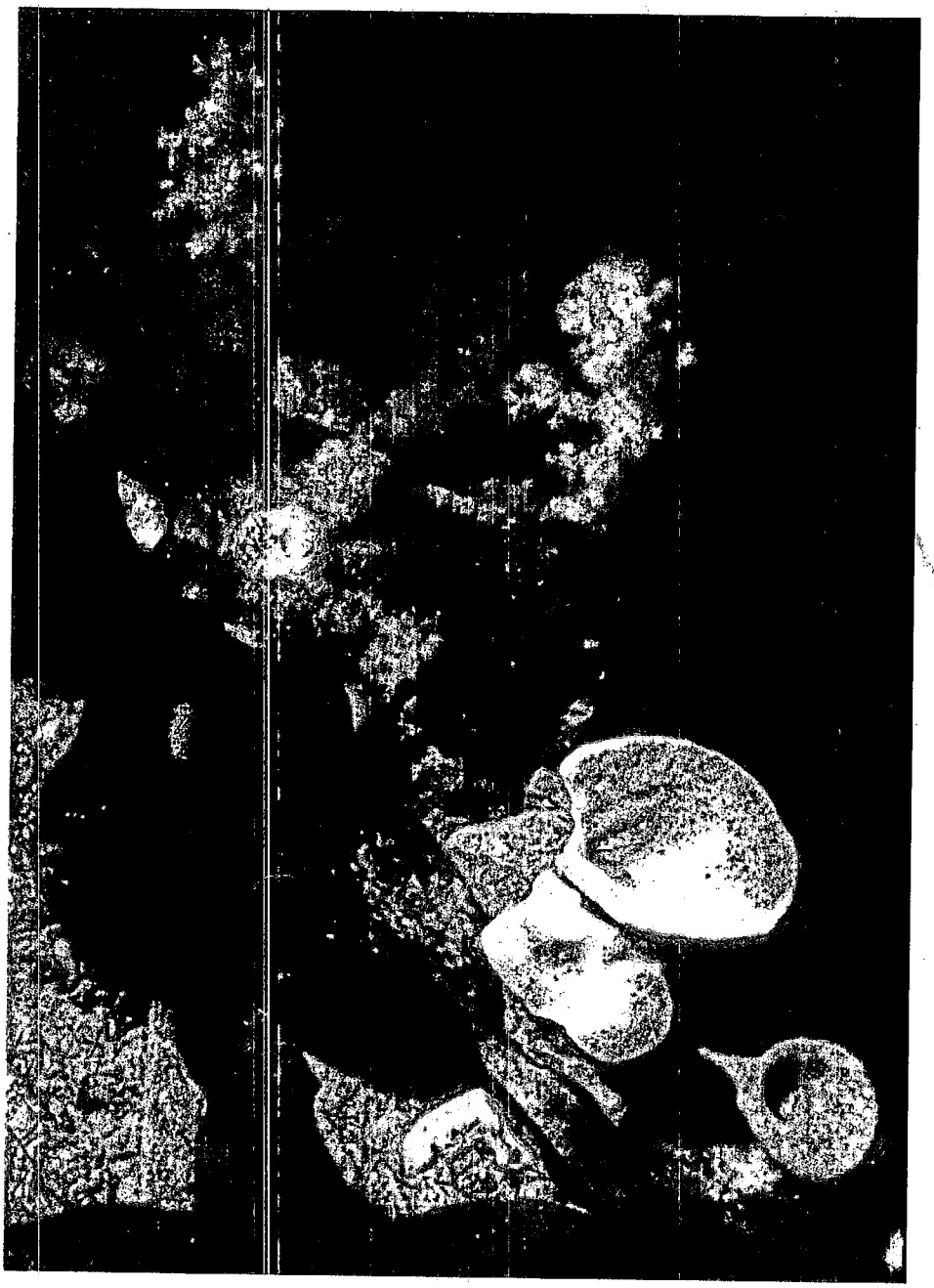
OCS Study
MMS 98-0038



ARCTIC KELP WORKSHOP

PROCEEDINGS

May 12, 1998
Anchorage, Alaska

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

OCS Study MMS 98-0038

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Prepared for:

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Dr. Thomas Newbury
Workshop Coordinator and
Proceedings Editor

Logistical Support and Report Preparation by:

Kathryn L. Mitchell
MBC *Applied Environmental Sciences*
3000 Redhill Avenue
Costa Mesa, California 92626

August 1998

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Cover photograph taken at Dive Site 11 in Stefansson Sound "Boulder Patch" by K.H. Dunton, 1979.

TABLE OF CONTENTS

Page

INTRODUCTION 1

RECENT SURVEYS AND OBSERVATIONS 4

SONAR AND VISUAL IMAGES OF STEFANSSON SOUND: 1997-1998 BOULDER PATCH SURVEY
Mr. Craig Leidersdorf and Mr. Peter Gadd, Coastal Frontiers Corporation and Mr. Terry Sullivan, SeaVisuals, Inc. 4

1997-1998 BOULDER PATCH: WINTER ROV SURVEY
Dr. Benny Gallaway and Dr. Larry Martin, LGL Ecological Research Associates 6

Summary of the brief discussion following the presentations by: Mr. Leidersdorf, Mr. Sullivan, Mr. Gadd, Dr. Gallaway and Dr. Martin 7

PREDICTED SEDIMENTATION ON STEFANSSON SOUND KELP
Ms. Sue Ban, Woodward-Clyde Consultants 7

SONAR AND VISUAL IMAGES OF CAMDEN BAY KELP
Mr. Bill Penrose, Fairweather E&P Services, Inc. 8

Summary of the discussion following the presentations by Ms. Ban and Mr. Penrose 9

ECOLOGICAL PERSPECTIVES 10

Dr. Kenneth Dunton, University of Texas at Austin 10

Summary of the extensive discussion during and following the presentation by Dr. Dunton 10

Dr. C. Peter McRoy, Institute of Marine Sciences, University of Alaska Fairbanks 12

Summary of the discussion following the perspective by Dr. McRoy 14

Dr. Michael Stekoll, University of Alaska Southeast 14

Summary of the discussion following the perspective by Dr. Stekoll 15

CONCLUDING DISCUSSION 15

TABLE OF CONTENTS
Continued

ATTACHMENT 1 - Barnes, P.W. 1981. Camden Bay "Boulder Patch."

APPENDICES

A - Agenda

B - List of Participants

C - Selected References

LIST OF FIGURES

Page

Figure 1. The eastern Alaskan Beaufort Sea shelf. Solid circles denote the locations of suspected macroalgal beds based on biological or geological evidence (from Dunton et a. 1982) 1

Figure 2. Southeastern portion of the Stefansson Sound Boulder Patch (adapted from BP Exploration (Alaska) Inc. 1998) 2

Figure 3. Proposed surface location for ARCO Alaska Inc.'s Warthog No. 1 Exploration Well and approximate location of kelp patches (adapted from Figure 2-1 in Fairweather E&P Services 1997) 3

ARCTIC KELP WORKSHOP

INTRODUCTION

The first scientific reports of kelp along the Beaufort Sea coast were during the Canadian Arctic Expedition from 1912-18. During 1971 and 1972 Erk Reimnitz and other scientists from the U.S. Geological Survey (USGS) collected samples along several transects in Stefansson Sound near Narwhal Island, and described the distribution of a "Boulder Patch" with rich marine fauna. A few years later, the Minerals Management Service (MMS) began sponsoring surveys and studies. One of the surveys, conducted by Peter Barnes from USGS, determined the specific location of a Boulder Patch and kelp community in Camden Bay (Attachment 1). The boulders were in an area near Kayutak and Konganevik Point where native people knew that the sea bottom was hard (Jacobsen and Wentworth 1982). Another MMS-sponsored study, conducted by Ken Dunton, Erk Reimnitz, and Susan Schonberg, led to a detailed description of the Stefansson Sound Boulder Patch (Dunton et al. 1982). The report includes a more complete history of Arctic kelp investigations, an updated map of their distribution along the Alaskan Beaufort Sea coast (Figure 1), and a description of the predominate kelp, *Laminaria solidungula.*

Subsequent surveys were conducted by the oil industry in association with exploration of the BF-37 prospect and development of the Endicott field near the Boulder Patch. Recent surveys include several for BP Exploration (Alaska) Inc., which has proposed the Liberty Development Prospect near the Boulder Patch (Figure 2); and one for ARCO Alaska, Inc., which conducted exploratory operations near the Camden Bay kelp patch (Figure 3). The surveys have provided new video and side-scan sonar data on the distribution of kelp.

The overall purpose of the workshop was to provide an update of the available information on the kelp communities, but it was not to review any specific survey program or regulatory decision. As shown on the attached agenda (Appendix A), the workshop began with a series of presentations on recent kelp surveys and observations. The Proceedings contain summaries of these presentations; detailed reports on some of the surveys are available as separate documents. Others are still being documented for the

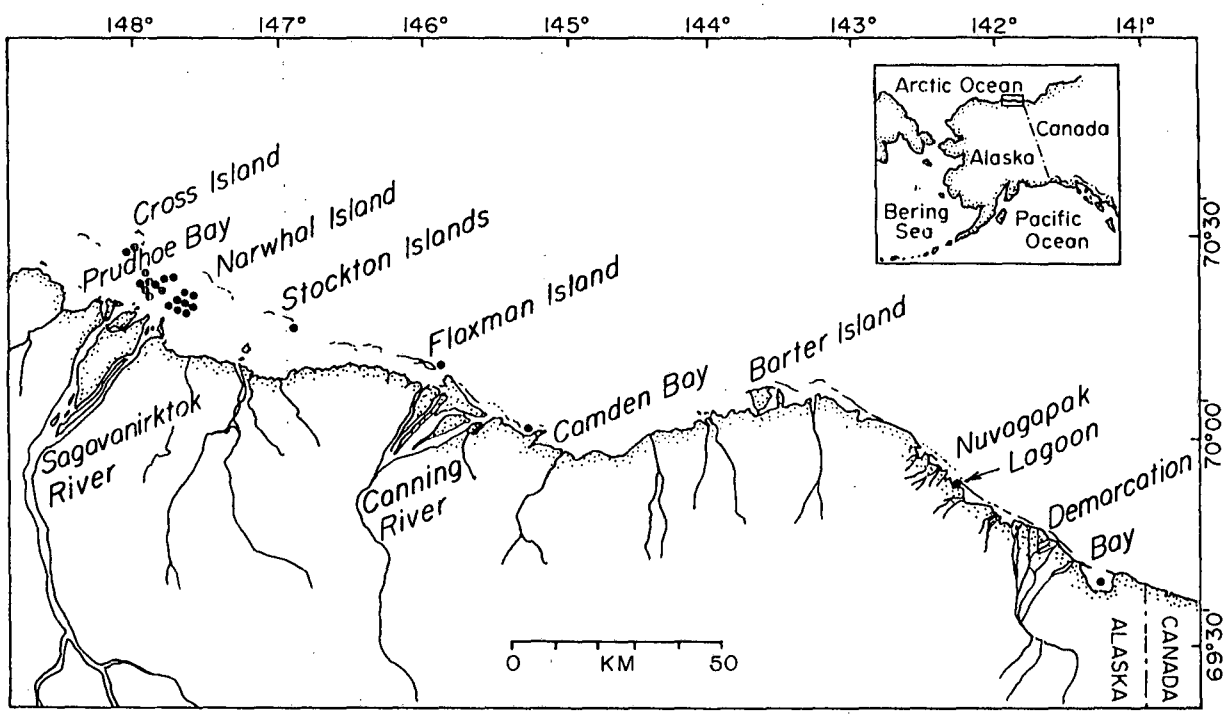
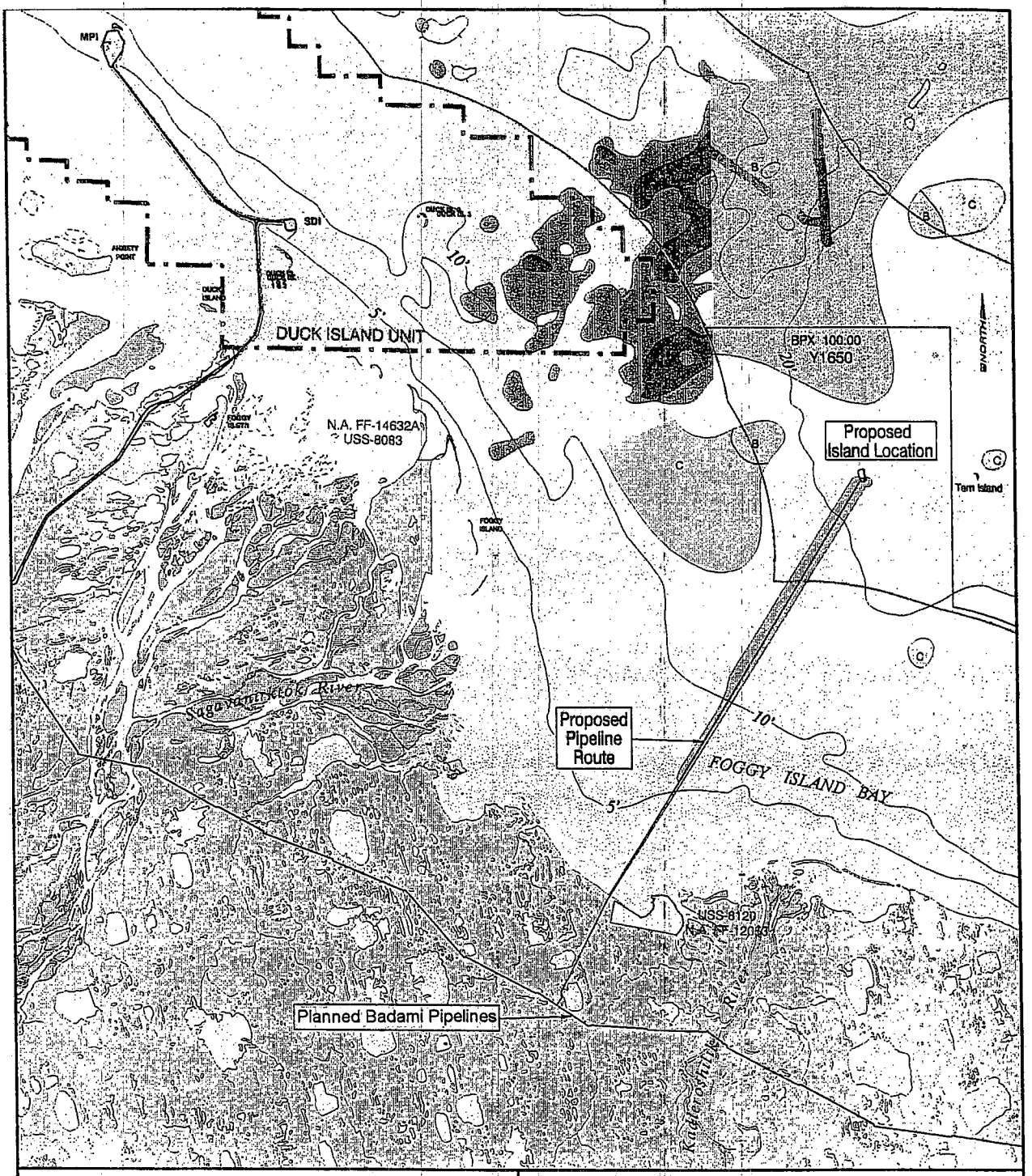


