LGL

Ecological Research Associates

BOWHEAD WHALE MONITORING PROGRAM
CORONA PROSPECT

RESEARCH PROPOSAL

by
LGL Ecological Research Associates, Inc.
1410 Cavitt Street
Bryan, Texas 77801
U.S.A.

to
Shell Western E & P Inc.
200 N. Dairy Ashford
P.O. Box 576
Houston, Texas
U.S.A.

8 May 1986

BOWHEAD WHALE MONITORING PROGRAM
CORONA PROSPECT

TECHNICAL PROPOSAL

by

LGL Ecological Research Associates, Inc.
1410 Cavitt Street
Bryan, Texas 77801
U.S.A.

to

Shell Western E & P Inc.
200 N. Dairy Ashford
P.O. Box 576
Houston, Texas
U.S.A.

8 May 1986

TABLE OF CONTENTS

Page

INTRODUCTION

This proposal is submitted in response to a Request for Proposal (RFP) from Shell Western E & P Inc. (SWEPI) to conduct a bowhead whale monitoring program in conjunction with offshore drilling at the Corona prospect in the summer and fall of 1986. There has been serious regulatory and public concern that offshore hydrocarbon exploration in the Alaskan Beaufort Sea may interfere with the westward fall migration of bowheads through these near-shore waters. Small changes in migration routes could have important implications for the success of the hunt by Eskimo whalers, even though such deviations may be biologically inconsequential to the whales.

There has been a reluctance to allow offshore drilling until the potential disturbance effects of such operations are better understood. However, it is not possible to gather unequivocal data on bowhead responses to drilling if such operations are not permitted to occur. In 1985, LGL designed a bowhead research protocol for evaluating the responses of bowheads to offshore drilling. This design was developed for SWEPI, with input from government agencies and the North Slope Borough. Based on the implementation of this research design, SWEPI was granted federal regulatory approval to drill from Sandpiper Island and at Corona during the bowhead fall migration in 1985. The decision for Corona was rendered academic by the heavy ice conditions at the time of approval in mid October. The approval at Sandpiper Island was nullified by native concerns that the drilling would affect the bowhead hunt. Thus, drilling approval was delayed until the local bowhead quotas were filled. However, no bowheads were taken in this area in the fall of 1985 and drilling was not permitted until deteriorating ice conditions terminated the whaling efforts.

The SWEPI RFP for 1986 contains the basic elements of the study design approved by the agencies last year. The RFP proposes some modifications to last year's approved design and we propose some further improvements based on our experience in implementing the design in 1985. As outlined in the RFP, our proposal has two major elements. Task 1 is an acoustic study to document noise levels and characteristics generated by an offshore drilling operation and by its component parts. In addition, a hydrophone array would be used to monitor whale calls on a near real-time basis. Task 2 is an intensive study of the behavior of bowheads in response to various levels of underwater noise generated by the drilling operation. The acoustical study is ship-based, whereas the behavior study uses aerial techniques.

It is essential that the acoustic and behavior elements of the study be closely integrated so that changes in whale behavior can be attributed to the appropriate industrial activity. We propose to achieve this integration by using a highly experienced study team whose members have worked together on similar projects for several years. LGL is the prime contractor on this proposal. LGL will conduct the biological studies and will have overall responsibility for the entire project and the final report. Greeneridge Sciences Inc. will conduct the acoustic phases (Task 1) of the study. LGL and Greeneridge have conducted joint studies of whale behavior and underwater acoustics in arctic, ice-covered waters since 1980.

Our technical proposal addresses, in detail, all components of the RFP. The acoustic studies are presented first (Task 1) followed by a description of the behavior studies (Task 2). Before presenting the detailed technical proposal, we provide a brief overview of the available information on the timing of bowhead use of nearshore waters of the Alaskan Beaufort Sea near the Corona prospect. This background information illustrates that relatively few bowheads are expected to be found in the Corona area. Thus, a major element of the study is a design that maximizes the likelihood of finding whales so that behavioral studies can be instituted.

It is important to note a critical assumption that is made in this proposal. In accordance with the RFP we assume that no other offshore drilling operations will occur near Corona in 1986. The 'Eric' prospect, which is being examined by Amoco is only 17 n.mi. east of Corona. If drilling occurs at Eric during the Corona study, then major changes to the design of the Corona study would be necessary, although the basic study techniques of the present proposal would still be used. The problem occurs because Eric is upstream of Corona and migrating whales would have to pass close to Eric in order to reach Corona. Thus, drilling at Eric would occur in the center of the planned control area for undisturbed behavior for whales approaching Corona. The LGL/Greeneridge team has extensive experience in re-designing studies in response to changes in plans for industrial activities. As evidenced by our 1985 activities on behalf of SWEPI, these changes can be done on very short notice, if necessary.

BACKGROUND

Bowhead Distribution and Migration

As a basis for designing the proposed study, it is important to review the available information on the timing and distribution of bowhead migration through the Alaskan Beaufort Sea in relation to the location and timing of activities planned for the Corona site in 1986. This review is necessary to define the optimum spatial and temporal boundaries on the bowhead monitoring program related to Corona. The most extensive series of synoptic data on bowhead distribution and migration patterns in the Alaskan Beaufort Sea are the aerial surveys conducted by Naval Ocean Systems Center (NOSC) for Minerals Management Service (MMS). These surveys have been conducted for seven years from 1979 to 1985 and will continue in 1986. The principal results of these surveys are summarized below as they relate to the Corona site.

Summer Distribution

There is good evidence that most, if not all, of the western arctic population of bowheads spends the summer (July, August) in Canadian waters (Davis et al. 1982) in most years. However, in some years bowheads have occurred in the Alaskan Beaufort Sea in August. The numbers present in August are apparently highly variable from year to year. Interpretation of the normal patterns is complicated by the somewhat uneven aerial survey coverage that is available since 1979.

Large numbers of bowheads have been recorded in August in only one (1982) of the last seven years. In 1982, bowheads were present in the eastern Alaskan Beaufort Sea north of 70°25'N and east of 144°W from 2 to 24 August. Thus, the southwestern limit of the area occupied was about 20 n.mi. east of the Corona drillsite. After 24 August, the bowheads apparently left eastern Alaskan waters with the only sightings in the last week of August being well to the north at 71°05'N and 71°55'N. Ljungblad et al. (1983) suggest the reasonable hypothesis that bowheads found in the eastern Alaskan Beaufort Sea in August represent summering animals that have not penetrated far into Canadian waters rather than representing early migrants out of Canadian waters. In fact, the Alaskan animals in August 1982 may have been part of a larger group that extended east into Canadian waters near Herschel Island (Davis et al. 1983).

In 1979, 17 surveys were conducted throughout August; the surveys extended east to 143°W (Ljungblad et al. 1980). Bowheads were recorded during only two flights--on 20 and 21 August. The whales were present from 70°31'N to 70°40'N and between 143°W and 144°30'W. Thus, a few whales were present for a short period of time about 20 n.mi. ENE of the Corona site.

In 1980, surveys were conducted on only five days from 2 to 30 August (Ljungblad 1981). The surveys extended east to 140°W and included areas south of 70°30'N. No whales were recorded. The coverage was too limited to conclude that bowheads were not present at any time near the Corona site in August 1980.

In 1981, seven aerial surveys were conducted from 15-30 August (Ljungblad et al. 1982a). No bowheads were recorded even though coverage extended east as far as 140°W. It is apparent that bowheads were not present near the Corona site in the last half of August 1981.

In 1983, aerial survey coverage of the Alaskan Beaufort Sea was good with 22 flights from 2 to 31 August (Ljungblad et al. 1984a). Bowheads were present in Canadian waters close to the border at 141°W throughout August. Some of these animals drifted into Alaskan waters on 10 August and remained just west of 141°W until the end of the month. Most animals remained east of 141°15'W and north of 70°45'N.

Good coverage of the Alaskan Beaufort Sea was obtained in August 1984 (Ljungblad et al. 1985). Eighteen flights provided even temporal coverage from 1 to 29 August. No whales were recorded in Alaskan waters except for a few sightings close to the Alaska/Yukon border (141°W) on 16 and 29 August. Bowheads were not near the Corona site in August 1984.

The results of the 1985 MMS studies have not yet been released. However, we were in frequent communication with the NOSC crew during August 1985 in connection with our concurrent bowhead studies in Canadian waters. Thus, information on general distribution patterns is available. A few sightings were made near the Alaska/Yukon boundary but no bowheads were seen farther west in August. None were close to the Corona site.

The aerial survey results for the past seven years suggest that bowhead whales do not occur at the Corona site in August, although animals occurred nearby in 1979 and 1982.

Patterns of Fall Migration

The fall migration of bowheads proceeds on a fairly broad front through the nearshore waters of the Alaskan Beaufort Sea in September and October. Plots of sightings made during the MMS surveys in the fall of 1981, 1982, 1983 and 1984 are presented in Figures 1-4. It is quite evident that migrating bowheads can be expected near the Corona site. Ljungblad et al. (1984a) suggest that the rate of migration may be related to ice conditions. In light ice years, such as 1982, migration tends to be slower with more animals in relatively shallow (<50 m) waters (Fig. 2). In heavier ice years, such as 1983, bowheads tend to move through more quickly and to occur in deeper waters (Fig. 3). Maps from the 1985 MMS surveys are not yet available, but the results of the much more intensive industry-funded surveys are presented in Figure 5. Even with the intensive coverage in 1985, very few whales were seen near the Corona site. Comparison of the 1985 results with those from 1981, illustrates that large annual variations are expected in the numbers of bowheads near the Corona site.

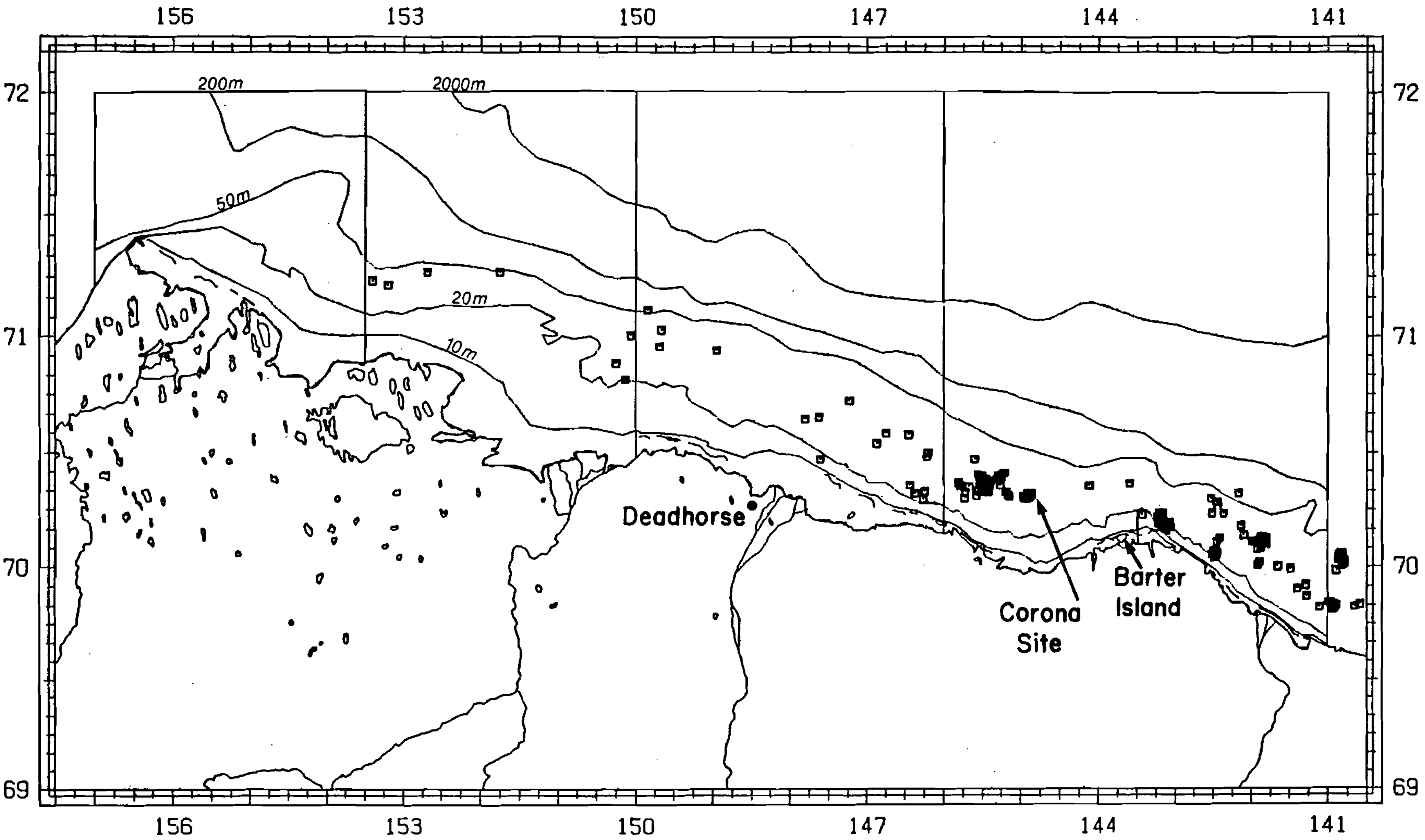

Figure 1. Plot of bowhead whale sightings made during the September-October 1981 aerial surveys of the Beaufort Sea. (Note: Little survey effort in waters over 50 m deep in 1981.) (Data from Ljungblad et al. 1982.)

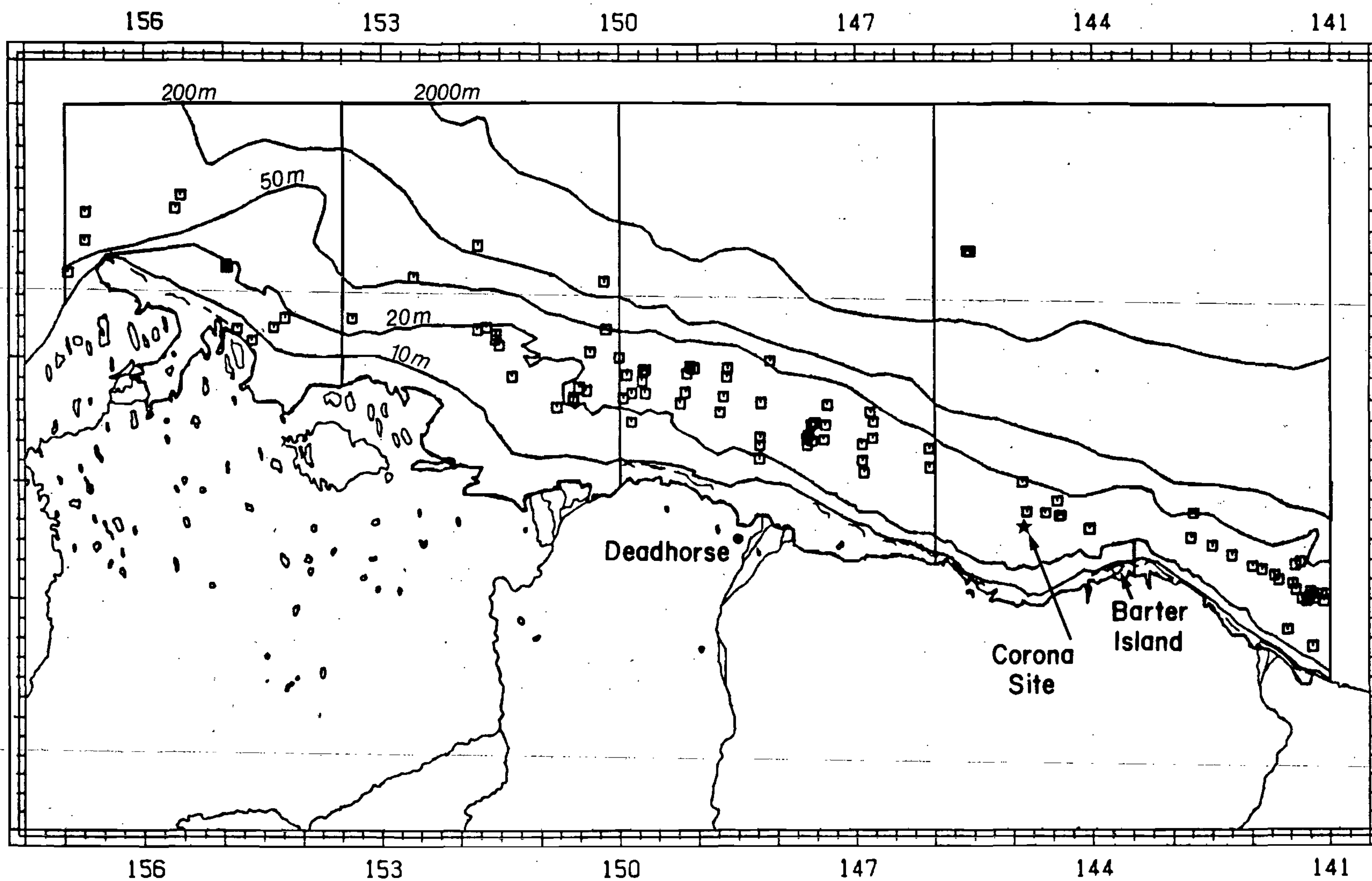

Figure 2. Plot of bowhead whale sightings made during the September-October 1982 aerial survey of the Beaufort Sea. (Data from Ljungblad et al. 1983.)