Figure 1. The eastern Alaskan Beaufort Sea shelf. Solid circles denote the locations of suspected macroalgal beds based on biological or geological evidence (from Dunton et al. 1982).



Pipeline Sediment Outfall

Proposed Pipeline Route

BOULDER PATCH HABITATS

10 - 25% Boulders and Cobble

> 25 % Boulders and Cobble Lee and Toimil (1985)

Widely Scattered or Probable Boulders and Cobble

Boulders and Cobble Reimnitz and Ross (1979)

BP EXPLORATION (ALASKA) INC.
LIBERTY DEVELOPMENT PROJECT

Figure 2. Southeastern portion of the Stefansson Sound Boulder Patch (adapted from Figure 5-6 in BP Exploration (Alaska) Inc. 1998).

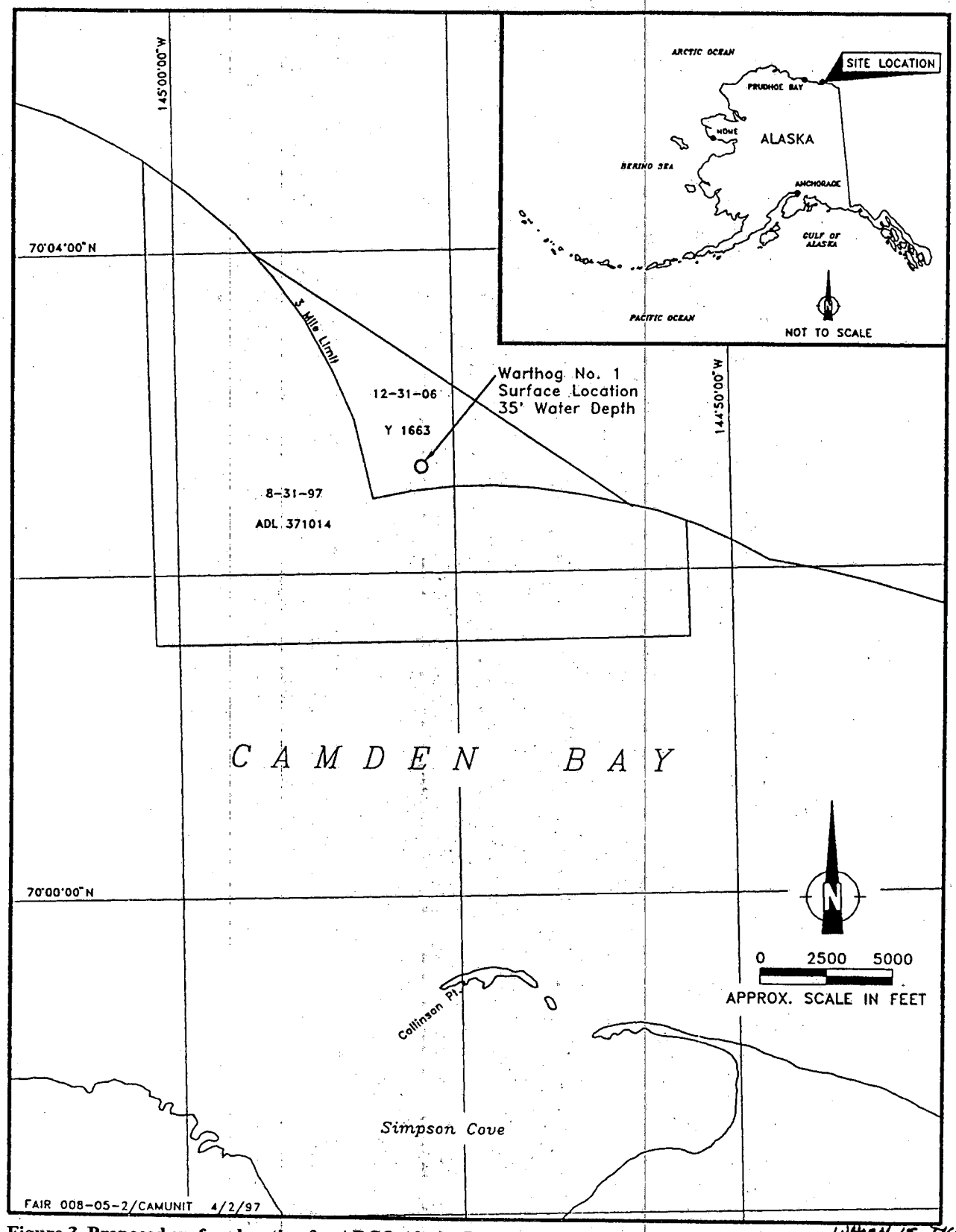


Figure 3. Proposed surface location for ARCO Alaska Inc.'s Warthog No. 1 Exploration Well ~~and~~ WHICH IS THE approximate location of kelp patches (adapted from Figure 2-1 in Fairweather E&P Services 1997).

sponsoring companies. And some of the information is described in the 1998 Environmental Report for the Liberty Development Project, prepared for BP by LGL Alaska Research Associates, Inc., Woodward-Clyde Consultants, and Applied Sociocultural Research (LGL et al. 1998).

After the initial presentations, the workshop included formal reviews or "ecological perspectives" on the initial presentations. The perspectives were presented by three well-known experts: Dr. Kenneth Dunton from the University of Texas, Dr. C. Peter McRoy from the University of Alaska Fairbanks, and Dr. Michael Stekoll from the University of Alaska Southeast. The Proceedings include brief summaries of their formal presentations.

The workshop concluded with a long discussion period among all of the participants (Appendix B-List of Participants). Several of the participants were members of the interagency Arctic Biological Task Force (ABTF) which advises MMS about the effects of operations on kelp communities. The Proceedings contain summaries of the main points that were discussed and a list of concluding notes.

RECENT SURVEYS AND OBSERVATIONS

SONAR AND VISUAL IMAGES OF STEFANSSON SOUND: 1997-1998 BOULDER PATCH SURVEY

Mr. Craig Leidersdorf and Mr. Peter Gadd
Coastal Frontiers Corporation

and

Mr. Terry Sullivan
Seavisual Consulting, Inc.

Overview

This and the succeeding presentation describe a sea bottom survey undertaken in Stefansson Sound during the 1997 open-water season and 1998 winter season. The work was performed in support of BP Exploration (Alaska) Inc.'s Liberty Development by Coastal Frontiers Corporation, which was responsible for the physical oceanographic aspects of the study, and LGL Ecological Research Associates, which was responsible for the biological aspects (Coastal Frontiers, Inc. and LGL 1998). Three candidate pipeline routes were investigated:

1. West Pipeline Route: The West Pipeline Route extends southwest from the proposed production island site to a landfall west of the Kadleroshilik River mouth.

2. *East Pipeline Route:* The East Pipeline Route extends southeast from the island site to a landfall east of the Kadleroshilik River mouth.

3. *Satellite Drilling Island (SDI) Pipeline Route:* The SDI Pipeline Route extends northwest from the island site to the Endicott SDI.

The primary objective of the survey was to characterize potential Boulder Patch habitat in areas that could be affected by the offshore portion of the proposed lease development. Specific objectives were as follows: (1) to document the absence or presence of Boulder Patch communities at the planned site of the Liberty Production Island; (2) to document the absence or presence of Boulder Patch communities on the three candidate pipeline routes; and (3) to estimate the distribution of Boulder Patch habitat along fifteen North-South transects that encompass a large region in Stefansson Sound surrounding the project site.

The study plan was based on the environmental survey requirements prescribed by the ABTF in 1980. At that time, "Boulder Patch" habitat was defined as "kelp attached to boulders in concentrations of greater than 10% in 100 m^2." This definition was repeated by the U.S. EPA in the National Pollutant Discharge Elimination System (NPDES) permit for discharges from oil and gas exploration facilities on the Outer Continental Shelf and in contiguous state waters: "an area which has more than 10% of a 100 m^2 area covered by boulders to which kelp is attached."

The survey program consisted of two phases. The first, conducted during the 1997 open-water season, included an initial dive calibration, an extensive side scan and multi-beam sonar survey, and an attempt to verify the sonar findings using a remotely-operated underwater vehicle (ROV). The verification effort was hampered by extremely poor visibility in the water column, prompting additional ROV work to be undertaken through the sea ice in April 1998.

Sonar Data Acquisition and Analysis

The equipment utilized for the sonar survey included a SeaBat 9001 Multibeam Echo Sounder, and EdgeTech 260-TH Side Scan Sonar system and ISIS side scan sonar digital data acquisition system, and a Trimble 4000 RS GPS receiver. The side scan sonar system constituted the primary tool for identifying areas of the sea bottom with the potential for supporting Boulder Patch communities. Side scan provides a two-dimensional, photo-like image which varies with the surface relief and acoustic reflectivity of the sea bottom. Both of these characteristics are useful in differentiating rocky substrate from sand, silt, and clay. The unit was operated at a nominal frequency of 500 kHz, based on initial field tests that indicated a greatly improved ability to distinguish small targets (such as cobbles) compared to an operating frequency of 100 kHz. The use of the ISIS system enabled the side scan data to be recorded (and later analyzed) in digital as well as analog form.

The multi-beam sonar system was employed both to obtain bathymetric data along the track lines, and to map sea floor features such as ice gouges, strudel scours, and apparent boulders. Unlike side scan, multi-beam sonar provides a true three-dimensional image of the sea bottom, with a vertical resolution of 0.3 ft. Although not as useful as the side scan record in identifying potential Boulder Patch habitat, the multi-beam record nevertheless provided assistance in recognizing and quantifying areas of high relief (especially boulder fields).

Side scan and multi-beam sonar data were acquired along fifteen North-South transects spaced at 0.5 nautical mile intervals, three short intermediate lines (in areas identified during the dive calibration as containing Boulder Patch), and the three candidate pipeline routes. The total track length was approximately 157 nautical miles.

The analysis of the sonar data was guided both by the aforementioned definitions of Boulder Patch habitat, and by the characteristic sonar signatures of the features of interest. With respect to the latter, boulders tend to produce distinctive dense returns ("targets") and adjacent shadows on the side scan record, and pronounced surface relief on the multi-beam record. Cobbles and gravel are more difficult to discern, in that they often produce dense returns but no shadows on the side scan record, and no signature on the multi-beam record. Unfortunately, kelp and other algal growth characteristic of Boulder Patch habitat cannot be detected by either sonar system.

The approach adopted for analyzing the sonar data was to classify the sea bottom beneath each track line according to target concentration. Four categories were employed: "None," "Light" (less than or equal to 10%), "Moderate" (greater than 10% but less than or equal to 25%), and "Heavy" (greater than 25%). The latter two categories represent a necessary (but not sufficient) condition for the existence of Boulder Patch habitat as defined by the ABTF.

The side scan records were viewed first in analog form, and compared with templates displaying 10% and 25% target concentrations. In areas where the analog record did not lend itself to unambiguous interpretation, the record was viewed in digital form using the ISIS software. (ISIS is a commercially-available software package suitable for the digital acquisition, display, and enhancement of side scan sonar data.) Additional information was obtained from the multi-beam sonar record, particularly with respect topographic relief. Once a consensus was reached regarding target concentrations, the linear extent of each category was superimposed on the vessel track line. Both the multi-beam and ISIS data were used to estimate the dimensions of some of the larger boulders encountered.

Sonar Survey Results

Of the 118 nautical miles of track line surveyed along the fifteen North-South transects and three short intermediate lines in Stefansson Sound, 25% was found to contain target concentrations in excess of the 10% threshold specified in the ABTF definition of Boulder Patch habitat. An additional 10% was characterized by target concentrations less than or equal to 10% while the remaining 65% contained no hard substrate. The heaviest target concentrations were found to lie to the north and northwest of the planned Liberty Island site.

Of the three candidate pipeline routes investigated, only the SDI Route contained target concentrations classified as Moderate to Heavy. No discernible targets were found at the island site and on the East Route, while concentrations ranged from None to Light on the West Route.

Summer ROV Verification

As indicated earlier, sonar data alone cannot provide conclusive evidence of the absence or presence of Boulder Patch habitat. Consequently, an ROV program

was undertaken at the conclusion of the sonar work in an attempt to acquire "ground truth" verification data in key areas that included the planned island site and the West Pipeline Route.

The ROV work was conducted using a Benthos MiniRover Mark II equipped with a video camera and high-intensity lights. Twenty-four sites were visited, consisting of ten on the North-South transects, one at the planned island site, and thirteen on the pipeline routes. Unfortunately, high turbidity levels engendered by severe wave conditions reduced the underwater visibility to less than 1 ft for the duration of the summer ROV program.

Despite the limited field of view of the camera, the video images evidenced a high degree of correlation with the side scan data. On the North-South transects, for example, kelp or rock with attached biota was noted at seven of the eight sites with Moderate or Heavy target concentrations. Gravel was found at the one site with Light target concentration, while no rock was observed at the site devoid of sonar targets.

Although useful data were extracted from the summer video tapes, it was concluded that a supplemental ROV program conducted through the ice in clearer water would provide more definitive ground truth data for verification of the sonar findings. Accordingly, the winter field program described in the next presentation was added to the survey plan.

Conclusions

The three-part survey program employed for the 1997-98 Boulder Patch survey, consisting of an initial dive calibration, an extensive sonar survey, and ROV verification in selected areas, demonstrated that side scan sonar constitutes a reliable and cost-effective means of detecting Boulder Patch habitat. Visual calibration is necessary to insure that the sonar records are interpreted correctly, but need not be undertaken if such data are available from prior investigations in the study area.

Both diving and ROV operations can be utilized to obtain the requisite calibration data for the sonar records. The former offers the advantage of first-hand exposure to the nature of the sea bottom, while the latter provides the capability to visit many more sites in a given period of time. It is noteworthy that useful calibration data were obtained from the summer ROV work despite extremely limited underwater visibility.

The locations and densities of Boulder Patch habitat derived from 1997-98 survey evidence general agreement with those reported by previous investigators. Factors that may have contributed to the differences include a high degree of local variability in Boulder Patch density and the use of less capable sonar and positioning equipment for the earliest surveys.

1997-1998 BOULDER PATCH: WINTER ROV SURVEY

Dr. Benny Gallaway and Dr. Larry Martin
LGL Ecological Research Associates

Since the summer survey with the Remotely-operated Vehicle (ROV) was unsuccessful in obtaining good video images, a second ROV survey was conducted in April 1998. This winter survey was accomplished from a Rolligon equipped with a Differential Global Positioning System (DGPS) and used the same Benthos Mini-Rover that was used during the summer survey. Video images in VHS and broadcast-quality Beta formats of the seafloor at 17 sites were recorded.

The goal was to ground-truth the entire proposed pipeline corridor within the depth range that we expected that kelp might occur. The survey was carried out in an X configuration so that 100% coverage of the proposed pipeline alternatives could be obtained. The Island site was also surveyed. There were sample sites along the Satellite Drilling Island corridor and Dive Site-11. The ROV was equipped with paired lasers so that the width of the field of view as well as the size of objects could be delineated. The ROV was also equipped to provide a read-out of the compass bearing, the date, the time, and depth.

The same classification categories of the summer survey were used in the winter survey: NONE, LIGHT, MODERATE, HEAVY. The ABTF and EPA definition of Boulder Patch was also followed. The goal, again, was to determine the presence or absence of a Boulder Patch habitat.

During this workshop, four videos were shown illustrating the four classification categories.

There is a rather extensive analysis planned for the winter ROV data, but it had not been completed as of the workshop date. All of the video tapes will be reviewed. The analytical work has not yet been completed. Afterwards, it will be determined if a more

extensive analysis is warranted from either a project sense or a scientific sense.

Summary of the brief discussion following the presentations by: Mr. Leidersdorf, Mr. Sullivan, Mr. Gadd, Dr. Gallaway, and Dr. Martin

Ms. Pamela A. Miller asked for clarification on the objectives of the winter survey with a ROV. She wanted to know whether or not any biological sampling was conducted or classification of species. Dr. Gallaway responded that while some species are readily identifiable, the study was to characterize whether or not a Boulder-Patch community was present. It was not to characterize the community composition. Ms. Miller also asked for clarification on the comparison of the different track lines. She was concerned that segments of the video tape seemed to be taken at different depths. Dr. Martin responded the ROV was guided by divers at different depths. When the ROV was guided over a featureless bottom, it could be kept much closer to the bottom.

A comment was made that there did not seem to be any fish in the Boulder Patch community. Dr. Dunton responded that, in fact, there are a lot of fish underneath the kelp canopy, including arctic cod and a several other species. The fish are not dense but they are definitely there.

PREDICTED SEDIMENTATION ON STEFANSSON SOUND KELP

Ms. Sue Ban
Woodward-Clyde Consultants

Winter construction of the offshore gravel island could cause increased suspended sediment concentrations in marine waters during placement of fill material. Suspended sediment concentrations and physical dimensions of the turbidity plume generated by the construction activities depend on a number of factors including: timing of the construction activities, physical characteristics of the fill material, water depth at the construction site, and circulation patterns in the vicinity of the site

Effects of the winter construction of islands in the general area have been reported by Toimil and England in a 1982 report, and Toimil and Dunton in 1983 and 1984 reports. These studies report the environmental effects of winter gravel island construction at Exxon's BF-37 island located north of Endicott in 6 m (20 ft) of water. Results of the work showed the concentration of suspended sediments, measured at radial distances of 170 and 140 m (560 and 460 ft) from the island center, did not noticeably increase during the first seven days of fill material placement. The highest suspended sediment concentrations measured were within 3 mg/L of the ambient level of 6.7 mg/L. Three factors were suspected to restrict formation of a turbidity plume: low current velocity, ice-bonding of fine fractions, and formation of silt/ice agglomerates.

Therefore, increases in water turbidity and sediment deposition in the downstream plume area from winter island construction are likely to be at lower levels than from construction in the summer. However, during winter, marine water beneath the ice cover becomes clear due to settling of suspended sediments in the more quiescent conditions and lack of river-borne turbid inflow. Introduction of gravel and associated sediment will likely be more noticeable in winter than in summer, when river-borne and wave-induced resuspended sediments typically create very turbid conditions in the area. The effects of turbidity increases due to extensive tug and barge traffic required for summer construction, although less noticeable because of existing turbid conditions, will be eliminated with winter island construction.

To analyze the case of Liberty Island, an upper planning range quantity of gravel for island construction was assumed to be approximately 577,500 m^3 (750,000 yd^3) of fill material, with a maximum of 15,500 m^3 (20,000 yd^3) placed per day in two, 12-hour shifts over a period of about 45 days. The Lisburne Offshore Project Environmental Assessment determined that most of the fill material used for construction in the Prudhoe Bay area has a maximum of 10 percent fines (i.e., fine particles), and assumed that 10 percent of the fines in the fill material below mean water level will be washed out during construction. However, others contend that the construction standard for gravel in the Prudhoe Bay area is only 5 percent fines, and the material used to construct Tern Island in Foggy Island Bay had an average of only 2 percent fines. NORTEC estimated that up to 12 percent fines contained in fill material placed below water during open water construction may be entrained during construction.

Therefore, a worst-case analysis can be developed which assumes that fines (silt and clay-sized particles) account for approximately 5 percent of the fill materials and a 12 percent resuspension of the fine

materials. Under this scenario, 92 m^3 (120 yd^3) of material will be released to the water column per day. Using a typical specific gravity of 2.6 g/ml for the material, this corresponds to 240,000 kg/day or 2.8 kg/s. For comparison purposes, a best-case scenario was developed where fines were assumed to account for 2 percent of the fill material, and 10 percent of the fines would be resuspended. With this scenario, 31 m^3 (40 yd^3) would be released per day. This calculates to 80,600 kg/day or 0.9 kg/s. It is likely that the actual amount will vary but will be somewhere between these two amounts.

Assuming that the grain size for these fine materials ranges from 5 to 100 μm (very fine silt to very fine sand), the under-ice currents are 2 cm/s (0.04 knots), and the water depth is 6 m (20 ft), the majority of the material will have fallen out of the water column within 1 km (1,100 yds) downstream of the island. This is a worst-case estimate for settling distance downstream in 6 m of water, since much of the fill material will be placed near the bottom of the water column and will not have to settle through the entire water column (expected to be 4 to 5 m deep under ice cover), and the number of particles (suspended solids concentration) also decreases with distance, as settling removes particles from the water column.

Under-ice currents are not directly affected by meteorological processes (i.e., not by wind stress, but as the result of the small Beaufort Sea tides and atmospheric pressure variations over the ice sheet). The current is consistently westerly/northerly. Therefore, the materials are likely to be deposited in a narrow band to the northwest, following bathymetric contours. Since settling distance from the island is dependent on both current speed and water depth, changing either of these variables will affect the calculated settling distance. For example, as the sediment plume moves into more shallow water, the settling distance will decrease. Since water depth decreases to the west and northwest of the island, it is likely that all materials larger than clay-size particles (5 μm) will have settled out within 11 km (3 to 7 mi) of the island.

About 0.2 sq. mi. (about 130 acres) has the potential to be affected by sediment deposition of particles larger than 15 μm. Of the 0.2 sq. mi., 0.10 sq. mi. may consist of boulder and cobble substrate and may support a Boulder-Patch community. The potential area of impact for particles <5 μm is about 4 sq. mi. (about 2,500 acres), with about 0.3 sq. mi. (about 200 acres) consisting of >25 percent boulders. However, a very small percentage (<1 percent) of the fill material is expected to consist of clay size particles <5 μm.

Material excavated from the bottom during trenching operations along the proposed project (western) route is expected to consist of fine sand, silt, and clay down to about 2.4 m (8 ft). Most of the sediments along the pipeline route are smaller than 70 μm. The clays tend to be cohesive and form large clumps when disturbed. The large clumps fall out of the water column at the location of disturbance (D. Miller, Duane Miller and Associates, pers. comm.). Using a typical mean grain size of 30 μm, a typical under-ice current of 2 cm/s (0.04 knots), and a water depth of 6.1 m (20 ft) at the island site (which would be 1 to 2 m less due to ice thickness), the possible extent of increased sedimentation from trenching is about 300 m (about 1000 ft) west/northwest (downcurrent) of the trenching activity. This is a worst-case estimate. In shallower water, this distance will be reduced. For example, in 3 and 1.5 m (10 and 5 ft) of water, the effective downstream distances could be about 150 and 75 m (about 500 and 250 ft), respectively. For the proposed project, an area of 1.0 sq. mi. (about 600 acres) has the potential for increased turbidity due to trenching. Of this area, approximately 0.1 sq. mi. (about 60 acres) exhibits scattered boulders and cobbles.

A similar but more complete analysis, including references, of the predicted sedimentation is included in the Environmental Report for Liberty Development Project, dated February 1998, which is available from BP Exploration (Alaska) or MMS (LGL et al. 1998).

SONAR AND VISUAL IMAGES OF CAMDEN BAY KELP

Mr. Bill Penrose
Fairweather E&P Services, Inc.

In March 1997, Fairweather E&P Services was contracted by ARCO Alaska to drill a well at a site in western Camden Bay (Figure 3). Fairweather planned to use the Glomar *Beaufort Sea I* also known as the Concrete Island Drilling System (CIDS). Federal regulations require that a site clearance be performed prior to the placement of the drilling rig. Side scan sonar was one of several tools used to clear the site. Side scan sonar is important for locating any hazards to drilling such as rocks that could damage the base of the rig and for locating any important biological communities which could potentially be harmed by drilling operations. Site clearance operations also

involved soil sampling to enable the calculation of the structure's resistance to lateral ice forces. Video surveys were also conducted to identify any seafloor anomalies identified by sonar.