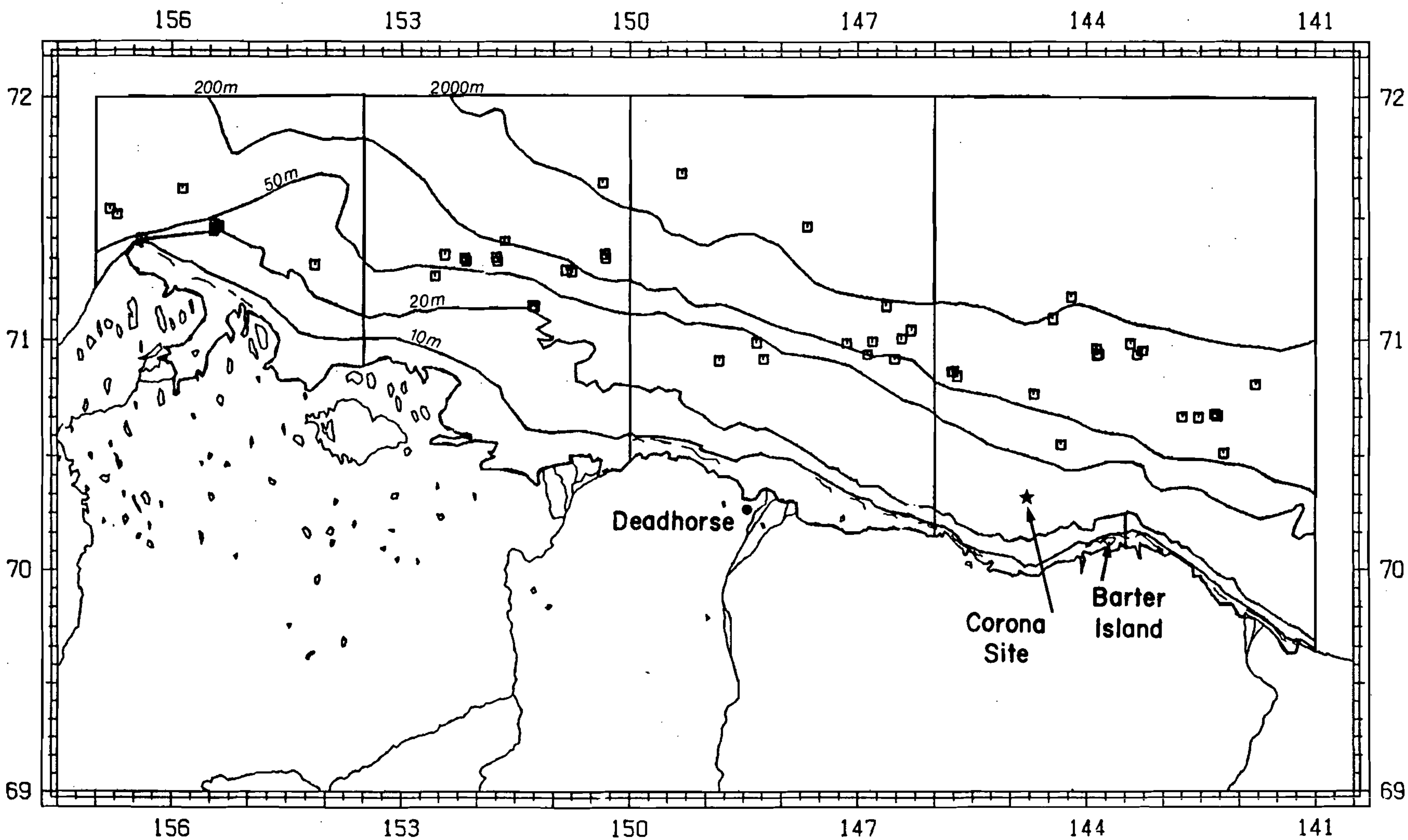

Figure 3. Plot of bowhead whale sightings made during the September 1983 aerial survey of the Beaufort Sea. (Data from Ljungblad et al. 1984.)

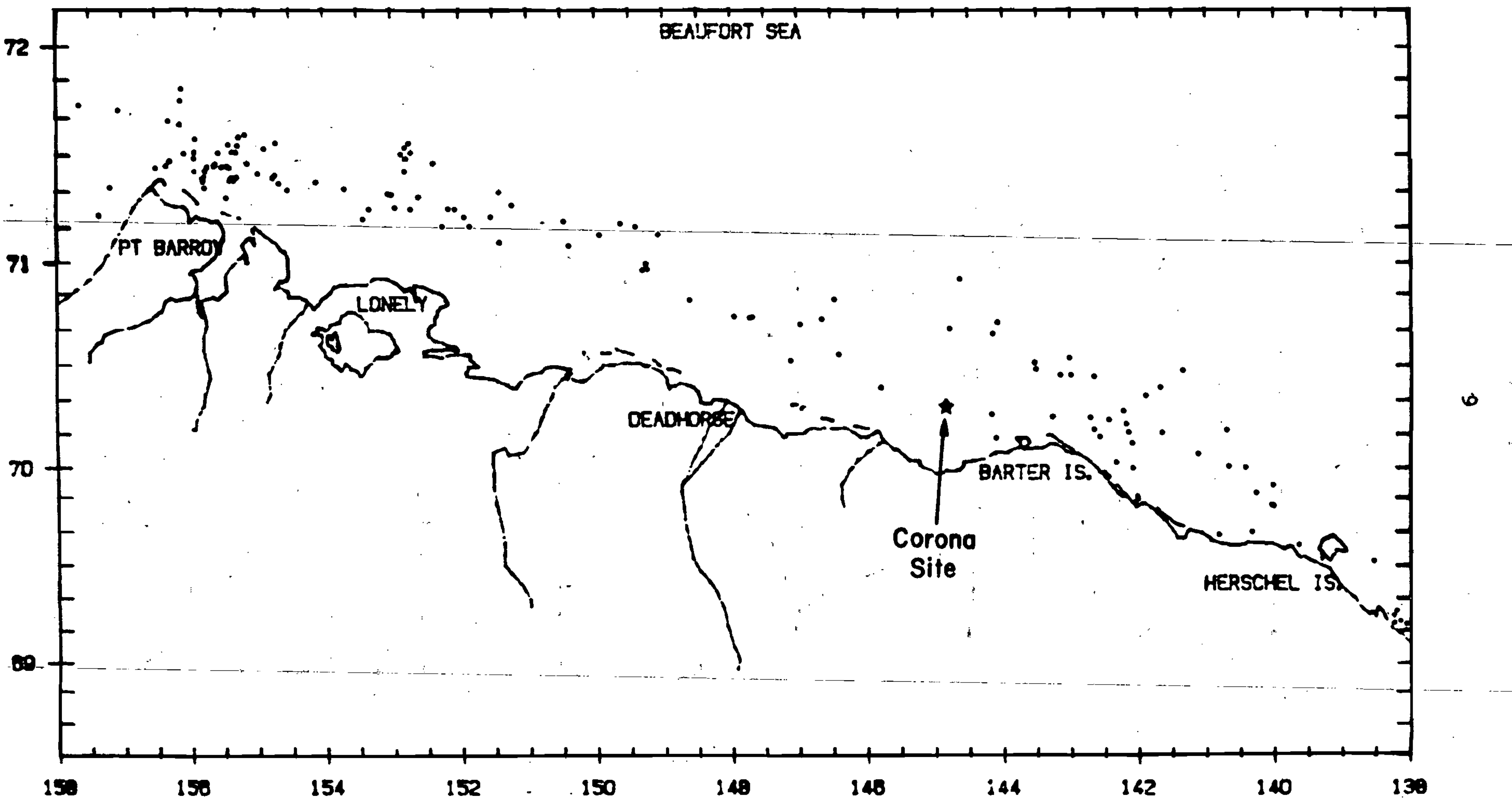

Figure 4. Plot of bowhead whale sightings made during September-October 1984 aerial surveys of the Beaufort Sea. (Data from Ljungblad et al. 1985.)

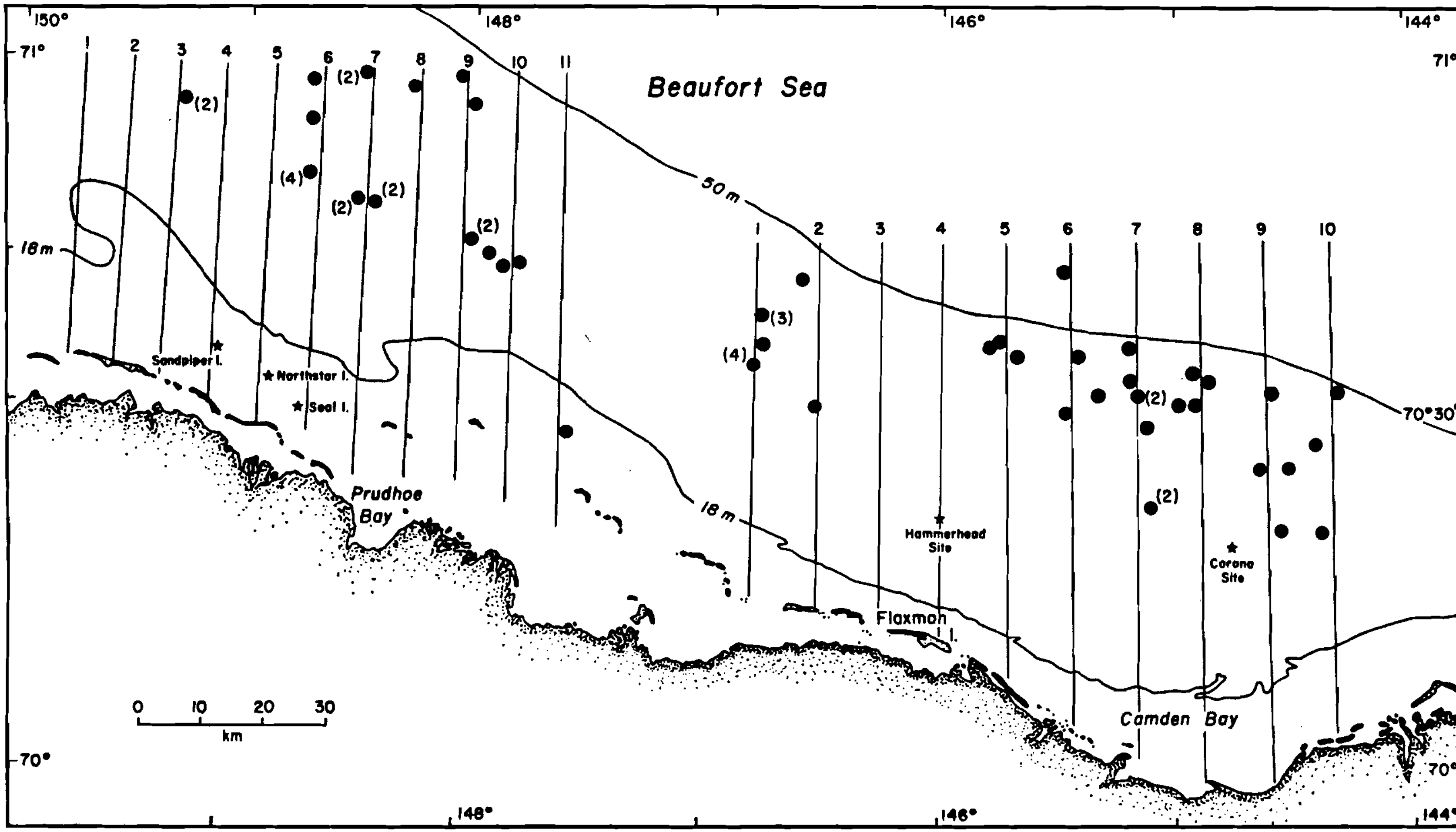

Figure 5. Locations of bowhead whale sightings recorded during aerial surveys conducted in the Alaskan Beaufort Sea between 144°W and 150°W by LGL Ltd. from 5 September to 20 October 1985.

In general, apart from the bowheads that are occasionally present in August, the early stage of the fall movement consists of a general westward drift of animals to the nearshore waters between the Canadian border (141°W) and Barter Island. This zone appears to be used by feeding bowheads on a regular basis in September (e.g., see Figure 1). Intensive surveys of this region on 22 September 1982 found several hundred bowheads in the area between 141°W and 143°W and extending from the barrier islands offshore to about 70°05'N (Johnson 1983). The general area between Barter Island and the border is the major feeding area used consistently in September in the Alaskan Beaufort Sea.

In the feeding area east of Barter Island, Johnson (1983) found bowheads equally distributed through water depths ranging from less than 30 ft (9 m) to over 90 ft (27 m). However, west of Barter Island there is a trend for bowheads to avoid waters less than 60 ft (18 m) deep (see Figures 1 to 5). However, this is not an ironclad rule since some individuals do occur on occasion in waters between 30 and 60 ft (9-18 m) deep (e.g., see Figure 2; Hickie and Davis 1983). In fact, there are very occasional records of bowheads in waters less than 30 ft deep (Ljungblad et al. 1983; Braham et al. 1984). On the whole, however, the great majority of the whales use waters over 60 ft deep west of Barter Island. There is also evidence that some concentration of whales occurs along the 60 foot depth contour.

To evaluate when bowheads first reach the vicinity of the Corona site during fall migration, the individual maps of results for each of the 222 MMS surveys conducted in September and October from 1979 to 1984 were examined. The start of the migration period was taken to be the date that bowheads reached or had passed the longitude of 144-146°W. The results of the industry-funded studies were used to determine first arrivals in the Corona area in 1985. Over the seven years of study, the first arrivals of bowheads near the Corona prospect were:

1979 - September 7
1980 - September 9
1981 - September 25
1982 - September 2
1983 - September 3
1984 - September 7
1985 - September 11

Based on these data we later recommend that the behavior study begin on 1 September rather than on the 15 August date suggested in the RFP. The acoustic study would begin on 15 August to allow time for deployment of the acoustic array before bowheads arrive in the area.

TASK 1. ACOUSTIC STUDIES

Several types of acoustic measurements are needed during this project:

1. Industrial sounds received at various distances and bearings from the drillsite, and at various depths in the water column, should be quantified. These results should be compared with natural ambient noise levels.

2. Temporal variation in the industrial sounds emanating from Corona should be quantified over an extended period, and related to changes in industrial activities and environmental variables such as wind and ice.

3. The levels and characteristics of the sounds emanating from each of the major vessels operating at Corona should be documented in order to further assess their relative contributions to the overall composite noise field. The effects of variations in the activities of the main vessels should also be determined (e.g. drillship drilling, tripping, logging, or not; icebreaker idling vs. breaking ice; supply boat idling vs. traveling, working anchors).

4. Acoustic methods (as well as visual techniques) should be used to document the presence and movements of bowheads near the drillsite.

5. Sounds reaching whales whose behavior is observed should be documented.

6. Natural ambient noise levels should be documented for the Corona area. Ambient noise data are necessary in order to estimate the potential zones of audibility and whale responsiveness.

The rationale and methods for each of these six types of measurements are given in detail in the six subsections below. The relationships of the measurements proposed here to those likely to be acquired in the BBN/MMS site-specific noise study are also mentioned in each of the six subsections. The two studies are largely complementary rather than duplicative. Coordination between the two studies is desirable to maximize the overall results and to minimize or avoid the few potential areas of unnecessary duplication. Following the subsections on the six types of acoustic measurements, we describe the main logistical requirements for the proposed acoustical field program, the potential logistical problems, and how these can be overcome.

1. General Industrial Noise vs. Distance, Bearing and Depth

Background and Rationale

Subtask 1 is designed to document the levels and spectral characteristics of industrial sounds received at various distances and bearings from the Corona drillsite, and at various depths in the water column. Levels and characteristics of industrial noise have been measured at several distances from Explorer II and other drillships drilling in the Canadian and Alaskan Sea in previous summers (Greene 1982, 1985; LGL and Greeneridge in prep.). Measurements of noise from Explorer II were acquired in 1981 and 1985. Figure 6 shows received levels in the 20-1000 Hz band as a function of range from various drillsites in the Canadian Beaufort Sea. At all ranges up to 7.4 km, received levels from Explorer II were well above the average ambient level in the 20-1000 Hz band (98 dB re 1 μPa). Sound propagation tests were not possible at Corona during the 1985 BBN/MMS site-specific noise study. However, ongoing analyses for sites near Corona suggest that Explorer II sounds in some frequency bands may be above the median ambient level out to ranges as great as 50 km (BBN and LGL in prep.).

None of the aforementioned data were acquired at Corona, and most were obtained in late summer, before the bowhead migration season. Furthermore, spectral characteristics of sounds from Explorer II changed between 1981 and 1985 (LGL and Greeneridge, in prep.), and may change again in 1986. Sound propagation in shallow water is highly site-specific, depending on water depth, bottom conditions, and temperature and salinity profiles (Urick 1975). Thus, measurements of noise characteristics and noise propagation are needed at the same location and time as behavioral observations. Systematic data on noise characteristics near the Corona drillsite will be needed to interpret the observations of whale behavior to be acquired during this project.