Site clearance activities took place in August, 1997. The side scan sonar yielded a widespread, uncharacteristically blurry response in addition to isolated normal sharp responses from cobbles and ice. Also very little ice scour was seen which is unusual for that area. However, the bathymetric charts for the area indicated surrounding shoals which would prevent ice thick enough to cause scouring from entering the area. It was felt the blurry images resulted from a calibration problem which could be filtered out later in processing. Later in the efforts to clear the site, a vibracorer was sent to the bottom to recover soil samples. Instead of penetrating the bottom, it hit the bottom, bounced, and then laid down. When the vibracorer was hauled back up there was kelp adhering to it. That brought everything together: the lack of significant scouring; the very hard bottom; the diffuse, shadowy sonar images; and the kelp on the coring tool indicated a biological community on the bottom which needed documenting before permission could be obtained to operate there.

To investigate this further, a video survey was performed over the area. The video camera was deployed over the side of the survey vessel and lowered to within three feet of the seafloor and the vessel was allowed to drift with the wind from west to east. While the camera's location was constantly monitored and documented, there was no attempt to run a formally laid-out grid as the intent was to ground-truth the sonar. Thus, in a given location, the video camera was looking at what the sonar had recorded. It turned out that defining the hard bottom also defined where the kelp was. The softer, sandier areas didn't have kelp. Fortunately, the sandy areas were the areas best suited to deploy the drilling rig so that the 5 ft skirts could penetrate the bottom and achieve sufficient lateral ice load resistance.

Once the video and sonar documentation had been reviewed, the MMS was contacted. The MMS looked through the entire 2 hours, 8 minutes of tape, then decided that the ABTF should be consulted because the kelp patches were similar to the *L. solidungula* patch in Stefansson Sound, and the one about 10 km west near Konganevik Point (Attachment 1). In preparation, every single kelp frond that occurred in the 2 hour, 8 minute video was counted for a total of 360 occurrences; over the site surveyed, there existed a kelp density of 3.6/m^2 per occurrence. (Copies of the video were distributed during the workshop.) When the ABTF met, they reviewed all of the sonar and video images. The recommendation of the ABTF to MMS was that a kelp community was present but was so diffuse and wide-spread that the drilling operation would not have a significant impact. Regardless, the drill site was moved to the sandy area where the CIDS skirts would penetrate the sea bottom and kelp was not observed.

Summary of the discussion following the presentations by Ms. Ban and Mr. Penrose

Ms. Melanie Duchin asked a question about factors that would affect the direction of the sediment plume (e.g., storms). Ms. Ban replied that the plume would be under ice and therefore not affected by meteorological events. And that under the ice, the direction of the plume can be predicted fairly well. Dr. Dunton added that meteorological events, such as high and low pressure systems, can affect under-ice water circulation. Under high offshore pressure systems, the ice is pushed down and that forces the water to move onshore during the winter. Ms. Ban added that one should keep in mind that the construction phase of Liberty Island is a finite event lasting approximately 45 days. There would not be a continual input of sediment. There may be some drift of the plume east or west.

A question was raised if the workshop was going to cover any kind of plume that might result once the island had been placed and what would be the impacts over the life of the project. Mr. Gadd responded that the island was to be covered by a geotextile mat so no "weeping" or winnowing of sediment would be expected. Also, he expected future impacts to be minimal.

Mr. Dan Ritzman asked, once the construction plume has settled, what would be the impact of that additional sediment being resuspended during summer storms. Ms. Ban responded that the fine material is only 2% of the total and that it could be spread out. But for the worst case scenario, there would be 240,000 kg/day. In comparison to the natural sediment load in summer, that is not a lot of material.

Ms. Amanda Dreyer commented that it might be better to do the construction in the summertime, given the turbidity present then. Maybe the kelp would be more susceptible to sediment effects in the winter time. Dr. Dunton responded that the important factor is not

necessarily the sediment burial but the light attenuation. There are high ambient levels of sedimentation and the plants are dealing with it. Sedimentation on the seabed would not affect the plants greatly. What is more important is the resuspension of those sediments and what it does to water column light attenuation. The next step should be calculation of the coefficients that indicate the light transmission through the water column. That in turn would indicate the amount of photosynthesis and plant growth. The plants' total photosynthetic capabilities are restricted to the summer open-water period. That is why that summertime coefficient is important.

Ms. Miller asked about the disposal of drill cuttings and/or the disposal area on top of the ice surface. Ms. Ban replied that the drill cuttings will all be reinjected. However, during the pipeline trenching operation, most of the sediment is placed back on top of the pipe. There may be some material that will be placed in spoil piles and permitted for ocean dumping. But that is just the same material from the seafloor.

A question was asked if the plume from the Sagavanirktok River extends out to the Boulder Patch. Mr. Leidersdorf responded that the Sagavanirktok Delta is a very sediment prone area—due to river outflow in the summer and resuspension whenever the wave heights exceed 1 m. The Sagavanirktok plume can reach far offshore.

Ms. Jeanne Hanson asked if anything has been done by ARCO or Fairweather to further characterize the environmental factors affecting the kelp patches near the Warthog drill site. Mr. Penrose responded that there were probably several factors which contributed to the success of kelp in the area: the relatively shallow water, and the hard-bottom areas that were sheltered from ice scour by the shoals offshore. However, studies of all the affecting factors would take a great deal of time and effort. They were required to determine only the distribution of kelp; but they were not required to complete further studies.

Mr. Brian Havelock asked if virtually every cobble had kelp on it. Mr. Penrose responded affirmatively, adding that during his review of the two-hour survey, he saw only one cobble that didn't have a piece of kelp on it.

ECOLOGICAL PERSPECTIVES

Dr. Kenneth Dunton
University of Texas at Austin

Light and nutrients usually are available simultaneously for plants in both terrestrial and aquatic environments. This is true for kelp and other macroalgae and phytoplankton in temperate latitudes. But in the Arctic, nutrients and light are not normally available to macro algae during their primary growing period in the late winter and early spring. Phytoplankton are adapted to take up nutrients far more efficiently than macroalgae. Consequently, the algae cannot compete with phytoplankton for nutrients, and when the phytoplankton are present, they literally strip the nutrients from the water column, leaving nothing for the algae.

But the phytoplankton disappear in winter. They cannot maintain a high density in winter because no light is available for photosynthesis, and therefore they die and disappear. The macroalgae, the kelp in particular, are very large organisms and can store carbon and energy. They photosynthesize in the summer, store that carbon, wait until nutrients are available in the wintertime, and then that is the period in which they accomplish nearly all their linear growth. So, conditions during the winter are important for them.

Summary of the extensive discussion during and following the presentation by Dr. Dunton

A question was asked about long-term global changes in Arctic kelp communities, especially due to the increased frequency of storms and increased turbidity. Dr. Dunton responded that it will vary depending upon where you are in the Arctic. On the one hand, there may be more nutrient regeneration as ice melts farther offshore during summer. There would be more cycling of deep upwelled nutrients onto the shelf with increased circulation and the plants might actually do better. But on the other hand, with increased storm activity there would be less light available in the summertime and, therefore, less growth. It is pretty speculative at this point. Dr. Dunton's research in this area is focused on ozone depletion and ultraviolet effects. He mentioned that there is a new initiative dealing with the effects of global change on the Arctic shelf and basin.

A question was asked whether the kelp, *Laminaria saccharina*, grows in winter as well as in the summer. Dr. Dunton responded that it would not grow well in the winter in the Boulder Patch. It is a rapidly growing, opportunistic species. It would grow well in winter only in the east where there is clear ice and a nutrient supply.

Dr. Gallaway asked about mysid dependency on kelp and, specifically, if there was seasonal variation in that. Would the carbon-isotope composition of mysids collected from the Boulder Patch be similar to those from other areas? Dr. Dunton replied that mysids do show changes in their isotopic composition seasonally. In summer, when the mysids are isotopically lighter, they are deriving most of their carbon from the phytoplankton which is abundant in the summertime. During the winter, the isotopic signature is more enriched with C^{13}. Since kelp are rich in C^{13}, and phytoplankton are virtually absent, the conclusion is that the mysids are depending on carbon derived from kelp tissue in the wintertime. Dr. Dunton stated that he would not expect mysids from the Boulder Patch to have the composition of mysids from Simpson Lagoon because there is no kelp in Simpson Lagoon.

Dr. Dunton explained that he had started a new project on the effects of ultraviolet radiation with a scientist from the Smithsonian Institution. They know that kelp are sensitive to UV light, that the kelp photoinhibit in bright light, and that UV light does not penetrate through turbid water very well. They are finding that UV light and photoinhibition seem to affect kelp in the clear water of the Canadian Arctic, but probably do not affect the kelp along the Alaskan Beaufort Sea coast.

Dr. Dunton explained that he has records of kelp growth and light levels from 1984 to 1991. The growth from year to year varied considerably. If the ice was clear and the plants received even a small amount of light during the winter, they grew a fair amount. The growth during 1990 was exceptional, but 1988 was a really bad year for photosynthetic carbon fixation by kelp. No carbon was stored during 1988. That meant that during the following year, 1989, only small blades or fronds were formed.

Dr. Newbury commented that most of the kelp fronds in the Camden Bay looked relatively large to him. He was surprised because the kelp in Camden Bay were in deeper water where there would be less light; the Camden Bay kelp are under 35 m of water, whereas the kelp in Stefansson Sound are under 20 m. Dr. Dunton responded that he thought the kelp growth was related to the light and nutrient conditions during winter. He noted that it is not unusual for there to be turbid ice in Stefansson Sound, and that he thought that kind of ice was probably unusual in Camden Bay. He thought the difference in kelp size would be due to growth during the late winter ice-covered season.

Dr. Dunton added that he studied the kelp in Camden Bay, Nuvagapak Lagoon near Barter Island, and in Demarcation Bay during the early 1990s. One of the kelp species near Konganevik Point in Camden Bay is *Alaria esculenta*. In Demarcation Bay the kelp species is *Laminaria saccharina*. The fronds almost disappear during the winter, but grow rapidly each year to two meters or more in length.

Dr. Tom Newbury asked about the genetic isolation of kelp in the Alaskan Beaufort Sea. Dr. Dunton explained that this is a scientifically-important community. A lot has been learned from the plants in this area. The physiology of these plants is unique and not observed elsewhere. We have learned a lot about the distribution of Arctic plants in the Beaufort Sea. The Boulder Patch has told us a lot about how they got there and the predominant current patterns that have existed since the Pleistocene. The biogeography of these plants is interesting; they are part of the Atlantic flora rather than the Pacific flora.

Dr. Ray Jakubczak asked if the presence of a gravel island would measurably affect water turbidity. If so, to what degree and for how long, and has any work been done on that? Dr. Dunton responded that there was some work done on the BF-37 gravel island near the outer edge of the Boulder Patch, but it was a short-term study. That island was also "bagged" which successfully limited the amount of sediment in the water column. It was very effective. Regarding background levels of sediment in Stefansson Sound, Dr. Dunton recalled that levels above 10 mg/L have not been seen during summer measurements in the early 1990s at Dive Site-11 and BF-37. Apparently, no one went back to examine the area after the bags were removed.

Mr. Penrose asked a question about the natural barrier islands as a source of sediment when the winds are strong. Dr. Dunton stated that the islands are very old geologically and that the fine sediment has pretty much been winnowed away. During a big storm, one seldom sees any plumes from those islands. The islands are mostly coarse sands and gravels.

Mr. Leidersdorf explained that, from an engineering and economic point of view, islands without slope-protection systems tend to erode too rapidly in deep water. As a first approximation, armor is warranted when the water depth exceeds 2 m. The armor typically consists of a geotextile filter held in place by sizeable units such as gravel filled bags or concrete mats.

Dr. Jakubczak explained that the concrete mat appears to be the state-of-the-art system. A problem with the bags is that they deteriorate and break away, thus creating a litter problem. Mr. Gadd mentioned that Northstar Island, built in 1985 in 45 ft of water and about 15 mi northwest of Prudhoe Bay, was protected with a concrete-mat system. After seven or eight years, small kelp plants were growing on those concrete blocks. Mr. Gadd wondered whether or not any hard substrate that is placed on the sea bed near the Boulder Patch may provide a colonization site for kelp, and what would be the time scale. Dr. Dunton stated that there should be no reason why kelp would not grow on any hard substrate if there is sufficient light and not a lot of turbidity. Colonization should happen very quickly. There needs to be some weathering on the surface and colonization by bacterial films before the kelp gametophytes will settle. Certainly within a few years, small plants would have developed.