Drillships do not operate independently; they are supported by stand-by

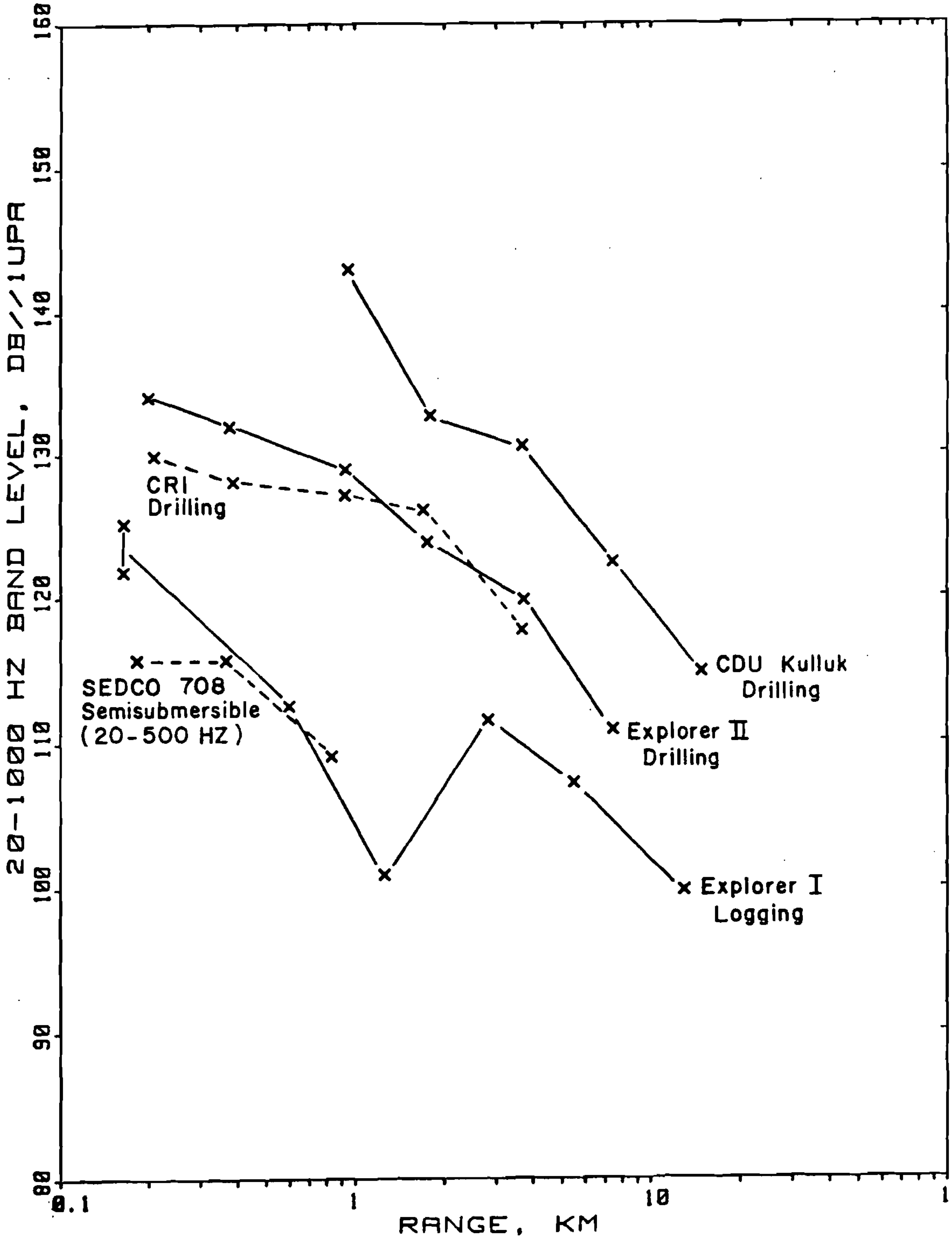

FIGURE 6. Drillship sound levels in the 20-1000 Hz frequency band vs. range for three drilling vessels. Levels near drilling operations on a caisson-retained island (CRI) in the Canadian Beaufort Sea and a semisubmersible near the Aleutians (Greene, in press) are also shown for comparison. The hydrophone depth was 9-18 m in each case.

vessels, supply boats, helicopters and, in the Beaufort Sea, icebreakers. The underwater sounds recorded at any point near a drillship are a composite of the sounds from each of these sources, plus natural ambient noise. Previous studies of underwater sounds near drillships have recognized this fact, and have attempted to isolate the sounds attributable to the drillship itself by making some recordings very close to the drillship. However, previous studies have not attempted to determine the relative contributions of the drillship vs. other vessels to the composite underwater sound received at various longer ranges. This has several important implications for the present study:

1. Underwater sounds at any one location near the drillsite will be quite variable, depending on the positions and activities of the various vessels as well as the variable activities of the drillship itself.

2. Close to the drillship, received levels of underwater sounds are not expected to diminish in any standard way, e.g. 20*log(range) or 10*log(range), with increasing distance from the drillship until the range becomes long compared to the separation of sound sources. Only a fraction of the noise will come from the drillship, and there will be no one point source.

3. In order to interpret noise measurements, it will be important to know the positions of all potential noise sources relative to one another and to the recording site. It will also be important to determine the characteristics of the sounds emanating from each major vessel operating at the drillsite in order to interpret the composite sounds. Furthermore, during each session when the composite sounds are measured, it will be important to know the nature of the activities aboard each vessel that might be contributing to the composite sounds.

4. Propagation losses with increasing distance are normally measured by making successive recordings of underwater noise at various distances. However, source levels and characteristics of the sounds emitted by one or more of the vessels at the drillsite are likely to change during such a series of measurements (Greene 1985). Hence, it is essential that provision be made to recognize and quantify any temporal changes in the sounds during periods while propagation loss measurements are being taken. If this is not done, unrecognized temporal changes in sounds might be mistakenly considered in propagation loss calculations.

In this section we outline the proposed procedures for quantifying the overall industrial noise levels and characteristics at various distances and bearings from Corona, and at various depths in the water column. In later sections, we describe how we will document the temporal variability in composite sounds, and determine the relative contributions of different vessels.

Relationship to BBN/MMS Site-Specific Noise Study

BBN Laboratories did not obtain usable data on sound propagation at Corona during the 1985 phase of their study for MMS. Hence, they have not developed a sound propagation model for Corona. BBN may conduct propagation experiments near Corona in 1986, using an underwater sound projector to determine the propagation loss rates for each of several standard frequencies. However, the BBN/MMS study must investigate several different sites within a 1-month field season. Hence, BBN is unlikely to be able to obtain replicated measurements at any one site. They will not be able to determine the full range of variability in the industrial sounds near Corona, or the factors responsible for this variability.

This component of our proposed study is designed to obtain detailed, replicated data on industrial noise as a function of distance and bearing from Corona, and depth in the water column. These data cannot be acquired in one or two brief measurement sessions, and thus are not likely to duplicate data acquired by BBN.

We do not presently propose to conduct propagation tests with an underwater noise projector, since this is likely to be done at Corona by BBN. However, we do plan to use such a projector for calibration of the acoustic array described later in this proposal. Hence, we could perform the propagation experiments if it is mutually agreed amongst Shell, MMS and BBN that we, rather than BBN, should do this work.

We propose to coordinate with BBN in order to avoid duplication and to use all relevant data collected by ourselves and BBN in order to develop the best possible model for sound propagation in the Corona area. This approach would be consistent with the practice agreed to amongst Shell, Union, MMS, BBN, Greeneridge and LGL in 1985. Some of the recordings of industrial noise obtained by Greeneridge and LGL in 1985 were used by BBN. This cooperative process will be facilitated by the fact that LGL is a subcontractor to BBN for parts of the BBN/MMS site-specific noise study.

Procedures for Measurements at Various Distances

We propose to record composite sounds at several standard distances from the drillsite (approx. 0.2 to 15 km) using high-quality calibrated hydrophones deployed from a boat drifting quietly. These data will provide systematic information about the received levels and spectral characteristics of the noise at various distances and bearings from the drillsite, and at various depths in the water column. The data will be acquired in ways directly comparable to those used in previous related studies in the Alaskan and Canadian Beaufort Sea. However, several procedural refinements are also proposed in order to improve the consistency and interpretability of the results. Also, if a suitable boat is not always available, or cannot travel far enough from the drillsite (see 'Logistical Problems', below), sonobuoys dropped from an aircraft can provide some of the necessary data.

Replication. The measurements at various distances will be repeated, logistical arrangements permitting, on at least three days and on at least three azimuths (north, east and south of the drillsite). If possible, data will also be acquired to the west of the drillship, although this is a lower priority considering the direction of travel of whales in autumn. This replication will provide information on temporal and spatial variability in the sounds and in propagation conditions.

Standard Measurement Distances. The specific distances from the drillsite at which sounds will be measured are not critical, as long as they can be measured accurately. Accuracy will be maximized by choosing a series of distances that match the range rings on marine radar displays (e.g. 0.1, 0.2, 0.5, 1, 2, 4 and 8 nautical miles, equaling 0.185 to 14.8 km). This series of ranges is consistent with those used in most of our previous related work. If the 'sound boat' is not equipped with radar (see 'Logistical Considerations'), the position of the sound boat will have to be determined through radio reports from a radar observer aboard the drillship or other vessel. An optical rangefinder will be used on the sound boat for ranges less than 1 km.

Hydrophone Depths. At each distance from the drillsite, a vertical string of three high-quality, calibrated, broadband hydrophones (ITC Model 6050C) will be used to obtain simultaneous measurements at three depths (9 m, 18 m, and 5 m above the bottom). By comparing simultaneous rather than serial measurements at three depths, there is no possibility that temporal changes in sounds might be misinterpreted as depth effects. The hydrophone string will be suspended below a spar buoy, which eliminates most of the vertical motion that wave action would otherwise cause. It also isolates the hydrophones from the pitching motions of the boat. The spar buoy approach is very important in order to reduce spurious noise. It is also important to use a fairing with the vertical string to eliminate cable flutter.

The standard string of three hydrophones will obtain data at depths 9 m and 18 m below the surface, and 5 m above the bottom. The 9 m and 18 m depths are proposed partly because these are the hydrophone depths used in most previous measurements of industrial noise in the Beaufort Sea. Received levels are known to depend somewhat on the depth of the hydrophone (e.g. Greene 1985; Davis et al. 1985), so it is important that the hydrophone depths used in this study be consistent with those in previous related projects. The 18 m depth is also appropriate because it is mid-way between the surface and bottom. Furthermore, use of a hydrophone at 18 m will provide data comparable to those from the sonobuoys mentioned later in this proposal; the 'shallow' depth setting on standard sonobuoys provides measurements from 18 m depth. The '5 m above bottom' hydrophone will be used in order to provide data from the same depth as will be used in the array of hydrophones proposed later.

We do not propose to measure received levels just below the surface (e.g., at 3 m depth), even though we have acquired data at 3 m in some previous projects in the Beaufort Sea (e.g. Greene 1985). It is difficult to obtain reliable data at such shallow depths, since wave action causes strong pressure transients. Theory and previous studies in the Beaufort Sea have provided information about the relationships between hydrophone depth, frequency, and received level. If estimates of received levels are required for 3 m or some similar shallow depth, these figures can be obtained most reliably by considering measurements at 9 m or 18 m along with existing knowledge about the depth dependence of sounds at the relevant frequency.

Recording Procedures. At each measurement station, we will record for at least 3 minutes. If the sounds are obviously variable or if there is intermittent interference from other noise sources (e.g. seismic vessels), the recording period will be extended to 5 min or more if it appears likely that this will help in acquiring representative data. The signals from the three hydrophones will be recorded on three channels of a calibrated 4-channel Fostex Model 250 tape recorder; the fourth channel will be used for voice announcements. This type of cassette recorder operates at twice the normal cassette recorder speed, and provides useful data from 20 Hz to at least 18 kHz.

The Fostex tape recorder response is flat within $\pm$ 2 dB over the range 50 Hz to 18 kHz, and adequate at frequencies as low as 20 Hz. The analysis system corrects for uneven frequency response. Each hydrophone and tape recorder will be individually calibrated for this study. The actual sensitivity of each hydrophone and tape recorder at each frequency is taken into account by Greeneridge's analysis procedures, which include correction for frequency-dependent variations in the sensitivity of the tape recorders, hydrophones, and other electronic components. This refined approach to calibration data has also been used in all previous acoustic studies conducted by Greeneridge Sciences in the Beaufort Sea.

Detection of Changes in Source Level During Measurement Series. It will require about 2-3 hours to acquire a series of noise measurements at various ranges out to 15 km from the drillsite. During a 2-hour period, activities aboard the drillship may change, and the positions and activities of support vessels are very likely to change. Throughout each of these 2-3 hour measurement periods, we propose to monitor underwater sounds continuously at one or two fixed locations in order to detect and quantify temporal changes in the sounds that might otherwise be mistaken for propagation-related effects. This refinement has not been used in any previous study in the Beaufort Sea. This approach should be very helpful in resolving the reason for any irregularities in the relationship between received levels and distance, e.g. irregularities such as that in the Explorer I data in Figure 1. If the sound levels recorded at the fixed location change during a measurement series, it may be appropriate to adjust the levels received at the sound boat upward or downward by corresponding amounts in order to estimate the levels that would have been received at each measurement station if the source level had remained constant.

The array of hydrophones described later, under 'Acoustic Monitoring of Bowheads' (Subtask 4), will provide one source of continuous sound data from locations several kilometers from the drillsite. Array data will be analyzed for the times when the sound boat made recordings at the various measurement stations. We will also acquire continuous data from a closer site, using an acoustic buoy of the same type as in the array, but moored about 1 km from the drillship.

Propagation Conditions. Conductivity-temperature-depth (CTD) profiles of the water column will be acquired at the drillsite and at the most distant measurement station along each measurement azimuth. This will be done on each day when measurements are made at various ranges from the drillsite. A Hydrolab CTD instrument will be used. From the CTD data, sound speed profiles and theoretical ray paths will be calculated (e.g. Greene 1982, 1985) These data will be important in recognizing and evaluating temporal and spatial variability in propagation conditions.

Use of Air-Dropped Sonobuoys. A boat suitable for acquiring these noise measurements may not always be available. Even when it is available, it may not be able to travel as much as 15 km away from the drillsite and its support vessels (see 'Logistical Considerations', below). Presence of ice within 15 km may prevent the boat from reaching the most distant measurement station(s). In these circumstances, the aircraft to be chartered for behavioral observations can be used to drop standard naval sonobuoys at one or more of the standard measurement stations. The aircraft will, in any case, be outfitted to drop sonobuoys near whales (see Subtask 5, later), so no additional equipment will be needed in order to use sonobuoys to supplement boat-based measurements.

We will use standard AN/SSQ-57A sonobuoys (Sparton Electronics or equivalent) set to deploy their hydrophones to 18 m depth and to operate for 8 hours. These sonobuoys operate reliably when the water depth exceeds about 20 m, as it does near Corona. (We will also have available some specially-constructed -57A sonobuoys set to deploy their hydrophones to only 9 m depth, in case it is necessary to measure sounds in water shallower than 20 m.) The useful frequency response of these buoys is from 10 Hz to 20 kHz, and they are individually calibrated. The sounds detected by the sonobuoy hydrophone will be broadcast by the sonobuoy's radio transmitter. These telemetered signals normally will be received and recorded by calibrated equipment aboard the project aircraft (same equipment and procedures as used by Greene 1985). The aircraft will circle at least 2 km away from the sonobuoy while recording sonobuoy signals in order to avoid contaminating the underwater sound field with aircraft noise (Greene 1985). It may occasionally be possible to receive and record the sonobuoy signals aboard a vessel if one is within telemetry range.

The sensitivity of sonobuoys is far from 'flat'; they are designed to be much more sensitive to high than to low frequencies. The digital analysis procedures used by Greeneridge Sciences make use of each sonobuoy's calibration data to correct for the highly uneven frequency response. Useful quantitative data on sound levels and characteristics cannot be acquired from standard sonobuoys unless this adjustment is made.

Analysis of Acoustical Data. Sounds recorded at each location and water depth will be analyzed in the Greeneridge Sciences laboratory using the computerized acoustic analysis system described by Greene (1985) and Davis et al. (1985). Recorded sounds are digitized with a 12-bit analog to digital converter and subjected to power spectrum analysis on Hewlett Packard 9816 or Vectra computers. This analysis procedure produces information about the intensity of the received sounds at each frequency of interest. The results will be presented as

- power spectra, which are graphs of intensity in each 1 Hz band vs. frequency,

- 1/3-octave band levels, for consistency with some previous studies and for use in 'zone of potential influence' analyses, and
- overall level in various one-octave and other broad bands, including 20-1000 Hz for consistency with our previous studies.

In addition, if some of the sounds vary considerably over short intervals (e.g. <5 s), we will include waveform data showing pressure vs. time, or 'waterfall diagrams' showing changes in both frequency and intensity over time.

The computerized analysis system takes full account of the calibration data for each component of the recording system, i.e. the hydrophone and tape recorder in the case of conventional boat-based measurements; the sonobuoy, receiver and tape recorder in the case of the sonobuoy system. The analysis system does not assume flat response across all frequencies.

The analysis system can be instructed to process a variety of frequency bands, and to average over a variety of times. For low frequency analyses, our normal procedure will be to process data at frequencies up to 1000 Hz; each analysis will average over 32 seconds, and the resolution will be 1.7 Hz. The analog to digital converter will sample the recorded data 65,536 times in each 32-s segment. We plan to analyze four 32-s segments of data from each measurement station and depth. This will provide an averaging time of 2 minutes, but will also provide information about the variability of the sounds within that 2-min period.

For higher frequency analyses, we propose to process data at frequencies up to 8000 Hz. In this case, a higher sampling rate is necessary; the 65,536 samples used in each analysis will be acquired over 4 seconds, and the resolution will be 3.4 Hz. Again, we propose to obtain four replicate measurements for each station and depth.

The ability of the Greeneridge analysis system to average the results from several short segments of recorded data will probably be very important in this study. It is very common for underwater sound recordings in the Beaufort Sea to be 'contaminated' by strong noise pulses from distant seismic vessels at 10-15 second intervals. In this situation, we will analyze several 'between seismic' segments of sound from each station and depth, and average the results.

The results of these analyses will be used to document the distance, bearing and depth dependence of the received industrial sounds. The data will be tabulated and graphed in the report. They will also be used to develop best-fitting sound propagation models for the Corona area. We recommend that Shell authorize us to coordinate this effort with the related work that may be done by BBN Laboratories on behalf of MMS. BBN was not able to develop a sound propagation model for Corona in 1985, but they may do so in 1986. We will investigate whether the general type of shallow-water sound propagation model that they developed for other sites in the Alaskan Beaufort Sea during 1985 is appropriate for Corona. If so, we will coordinate with BBN so that all available data can be used to derive the best possible estimates of the model's various parameters.

The detailed analyses outlined above will be done in the Greeneridge laboratory after the field season, based on underwater sounds recorded on calibrated equipment. However, the HP Vectra computer analysis system is transportable, and we propose to use it for near-real-time processing of a subsample of the recorded industrial sounds aboard ship at Corona. This 'quick-look' capability will ensure that there are no unrecognized problems in the field recording process. If problems are detected, the field analysis capability will assist us in recognizing and eliminating them while the fieldwork is still underway.

2. Variations in General Industrial Noise over Time

Background and Rationale

Subtask 2 is designed to document the range of variability of underwater noise near Corona, and to examine which factors (industrial and environmental) are responsible for this variation. As noted earlier, operating drillships are accompanied by various other vessels. The activities and relative positions of these vessels vary over time. Thus, the noise levels reaching any given location near the drillsite can be expected to be quite variable as a result of changes in the industrial operations. Variations in natural noise levels will also contribute to the variability in overall noise level if the measurement location is far enough from the noise sources.

The only previous detailed measurements of the variation in underwater noise levels near a drillship were obtained near Explorer II as it operated at Hammerhead, north of Flaxman Island, in 1985 (LGL and Greeneridge, in prep.). Noise levels reaching hydrophones 10-11 km east of the drillship varied markedly over 8 days of hourly measurements. These data were acquired in the 5 to 13 September 1985 period, before bowhead migration past the drillship began. The data were acquired during a period when ice conditions near the drillship were light and little icebreaking was underway. The data acquired in 1985 are useful as a guide to the range of variability that may be expected at Corona. However, actual noise levels to be expected at Corona in mid-late September and early October may be different, and possibly more variable, due to differences in weather and ice conditions, increased icebreaking activity, and site-specific or seasonal differences in sound propagation.

The only other detailed measurements of variability in noise levels near an industrial site in the Beaufort Sea were those acquired by bottom-mounted hydrophones near two artificial islands northwest of Prudhoe Bay in 1984 (Seal Island; Davis et al. 1985) and 1985 (Sandpiper Island; LGL and Greeneridge, in prep.). These data also showed that there are very wide variations in noise levels near industrial sites in the Alaskan Beaufort Sea, and that much of this variation is attributable to changes in industrial activities at or around the sites.

These results indicate that the noise emitted by some oil industry sites is highly variable. Carefully designed but brief measurement programs can provide useful information about relative levels at different distances, bearings, and depths. However, the range of variation of the noise cannot be characterized adequately by observations at one time, or even a few times. Longer-term measurements at one fixed measurement station are needed to characterize this variability. Such data, along with occasional measurements of relative levels at different distances and bearings (see Subtask 1, above), provide a practical way to understand the temporal and spatial variation of the noise field around a drillsite.

Relationship to BBN/MMS Site-Specific Noise Study. The BBN/MMS study is not designed to document long-term variability in the noise emanating from any one site. Observations at each site are acquired for only a few hours on one or two days before the investigators must move to a different site. In 1985, the lack of long-term measurements was recognized as a significant but unavoidable data gap in that study. In 1985, it was agreed amongst Shell, Union, MMS, BBN and ourselves that we would be responsible for acquiring these types of data for Explorer II at Hammerhead and for Sandpiper Island. We assume that the situation at Corona in 1986 will be analogous to that at Hammerhead and Sandpiper in 1985, and that the present project should acquire the necessary data on temporal variability in underwater sounds near the drillsite.

Procedures for Long-Term Measurements

Hydrophone Deployment. The exact position of the hydrophone to be used for the long-term measurements is not critical, as long as it is at a fixed location within the radius where industrial noise levels are expected to exceed ambient levels much of the time. Industrial noise levels are expected to exceed average ambient levels out to ranges well in excess of 10 km from Corona (e.g. Fig. 1). We propose to obtain long-term data from two stations: one location several kilometers east of the drillship, and another within about 1 km from the drillship. These hydrophones will also be used in Subtasks 4 and 1, respectively.

Under Subtask 4, below, we propose to establish a bottom-anchored array of five hydrophones several kilometers east of Corona, similar to the array established east of Hammerhead in 1985. The primary purpose of this hydrophone array will be to listen for calls from bowhead whales and, when bowhead calls are detected, to localize the whale (see Subtask 4, below). However, one or more of these hydrophones can also be used to obtain repeated measurements of noise levels and characteristics. These hydrophones will be monitored during the bowhead migration season, ideally for several weeks. Sounds detected by each hydrophone in the array will be telemetered to a receiver aboard one of the ships operating at Corona, and recorded on a multichannel tape recorder. Details are given under Subtask 4, 'Acoustic Monitoring of Bowheads', below.

As explained under Subtask 1, we also propose to deploy one hydrophone much closer to the drillship, probably about 1 km away. For purposes of Subtask 1, this hydrophone will be used to determine whether industrial sound characteristics change within the various 2-3 hour periods while measurements are being made at various distances. However, the signals from this buoy can also be recorded continuously on the same multichannel tape recorder that will be used to record signals from the hydrophone array. This will provide a set of long-term data from a location close to the drillship, where noise from the drillship will dominate the sound field much of the time.

Documentation of Industrial Activities and Environmental Conditions. To interpret the variations in noise levels received at the hydrophones, we will obtain detailed records of the activities and movements of the vessels operating near Corona. One member of our crew stationed aboard vessels at Corona will acquire these records, coordinating with Shell's drilling contractor. For each hour, we will need to document the activity of the drillship, plus the activity and location of each associated vessel. Activities of interest will be those that might affect the level and spectral characteristics of underwater noise, e.g. whether the drillship is drilling, logging, running casing, etc.; number of generators operating aboard *Explorer II*; occurrence and position of icebreaking; locations and engine speeds of all vessels in the area. Since wind speed, wave height, and ice conditions all affect ambient noise, these environmental variables will also be recorded on an hourly basis.

Helicopter traffic between Prudhoe Bay and the drillsite will not pass near the hydrophone array east of Corona. It is well established both theoretically and empirically that noise from aircraft is not detectable in the water more than a few hundred meters away from the helicopter's path (Urick 1972; Greene 1985). Hence, helicopter sounds will not contribute to the sounds recorded by the array. However, helicopter sounds may well contribute on an occasional basis to the sounds recorded by the hydrophone near the drillship. Hence, the exact times of arrival and departure of helicopters will be recorded, along with helicopter type. When possible, we will also record the estimated lateral and vertical distances of closest approach of the helicopter to the hydrophone.

Analysis of Long-Term Acoustical Measurements. Following the procedure at Seal Island in 1984 and at Sandpiper Island and Hammerhead in 1985, we propose to analyze one noise sample per hour from each of the two long-term hydrophone stations (array and near drillship). When possible, each noise sample will be 32 seconds in duration. However, if seismic pulses are being received, a number of shorter 'between seismic' samples will be analyzed and averaged. The spectral analysis procedures will be done with Greeneridge's computerized acoustic analysis system in the same manner as described for Subtask 1, above.

The results for each hour and location will include the power spectrum, the received level in each 1/3-octave and one-octave band, and the received levels in various broader bands including the 20-1000 Hz band. These hourly data will be accumulated in disk files for subsequent summarization and analysis. Summary statistics will include, for each frequency and each band, the levels exceeded 95%, 50% and 5% of the time. These statistical data will be in the same format as in the Seal Island, Sandpiper Island, and Hammerhead studies. The noise statistics from the array will be comparable with the Hammerhead data, which were collected a similar distance from the drillsite and in a similar water depth.

The levels received at the two locations during each hour will also be examined relative to activities and environmental variables at the drillsite. This will be done using simple and multiple correlation techniques. Industrial activity variables will include the presence or absence of drilling, other activities in the well, number of generators running aboard Explorer II, occurrence of icebreaking, and distance from the hydrophone to the closest vessel. The multiple correlation methods will be used to assess how much of the hour-to-hour variability in the received noise level at each location can be attributed to each of the industrial and environmental variables. These multiple correlation analyses will be done separately for the two hydrophone locations, and for various noise bands.

We hypothesize that sound levels at the nearer station will be dominated by industrial noise most or all of the time, and that activities aboard the drillship itself will be strongly correlated with the received noise level. The sound levels at the distant station will often be dominated by industrial noise, but this may be from either the drillship or other vessels. Also, sounds at the distant station may show some correlation with environmental variables, since ambient noise levels in certain bands may exceed industrial noise at times when there is much wave or ice action.

3. Contributions of Icebreaker and Other Vessels to Composite Noise

Background and Rationale

Subtask 3 is designed to obtain direct measurements of the noise levels and spectral characteristics resulting from each of the major vessels and industrial activities at Corona. This subtask is complementary to Subtask 2. In Subtask 2, variations in the composite noise field will be measured, and correlation methods will be used to assess which industrial and environmental variables seem to be most responsible for the noise and for its variability. Subtask 2 will be valuable in understanding the characteristics of the overall noise field. However, in the absence of experimental control, the correlation methods to be used in Subtask 2 probably will not be able to determine the relative contributions of some industrial and environmental variables to the overall noise field. In Subtask 3, we will make direct measurements of the noise emanating from each major vessel at Corona during different operating conditions.

Besides the drillship, the major vessels operating at Corona will include supply ships and the icebreaker 'Robert Lemeur'. Some information on levels and spectral characteristics of sounds from supply vessels was obtained in the Canadian Beaufort Sea by Greene (1982, 1985). However, a detailed investigation of supply ship sounds was not within the scope of that study. A preliminary investigation of sounds from the icebreaker 'Robert Lemeur' was done on 21 October 1985 as this ship broke ice at Corona. A sonobuoy was deployed from the ship, and then the vessel moved away from the buoy breaking ice as it went. Sounds received at the sonobuoy were recorded at ranges up to 4 km (Greeneridge in prep.). However, it was not possible to obtain measurements of the noise from Robert Lemeur at different aspects or under different operating conditions. More extensive data on icebreaker sounds have been obtained in the Canadian High Arctic (Finley et al. 1983, 1984; Thiele 1984) and in the Baltic (Thiele 1981). The designs of the icebreakers involved in these Canadian and European studies were quite different from the design of Robert Lemeur.

Page 5 of the RFP implies that the contribution of helicopter sounds to the composite sound field at Corona should be considered. The underwater sounds of a Bell 212 helicopter passing overhead at various altitudes were studied by Greene (1985). He also obtained limited data on sounds from Bell 214 and Sikorsky 61 helicopters. Although there is undoubtedly considerable additional information in classified sources, we know of no other published data on underwater sounds from helicopters. However, the theory of air-water transmission of sound is well developed, and there are a few publications on underwater sounds from fixed-wing aircraft. In general, sounds from aircraft at low-medium altitude are not detectable underwater more than a few hundred meters to the side of the flight path.

Relationship to BBN/MMS Site-Specific Noise Study

The 1985 phase of the BBN/MMS study did not acquire data on noise from the drillship Explorer II, supply vessels, icebreaking, or helicopters. If BBN proposes to acquire any of these types of data in 1986, we plan to coordinate our efforts with theirs. The aim will be to avoid unnecessary duplication and to maximize the variety of vessels and industrial activities whose sounds are recorded by either ourselves or BBN.

Procedures for Measurements of Noise from Specific Vessels

We plan to document the sounds emanating from the drillship Explorer II, the icebreaker Robert Lemeur, and the two major support vessels. We will also document the underwater sounds from some of the helicopters that fly to Corona.

General Approach. The primary requirement in this subtask will be to obtain measurements at locations close enough to each vessel of interest, and far enough from other vessels, that the underwater sound field will be dominated by sounds from the target vessel. To confirm that each frequency component is actually from the target vessel, it will also be necessary to obtain measurements from at least a small range of distances, for example 0.185 to 1.85 km (0.1-1 n.mi.). Sounds from the target vessel will diminish markedly in level (by 10-20 dB) over this range, whereas any 'contaminating' sounds from distant sources will not change appreciably.

Sounds at various distances from the drillships will be recorded as part of Subtask 1. The measurements at long distances from the drillship will represent composite sounds from all vessels in the area, but the measurements closest to the drillship will represent drillship sound *per se*. The measurements specified in Subtask 1 will be obtained on at least three different days and on three different aspects. If these days do not encompass all of the main operating modes of the drillship, we will attempt to obtain additional series of measurements at close ranges (0.185-1.85 km) if logistical arrangements permit. However, these additional measurement series will not be essential. The hydrophone that we propose to deploy near the drillship on a long-term basis (Subtasks 1 and 2) will provide continuous data from a location where the underwater noise is expected to be dominated by drillship sounds.

The modes of drillship operation to be compared will depend on the activities of the drillship during the field season. We hope to measure sounds during times when the ship is drilling, raising and lowering the drill string, running casing, well logging, and inactive. We also hope to compare sounds during times when different numbers of generators are operating.

Explorer II has seven generators, but the number operating at any one time is variable. The drillship also has thrusters, which are occasionally used to repel ice from alongside the ship. Thrusters on a supply ship have been shown to produce strong tonal sounds (Greene 1982). We will attempt to compare sounds during periods when the drillship's thrusters are active and inactive.

Sounds from vessels underway in open water (supply vessels and icebreaker) will be studied by positioning the recording boat ahead of the approaching vessel and recording sounds as the vessel approaches, passes, and moves away. We will coordinate with the vessel to arrange for it to pass about 100 m to the side of the sound boat. This will provide data from various ranges at both bow and stern aspect, plus data from beam aspect at range 100 m. It should be possible to make these measurements without requesting the industry vessels to make more than minor adjustments in course. These measurements will be made at places and times when the target vessel is the only vessel within a few kilometers of the sound boat.

We will also record underwater sounds near support vessels engaged in other typical activities, including idling, operating thrusters, and moving drillship anchors.

It will be important to obtain detailed information about the machinery operating aboard the vessels at the exact times when their sounds are recorded. These data should include the rotation rates of engines, generators, and other machinery. The frequencies of tonal sounds are directly related to the rpm figures for the machinery creating those sounds. By finding matches between rpm data and tonal frequencies, we will be able to identify the specific machinery responsible for some sound components. To further facilitate this process, we will use a microphone and high-quality Sony TC-D5M tape recorder to record airborne sounds near machinery such as generators, drawworks, mud pumps, and rotating platforms. By analyzing these sounds and determining their tonal components, we will have additional information with which to document the specific sources of tones detected in the water.

Icebreaking Noise. Assuming that ice is present near Corona during parts of the study period, noise from a variety of icebreaking operations will be documented. The 'Robert Lemeur' is expected to be the main vessel involved in icebreaking. However, other support vessels may also participate in ice-management operations, and we will attempt to document sounds from any vessel engaged in icebreaking near Corona. Ideally, we would acquire these data from a quietly drifting 'sound boat'. For comparative purposes, it will be important to document sounds as the icebreaker moves forward in open water, moves forward continuously through thin ice, and moves forward and back to break heavy ice.

The most intense icebreaker noise is likely to occur when the icebreaker is in the bollard condition, i.e. pushing against heavy ice with full power but zero forward speed, or when it is reversing (Finley et al. 1983, 1984; Thiele 1984). Noise levels and spectral characteristics will be high and quite variable as the vessel cycles through the sequence forward motion into ice, the bollard condition, reverse pitch to back away from the ice, and return to forward pitch to repeat the cycle. We will attempt to record sounds continuously through several of these cycles, including measurements at both stern and beam aspects.

Ice conditions at Corona may not require the icebreaker to engage in all of these activities during our field period. If so, we will coordinate with Shell and the drilling contractor to determine whether the icebreaker could move some distance away from Corona to perform these kinds of icebreaking operations for purposes of the sound measurements.

Measurement Procedures. Sounds of specific vessels will be recorded from the sound boat using a string of three hydrophones at 9 m, 18 m and '5 m above bottom' depths, as in Subtask 1.

Use of Sonobuoys. No small vessel suitable for use as a sound boat may be available at the times when some of these measurements need to be acquired. If so, data about sounds from specific vessels will be obtained by using the project aircraft to drop one or more sonobuoys at required ranges from the target vessel (procedures as in Subtask 1). Alternatively, the sonobuoy can be deployed and monitored from the target vessel itself, as was done for the preliminary study of icebreaker sounds at Corona in 1985. The sonobuoy approach may be necessary in heavy ice conditions in which a small 'sound boat' could not operate.

We recommend the use of the sound boat rather than sonobuoys whenever possible. Standard sonobuoys have several limitations. They overload when they receive strong sounds from a nearby vessel. They deploy only one hydrophone to one depth (normally 18 m). Their distances from the target vessel may be difficult to measure precisely. Nonetheless, valuable data on levels and spectral characteristics of sounds from specific vessels can be obtained by sonobuoys if this approach proves to be necessary.

Measurements of Helicopter Noise. We will measure the underwater sounds from helicopters that are supporting the drilling operation at Corona. The sound boat will be prepositioned along the route that a helicopter is expected to fly. The boat will be stationed as far from the vessels at Corona as possible in order to minimize 'contamination' by vessel noise. The helicopter pilot will be requested to alter course slightly when he sees the boat in order to pass directly over the boat. Thus, useful data can be acquired without requiring the helicopter to alter its normal route appreciably.

More comprehensive information about helicopter sounds will be obtained if it is practical for a helicopter to make several replicate passes over the sound boat on one or more days. If sufficient helicopter time is available, we recommend that three passes be done at each of several altitudes: 500, 1000, 1500 and 2000 ft. These are the altitudes used in the one previous systematic measurement of helicopter noise that has been reported (Greene 1982, 1985).

The string of three hydrophones will be used to record helicopter noise at depths 3 m, 9 m and 18 m. The 9 m and 18 m hydrophone depths are consistent with depths used for other proposed measurements. The 3 m depth is recommended because helicopter sound, unlike vessel sound, will be stronger and detectable at greater range just below the surface than deeper in the water column (Urick 1972; Greene 1985). The selection of 3 m, 9 m and 18 m as the recording depths for helicopter sound is consistent with our previous measurements of helicopter noise in the Beaufort Sea.

Analysis of Vessel-Specific Sounds. Sounds from the various ranges, aspects and hydrophone depths will be analyzed by Greeneridge's computerized acoustic analysis system, as described in Subtask 1. Results will include power spectra along with levels in 1/3-octave bands and various wider bands. In the case of rapidly changing sounds, e.g. when the icebreaker changes propeller pitch, waterfall diagrams of frequency and intensity vs. time will be prepared. The levels for each band and each prominent tone will be examined relative to distance from the target vessel to confirm that each of these sound components originated from the vessel under study. To facilitate comparisons of noise from different vessels and operating conditions, levels received at each frequency and in each band will be converted to estimated levels at a standard distance of 100 m.

Sounds from helicopter overflights will also be analyzed by Greeneridge's system to determine power spectra and levels in various bands. Short averaging times (typically 4 s) will be used because received levels will change rapidly as the helicopter approaches, passes over, and moves away. Waterfall diagrams similar to Figure 7 will be prepared. By averaging the sounds received during the 4 s when the sounds are most intense (i.e. when the helicopter is passing overhead), the results for helicopters will be directly comparable to those of Greene (1985).