Mr. Brad Smith asked if all of these areas are subject to periodic ice scouring or if they are protected by the islands. Does the kelp exists because of the boulders and some protection or are they subject to periodic scouring to some degree? Dr. Dunton said that there is some scouring out there. However, if there was a lot of scouring, the community would not exist as it is right now. It would exist but not in the form that we see it in. The absence of scouring plays an important role in the maturation of this community. Dr. Dunton went further to explain that a lot of the plants shown in the photographs during his talk were over 40 years old. He has done some ageing studies on them by looking at the stipes. Approximately 0.5 cm of a stipe represents a year in age.

Dr. C. Peter McRoy
Institute of Marine Sciences
University of Alaska Fairbanks

Dr. McRoy presented a broader perspective, talking about not just the Boulder Patch but arctic coastal systems in general. Dr. McRoy reviewed the following topics which he thought were important for the workshop: Carbon Contributions, Controls of Production, Ecological Manipulations, and Ecological Significance.

Carbon Contributions

Building on Dr. Dunton's presentation about carbon inputs, Dr. McRoy suggested some modifications, and then identified some controls on productions. The main limits on production have already been discussed: light and turbidity, nutrients, etc. Dr. Dunton presented a budget for primary production, or for carbon inputs to the Boulder Patch. He concluded that under dirty ice, when ice algae is not very productive, the kelp are responsible for about 56% of the production.

However, one cannot calculate relative primary production for only the area of the Boulder Patch. As can be imagined, water flows over the community, carrying productive phytoplankton. One cannot assume that phytoplankton is stationary over the Boulder Patch. If the analysis is expanded to a larger area like Stefansson Sound, this might be the budget under clear ice: about 3% of the fixed-carbon contribution would be due to kelp, about 48% would be due to phytoplankton, and about 49% would be due to ice algae.

When you have turbid ice and you eliminate ice algae production, then 96% of the production would be due to phytoplankton and about 6% by kelp. The phytoplankton in Stefansson Sound could potentially support a lot more consumers. And, in fact, when you look at the isotope composition of Arctic cod, for example, they are 96% phytoplankton carbon. These numbers present a different perspective on the ecological significance of carbon contributions by kelp.

Controls of Production

There are three primary controls on primary production by kelp: light, nutrients, and habitat.

Light is an important factor; both natural factors and human activities affect the light regime of that system. The natural factors are the seasonal cycle, turbidity during summer, and during winter the turbid ice and snow cover on the ice. Dr. Dunton pointed out that some of the kelp plants may be 40 years old. During that time, they have surely been exposed to summers with turbid water and winters with dirty ice. In other words, kelp can probably survive a few years without light. They don't have to have good light every summer

to survive. That is a basic strategy or capability among long-lived plants and animals. In contrast, a plant like *Laminaria saccharina*, which grows best in the clearer water near the Canadian border, might not be able to make it unless there is plenty of light each year.

A point was made regarding nitrogen limitation. In a brief review of nutrient data, it looked like the rivers were adding quite a lot of nitrate. However the phosphorous input was zero, yet no one seems to be worried about the phosphorous regime in this system. It is assumed to be nitrogen-limited. In other words, phosphorous could be as important as nitrogen.

The other limiting factor on kelp production is habitat, i.e., hard substrate. There is not much hard substrate because the coastal plain has an eroding, sedimentary coastline without many rocks. Occasional rocks are washed out by coastal erosion or rafted in by ice. So, the small amount of hard substrate by itself drastically limits kelp production.

Artificial habitats have been used successfully to increase diversity in communities on many sedimentary shelves. Automobiles have been used to create artificial reefs. Part of the features of a kelp community is physical diversity of the bottom. It is not just light and nutrients. It is places for organisms to live, niches to avoid predation, and surfaces for microalgae.

Another important point has been mentioned several times: Stefansson Sound is an erosional environment in spite of the major sources of sediment. If it was not an erosional one, the kelp plants would not survive the sedimentation. The sediment is being cleaned out of the Boulder Patch, and it is essential for the kelp to survive. This suggests that the oceanographic currents ought to be studied a little bit more.

Ecological Manipulations

When you know what is controlling the system, there are some things that can be done to manipulate it. One example would be clearing the snow off the ice to increase the light. Ice clearing may not help if there is turbid ice. But if you increased light through the ice at a critical time of the year, such as April, it might compensate for reduce light levels due to increased turbidity.

Grazing experiments have been done with seagrasses both in Alaska and the tropics. Studies showed that mimicking grazing by sea turtles on seagrasses had a beneficial affect on plants, stimulating growth. However, Dr. Dunton mentioned that with the kelp this method could have a detrimental effect because the plant would lose the carbon that is needed for growth the following year. It would reduce the productivity of the plant in the following years.

Ecological Significance

The Boulder Patch is not just a patch that is out there by itself. There is a continuum of plants wherever there is the right habitat all the way into the Canadian islands. The kelp flora is associated with the Atlantic Ocean. There is no question about that; the Pacific water plume doesn't reach this area. What is the significance of this? How isolated are these populations? If they are 40 years old, is there regular genetic mixing? If they are, in fact, quite isolated and rare, then that increases the concern regarding mitigating any sort of human activities in these kinds of waters. The biogeography of these plants is important.

Global warming is going to change this. The prediction for global warming in the Arctic is that the ice will be diminished. We have already seen that. In the past few years, the distance from offshore to the ice pack has increased. That means more turbidity in the fall. There is more open water. The ice is thinning. Permafrost is being lost at a regular rate. That will have a longer term ecological impact on these communities. Changes in the ice cover—and what it does to prevent mixing and wind effects on these nearshore environments —might cause a definite change in kelp.

To summarize seven of the perspectives described:

1. Only about 3% of the carbon production in Stefansson Sound might be due to kelp.

2. Phosphorous limitation might be as important as nitrogen limitation.

3. Some kelp plants are 40 years old; so have survived years with high turbidity and low light.

4. The small amount of hard substrate by itself would drastically limit kelp production.

5. Artificial habitats have increased biological diversity on coastal sedimentary shelves.

6. The currents which naturally remove sediments from kelp areas ought to be studied.

7. Light could be increased during critical periods by clearing snow from the ice.

Summary of the discussion following the perspective by Dr. McRoy

Mr. Brian Havelock wanted to know if there was a link between the distribution of kelp and migratory fish, like arctic cisco. Both Drs. Dunton and McRoy responded negatively; however, Dr. Gallaway added that transport along the coastal zone is more often to the west than it is to the east, for the Mackenzie outflow. So, one would expect the transport of both fish and kelp from Canadian into Alaskan waters. The relationship would be that both young arctic cisco and young kelp might be transported into this region by prevailing nearshore currents.

Dr. Martin asked for more information regarding the grazing experiments with seagrasses and what actually takes place that increases the growth. Dr. McRoy responded that in tropical plants there seemed to be a growth stimulation. Getting rid of old leaves seemed to help the plants grow. Dr. Dunton mentioned that it was probably due to increased light levels; grazing sometimes helps to reduce self-shading. However, for kelp it works in reverse: when you trim off the kelp blades, you lose the carbon that is needed for growth in the following year.

Someone asked if kelp could be used as an indicator species. Dr. McRoy responded that *Laminaria saccharina* could be an indicator of a changing environment. It is an opportunist. Dr. Dunton mentioned that it could be an indicator of very bad summer conditions. Dr. McRoy added that there could be years in which no growth has taken place. Dr. Dunton recalled some of the original work he had done prior to any oil development. Through the studies, he was able to determine the years in which lots of light had penetrated the ice canopy. The plants had either grown 20 cm or 40 cm. The plants with 40 cm of growth were in areas where light had penetrated the ice canopy. So, their growth rate can be an indicator.

Dr. Ray Emerson pointed out that the kelp community was like a mature ecosystem with few young individuals. Dr. McRoy stated that the only way to get younger age groups is to get new space. Something has to physically remove the sponges or the kelp. Ice gouging could do it. Dr. Dunton stated that he sees it all the time. The sponges have a life span of 3 to 4 years. They fall off the rock and create new space. Chitons also graze on the kelp. Ice scour can also create new space. Fast currents can actually turn over cobbles and create new space.

Mr. Gene Pavia asked how the boulders and cobbles got to the Boulder Patch. Were they were carried by ice and dropped there, or were they an old geological layer? He wondered if ice-rafting occurred continually. Dr. Dunton stated that some arctic marine geologists would say that some are glacial drop stones. But that process is not responsible for most of the Boulder Patch. The consensus is that it would be very unlikely to have so many glacial or ice-rafted boulders in the same place. Another theory is that they are the result of a terminal moraine. However, the mineralogy for the rocks in the Boulder Patch is foreign to Alaska. The rocks on the Boulder Patch are from the Canadian Shield; they are not like other rocks in the State, according to geologists.

Dr. Michael Stekoll
University of Alaska Southeast

Dr. Stekoll presented an overview of a study on the commercial potential of seaweeds at Saint Lawrence Island, Alaska. The work that was done at St. Lawrence could provide a valuable perspective relative to the Boulder Patch.

St. Lawrence Island is located in the north end of the Bering Sea at latitude 64° N. It is not quite Arctic. Geologically it is at the meeting point of different plates in the ocean. There are different shore types all around the island. The island is about 90 km long. There are about 1,000 inhabitants, Siberian Eskimos, living in the two communities of Gambell and Savoonga. The south side of the island is ice-free during winter. So the ice does reach the island during winter. The water depths are relatively shallow around the island ranging from 5 to 20 m. The tides are mixed, semi-diurnal with a range of 1 m. There is pack and shore ice November through June. Water temperature in winter is around -1° C and goes up to 8° C in summer. Summer salinities are between 29 to 32 ppt. The currents are tidally driven near shore. There are strong currents around the island. According to the charts, the seafloor is mostly gravel, sand, and mud. We did find areas that were boulder fields and rocks that had not been charted. On those boulder fields and rocks there are seaweeds.

There is subsistence use of seaweeds by the native population on St. Lawrence Island. The seaweeds are a source of fiber and vitamins and minerals. The Natives who live there harvest the seaweeds as drift in the summertime. They also harvest it in the wintertime. Using a stick through a crack in the ice, they put it down and, finding some kelp, wind it up like spaghetti and pull it up.

The islanders of St. Lawrence Island wanted to find out if there was any commercial potential in harvesting of their local seaweeds. There were two potential commercial uses for the seaweeds or kelp from St. Lawrence Island. One is the health food market. *Laminaria* could be dried and packaged and sold as "Alaska *Laminaria*." Coming from a pristine area it would have high market value. The other value is in the form of alginates which is a type of colloid found in brown kelp. It has commercial value. When the alginate content in the St. Lawrence kelps was analyzed, the level in *Agarum* was about 25%, in *Alaria* 18-27%, and in *Laminaria* it was 20-23% dry weight. These are normal values, not high nor low. As it turned out, it would cost more to ship these seaweeds than what one would receive in payment. The alginate content would have to be in the 50% range or more to be commercially viable.

Some of the seaweeds that we found were *Enteromorpha* and *Ulva*. Some of the red algae species that may have economic as well as ecological importance are *Dilsea*, which is probably *Neodilsea integra*; and *Phycodrys* which had phycocolloids which could be commercially valuable. There are many species of red algae on St. Lawrence Island. There are five or six different species of browns: *Agarum cribrosum*, *Alaria crispa*, *Alaria paradisea*, *Laminaria groenlandica* which may be *L. bomgardiana* or actually it may be *L. saccharina*, and *L. saccharina*. Another species is *Desmarestia*. In the intertidal, *Fucus* grows on the rocks. It doesn't get very big because of ice scraping. It only grows right in the cracks.

Quantitative surveys were done in Aqeftapak Bay and near Savoonga. In Aqeftapak Bay, where there was mostly *Agarum* and some red algae, but no *Laminaria*, the algal density was 0.196 kg/m^2 and a total area of 45,000 m^2.

At the study site near Savoonga, the algal density measured was 0.316 kg/m^2 and the total area of the bed was 15,000 m^2. The biomass was: *Laminaria* 20%; *Agarum* 45%; red algae 15%, and *Alaria* 5%. In July 1990, 49 *Laminaria* plants, ranging in lengths from 23 to 100 cm were tagged and a hole punched in each blade. Plants were remeasured 36 days later, in August, and again in June 1991. In August 1990, we found that the growth rate for *Laminaria* averaged 0.23 cm/d. In June 1991 with only 22 plants remaining, the *Laminaria* averaged 0.08 cm/d or 40 cm/yr.

Summary of the discussion following the perspective by Dr. Stekoll

Dr. Emerson pointed out that *Laminaria saccharina* is referred to as an "opportunistic" species. Dr. Dunton added that it is referred to as opportunistic because it grows very fast. It does not seem to store carbon. It grows rapidly during the spring, goes through its entire reproductive cycle, and then disappears. Whereas, *Laminaria solidungula*, which is prevalent in the Boulder Patch, is a long-lived species. It can be 30 or 40 years old. Dr. Emerson went on to comment that the term opportunistic usually implies that a niche is opened by perturbation or disturbance. He asked if there was some sort of environmental disturbance associated with *L. saccharina*. What allows them to flourish? Dr. Dunton responded that more than just space is required for *L. saccharina*. Even if space for it were made available in the Boulder Patch, it would not survive very well there. It represents less than 10% of the population there. The reason is that it seems to be incapable of tolerating long periods of darkness. In Demarcation Bay in the eastern Beaufort, *L. saccharina* does very well. There is no *L. solidungula* partly because the two plants have different holdfast systems; *L. solidungula* needs hard substrate and there is none in Demarcation Bay, whereas *L. saccharina* has a rhizomatous holdfast and can actually grow on mud. There also must be enough light available which apparently there is in Demarcation Bay. In the Canadian Beaufort, both plants are found in a ratio of about 50:50. They are on an equal footing there because there is light available during the winter period.

CONCLUDING DISCUSSION

Mr. Smith asked a question regarding offshore seismic operations. Is mechanical damage to the community structure and the plants a concern? Dr. McRoy stated that, while it is obvious that they can take some disturbance, there would be some concern because that habitat is limited. Dr. Emerson asked if that would be of benefit to newer organisms. Dr. Dunton responded

that it would probably not. The older organisms are the huge "sori" that are important for the dissemination of myospores. The older ones are more susceptible to being picked up and moved by a cable. But it does not seem that there is that much geophysical activity taking place. If there was a lot of geophysical activity and a lot of dragging cables, it could be serious.

Mr. Leidersdorf mentioned that last summer they dove on a number of cable sites a year after the cables had been placed and moved. They could not find any evidence of damage. The cables are about the diameter of a pencil. They are usually deployed in a slack state onto the seafloor. It might have been better to examine the site immediately after the cables were removed. However, they could find no evidence of rocks overturned or plants severed a year later.

Mr. Smith suggested that evidence would also be the presence of kelp fronds on the cables as they are retrieved, or kelp fronds floating in the area. He asked if Mr. Leidersdorf had noticed any. Mr. Leidersdorf responded that they did not spend a great deal of time with the seismic crews and had not seen any retrieval operations. Mr. Gadd added that at the ten sites they examined last summer, they tried to find the exact locations of where cables had been deployed and retrieved, but they were unable to find any evidence of disturbance.

Dr. Martin also added that there were many overturned rocks on the control sites and cable sites due to natural processes.

Ms. Miller noted that a lot more cables are being deployed with the 3-D seismic operations now. She felt that the effect would be worthwhile investigating further.

Concluding Note: ***concern about effects of ocean-bottom cables***

Ms. Miller was also concerned that there haven't been specific studies of the biological communities at the specific site of the proposed island and the area around it with the greatest potential of sedimentation effects. One of the criticisms of the Endicott project was that there were not enough pre-development studies. There were only one to three years of data. For the Liberty Island project, if it is on schedule, we would not even have that much data. She was concerned about the difficulty of measuring the potential effects of this project without more data on the plants and animals—except for one species of kelp collected in a very general way. It is a biological community about which very little is known.

Dr. Gallaway added that the background information that is available as part of the monitoring program was not described. There is nearly a decade of data, including that from stations on a transect from Endicott through this region. So there is considerable baseline data in the region that is projected to be in the range of fine sediments. So the habitats and communities are known quite well in this general region. LGL did not find the density or coverage of kelp in the specific Liberty area. The Liberty area is basically devoid of those community types.

Ms. Miller stated that she did not see any evidence in the presentation this morning that those things were measured in the Liberty region with sufficient quantification to do a pre- and post comparison. What lives down there in terms of the species? Ms. Miller stated that she did not think there is sufficient data. In the pre- and post-studies on Endicott, there were declines in species diversity for both the controls and impacted sites—which could mean that the controls weren't really controls. Ms. Miller felt that the diversity of life is something that should be examined in this area. The benthic community, whether concentrated or scattered kelp, extends into this project location in the southeast corner. Ms. Miller felt that it needed to be examined in more detail.

Concluding Note: ***Concerns about pre-project data and changes in species diversity***

Dr. Gallaway stated that there are rocks with kelp attached to them but not at densities that have been defined as Boulder-Patch community.

Ms. Miller added that it is a biological community that we know very little about. It is an area that is most likely subject to sediment from the island and potential discharges from the project. Now is the time that we can learn something before the project. We won't have that opportunity to know what changes occur if we don't examine it beforehand.

Dr. Gallaway stated that we do have data in the non-kelp areas. We know that those areas are depositional with soft muddy substrate, and there is a great deal of information. Dr. Gallaway felt that there was sufficient information available and did not see the need.

Ms. Miller was concerned that if it is a depositional area, it seems like there might be additional sediments

deposited there. So what is the productivity? Could it be reduced by the project? Those are her concerns.

Dr. Emerson mentioned a study done in the early 1980s that characterized the Boulder Patch. He thought that it was done to such a detailed level that species diversity indices could be calculated. Dr. Dunton mentioned that as part of the Outer Continental Shelf Environmental Assessment Program, species-diversity indices were done for all of the Beaufort Sea coast.

Dr. Dunton added that there is a base map because Exxon funded a lot of work during the 1980s in that area. He thought that subsequent work would help finish the map and better define the areas. Dr. Dunton was concerned that at this point we really can't see the "big picture." First, we know that in the worst-case scenario that sediment is going to be distributed so many kilometers downstream from the project. But we aren't sure of the direction because of variable currents in winter time. Second, we aren't sure of the limits of the Boulder Patch. On maps you can see where Reimnitz and Barnes found it. Their work, which was done with the sonar and video, is exceptional. But why isn't it being expanded, finishing the maps, especially in relationship to the Liberty Island project? There have been incredible advances in Geographic Information Systems (GIS). The map appears to be in AutoCADD. It would be a small step to put all of the video into a GIS database. That would benefit everyone in terms of making wise decisions concerning the resource. That would help industry and also protect as much of this resource as one can. Dr. Dunton said that he thought there should be more information, and that the map should be finished. He was also concerned with increased sediment loads on light attenuation, except when the slope is protected with fabric and concrete. But what about the pipeline route? Where will the sediments go when you dredge?

Ms. Karen Wuestenfeld stated that the dredging operation is going to be a continuous "dig and dump." Basically, redepositing the sediments back in the trench. There is a contingency disposal area for excess material.

Ms. Miller said that, after reading the project documents, she wasn't clear if the island would indeed be enclosed all the way down to the bottom, to the floor of the seabed. Ms. Wuestenfeld responded that filter fabric would be placed all the way down to the toe of the island. It will be completely covered with concrete mats up to and above the water surface.

Ms. Hanson wanted to know if the MMS could step in and do the environmental studies that Ms. Miller was concerned about. Dr. Newbury responded that MMS usually conducts studies at the lease-sale stage, and that site-specific development studies are the responsibility of industry.

Dr. Jerry Shield commented that he felt there was the potential to obtain more data from the videos. Ms. Hanson also asked if anyone had looked at the biological, the chemical, and/or physical aspects of what supports these communities so that it can be used as a predictive tool. Dr. Gallaway replied that there is a rather extensive analysis planned. The videos had only been taken in the last month. The first step in the survey was to verify whether there were targets in sufficient density to elicit major concern. Then, after providing that information, determine if a more extensive analysis is warranted from either a project or scientific perspective. LGL is putting together a high-quality video which should be ready a few days after the workshop. Then they will prepare their recommendations for future analysis.

Concluding Note: ***Suggestions to extract data on species diversity from ROV surveys, and to use previous studies as a background for new ones***

Dr. Newbury suggested that, given the new computer programs for analysis of sonar records, it should be possible to locate the most-important targets (i.e., large boulders with many large kelp plants) and then to miss all of them or move them out of the way.

Ms. Duchin was concerned about Dr. Newbury's comment in that it assumes that all disruption is localized and that there are no general, cumulative impacts. She thought that areas away from pipelines and islands could be affected.

Concluding Note: ***Concern about long-range cumulative effects***

Mr. Smith commented that Ms. Duchin's remarks were similar to discussions regarding subsea permafrost. He felt that it is important to have a map of the general distribution of kelp communities in the Beaufort Sea, but he didn't know how to do that. Is there any proprietary data that could be used, such as high-resolution seismic data? In the meantime, the techniques discussed in the workshop will help to identify and avoid the sites locally. Mr. Smith recommended that as part of a future lease sale, that MMS consider obtaining a greater understanding of the

distribution of these communities throughout the Beaufort Sea. Ms. Hanson added that she agreed with Mr. Smith's comment about the importance of looking at the big picture with regard to kelp communities.

Ms. Dreyer's comment about summer versus winter operations was revisited. She felt that she got a partial answer to her question, and was still concerned about the sensitivity of kelp to sediments. Dr. Dunton responded that he thought there would not be a significant impact from sediment on the kelp blades. However, if the ice is clear, the plants may not benefit from the transmitted light if there is poor water-column transparency. The plant will not put on additional growth.

Ms. Miller asked again about the methodology of the field check for the side-scan sonar survey. The difference between one color on the map and another is the 10% of boulders and cobbles with kelp attached. She didn't see a systematic quantification of the video data to correlate with the side scan sonar to say, yes, the sonar is picking up all of the rocks. It seemed like the map is saying that the southernmost part of the Boulder Patch that was mapped by the USGS is no longer in the Boulder Patch.

Concluding Note: ***Questions about methods by which kelp/boulder density is calculated, and suggestion to use survey grids rather than parallel survey lines***

Mr. Terry Sullivan commented that the side-scan sonar generally detected more boulders than the ROV. The sonar map is a conservative one in general. The ROV does not detect everything that the sonar does. One of the main conclusions of the winter work was that we thought there would be rocks, judging by side-scan sonar survey, but the ROV survey showed that there was nothing there.

Mr. Leidersdorf reminded the participants that the majority of the rock substrate consists of gravel and cobbles of low relief. With a thin layer of sediment deposited by a fall storm season, the ROV might not detect these small features. The sonar detects objects that are good reflectors of acoustical energy. It is probably a better indicator over a wide area than video data obtained with the ROV. However, the ROV can tell us if the targets are indeed rocks, and if there is biological activity on those rocks. The two techniques give a somewhat different but complementary picture—rather than affirming or denying one another. Also, it wouldn't be practical to use the ROV to map the large areas.

Concluding Note: ***Questions about side-scan sonar analyses***

Dr. Jakubczak added that starting the workshop with the LGL-video presentations might have left some people confused. The ROV effort in particular was not intended to be mapping or characterization of the Boulder Patch. Much of that work has been done previously in conjunction with the Endicott Project and is published in the papers by Drs. Dunton, Martin, and Gallaway, including a suite of reports that cover an even broader scope. The ROV survey was done to serve a very narrow, focused function: to confirm the results of the sonar survey that the pipeline route did not cross the Boulder Patch. Dr. Jakubczak said that the ROV survey was able to confirm that. Initially, the Liberty project had been designed with the results of only the sonar survey. When the sonar survey results were analyzed, areas with heavy boulders were found on one of the pipeline routes—the route to the Endicott causeway. We thought that it would be prudent to take a closer look. If the ROV results confirmed the sonar results, then perhaps we would be comfortable in the future relying on only the sonar. The ABTF agreed that the ROV survey would be done as a confirmation. If some surprises had been found, such as substantial quantities of kelp, then the issue would have been revisited.

Dr. Dunton stated that if these data are being used simply to clear the site and the pipeline route, then it has convinced him that there is no problem with the pipeline route in terms of direct impacts on the kelp community. However, a broader question that the ABTF, industry, and the MMS have to consider is the long-term one of sediment dispersion. Dr. Dunton stated he thought, based on the design of this project compared with previous projects, that this project was going to result in minimal sediment resuspension in the water column—although he would not be convinced until the data are presented. He added that the sedimentation calculations need to include the effects of the pipeline excavation.

Dr. Eric Taylor pointed out that the map shows a line separating two different zones. He was surprised that no one explained it, even though he realized that the workshop was just about the area near the Liberty island and pipeline.

Concluding Note: ***Question about the meaning of two data categories on maps***

Ms. Kris O'Connor mentioned how the ABTF debated the definition of Boulder Patch for hours in the 1980s and that maybe the time has come to take another look at them. She added that she thought some sort of on-going monitoring should be done for this project, like that which was done for Tern Island, in order to gain a long-term perspective on the disintegration of an island. Ms. O'Connor asked about the life of the project. Ms. Wuestenfeld responded that the island is designed for a working life of 20 years; and Mr. Gadd added that it was designed, however, to survive extreme 100-year events. Mr. Gadd also mentioned that the abandonment process is undefined at this stage. It will be dependent upon the regulations and requirements in effect at that time. He explained that the abandonment of Tern Island would be a good analog to any potential future abandonment of Liberty. Mr. Leidersdorf commented that past protocol has been to remove all anthropogenic materials, including slope-protection materials. What is left would be a gravel mound which, over a period of years, would erode below the sea surface. For example, Tern Island eroded below sea level last year for the first time following abandonment in 1990. The island footprint would tend to enlarge at a rather slow rate spreading in a southwesterly direction. The island would be planed off on top, and that material would be distributed down the slope. The larger cobbles would tend to end up as a lag deposit above depths of about 10 ft. Over a long time, the fines would be washed out and coarser material would armor the mound. We have seen these changes in islands such as Mukluk, which was abandoned 10 years ago. It now persists as a relatively stable mound about 6 to 7 ft below the sea surface.