4. Acoustical Monitoring of Bowheads

Background and Rationale

Recent studies at Point Barrow during the spring migration of bowheads have demonstrated that bowhead calls can often be detected when no bowheads can be seen visually, and that the positions of many of these calling whales can be determined by acoustic localization techniques (Beeman et al. 1985; Cummings and Holliday 1985). The advantages of the acoustic method are that it can detect and localize some whales in darkness, on foggy days, under ice,

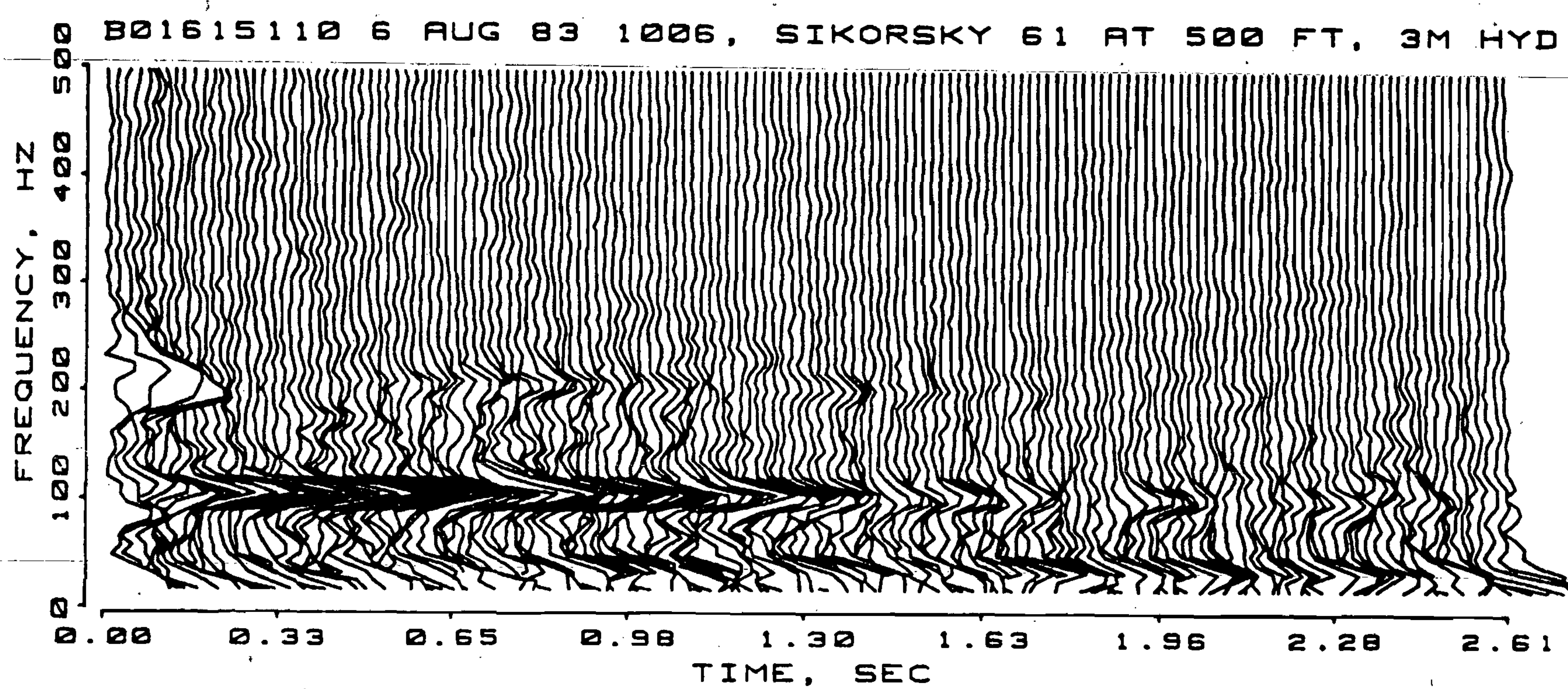

Figure 7. Waterfall spectrogram of the sounds from a Sikorsky 61 helicopter, altitude 500 ft, flying over a hydrophone at depth 3 m. The spectral peak at 200 Hz at the start is from a seismic survey pulse.

and at distances exceeding those to which bowheads can be seen visually. On the other hand, the acoustic method suffers from some limitations as well. It cannot detect a whale unless the whale calls, and it cannot determine the number of whales present. It can only determine the path of motion of a whale if that whale calls repetitively, and even then there may be ambiguity if more than one whale was known or suspected to be calling in the same general area. Thus, an acoustic monitoring and localization program has the potential to provide valuable and otherwise unavailable data on the occurrence and movements of bowheads near a monitoring location. However, it cannot provide all of the necessary data on whales for a project such as this.

In 1984, a hydrophone array was installed near the Seal Island, an artificial island constructed by Shell northwest of Prudhoe Bay, to monitor for bowheads passing near the island during the fall migration. The hydrophones were on the bottom 1.65-2.5 km from the island. The sounds were transmitted to the island along bottom cables. This site was in shallow water (about 13 m) south of the main migration corridor. As expected at such a site, only a few bowhead sounds were detected and localized (Davis et al. 1985). However, the acoustic monitoring effort did show evidence that a few bowheads approached closer to Seal Island than had been detected by any other method of study.

In 1985, an array of hydrophones was established 10-12 km east of the Explorer II drillship while it was working at Hammerhead site, about 45 km west of Corona and at a similar water depth. These hydrophones transmitted the underwater sound data by radio to receivers aboard a ship at Hammerhead. The array of hydrophones was established successfully in the relatively deep water, transmitted their signals to the receiving ship reliably for 10 days, and provided accurate localization information during tests with non-biological noise sources (Greeneridge and LGL, in prep.). No bowhead calls were detected by this array, which is consistent with the fact that no bowheads were seen within 25 km of the drillship during intensive aerial surveys around Hammerhead in 1985.

Acoustic localization depends on the use of multiple hydrophones. The source of the sounds can be determined based on time-of-arrival differences at several widely-spaced hydrophones. In this approach, at least five hydrophones are required in order to provide unambiguous position-finding capability on all azimuths. (Fewer hydrophones are needed at Barrow in spring, where the hydrophones are placed along an ice edge and the whales can be assumed to be in a 180° sector.) Another localization approach is to use phase or other information to determine the bearing of the source from two or more hydrophone locations, and to locate the animal through triangulation. These two approaches each have their own advantages and limitations. Both approaches have been used to localize bowheads and other whales in recent years, but the time-of-arrival method has been used in the most recent studies at Barrow and in the Beaufort Sea.

We propose to establish an array of five hydrophones east of Corona during this project, generally comparable to the system that was tested successfully at Hammerhead in 1985. The main purpose of this array will be to detect the presence, and possibly the paths of motion, of whales approaching Corona. These data will be useful in themselves, and will also be helpful in alerting the behavioral crew to the presence and locations of whales. For example, if whale calls are heard and localized during the night or early morning, the behavioral crew will not have to search for and find bowheads, but can instead proceed directly to the whale location as soon as lighting conditions are adequate for behavioral observations. For this purpose, we will have the capability of near-real-time processing of the hydrophone signals in order to localize the positions of calling whales. The array will also provide continuous time-series data on industrial sounds reaching its fixed location several kilometers east of Corona. These data will be used in Acoustic Subtask 2, the analysis of temporal variability in industrial noise, and the factors affecting this variability.

One of the major factors affecting the success of the acoustic localization effort will be the amount of 'interference' by industrial noise from the Corona area. Bowhead calls can be detected and localized only if they are not masked by industrial (or natural ambient) noise. Results from Hammerhead in 1985 showed that industrial noise levels were high at the array location 10-11 km east of Hammerhead. Masking problems can be reduced by placing the hydrophones farther to the east of Corona. However, this may not be very effective if there is also industrial activity at the Erik site, 32 km east of Corona, during the study period. Furthermore, if the hydrophones are placed too far away from Corona, the relevance of the resulting data to the Corona site will diminish. A partial solution to the masking problem may be to place the hydrophones closer together than the 1 km spacing used at Hammerhead. Another approach is to ensure that the signal processing system is optimized to allow localization of calling whales at the lowest possible signal-to-noise ratios.

We have made arrangements for Drs. C. Clark and Wm Ellison to participate in the project as consultants in order to take advantage of their experience with acoustic localization at Barrow and elsewhere. They will participate in the design phase of this project when the optimal hydrophone positions and spacings are being decided. This will allow the project to take advantage of their experience with ice-mounted arrays at Barrow (in the absence of industrial noise) as well as our own experience in designing, deploying and using arrays near industrial sites in the Beaufort Sea in autumn. In addition to obtaining their input during the design phase, C. Clark will, after the field season, apply his sound localization system to localize whale calls (and calibration signals) recorded by the array. In this way, we will determine whether his signal processing system has any greater capability than the Greeneridge system to localize whale calls in the presence of masking by industrial noise.

Relationship to Other Studies

The array proposed here will be a proven and relatively straightforward design, very similar to that used at Hammerhead in 1985. It will provide data needed to meet the objectives of the study, including near real-time information about presence and locations of whales approaching Corona. This effort will not duplicate the more elaborate but experimental system proposed by Honeywell and outlined in an addendum to the RFP. Even if the Honeywell system works successfully, it will not provide real-time data; the sounds are to be stored on tape at the hydrophone stations until retrieved by a ship.

Thus, we recommend that the proven system proposed here be operated in 1986 whether or not the experimental Honeywell system is tested. If the Honeywell system is proven successful in 1986, then a decision should be made regarding use of a single, optimal system in any future year when a similar study is done. The optimal system for a future year might include elements of both the presently proposed system (e.g. telemetry of signals to allow real time processing) and the Honeywell system (more elaborate hydrophone installation).

The BBN/MMS site-specific noise study does not include any bowhead monitoring or localization effort, so there is no overlap between this subtask and the BBN study.

Procedure for Acoustical Monitoring of Bowheads

Buoy Description. The hydrophone array will consist of five moored buoys. At each buoy, a hydrophone sensor package will be buoyed up 5 m above an anchor using a faired armored cable to eliminate self-noise from cable strumming. The hydrophone package, adapted from a sonobuoy, will include a low noise preamplifier to minimize signal losses and noise induced in the cable. The armored cable will be attached to a 40-m length of chain extending over the bottom to a second anchor, where the battery housing will be located (Fig. 8). Each buoy in the array will be provided with batteries sufficient for 60 days' operation. The power and hydrophone signal will be carried in a taut-line, faired armored cable from the second anchor to a surface buoy containing the radio transmitter and antenna. The fairing will minimize drag, reducing the effects of current. The surface buoy will be a 12-m long sparbuoy with the antenna 3 m above the water surface. The top of the sparbuoy will house the radio transmitter electronics and the vertical, half-wave antenna. This configuration will provide maximum immunity to damage or loss from passing ice. The sparbuoy can be pushed aside or pushed temporarily below the surface without suffering permanent damage.

We propose to experiment with the sparbuoy configuration in the Santa Barbara Channel to assure adequate, low-angle radio signal transmission for maximum range. The 3-m height should obviate the need for antenna ground

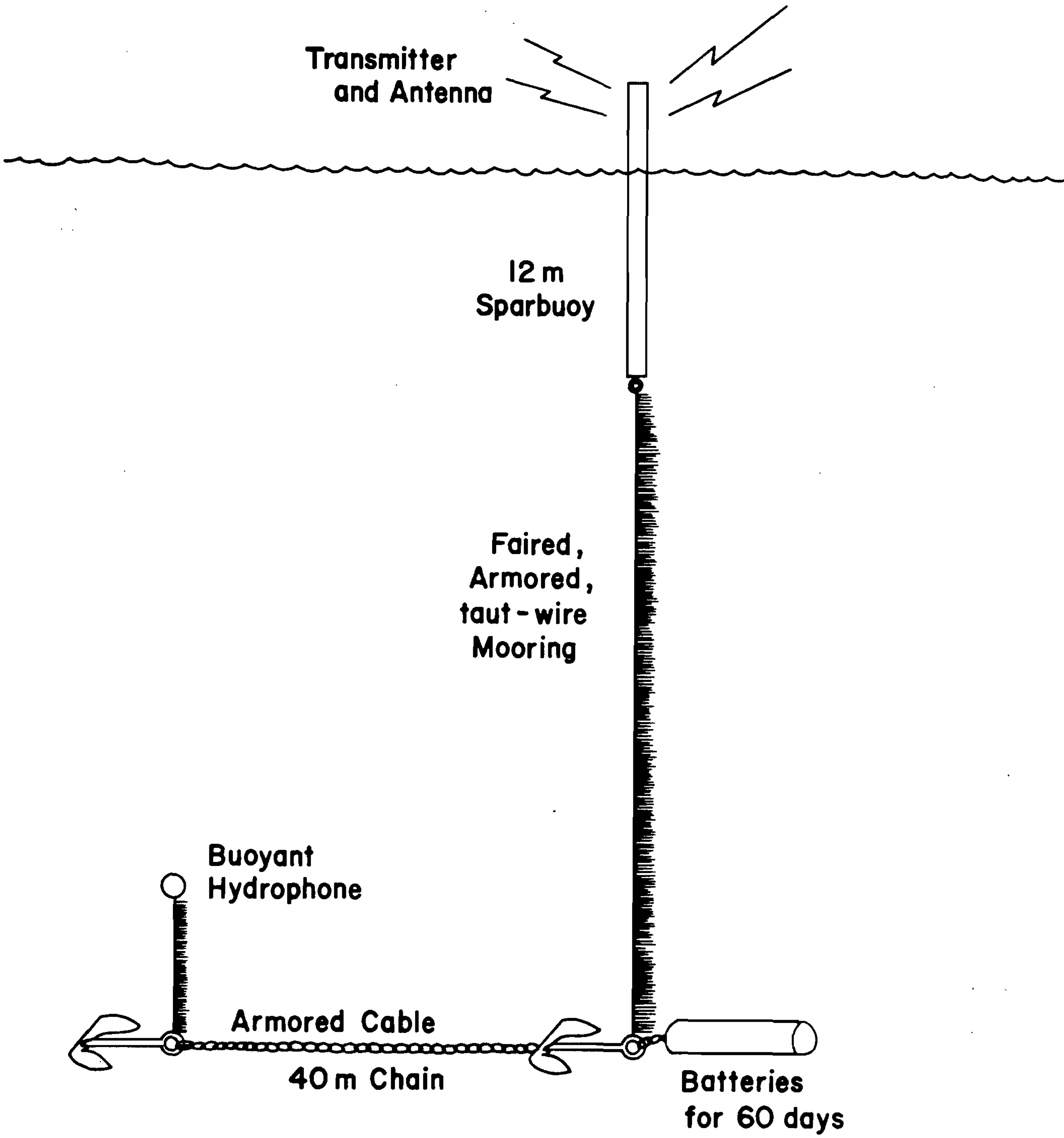

Figure 8. Sketch of a moored buoy (not to scale).

plane radials, which would otherwise protrude from the buoy and have to be protected to prevent them from catching on passing ice floes.

The proposed buoy configuration is simpler than the one used at Hammerhead in 1985 in that there is no buoyant, subsurface buoy (Fig. 9). Also, the hydrophone is floated up a short distance above the bottom rather than being on the cable between the bottom and the surface. This arrangement helps to minimize the risk of hydrophone damage from deep-draft ice floes. The proposed system is also superior in its use of two 50-kg anchors, each of which is heavier than the single Danforth anchor with lead clump used in 1985.

In our basic system we propose to use the hydrophones and transmitters from standard Navy sonobuoys, as was done at Hammerhead in 1985. However, instead of using parts from production sonobuoys, we plan to use slightly modified equipment provided by the Sippican Corporation. These components will be identical to those used during the North Slope Borough's acoustic census work in spring 1985 (Beeman et al. 1985). The units proved superior in reliability in that application as compared to the sonobuoys used at Barrow in 1984. The frequency response is quoted to be 10-10,000 Hz with the response down 3 dB at 10 Hz, flat from 30-5000 Hz, and a +15 dB resonance response at 7.5-8.5 kHz. These units are like standard AN/SSQ-41B sonobuoys in that individual calibrations are not normally provided. However, suitable calibrations can be inferred from measurements on many identical units. This equipment will be more than satisfactory over the range of frequencies up to 2500 Hz planned for our recordings. In addition, we plan to make simultaneous test recordings from each buoy hydrophone signal vs. the boat-based 6050C hydrophone at the same depth. In that way, we can use the calibrated response of the 6050C to calibrate the response of the buoy hydrophone/transmitter/receiver/recorder system.

The installation locations of the buoys will be measured with the precision navigation system in use by the drilling contractor for positioning the drillship and its anchors. The system provides position accuracies of about 2 m and is computer-based for real-time graphical display of positions and tracks. This method worked very well at Hammerhead in 1985.

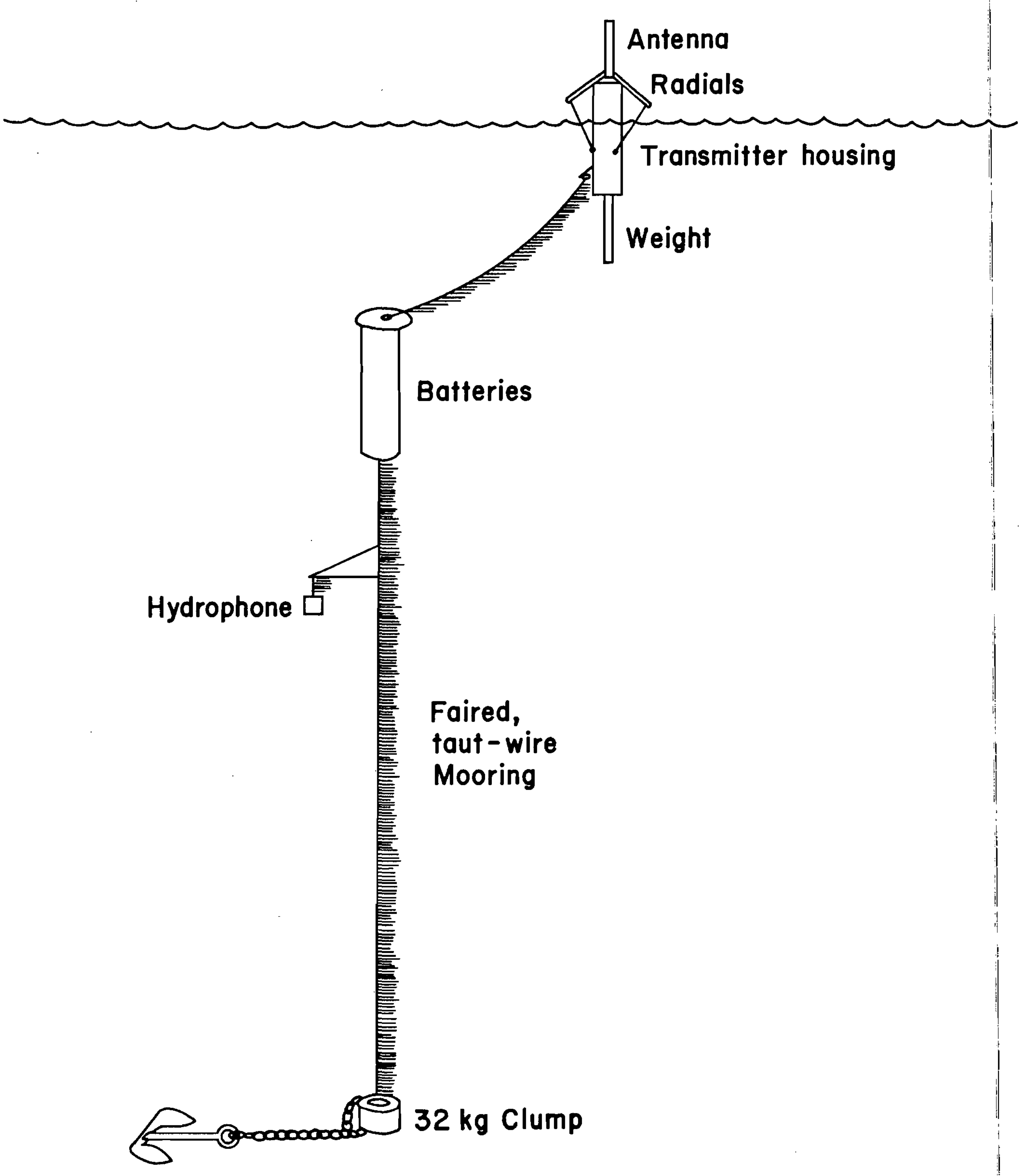

Figure 9. Sketch of a moored buoy at Hammerhead. Water depth 32 m, hydrophone depth 16 m (not to scale).

Option for Direction-Finding Buoys. As an option, instead of the single, omnidirectional hydrophone from standard sonobuoys, we are considering the use of components from newly-available three-channel sonobuoys that include the usual omnidirectional channel plus two directional channels. The signals in these channels are multiplexed over the same type of wide-band FM channel used by the standard sonobuoys. The audio frequency band is limited to 10-2400 Hz. The advantage of these components is that, with appropriate signal analysis, it is possible to compute the direction from which signals are being received at each individual buoy, independent of data from any other buoy. Each buoy in the array will have the capability of providing bearings to whale calls. Thus, calling whales can be localized by either of two methods--by the time-of-arrival differences at different buoys, as in the 1984-85 studies; or by triangulation of bearings from two buoys. The latter approach has some of the same advantages as the system proposed by Honeywell, but would require buoys that were little more elaborate or expensive than the type used at Hammerhead in 1985.

Whale call localization with directional sonobuoy sensors is untried, but the equipment and techniques have been in use by the Navy for 15 years. This equipment was declassified two years ago. The physical design of the buoys would be the same as that for the basic system, and the omnidirectional channel would provide the same data as the basic system. Thus, there is no extra risk in using the components from directional sonobuoys. The cost of these components is little more than that of standard omnidirectional sonobuoys and they may in fact be more readily available than omnidirectional sonobuoys during the summer of 1985.

Array Configuration. The five-hydrophone array will be nearly identical in configuration to the array used at Hammerhead in 1985. The pattern will be a "+" sign with hydrophones at the north, east, south, west and center positions. The distance from the center hydrophone to each of the other four hydrophones is tentatively proposed to be 1000 m, as in 1985 at Hammerhead. However, the optimal hydrophone spacing and distance from Corona will be two of the matters to be evaluated amongst Greeneridge, LGL, C. Clark and Wm

Ellison during the design phase. The relative positions of the buoys will be recorded to the nearest meter for use in the localization program.

Radio Receivers and Signal Recording. A single VHF antenna for all radio signals will be installed as high as possible on the receiving ship. Height is important for two reasons: (1) to allow the widest operating range from the buoys, and (2) to minimize interference from structures on the ship that may be between the receiving antenna and the buoys when the ship's heading is not optimum. We require a clear signal independent of the ship's heading and at ranges as great as possible. For line-of-sight radio operation such as with sonobuoys, the rule of thumb is that radio range in miles is the square root of twice the height in feet. Thus, for a 10 mile range the antenna height must be 50 ft.

The antenna signal will be amplified and conditioned to provide quality input signals to six receivers. (One receiver is for the buoy placed 1 km from the drillship for purposes of Subtask 2.) In the basic system, a 7-channel tape recorder is needed to read the six buoy signals plus one voice announcement channel. In the system using directional sonobuoy components, each receiver will demodulate and demultiplex its buoy signals into the omnidirectional and two directional signals for recording. With 3 channels for each of five buoys in the array, one channel for the near- drillship buoy, and one voice channel, a 17-channel tape recorder will be required. It will be operated at a tape speed adequate for FM recording over the 0-2.5 kHz frequency band (9.5 cm/s). The voice channel will be used for annotation.

Array Calibration. It is imperative that the array localization capability be calibrated. The effects of uncertainties in actual array geometry, sound velocities, and multipath sound propagation effects can be largely eliminated through calibration. Calibration will be achieved through the use of an underwater sound projector (U.S. Navy model J-11) suspended at depth 18 m from a ship with the precision navigation system installed. The projector will transmit a bowhead call-like FM sweep signal, spanning frequencies from 100-400-100 Hz in 2-3 seconds. The transmitted signal will be prerecorded on an endless-tape cassette so it can be projected repetitously for at least a minute to assure adequate reception at all five buoys even if there is intermittent interference by seismic pulses. For comparative purposes, the tape loop will also include recordings of actual bowhead calls. This will permit us to determine the localization accuracy of the array system on actual calls as well as the 'ideal' test signal. These types of projected test signals will provide better calibration data than could be obtained by using noise from a ship at known locations. Ship noise is continuous, whereas the array is designed to localize sources of transient or rapidly changing sounds.

Initially, after the array is installed and before migration begins, calibration will be performed at many azimuths and ranges from the array. Afterwards, a calibration operation will be conducted at least once per week from a position of opportunity. After migration begins, calibration will not be done without assurance from native subsistence hunters that the sounds will not interfere with their hunting for bowheads.

The calibration signals received at the array and recorded on the support ship will be analyzed on site using the HP Vectra computer that will be in the field for various near-real time analysis tasks (see Subtask 1, above). This process will reveal any unforeseen problems early in the field seasons, when they can be addressed, rather than back in the lab when it is too late.

•

Sound Monitoring. During whale migration, the array signals will be monitored for bowhead calls on a 24 h/day basis. The tape recorder will also be run 24 h/day. Detailed log books will be kept and voice track annotations made of unusual sounds heard and events seen. Hourly, detailed meteorological and operational notations will be made to support the study of long-term variability in the site noise (see Subtask 2, above). When bowhead calls are heard, the tapes will be analyzed off-line (so that no new incoming data will be missed) to determine bowhead locations. These will be reported to the behavioral/aerial survey crew to facilitate their efforts in locating whales for behavioral observations (see Task II, below). The necessary programs for sound localization by the HP Vectra computer were developed and tested during the 1984 Seal Island and 1985 Hammerhead studies.

Before migration begins the array signals will be recorded for five minutes per hour (rather than continuously) as part of the study of drillsite noise variability. We propose to analyze these recordings on-site using the Vectra computer.

Array Signal Analysis. The hourly analyses power spectrum of industrial noise reaching the array will be done as described earlier (Subtasks 1, 3). The array signal analysis for call localization will be done two ways: using crosscorrelation analysis by the Vectra computer on site, and using C. Clark's minicomputer/array processor system in his lab. The crosscorrelation approach has been described (Seal Island: Davis et al. 1985; Hammerhead: LGL and Greeneridge, in prep.). Sounds recorded from each pair of buoys are compared mathematically to determine the signal travel time difference for each pair. The travel time for one pair of buoys defines a hyperbola of positions along which the whale must have been located. The intersection point of the hyperbolae defined by pairs of buoys represents the actual position of the whale.

Clark's approach involves a form of magnitude crosscorrelation in which sound spectral magnitudes are crosscorrelated to take advantage of the fact that bowhead calls, for short periods of time, tend to be concentrated near a single sinusoidal frequency. Clark's system provides for digital filtering to exclude noise at frequencies other than those of the particular call being processed. Calibrations for an array with similar hydrophone spacing to what is proposed here resulted in range errors less than 3% and bearing errors less than 0.3° for ranges to a maximum of 4.8 km. At greater ranges the range errors will increase but useful measurements should be possible to at least 20 km if calls are detected from that range.

As outlined in the 'Background and Rationale' section for this subtask, localization results from the Greeneridge and Clark analysis systems will be compared, and the data from the most sensitive system will be used.

5. Sounds Reaching Bowheads Whose Behavior is Observed

Background and Rationale

In order to interpret behavioral observations of bowheads in the general vicinity of Corona, it is important that the presence, levels and spectral characteristics of those sounds be determined. This cannot be done reliably through use of propagation models or any other indirect means. Propagation losses depend on a variety of variables, including the variable temperature/salinity attributes of the water mass and changing ice conditions. No existing or foreseeable propagation model will provide reliable data on the detailed characteristics of sounds reaching any specific point many kilometers from Corona. Furthermore, the industrial sounds reaching whales may come from a variety of sources, not just Corona (e.g. seismic vessels).

Thus, it is necessary to measure the sounds reaching the whales whose behavior is observed. This can be done quite simply by dropping standard naval sonobuoys from the observation aircraft. This approach has been used in most previous MMS- and industry-funded studies of bowhead behavior.

Relationship to Other Studies

Data on sounds reaching the specific whales observed by the behavioral crew must be obtained simultaneously with the behavioral observations. Thus, no other study could duplicate this effort. The recorded sonobuoy data will be analyzed using Greeneridge's computerized acoustical analysis system, as used for the other acoustical components of this study. The results will be directly comparable to those acquired by hydrophones or sonobuoys during other phases of this project, and in other related studies (received power spectra, 1/3-octave band levels, and broadband levels).

Proposed Methodology

The methodology for acquiring and analyzing acoustical data via sonobuoys is explained under Subtasks 1 and 3, above. The application of this approach to the task of documenting the noise exposure of whales is discussed under Task II, Behavioral Studies, below.

6. Ambient Noise Levels

In order to estimate the distances to which industrial sounds are expected to be audible, it is necessary to know the natural ambient noise level. The natural noise is a result of wind and wave action, ice motion, ice melt, biological sources, and various other factors (Wenz 1962; Greene and Buck 1964; Urick 1975). To a first approximation, industrial noise will not be detectable at ranges where its received level is less than that of the ambient noise at comparable frequencies.

Natural ambient noise levels cannot be determined at locations near Corona when vessels are operating at that site. At many frequencies, industrial sounds will be stronger than ambient sounds at ranges out to at least 20 km, and often to greater ranges. Sound levels 10 km from the Hammerhead drillsite in 1985 were dominated by industrial noise.

The BBN/MMS site-specific noise study acquired some ambient noise data from Corona in 1985, when no vessels were nearby. That study is also preparing estimates of the 5th, 50th and 95th percentile values for ambient noise at Corona, based on the few available measurements plus wind statistics and theoretical considerations.

In the present study, we will acquire limited additional data on ambient noise when sonobuoys are dropped near whales distant from the Corona site (see Subtask 4, above, and 'Behavioral Studies' section, below). Samples of sounds recorded from all sonobuoy drops regardless of distance from Corona will be analyzed to determine spectrum levels, 1/3-octave levels, and broadband levels. We will examine these data in relation to distance from Corona in order to identify those cases where the recorded sounds are largely or totally natural. We will also listen to the recorded sounds, since the human hearing system has good capabilities for identifying the likely source of many underwater sounds. The results from the propagation loss measurements of Subtask 1 will also be helpful in estimating the expected levels of industrial sounds at various frequencies and ranges, and thus in evaluating whether the sounds received at a given sonobuoy location might be expected to include industrial components. In situations where industrial noise is absent, spectra and band levels will be tabulated as a function of sea state and ice conditions.

Zone of Potential Noise Influence

The BBN/LGL/MMS site-specific noise study is estimating the potential zones of noise influence around various industrial sources that might operate at several sites in the Alaskan Beaufort Sea. The Corona site is one of the sites of interest in that study. No zone of influence estimates were made for Corona in the 1985 phase of that study, but such estimates probably will be made for Corona in 1986.

Most of the types of data to be acquired in this study will be relevant to the task of defining the probable zone of influence around Corona. Such data include propagation loss data, long-term measurements of variation in noise, data on source levels and characteristics of noise from each vessel, and ambient noise data. The BBN/MMS study will not be able to acquire as much information of these types as is to be acquired in this study, since Corona is only one of several sites of interest in the BBN/MMS study. We will also acquire data on bowhead responsiveness, which the BBN/MMS fieldwork is not addressing. On the other hand, BBN/MMS will probably perform sound propagation measurements near Corona using test tones; such measurements would be valuable in developing a propagation loss model for Corona, but there is no need to duplicate them in this study.

Subject to negotiations amongst Shell, MMS, BBN and ourselves, we propose to cooperate with the BBN/MMS study to the mutual advantage of both studies. As noted earlier, LGL would be involved in both projects, and could efficiently coordinate the two efforts to minimize overlap and maximize the overall quantity of data acquired. In that way, the sound propagation model and zone of influence analyses being developed for Corona in the BBN/LGL/MMS site-specific noise level would make use of the detailed data to be acquired in this study. In addition, their results would be taken into account in our interpretation of the acoustical and behavioral measurements to be obtained in this study for Shell.

Logistical Considerations for Acoustics Program

Having worked at Hammerhead on Canmar Supplier I for three weeks, then at Corona on Robert Lemeur for two days in 1985, we have first hand experience with the benefits and difficulties of conducting acoustics work from the vessels supporting a drillship operation in the Beaufort Sea. Although the details may change somewhat, we expect the basic elements and operational aspects to be similar at Corona in 1986 as they were at Hammerhead in 1985. We believe we can accomplish our objectives without interfering with the operational requirements and constraints of the drill-site vessels. In this section of the proposal we review those requirements and constraints, our personnel and facilities requirements, and how we propose to accomplish our objectives using the available support or a chartered boat.

Review of the Drillsite Vessels

The drillship, Canmar Explorer II, will normally be fixed in an 8-anchor mooring for drilling. The ship has very limited berthing space compared to the demands of the ship's crew, the drilling crew, and the "Company Men", in this case personnel from SWEPI and its two partners. From time-to-time space is required by contractors for welding crews, well-logging teams, divers, etc. In 1985, neither work nor living space was available on the drillship for the two-person acoustics crew. Furthermore, Coast Guard regulations prohibit any electrical equipment, even passive receiving antennas, from being installed on the derrick unless stringent fire and explosive atmosphere requirements are met. Generally this means the equipment must be enclosed and purged by an inert gas. In its favor, the drillship is a communications center, with telephone, radio, and facsimile equipment; it is where the drilling activities occur; and it is where the on-site decision makers are.

At Hammerhead, Canmar Supplier I was the primary relief vessel for the drillship in the event of a hydrogen sulfide gas emergency and had to be within 20 minutes range (3 n.mi., 5.6 km) if drilling or testing operations were underway. Supplier I was equipped with the precision navigation system and was responsible for anchor recovery in the event the drillship had to be moved off site to avoid ice encroachment. Thus, her deck was kept clear. She had a crew of 13 and bunks for three passengers. Storage and work space were both at a premium. At Hammerhead, the two-man acoustics crew was berthed on Supplier I, setting up the sound recording apparatus in a "corner" of the bridge, partially blocking a passageway. If we had had on-site analysis equipment, the most suitable place for it would have been on a mess table in the galley. Our equipment was stored with the cook's dry stores, in the laundry, and in the winch room. There was only an unsatisfactory "portable" telephone that required the ship to be within 50 m of the drillship for operation. The ship had a 14 ft Boston Whaler that we used for a sound boat, but we were not allowed beyond 3.7 km from Supplier I for safety reasons.

Robert Lemeur is a Class 3 icebreaking supply ship. At Hammerhead she was used for icebreaking and for storing equipment from the drillship; her deck was fully loaded. This vessel has a 2-tonne crane. She had a crew of 16 and berthing for 10 passengers. Her passenger quarters were often assigned to workers who might otherwise have been on the drillship--there were nine welders on board in late August 1985, for example. A precision navigation system was installed and operating when Robert Lemeur was at Corona late in the 1985 season, but this system was not operating at Hammerhead in early September. The ship had adequate storage and work space. The ship's office was spacious and largely unused--it would be well-suited for our on-site analysis equipment. There was room on the bridge for the receiving/recording equipment. There was a telephone.

Canmar Supplier VII was the third support vessel at Hammerhead. She performed general icebreaking and supply boat functions. She did not have a precision navigation system. Her crew numbered 13 and she had berthing for six passengers.

All the support ships performed icebreaking. An ice observer on the drillship plotted ice drift and periodically notified the other ships of the ice drift directions and speed. The icebreakers would work along the line of drift to push the larger pieces away. It was not unusual for the icebreaking to occur at distances of 12 km from the drillship. Supplier I would sometimes work close to the drillship to free the anchor lines of ice floes. The drillship would operate its transverse thrusters to repel ice from the side of the ship.

Operational Requirements, Acoustics

Drillsite Noise (Subtask 1). We require a quiet boat (engine off) from which to make 3-minute sound recordings from a vertical string of three hydrophones suspended from a sparbuoy to a depth of 30 m. These recordings will be made at distances from 0.2 to 15 km (8 n.mi.) from the drillship. No "mother ship" can be in the vicinity--our experience at Hammerhead demonstrated that significant noise was received even from an idling supply boat at 3.7 km range. The measurements are to be made at three or, if possible, four aspects from the drillship and on three separate occasions, including at least once after migration has begun. Range measurement will be by optical range finder at short ranges (0.2-1.0 km) and by ship's radar at longer ranges. We propose to provide an inexpensive but functional radar target for the sound boat.

In addition to the acoustics crew on the Canmar vessel, we propose to use two scientific crew on the sound boat. They will deploy the hydrophones, operate the tape recorder, and complete log sheets. There will be someone on the drillship observing and recording activities from the rig floor and transmitting brief descriptions to the crew of the sound boat.