Dr. Emerson said he found it interesting that the concrete mats in the slope-protection system are basically a geometric boulder which can be colonization by the opportunistic kelp plants. The blocks actually create new habitat. He thought that perhaps the concrete blocks should be left in place as new habitat. Mr. Gadd felt that at the time of abandonment, if kelp was growing on the blocks, that abandonment requirements would reflect that. Perhaps an evaluation would be made at that point of time as to the appropriate abandonment process.

Concluding Note: ***Additional substrate on concrete blocks***

Dr. Stekoll brought up the point of using percent cover as a criteria for when a kelp bed exists. He feels that it does not make any sense to use percent cover of kelp. What really needs to be calculated is the number of plants per m^2, the biomass per m^2, and the productivity per m^2. Those three should be used to define what a kelp bed is, not 10% cover. He also asked if several of these drilling islands could possibly affect the currents near the Boulder Patch. Mr. Leidersdorf said that they are very small compared to the whole area. He did not think they would affect the currents.

Concluding Note: ***Suggestion to calculate biomass or number of plants per square meter rather than percent cover***

Dr. Taylor asked Dr. Dunton if we could predict the temporal and areal effects of a sediment plume if the depths of the sediments on the plants were known. He wondered if it would it be possible to predict the effect on the vigor or mortality of the plants. Dr. Dunton responded that those sounded like two different issues and that he could not address the sediment-transport aspect. However, as far as the effects on water-column transparency were concerned, all of the data are available. The quantitative effect due to increase water-column light attenuation could be determined. He thought that both a sediment-transport model and water-column light attenuation model should be generated.

Concluding Note: ***Concern about magnitude of sediment effects***

Ms. Ban felt that maybe the sedimentation analyses should be taken a step further, estimating the effect of the added sediment as it possibly gets resuspended the next summer.

Dr. Gallaway commented on the importance of erosional environments for this species. He said that Dr. Alan Neidoroda and Dr. Jack Colonell had done some sediment flux modeling for this general area. He had some reprints describing the areas which were erosional and describing the importance of these processes to kelp over the long term.

Concluding Note: ***Data on erosional areas***

Dr. McRoy mentioned the uniqueness of the Boulder Patch and its genetic isolation. He felt that further studies of the recruitment and population dynamics should be considered.

Concluding Note: ***Degree of genetic isolation***

Mr. Leidersdorf commented on the large amount of data that is accumulating from both periodic studies and anecdotal observations. The incorporation of all that data into a database would assist the ABTF in short-term decisions. Perhaps the ABTF, MMS, and/or industry could sponsor the database.

Concluding Note: ***Suggestion to organize a kelp database***

ATTACHMENT 1
Barnes, P.W. 1981. Camden Bay "Boulder Patch."

This kelp report is attached because it is not readily available.
The complete reference is in Appendix C with other Selected References.

ANNUAL REPORT

Research Unit: 205
Reporting Period: April, 1980-
March, 1981

GEOLOGIC PROCESSES AND HAZARDS OF THE BEAUFORT AND CHUKCHI SEA SHELF AND COASTAL REGIONS

Peter Barnes
Erk Reimnitz
Ralph Hunter
Larry Phillips

Pacific-Arctic Branch of Marine Geology
345 Middlefield Road
Menlo Park, California 94025

April 1, 1981

TABLE OF CONTENTS

I. Summary of objectives, conclusions and implications.....3
II. Introduction.....5
A. General nature and scope of study.....5
B. Specific objectives.....5
C. Relevance to problems of petroleum development.....5
III. Current state of knowledge.....5
IV. Study area.....5
V. Sources, methods and rationale of data collection.....5
Product submission status.....6
VI, VII, and VIII. - Results, Discussion, Conclusions.....7
(as attachments to report)

A. Sedimentation related to causeway construction, Prudhoe Bay, Alaska

B. Camden Bay "Boulder Patch"

C. Geologic comparison of two arctic shoals

D. Survey of ice-gouge characteristics, Beaufort Sea, Alaska

E. Some reflections on a mini-storm surge at Prudhoe Bay

F. Pack-ice interaction with Stamukhi Shoal, Beaufort Sea, Alaska

G. Finger Shoals survey: An unusual field of linear bedforms in Harrison Bay

H. A summary of U.S. Geological Survey Marine Gelogic Studies in the Beaufort Sea, Alaska, July through September 1980

I. Ice-gouge data 1972-1980, Beaufort Sea, Alaska

J.

K.

IX. Needs for further study.....7

X. Summary of fourth quarter operations.....8

XI. Published Reports.....10

XII. Reports submitted for publication.....11

ATTACHMENT B

Camden Bay "Boulder Patch"

By: Peter Barnes

During reinvestigation of a boulder ridge on the beach near Camden Bay (Barnes and Ross, 1980) studies were made of the sea floor offshore to ascertain the presence or absence of boulders. In Stefansson Sound near Prudhoe Bay, seabed boulders have been shown to support a unique benthic community (Reimnitz and Ross, 1979; Dunton, 1979; and Schonberg, 1979). The uniqueness of this community has led to stipulations on development activities in the boulder community area (Weller et al., 1980).

In this report we describe another location where a protected boulder seabed supports a diverse benthic community 110 km to the east of Prudhoe Bay. Similarities and differences between this boulder locale are compared with those of the Stefansson Sound Boulder Patch.

In 1979 a boulder ridge in Camden Bay was studied (Barnes and Ross, 1980). Sonographs and fathograms suggested that boulders might exist extensively in the offshroe area (Barnes and Ross, 1980). During the summer of 1980 the area was revisited to study changes in the boulder ridge and to observe the offshore area directly, using underwater television as well as sonographs and fathograms.

Observations - Comments

The navigation chart that covers the lagoon to the east of the Canning River, particularly in the vicinity of Konganevik Pt. (NOAA Chart 16044), shows foul areas in the shallows and along the coast indicating widespread distribution of boulders (Fig. 1). Barnes and Ross (1980) suggest that boulders will not be prevalent in depths of 1-2 m due to sorting processes involved in ice growth and ice movement in these shallow waters. However, in deeper waters we might expect to encounter boulders which are relict, having escaped the sorting process during the transgression, or moved here by ice-rafting.

Using underwater television, we visually examined 10 sites in the area for boulders and an attached benthic community (Fig. 2). Water clarity at all sites was about 1 m, thus the television images were readily usable but of insufficient clarity for reproduction in this report. Boulders were found at only two of the sites and a vigorous benthic community was found at only one of these (Fig. 2). Boulders were observed immediately seaward of the boulder ridge locality in water depths of 3 m. The boulders were sparse (less than 5%) and were strewn on a rippled sand bottom with clasts up to 25 cm in diameter. The bottom cobbles and boulders were esentially devoid of an attached benthic community.

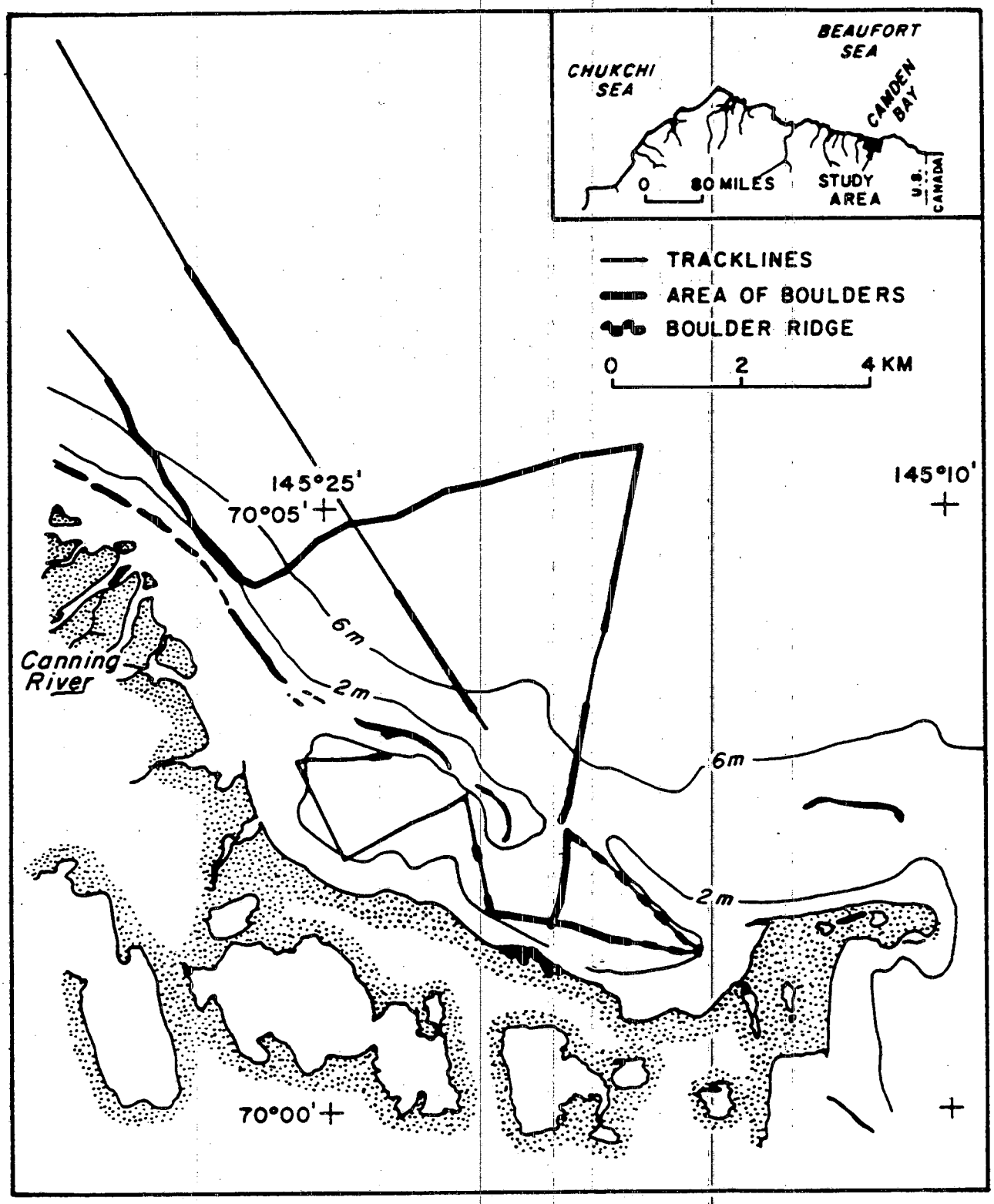


Figure 1. Location map of Camden Bay showing the areas where cobbles and boulders were identified on sonographs in 1979. (From Barnes and Ross, 1980).

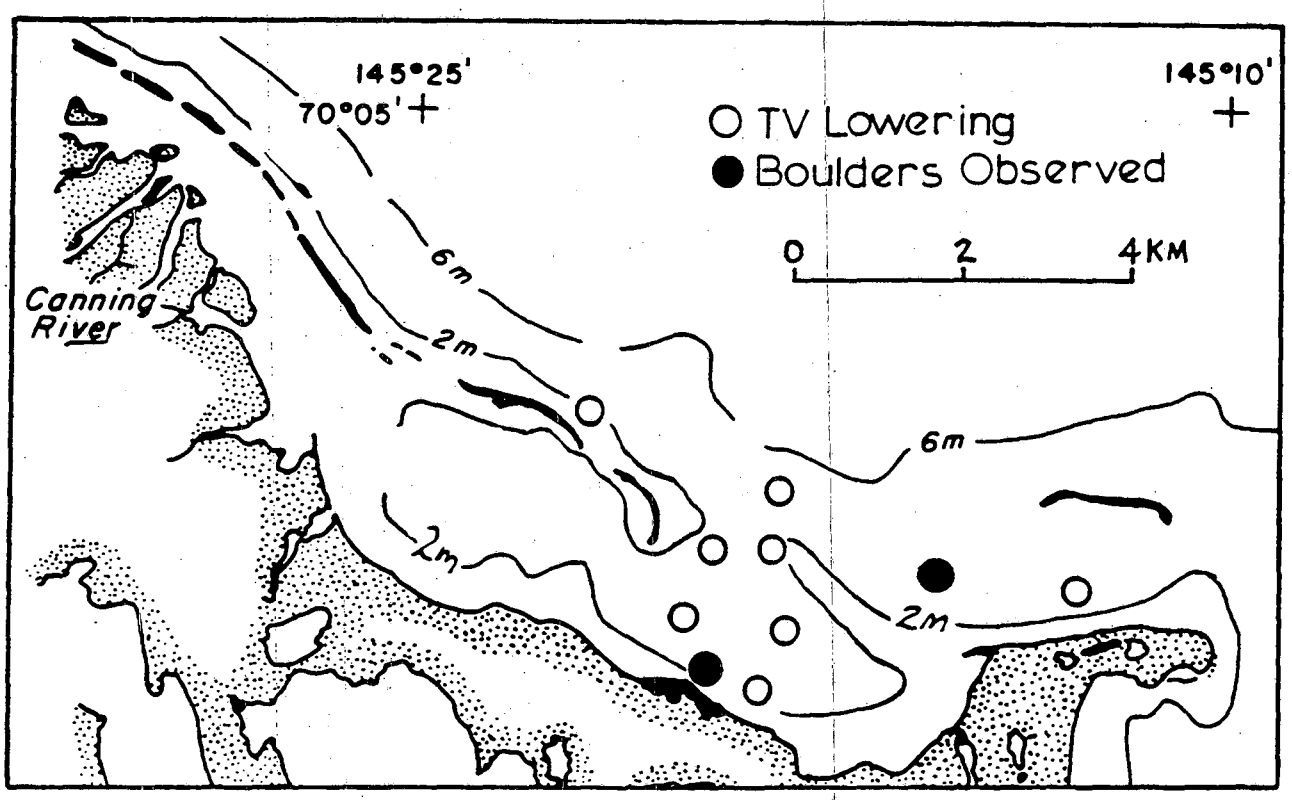


Figure 2. Television lowering in the area of boulders shown in Figure 1 during the summer of 1980. The solid circles are the two locations where boulders and cobbles were observed on the seabed.