Individual Vessel Noise (Subtask 3). Again, we require a quiet sound boat from which to deploy the sparbuoy and vertical string of three hydrophones for recordings. We propose to operate remotely from the drillship, 15 km if possible, to reduce the level of interference from the drillsite. Radiated noise from each support ship will be measured in turn. We propose to have each ship begin at range 3.7 km, run at standard speed past the sound boat (closest point of approach 100 m), and then continue away to range 3.7 km. This type of run will provide a measure of the aspect dependence of the sounds, from bow to stern. The sounds of each ship's thrusters, and the sounds from the ship while idling, will be recorded. We propose to measure sounds of icebreaking by having each ship push on an ice floe in the "bollard" condition of full power but little or no forward progress, then shift into reverse and back away, then shift back to full ahead and ram the ice, all at measured distances. We propose to record sound from these icebreaking operations at both stern and beam aspects, and the bow if possible, because the propeller nozzles are likely to make the radiated noise highly aspect dependent. Two acousticians and the boat operator will constitute the team for these measurements, with a watchstander on the bridge apprising us by radio of the ship's power settings, etc.

<u>Moored Buoy Array (Subtasks 2 and 4)</u>. We propose to install the array 12-15 km from the drillship, subject to review before the field season. The support ship used must have a precision navigation system and be of sufficient size to handle the 50 kg anchors and the 12-m sparbuoy.

Calibration of the Moored Buoy Array will involve two tasks. (1) It is desirable to use the sound boat and its hydrophone string to approach each buoy and record the sounds at depth 30 m for comparison with the buoy signals being transmitted. (2) It is essential to calibrate the localization capability of the array by projecting a known underwater sound signal at known distances and bearings relative to the array. Such calibration requires a sonic projector weighing 70 kg. It helps to have 120 v a.c. power, although the system can be operated from several large batteries. The precision navigation system is required, but the vessel does not have to be quiet. Ideally data are desired from eight directions to distances of 15-20 km.

To monitor the array signals a vessel with space for a VHF antenna high on the ship, unobstructed by masts or other antennas, is needed. Work space on the bridge is needed to monitor and record the signals from the array; it is important for the observer to know what is happening around the ship--to have access to the radar, the navigation displays, and the marine radio. Other space is needed for the on-site signal analysis equipment.

Proposed Logistical Support

We believe we can operate from Robert Lemeur without interfering with her normal operations. Two people would constitute the acoustics team on Robert Lemeur until migration begins and 24 hr/day monitoring is required. Then, we propose a third person, perhaps a locally hired native, to assist.

The preferred method of making the drillsite noise measurements at long (15 km) ranges is with a small, independent sound boat. This boat would have a scientific crew of two. We propose to arrange to charter a boat from Prudhoe Bay for three week's work at Corona. We have checked on the availability of a boat on the order of 12 m long, and it appears that several are available.

An alternative is to use air- or boat-deployed sonobuoys at remote locations from the drillsite. This is the least desirable option because of possible problems with reception of the sonobuoy signal, interference from ice, and only one hydrophone depth.

TASK 2. BOWHEAD BEHAVIOR

Design Considerations

The principal objective of this study is to determine how bowhead whales react to an offshore drilling operation involving a drillship, an icebreaker, and two ice-breaking supply ships. The most direct and effective way of assessing whale reactions is to observe the whales from a circling aircraft when they are within and outside the zone of potential influence of the drilling operation. This observational technique is the core of the research program that we are proposing. However, we believe that the scientific value of the resulting data can be enhanced if the behavior observations are integrated with other techniques.

These other techniques are all designed to enhance the collection of behavioral data and/or to support the interpretation of the data collected. In all cases where more than one technique is feasible, the conduct of quantitative behavioral sampling will take priority. The other techniques discussed below are ancillary and supportive of the behavior objectives. The actual integration of the various techniques is discussed in subsequent sections. The main factors considered in setting priorities among the techniques are discussed in the section on 'Sampling Protocol' at the end of the discussion of Task 2.

Statistically, the most desirable behavior observation technique is to follow and observe a group of whales as it approaches, enters and leaves the zone of detectable underwater noise from the drilling operation. This technique provides the data for a paired comparison of the behavior of the same whales in undisturbed and potentially disturbed conditions. This approach will avoid many of the uncertainties and variables that would occur if different whales were observed in the presence and absence of industrial activity. The technique depends upon being able to find the same whales on successive aircraft flights and being able to reidentify naturally-marked whales. Unambiguous reidentification depends on the use of aerial photography. (A program of tagging whales as they approach Corona would introduce a bias [tagging disturbance] that could confound interpretation of response patterns of whales that reached the drilling operation even after being tagged.) In addition to allowing subsequent reidentifications of groups of whales for behavior observations, the photographic technique can provide other important information. For example, if some whales stop and feed near the Corona site, then it may be possible to document the residence times of individual whales through photographic reidentifications. This capability is particularly valuable if whales are seen in the vicinity of the drilling operation on several consecutive days. Documentation of residence times using aerial photography was successful in the MMS-funded study of bowhead feeding in the eastern Alaskan Beaufort Sea in 1985 (W.J. Richardson, LGL Ltd., pers. comm.).

It has now been well documented that the various age classes of bowheads are geographically segregated on the summering grounds in the Canadian Beaufort Sea and Amundsen Gulf (Davis et al. 1982, 1983, 1986, in prep.; Cubbage et al. 1984). It is reasonable to assume that the various age and reproductive classes may also be partially segregated during their fall migration through the Alaskan Beaufort Sea. Thus, it is unlikely that a random sample of the population will be exposed to drilling operations, which occur relatively close to shore. There is evidence that bowheads that occur near drilling activities in the Canadian Beaufort Sea tend to be small, subadult animals (Richardson et al. 1985b; Thomson et al. 1985; Davis et al. 1986). The larger animals, i.e. breeding and non-breeding adults, occur in other areas. There is also some limited evidence that behavior of subadult animals near industrial activity differs from adult behavior in undisturbed areas (Davis et al. 1986). These findings suggest that it would be useful to determine the approximate age (= length) and reproductive status (subadult, adult with calf, etc.) of animals that pass near the drillsite. This is especially important if different behavioral responses occur in different age classes.

Interpretation of the significance of the behavioral data depends on having reliable acoustic data. The principal components of the acoustics study are presented in Task 1. However, we emphasize here that it is necessary to document the specific levels and spectral characteristics of the underwater sounds to which the whales are exposed throughout the periods when whale behavior is being systematically quantified. This will be accomplished by deploying sonobuoys near the whales. Use of sonobuoys for this purpose has been a standard method in previous and ongoing behavioral studies for MMS. These data are required to provide unambiguous data on noise exposure to determine whether bowheads respond to particular levels and/or types of noise, and to unambiguously assign samples of behavioral data to undisturbed or potentially disturbed categories. It is not possible to accurately predict noise levels at various distances and bearings from the drillsite at any particular time, since transmission loss and received levels are a complex function of depth, bottom characteristics, ice conditions, temperature/salinity profiles, and wind conditions. In addition, noise levels received near whales depend on all ship traffic (supply ships, barges), seismic operations, and icebreaking activities in the general area, not just those at the drillsite. Thus, direct measurements of noise levels received by the whales that are under observation are essential for meaningful interpretation of their behavior.

In previous years, the most ubiquitous and intense industrial noises that have been recorded near bowhead whales have originated from the airguns used for seismic exploration. Seismic noises were present throughout the 10 days (5-15 September) of operation of a moored hydrophone array at the Hammerhead site in 1985. Hammerhead is only about 45 km west of Corona. Similar levels of seismic noise would be expected in 1986 unless there is a general decline in seismic activity or heavy ice cover that would curtail seismic operations. To interpret the behavioral observations it is important to know whether the whales that are under observation near a drillship are also being exposed to seismic pulses. Thus, it is necessary to use sonobuoys to measure noise levels near the whales during each session of behavioral observations.

One of the major considerations in designing this type of study is to obtain data that are relevant and interpretable. The study outlined in the RFP will provide valuable results if whales occur near the Corona site. However, in some years very few whales occur in the area (e.g, 1985). In such a situation, even intensive efforts near the Corona site might fail to find whales. Interpretation of the absence of whales near the site is likely to be quite controversial. It could be argued that whales avoided the site, and that such avoidance occurred at distances beyond the search area. It is important, therefore, to be able to place the absence of whales near the site in the context of distribution in nearby areas. In previous studies (Seal Island, Sandpiper Island, Hammerhead) this context has been provided by systematic aerial surveys. We believe that a modest program of systematic aerial surveys beyond the immediate vicinity of the Corona site would provide the data needed for interpretation in the eventuality that no or few whales are seen near Corona. Reduced survey coverage relative to that in previous studies is desirable to allow more time for behavior studies. The reduced survey coverage can be partially supplemented with survey coverage that will be provided by our MMS-funded study of bowhead feeding; that study will include some systematic surveys in their study area, whose western boundary is only 30 km east of the Corona site. In addition, less intensive broad-scale distribution data will again be available from the MMS survey program conducted by Don Ljungblad of NOSC.

Systematic aerial surveys around Corona are necessary not only to document distribution patterns around the site, but also as a means of finding whales for behavioral observations. The most efficient way of conducting these searches is to use systematic surveys supplemented by real-time monitoring of bowhead calls received by the moored hydrophone array east of the drillship (see Acoustic section, Subtask 4). It is important that some whales be located sufficiently far from Corona to allow behavioral observations in undisturbed 'control' conditions. Survey coverage east of the site would increase the probability of finding whales that could be followed toward the site.

The above summary outlines some of the factors to be considered in the design of the proposed study. The principal focus of the study is the collection of quantitative data on the behavior of whales in undisturbed ('control') and potentially disturbed (industry noise present) situations. Where possible, the same individual whales are to be observed as they move past the drillsite. A variety of other techniques can also provide useful information and should be integrated into the study. The details of the proposed study are provided in the following sections.

Study Area

The principal objective of the proposed study is to determine how bowhead whales react to the presence of an offshore drilling operation. It is necessary to maximize the number of samples of behavior of potentially disturbed animals while also obtaining representative samples of undisturbed behavior.

Therefore, the potential zone of influence of sounds from the drilling operation should be taken into account when determining the size of the study area. It is important that behavioral and other observations begin sufficiently far to the east of the drillsite to provide unequivocal 'control' observations of undisturbed whales. Although we have observed bowhead whales as close as 4 km from Explorer II (Richardson et al. 1985a,b), there are reasons to believe that some bowheads might be affected by noise from the drillsite at considerably greater ranges.

1. When recorded sounds from Explorer II were played back into the water near whales, some bowheads showed weak avoidance reactions when received levels of drillship sound equalled those as much as 12-16 km from the actual drillship (Richardson et al. 1985b, in prep.). These figures are based on the 1/3-octave band of maximum drillship noise : ambient noise ratio. This is the band that is being considered in the ongoing BBN/LGL/MMS site-specific noise and disturbance project.

2. Some other bowheads apparently did not react to playbacks of recorded drillship noise when received levels in that 1/3-octave band equalled those as little as 4-6 km from the drillship.

3. While bowheads have been seen within a few kilometers of actual drillships, including Explorer II, these 'closest' individuals may have been representative of relatively insensitive individuals like those noted in (2), above. Whales like those noted in (1) may avoid areas this close to drillships.

4. These results came from shallow waters of the Canadian Beaufort Sea, where sound propagation conditions are different than those near Corona. The above results also were obtained in the absence of icebreaking and its associated noise. Hence, zones of potential influence near Corona would be expected to differ.

5. Preliminary noise propagation and zone of influence results from the BBN/LGL/MMS site-specific noise study for sites comparable to Corona indicate that bowheads might hear the drillship at ranges as great as 50 km on a day with average ambient noise conditions. This

assumes that whales can hear industrial noise if its level equals or exceeds the ambient noise level in the corresponding 1/3-octave band. Of more relevance, some bowheads would be expected to react to drillship noise up to 9-11 km east of Corona. This estimate is based on the observation that some whales react when the drillship noise level exceeds the ambient level in the corresponding 1/3-octave band by at least 20 dB (Richardson et al. 1985b, in prep.). Subtle reactions may sometimes occur at ranges greater than 9-11 km, especially at times when the noise levels are elevated by intensive icebreaking operations.

These estimates of possible zone of influence are preliminary and subject to considerable uncertainties (BBN and LGL, in prep.). However, it is apparent that some behavioral data need to be acquired at distances well in excess of 10 km. We recommend that whales approaching the drillsite be observed from the time when they are at least 15-20 km away whenever this is possible, and that a sample of behavioral data be acquired at distances exceeding 20 km.

Based on these considerations we propose that an 'Intensive' survey grid be established to find whales for subsequent behavioral observations (see later section on Aerial Surveys). The proposed grid is 44 km by 40 km, offset from the drillsite so that the grid extends 28 km to the east and 16 km to the west of the site. In addition, an expanded search area would be used in some circumstances, primarily when no whale are present in the 'Intensive' grid (see sections on Aerial Surveys and Sampling Protocol).

Behavioral Observations

The principal objective of this study is to determine how migrating bowhead whales react to an operating offshore drilling operation. It is important to realize that the operation involves more than just a stationary anchored drillship. Two large ice-breaking supply ships and the Class 4 icebreaker Robert Lemeur will support the operation. Each of these vessels can generate substantial amounts of underwater noise. The icebreakers may operate at considerable distances (several km) from the drillship.

Field Methods

Standardized aerial observation procedures for systematically studying and comparing bowhead behavior near and far from industrial sites have been developed by LGL in 1980-84 (e.g., Richardson et al. 1985a,b). These same techniques are now (1985-86) being used in LGL's ongoing study of the feeding behavior of bowheads in the eastern Alaskan Beaufort Sea. The same methods will be applied here.

Observers in a Twin Otter aircraft will circle around the whales at an altitude of at least 1500 ft, which has been demonstrated to be high enough to avoid disturbance by the aircraft. While circling the whales, the aircraft crew will dictate systematic observations of whale behavior into tape recorders. Whale behavior will also be videotaped to supplement the real-time observations. Underwater sounds to which the whales are exposed will be recorded by sonobuoy techniques, as will bowhead calls. Activities and behavioral variables to be recorded will include the following:

- General activities of the whales will be noted: e.g., traveling, resting, socializing, feeding (at the surface, near the bottom, or in the water column).
- Relative speeds will be estimated for each surfacing (nil, slow, moderate, fast, as in our 1980-84 and 1985-86 behavioral studies).
- The presence of any cow-calf pairs will be noted.
- The heading of each whale will be noted at the start of each surfacing, and any turns during the surfacing will be recorded.
- Positions will be determined from the aircraft's VLF navigation system and relative to dye markers, ice pans and industrial activities. Dye markers will be used to permit the aircraft to remain above the whale's location while the whale is invisible below the surface.
- One or more sonobuoys will be dropped near the whales during each behavioral observation period; the signals will be monitored and recorded with calibrated equipment on the aircraft, in order to document industrial sounds reaching the whales as well as whale calls and call rates (see Acoustics section, Subtask 5).

- Standard behavioral data will be dictated into tape recorders; these data will include surface and dive times, respiration (blow) intervals, number of blows per surfacing, occurrence of pre-dive flexes, fluke-out dives, aerial behaviors (breaches, tail and flipper slaps, rolls, spy-hops), turns during surfacings, underwater blows, defecation.

Most of these data will be recorded in a systematic way for each surfacing of the 'focal' whales on which observations are being concentrated. Our procedure, as in past studies, will be for one behavior observer to watch the focal whale or group through binoculars to discern details of behavior, while another watches with the naked eye. The latter observer is better able to estimate headings, distances apart, and other aspects of behavior that require a broad field of view. Both observers dictate their observations through voice-actuated noise-cancelling headset-mounted microphones into a common intercom channel, which is fed into a continuously running audio tape recorder. A third biologist videotapes the whales that are being observed; the behavioral dictation is also recorded on the audio channel of the video recorder for backup and to facilitate later analysis of the videotape. The operator of the video camera monitors the behavioral dictation in real time, and prompts the two primary observers for any standard information about each surfacing that they may have neglected to dictate. The fourth biologist aboard the aircraft deploys sonobuoys and operates the sonobuoy receiving and recording equipment. He also watches for whales on the 'outside' of the area being circled, i.e. on the opposite side of the aircraft from the other observers.

As soon as possible after each flight (ideally the same evening), the behavioral dictation is transcribed onto standard data forms. Then the videotape is reviewed for any details not noticed in real time. (The real time dictation is generally very complete when only one or two whales are being observed at a time. However, some details are often missed when several animals are interacting. This information can be recovered from the videotape.) The transcription is checked by a second member of the field crew. Then the transcribed behavioral data are then recorded in a standard numerical fashion with one data record for each surfacing and each dive of each whale (Fig. 10). This same systematic data format has been used for all of LGL's systematic behavioral studies in the 1980-85 period, and will be used again in the 1986 phase of the LGL/MMS bowhead feeding behavior study.

BOWHEAD BEHAVIORAL DATA Date= ___ ___ 19___ Platform= ________ Flight #= ____ Behav. Obs. Sess. #= ____ Lat.= ___°___'N Long.= ___°___'W

Observers = ________ Coder = _____ Checker = _____

MON= DAY= FLIGHT= TSTART= : : TEND= : : SEAST= ICE= %

Date			ID	Time (local)			Blow Intervals (in sec)														No. of Blows	Durat.	Dur. Subsequent	Head-	Deg. of	Dis-	Water	Aircr. Alt (ft/100)	Dur. Preceding	Grp	Seq	Pos'n re Disturb.	
Mon	Day	Yr	No.	Hr	Min	Sec	1	2	3	4	5	6	7	8	9	10	11	12	13	14		Sfc. (s)	Dive (s)	ing	Turn	tur	Depth (m)		Dive (s)	Size	No.	Dist. (km)	° from Dist.

Figure 10. Example of standard LGL data form for recording bowhead whale behavioral data.