The second boulder site is located outside of the lagoon in the lee of a small sand island northwest of Konganevik Pt. in water 4 to 5 m deep (Fig. 2). Boulders and cobbles are estimated to cover about 10-20% of the sea floor and are characterized by abundant biota in the form of Laminaria and other hard-substrate critters. Clast sizes range upwards to 50 cm and boulders and cobbles often occur in patches rather than as solitary features.

Discussion

The presence of seabed cobbles and boulders is expected, given the abundant cobbles and boulders on the beach in the immediate vicinity (NOAA Chart 16044 and Barnes and Ross, 1980) and the boulders in the eroding Pleistocene Gubic Formation in coastal bluffs (Leffingwell, 1919). The lack of a benthic community at one site and its profuse presence at another is due to differences in physical setting between the two sites. The inshore, sparsely populated site (Fig. 2) is in shallow water and directly opposite the opening in the chain of barrier spits and islands. With dominant northeast winds, wave and more importantly ice motion, would be directed at this area, creating an environment with ice-seabed interaction as well as vigorous wave activity. Another detriment to growth of a benthic community in this area would be the extremes of salinity and temperature that would be encountered during brine drainage from growing ice in winter and from stream and snow melt in spring. We believe that many of these conditions are also applicable to other areas where boulders are abundant but do not support a dense benthic community.

In contrast to the barren inshore locale, the boulder site has a well-developed benthic community located in deeper water. At this site circulation with oceanic waters all year round is less restricted (Fig. 2), thus the thermo-haline regime will be less variable. Furthermore, to the northeast in the dominant direction from which waves and ice motion originate, a shoal and barrier island protect this site from gouging and intense wave activity. On a small scale the character and physical setting here are similar to the Stefansson Sound boulder area (Reimnitz and Ross, 1979).

The lack of boulders at the other sites studied (Fig. 2) suggests that, as in Stefansson Sound, their occurrence is patchy (Reimnitz and Ross, 1979). Our earlier observation that boulders on the seabed based on sonographs suggests either the distribution is quite sparse and "patches" were not encountered in the television observations in 1980, or the sonograph features interpreted as boulders are some other seabed feature.

Conclusions

The discovery and definition of this boulder-strewn seabed with its intense kelp-dominated community, substantiates that the Boulder Patch in Stefansson Sound is not uniuqe. Furthermore, we believe that locations where boulders with similar benthic communities would have physical settings similar to the two observed thus far, would be a boulder terrain with water 4 to 6 m deep in the lee of shoals or islands protected from ice gouging.

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APPENDIX A
WORKSHOP AGENDA

ARCTIC KELP WORKSHOP
MAY 12, 1998

AGENDA

8:00 am Summary of workshop goals by John Goll, Regional Director, and Workshop Chair (review recent observations of Beaufort Sea kelp communities and corresponding estimates of kelp density; provide expert perspectives on ecological significance; and discuss future study goals and workshop report).

RECENT OBSERVATIONS

8:15 am Sonar and Visual Images of Stefansson Sound Kelp

Craig Leidersdorf, Peter Gadd, and Terry Sullivan, Coastal Frontiers , California
And
Dr. Benny Gallaway and Dr. Larry Martin, LGL ecological research associates, Texas

10:00 am Break

10:15 am Observed and Predicted Sedimentation on the Sound Kelp

Sue Ban, Woodward-Clyde Consultants, Anchorage

10:45 am Sonar and Visual Images of Camden Bay Kelp

Bill Penrose, Fairweather E&P, Anchorage

11:30 am Lunch

ECOLOGICAL PERSPECTIVES

1:00 pm Dr. Ken Dunton, Professor, University of Texas at Austin

1:30 pm Dr. Peter McRoy, Professor, University of Alaska, Fairbanks

2:00 pm Dr. Mike Stekoll, Professor, University of Alaska, Southeast

2:30 pm Break

CONCLUDING DISCUSSION, moderated by Workshop Chair

3:00 pm Regular reviews of kelp information by the Arctic Biological Task Force, Specific goals for future environmental studies, plans for a workshop report, etc.

5:00 pm End of Workshop

APPENDIX B
LIST OF PARTICIPANTS

MMS ARCTIC KELP WORKSHOP
MAY 12, 1998

Attendees/Participants:

Glenn Aronwits
Watson Company
2440 E. Tudor Road, #1141
Anchorage, AK 99507
(907) 248-5352, FAX (907) 243-1834
Email: watson@alaska.net

Sue Ban
Woodward-Clyde Consultants
3501 Denali, Suite 101
Anchorage, AK 99503
(907) 561-1020, FAX (907) 563-3198
Email: smbanxx0@wcc.com

Robert Dolan
AK Dept. Of Environmental Conservation
555 Cordova Street
Anchorage, AK 99501
(907) 269-7565

Amanda Dreyer
Wartburg College
18836 Andreanof Drive
Eagle River, AK 99577

Melanie Duchin
Greenpeace
125 Christensen Drive, #2
Anchorage, AK 99507
(907) 277-8234, FAX (907) 272-6579

Dr. Kenneth Dunton
University of Texas at Austin
Marine Science Institute
750 Channel View Drive
Port Aransas, TX 78373
(512) 749-6744, FAX (512) 749-6777
Email: dunton@utmsi.utmsi.utexas.edu

Dr. Ray Emerson
Alaska OCS Region
Minerals Management Service
949 E. 36th Avenue
Anchorage, AK 99508

Valerie Elliott
Alaska OCS Region
Minerals Management Service
949 E. 36th Avenue
Anchorage, AK 99508

Peter Gadd
Coastal Frontiers Corp.
9420 Topanga Canyon Blvd., Suite 101
Chatsworth, CA 91311-5759
(818) 341-8133, FAX (818) 341-4498
Email: coastalf@aol.com

Dr. Benny J. Gallaway
LGL environmental research associates
1410 Cavitt Street
Bryan, TX 77801
(409) 775-2000, FAX (409) 775-2002

Glenn Gray
DGC-State
Box 110030
Juneau, AK 99811
(907) 465-8792
Glenn-Gray@gov.state.ak

Ken Holland
Alaska OCS Region
Minerals Management Service
949 E. 36th Avenue
Anchorage, AK 99508

Jeanne Hanson
NMFS
222 W. 7th Ave., #43
Anchorage, AK 99513
(907) 271- 3029, FAX (907) 271-3030

C. W. Hardie, Jr., M.D.
3515 Fordham Drive
Anchorage, AK 99508
(907) 276-2410

Brian Havelock
AK Dept. of Natural Resources
Division of Oil and Gas
3601 C Street, #1380
Anchorage, AK 99503-5948
(907) 269-88-7
Email: beh@dnr.state.ak.us

Casey Hessinger
University of Alaska Anchorage
Dept. of Biology
3211 Providence Drive
Anchorage, AK 99508
(907) 376-8259

Dr. Ray Jakubczak
BP Exploration (Alaska), Inc.
P.O. Box 196613
Anchorage, AK 99519-6613
(907) 564-4664, FAX (907) 564-4187

Fred King
Alaska OCS Region
Minerals Management Service
949 E. 36th Avenue
Anchorage, AK 99508

Craig Leidersdorf
Coastal Frontiers Corp.
9420 Topanga Canyon Blvd., Suite 101
Chatsworth, CA 91311-5759
(818) 341-8133, FAX (818) 341-4498
Email: coastalf@aol.com

Paul Lowry
Alaska OCS Region
Minerals Management Service
949 E. 36th Avenue
Anchorage, AK 99508

Dr. Larry Martin
LGL environmental research associates
1410 Cavitt Street
Bryan, TX 77801
(409) 740-3653, (409) 775-2000, FAX (409) 775-2002

Dr. Peter McRoy
University of Alaska Fairbanks
Institute of Marine Science
Fairbanks, AK 99775
(907) 474-7783
Email: ffcpm@aurora.uaf.edu or mcroy@ims.alaska.edu

Pamela Miller
Arctic Connections
P.O. Box 101811
Anchorage, AK 99510
(907) 272-1909, FAX (907) 272-9056
Email: alaskapam@msn.com

Dr. Thomas Dunning Newbury
Alaska OCS Region
Minerals Management Service
949 E. 36th Avenue
Anchorage, AK 99508
(907) 271-6560, FAX (907) 271-6507
Email: Thomas_Newbury@mms.gov

Kristina O'Connor
AK Dept. of Natural Resources
Division of Oil and Gas
3601 C Street, #1380
Anchorage, AK 99503
(907) 269-1908, FAX (907) 563-0415
Email: kmo@dnr.state.ak.us

Gene Pavia
Division of Governmental Coordination
411 W. 4th Avenue, Suite 2C
Anchorage, AK 99501
(907) 271-4317, FAX (907) 272-0690
Email: gpavia@jpo.doi.gov

Bill Penrose
Fairweather E&P Services
P.O. Box 10396
Anchorage, AK 99510
(907) 258-3446, FAX (907) 258-5557
Email: bill@fwx.fairweather.com

Dan Ritzman
Greenpeace
125 Christensen Drive, #2
Anchorage, AK 99501
(907) 277-8234

Gerald Shields
University of Alaska Fairbanks
Institute for Arctic Biology
Fairbanks, AK 99775

Brad Smith
NMFS
222 W. 7th Avenue, Box 43
Anchorage, AK 99513
(907) 271-5006

Dr. Mike Stekoll
University of Alaska Southeast
11120 Glacier Highway
Juneau, AK 99801
(907) 465-6441, FAX (907) 465-6447
Email: ffmss@aurora.alaska.edu

Terry Sullivan
Seavisual Consulting, Inc.
P.O. Box 2095
Gresham, OR 97030
(503) 663-2894

Dr. Eric Taylor
U.S. Fish and Wildlife Service
Northern Alaska Ecological Services
101 12th Avenue, Box 19, Room 110
Fairbanks, AK 99701-6267
(907) 456-0323, FAX (907) 456-0208
Email: eric_taylor@fws.gov

Dave Trudgen
BP Exploration (Alaska), Inc.
P.O. Box 196613
Anchorage, AK 99519-6613
(907) 564-5473

Mary Weger
U.S. Army Corps of Engineers
P.O. Box 898
Anchorage, AK 99506

Frank Wendling
MMS
949 E. 36th Avenue
Anchorage, AK 99508

Mike Williams
NMFS
222 W. 7th Avenue, Box 43
Anchorage, AK 99513
(907) 271-5006
Email: mikewill@ptialaksa.net

Karen Wuestenfeld
BP Exploration (Alaska), Inc.
P.O. Box 196613
Anchorage, AK 99519-6613
(907) 564-5490, FAX (907) 564-4187
Email: wuesteks@bp.com

APPENDIX C
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The Department of the Interior Mission

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 sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; 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 ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

The Minerals Management Service Mission

As a bureau of the Department of the Interior, the Minerals Management Service's (MMS) primary responsibilities are to manage the mineral resources located on the Nation's Outer Continental Shelf (OCS), collect revenue from the Federal OCS and onshore Federal and Indian lands, and distribute those revenues.

Moreover, in working to meet its responsibilities, the **Offshore Minerals Management Program** administers the OCS competitive leasing program and oversees the safe and environmentally sound exploration and production of our Nation's offshore natural gas, oil, and other mineral resources. The MMS **Royalty Management Program** meets its responsibilities by ensuring the efficient, timely, and accurate collection and disbursement of revenue from mineral leasing and production due to Indian tribes and allottees, States, and the U.S. Treasury.

The MMS strives to fulfill its responsibilities through the general guiding principles of: (1) being responsive to the public's concerns and interests by maintaining a dialogue with all potentially affected parties and (2) carrying out its programs with an emphasis on working to enhance the quality of life for all Americans by lending MMS assistance and expertise to economic development and environmental protection.