It is important that the behavioral data be collected in a standardized, systematic and objective way. This is necessary to avoid observer expectancy bias and to allow meaningful comparisons of behavior near vs. far from industrial sites. To allow comparisons with results from previous studies of bowhead behavior, it is also important that the data be collected and recorded in a manner consistent with those of previous aerial observation programs. It is difficult to observe some of the subtleties of bowhead behavior from an aircraft circling at an altitude of 1500 ft (457 m) and at a radius of about 1000 m. If the light is poor or the sea state is high, it is often difficult to discern details of behavior; for example, blows may not be seen. Experienced observers are essential in order to maximize the quantity and reliability of the observations. Equally important, experienced observers are necessary in order to recognize when the observations should be considered unreliable and should not be used in quantitative analyses.

The proposed aerial crew includes two individuals (R. Wells and S. Swartz) who have 2-3 seasons of experience as behavioral observers in previous MMS-funded systematic aerial studies of bowhead behavior, as well as other relevant experience. They have used the same observation procedures as are proposed here. In addition, one of the proposed project supervisors (W.J. Richardson) directed the LGL/MMS bowhead disturbance project in which these observation and data recording procedures were developed (1980-84); he is continuing to use those procedures in the LGL/MMS bowhead feeding study (1985-86).

A key requirement for meaningful behavioral observations is to obtain a long series of data from one or a few individuals rather than fragmented data from each individual that appears at the surface. This requires considerable experience and discipline amongst the observation team, since several whales are commonly found in the same general area. The natural inclination is to observe one whale for the minute or two until it dives, and then to move to the location of the next whale that is sighted, and then to still other whales. This unsystematic approach usually results in failure to resight any one individual. Behavioral observations of bowheads are difficult to acquire because the animals are generally below the surface and invisible for 70-90% of the time. Dives commonly last 10-25 minutes, and the whales commonly travel 0.25-1 km during a dive. It is critical that the observers note individually distinctive markings on the animals so that individuals can be recognized from one surfacing to the next.

The highest priority whales for study will be those that are first detected as they are heading generally toward the drilling operation from the east. Observations of such whales will have the greatest potential to determine whether, and at what range from the drillship, any deflection or behavioral change becomes evident. We will attempt to follow such whales for as long as possible as they approach, pass, and move away from the drilling operation. Whenever whales that are individually recognizable from natural markings are present, we will concentrate observations on these individuals.

Analysis of Behavioral Data

From the positional, heading and relative speed information acquired during successive surfacings, the courses and actual speeds of traveling whales will be estimated and mapped. Emphasis will be placed on determining the closest point of approach (CPA) to the drillship, or nearest support vessel, and whether there was any deflection or change of speed as the whales approached. We will use sonobuoys to determine noise exposure at one or two locations along the course, and to estimate exposure at other locations. Particular emphasis will be placed on documenting underwater sounds at any point of deflection and at CPA.

General activities of all whales seen will be tabulated in relation to distance from the drilling operation. General activities will also be tabulated in relation to the measured level of industrial noise when this is available from sonobuoy measurements. We will assess whether there is evidence that traveling is more common and other activities less common for the whales that are closest to ships.

For whales whose behavior was observed at various distances from the drillship, we will analyze the detailed behavioral parameters in relation to distance from the ship using correlation techniques. For example, surface times and number of blows per surfacing often decrease when bowheads are subjected to industrial disturbance (Richardson et al. 1985a,b). We will determine whether these and other behavioral variables are correlated with distance from the ship for any whales that are observed at various distances.

The systematically coded behavioral data (Fig. 5)) will be entered into a microcomputer and checked for internal consistency with LGL programs developed for validation of this specific data format. The data from each observation session will be summarized by another LGL program that summarizes and compares quantitative behavioral data acquired during different phases of an observation session, e.g. while a traveling whale was at different distances from the drillsite. Table 1 shows sample output from this program. Another program is available to convert the data from the format of Figure 10 into a form suitable for direct analysis by standard multivariate analysis programs. If appropriate, the behavioral data acquired in this study can be compared directly with results from the 1986 (or earlier) LGL/MMS behavioral studies; all of the data are in computerized data files in the same format.

Readers interested in more details of the analysis techniques are referred to the final report of the five year MMS-funded study of bowhead behavior on the summering grounds (Richardson 1985b).

Acoustical Studies Near Bowheads

The major acoustical study efforts are described in Task 1, which includes a moored hydrophone array that can track calling bowhead whales and provide an extended time series of data or variations in industrial noise from the drilling and associated operations. Detailed measurements will also be obtained of the source levels and spectral characteristics of sounds from the overall drilling operation and from its component parts. As discussed earlier, these measurements will not provide detailed data on the noise levels actually present in waters where whale observations are being made. Sonobuoys will be used for this purpose.

Table 1. Example of output from LGL program that tabulates and compares behavioral data aquired in different phases of a behavioral observation session. This example shows results from a playback of "Explorer II" sounds near bowheads on 18 August 1983. Observations during pre-playback control, playback, post-playback, and final control phases are compared. Behavioral variables considered include number of blow per surfacing, (NBLOWS), length of surfacing (LENSFC), blow intervals (BI and MEANBI), length of dive (LENSUB), speed of motion (MOTION), and occurence of turns, pre-dive flexes, and pre-dive 'flukes-out' (TURN, FLEX, FLUKES).

BOWHD.FILE.SUMMARY W.J. RICHARDSON LGL LTD. VERSION 1.2

INPUT FILE = TWG/18AUG83A.12DEC83,S5,D1 # CASES = 159 RUN DATE = 850204

PHASE DEFINITIONS USED:

PHASE	TYPE	MIN	MAX
CONTROL2	T	12.36	13.02
MID-PLBK	T	13.07	13.3659
POSTPLBK	D	22	22
CONTROL3	T	14.12	14.39

--- NBLOWS ------	MEAN	SD	N	MIN	MAX	SUM	SUM OF SQ
ALL NON-CALF	3.085	2.199	59	0	10	182	842
ALL UNDIST. NC	2.806	2.068	36	0	7	101	433
TOT.PHASES, NC	3.273	2.322	33	0	10	108	526
CONTROL2	2.5	2.07	8	0	5	20	80
MID-PLBK	2.733	1.831	15	0	6	41	159
POSTPLBK	5	3.162	6	1	10	30	200
CONTROL3	4.25	2.217	4	1	6	17	87

F = 2.106 DF = 3,29

--- LENSFC ------	MEAN	SD	N	MIN	MAX	SUM	SUM OF SQ
ALL NON-CALF	.782	.546	62	.03	2.22	48.467	56.082
ALL UNDIST. NC	.774	.502	39	.03	1.53	30.167	32.925
TOT.PHASES, NC	.776	.584	33	.03	2.22	25.617	30.812
CONTROL2	.665	.476	8	.03	1.33	5.317	5.117
MID-PLBK	.626	.556	15	.05	2.05	9.383	10.202
POSTPLBK	1.164	.75	6	.25	2.22	6.983	10.944
CONTROL3	.983	.477	4	.35	1.5	3.933	4.549

F = 1.554 DF = 3,29

--- BI ------	MEAN	SD	N	MIN	MAX	SUM	SUM OF SQ
ALL NON-CALF	14.54	6.946	215	-9	-9	3126	55774
ALL UNDIST. NC	14.7	7.96	110	-9	-9	1617	30677
TOT.PHASES, NC	14.318	7.09	148	-9	-9	2119	37729
CONTROL2	11.321	4.667	28	-9	-9	317	4177
MID-PLBK	14.952	6.155	63	-9	-9	942	16434
POSTPLBK	13.207	2.957	29	-9	-9	383	5303
CONTROL3	17.036	11.689	28	-9	-9	477	11815

F = 3.629 DF = 3,144

--- MEANBI ------	MEAN	SD	N	MIN	MAX	SUM	SUM OF SQ
ALL NON-CALF	15.106	6.24	78	7	45.5	1178.283	20797.955
ALL UNDIST. NC	15.759	7.622	39	8	45.5	614.583	11892.742
TOT.PHASES, NC	14.727	6.504	53	7	45.5	780.55	13695.431
CONTROL2	11.239	2.226	9	8	15.4	101.15	1176.445
MID-PLBK	14.899	5.164	26	7	25.5	387.367	6437.977
POSTPLBK	13.427	1.875	8	9.75	15.5	107.417	1466.896
CONTROL3	18.462	11.575	10	9	45.5	184.617	4614.114

F = 2.22 DF = 3,49

... continued

Table 1. cont'd.

INPUT FILE = TWG/18AUG83A.12DEC83,S5,D1 # CASES = 159 RUN DATE = 850204

--- LENSUB ------	MEAN	SD	N	MIN	MAX	SUM	SUM OF SQ
ALL NON-CALF	2.565	2.677	23	.12	9.3	59	309.064
ALL UNDIST. NC	3.133	1.942	11	.9	7.55	34.467	145.702
TOT.PHASES, NC	2.344	3.057	14	.12	9.3	32.817	198.451
CONTROL2	-9	-9	0	-9	-9	0	0
MID-PLBK	1.42	2.971	9	.12	9.3	12.783	88.79
POSTPLBK	3.917	3.778	3	.43	7.93	11.75	74.573
CONTROL3	4.142	.884	2	3.52	4.77	8.283	35.088

--- MOTION ---	0/UN- KNOWN	1/ NONE	2/ SLOW	7/MOD ERATE	3/ FAST	4/UN- SPEC.	5/ MILL	6/CH- ANGE	8/NO- SOME	9/SO- NONE	TOTAL
ALL NON-CALF	49	4	21	46	3	3	0	6	0	1	133
ALL UNDIST. NC	24	3	11	23	0	3	0	5	0	1	70
TOT.PHASES, NC	30	2	17	32	3	1	0	1	0	0	86
CONTROL2	6	1	1	9	0	1	0	0	0	0	18
MID-PLBK	16	0	4	18	3	0	0	1	0	0	42
POSTPLBK	5	1	4	3	0	0	0	0	0	0	13
CONTROL3	3	0	8	2	0	0	0	0	0	0	13

--- TURN ---	0/NO- TURN	1&2/1 TURN	3-5/ >1 TU	TOTAL
ALL NON-CALF	46	13	0	59
ALL UNDIST. NC	28	8	0	36
TOT.PHASES, NC	25	8	0	33
CONTROL2	6	2	0	8
MID-PLBK	12	3	0	15
POSTPLBK	4	2	0	6
CONTROL3	3	1	0	4

--- FLEX ---	0/NO FLEX	1/ FLEX	TOTAL
ALL NON-CALF	76	7	83
ALL UNDIST. NC	42	6	48
TOT.PHASES, NC	52	2	54
CONTROL2	10	1	11
MID-PLBK	23	0	23
POSTPLBK	9	0	9
CONTROL3	10	1	11

--- FLUKES ---	0/NO FLUKE	1/FL- UKES	TOTAL
ALL NON-CALF	99	6	105
ALL UNDIST. NC	55	2	57
TOT.PHASES, NC	59	5	64
CONTROL2	11	0	11
MID-PLBK	28	2	30
POSTPLBK	9	2	11
CONTROL3	11	1	12

Industrial Noise Near Bowheads

To determine the characteristics and levels of noise to which bowheads are exposed, the aircraft will be used to drop sonobuoys near whales (see Acoustics, Subtask 5). Emphasis will be placed on whales that are potentially near or within the area ensonified by the drilling operations, including ice management. Sonobuoys will be dropped near the whales on each occasion when behavioral observations are made.

We will use AN/SSQ-41B or AN/SSQ-57A sonobuoys (which are functionally equal) set for maximum endurance (nominally 8 h). The sonobuoys are designed to operate in waters over 18 m deep, which will be suitable for this project. We will also provide some sonobuoys specially built for use in water as shallow as 10 m, in case they are needed. These special shallow-water sonobuoys were acquired and used successfully in LGL's 1985 work for Shell (Sandpiper Island) and for MMS (feeding behavior study). The sounds detected by the sonobuoy's hydrophone will be broadcast by the sonobuoy's radio transmitter to a calibrated receiving and recording system on the aircraft. To ensure that information necessary for quantitative analysis of the sonobuoy data is available, the crew member responsible for operating the sonobuoy system will dictate voice announcements into the sonobuoy system's tape recorder, and will fill out standard LGL sonobuoy log-sheets (Fig. 11).

The sonobuoy recordings will be analyzed to determine the received levels and spectral characteristics of the industrial and ambient sounds to which the whale(s) are exposed. Recorded sounds will be analyzed in the Greeneridge Sciences laboratory using the computerized acoustic analysis system described by Greene (1985) and in the Acoustics section of this proposal. This analysis system makes full allowance for the fact that sonobuoys do not have a 'flat' frequency response; they are more sensitive to high than to low frequencies. The analysis system applies the appropriate calibration curve to allow for the 'sloped' frequency response of the sonobuoys. The results of the analysis will document the sounds to which bowheads were exposed in terms of their power spectra, 1/3-octave band levels, and broadband levels.

SONOBUOY SIGNAL RECORDING LOG Date________ Platform________ Purpose________ Page __ of __

Flight #____ Beh.Obs.Sess.#____ Operator____ Tapes & Logs ✓____ Cross ✓____

	Left Ch.	Right Ch		Left Ch.	Right Ch.		
S'buoy Type			Launch Time			Recorder #	
S'buoy Ch #			Launch Alt.			Sea State	
S'buoy Ser #			Launch Lat.			Sky Cover	
20 dB Atten?			Launch Long.			Visibility	
Depth Set'g?			Water Depth			Air Temp.	
Lifetime			Receiver #			Wind Speed	
Ice Cover			Converter #			Wind Dir'n	

- -Label tapes Axy for aircraft, Bxy for boat. Give date & start time on label.
- -Voice announcements on right channel at ~5 min intervals; give time, record levels, counter #, activities. Then disconnect microphone (mike interrupts line input).
- -Record level normally -7 to -5 dB, but don't allow peaks to saturate.
- -Announce & note rec.lev. changes.
- -Limiter off; mike atten. 0; Dolby on.

Chan # L	Chan # R	Tape #	Si #	Time (local)	Tape Counter	Rec.Lev L	Rec.Lev R	Whale Sounds or Activities	Industrial Sounds or Activities	Other Comments

Figure 11. Example of standard LGL sonobuoy log sheet.

These results will be directly comparable to the acoustic data from all previous and concurrent studies by LGL and Greeneridge for Shell, Union and MMS. The results will also be comparable to the noise data, sound propagation models and zone of influence analyses being developed by BBN and LGL for MMS as part of the ongoing site-specific noise and disturbance study. The BBN/LGL/MMS study emphasises 1/3-octave data, which are one of the data types produced by the Greeneridge analysis system.

Bowhead Call Rates

One of the major unknowns in evaluating the usefulness of a hydrophone array for monitoring bowhead migration is that it is not known how often fall-migrating bowheads call. It is, therefore, not known what proportion of the animals within range of the array are likely to be detected.

Call rates are quite variable. On some occasions when we have dropped sonobuoys near bowheads in late summer and monitored underwater sounds for an hour or more, no calls have been detected (Würsig et al. 1982, 1983, 1984b, 1985). On other occasions, high call rates have been recorded (20 or more calls per whale per hour). Occasions when high call rates were detected were usually occasions when the water was deep (100 m or more), the whales were engaged in social interactions, or both. The average call rate was 1 to 2 calls per whale per hour.

The present study will provide some data on call rates during fall migration. For each behavioral observation session an estimate is made of the number of whales present in the vicinity. We will determine the number of calls recorded by the sonobuoy in the water among the whales under observation. From these data, rough approximations of the number of calls per whale-hour can be made. This technique, of course, does not tell us whether all whales present were calling or whether only some of them called. Nonetheless, even the gross information on call rates obtained in the proposed study will be valuable for assessing the results obtained from an array.

Environmental Constraints on Behavioral and Acoustic Observations

Cloud Ceiling and Observation Altitude

Aerial observations of bowhead behavior should be obtained from an observation altitude of at least 1500 ft. This is the standard minimum altitude used in the MMS bowhead behavior studies. If bowhead behavior is observed from a lower altitude, it must be assumed that the behavior may have been affected by the presence of the aircraft. For example, respiration intervals of bowheads observed from 1000 ft altitude are significantly different than those of bowheads observed from 1500 ft or above (Richardson et al. 1985a,b).

Our normal procedure will be to conduct behavioral observations only when the downward view from 1500 ft is not obstructed by low cloud or fog. However, if whales are observed near or heading toward the drillsite and the ceiling is high enough to allow observations from 1000-1400 ft but not 1500 ft, we will observe whale behavior for at least a short time. This will allow us to document the general activities and route of travel of the whales. It must be recognized, however, that observations acquired from an aircraft circling below 1500 ft will not be fully comparable to those obtained from 1500+ ft, and may be confounded by aircraft disturbance. It should be noted that the sizes and individual identities of whales can often be documented by the photogrammetric method (see later), and noise exposure can be documented by sonobuoys, even if the ceiling is too low for meaningful behavioral observations.

High Winds and Sea States

Meaningful behavioral observations usually cannot be obtained when the wind speed exceeds about 15 knots and the sea state exceeds Beaufort 4. (An exception is the situation when it is windy but wave height is low because ice or a nearby shoreline reduces the fetch.) Under rough conditions, whales are difficult to sight when they first surface. This prevents accurate determination of the durations of surfacings and dives, or the number of respirations per surfacing. High sea states also hamper recognition of individual whales from one surfacing to the next. This makes it impossible to obtain long time series of data from specific individual whales. Experience has shown that attempts to observe bowhead behavior in rough seas do not produce interpretable data. Thus, behavioral observations normally will not be attempted under high sea state conditions.

Ice Conditions

There is some concern about the feasibility of making acoustic and behavioral measurements in the relatively heavy ice conditions than can occur, particularly in mid October. If sufficient open water is present to make behavioral observations, then sonobuoys can be successfully deployed into an open water area by the observation aircraft. Since the sonobuoy transmits to a receiver on the aircraft, there should be no problem recording the sounds to which bowheads are exposed, in spite of heavy ice conditions.

Apart from forcing drilling to cease, certain types of heavy ice conditions could also affect the study by making behavioral observations difficult or impossible. Extensive ice can make it impossible to follow whales and make observations of their behavior. The limiting factors here are the type of ice cover, the amount of ice cover, and the behavior of the whales under observation. If bowheads are stationary in an area, i.e., resurface near the locations where they last dove, then it is possible to make useful observations under heavier ice conditions than if the whales are moving through an area.

The configuration of the ice can be as important as the amount of ice. For example, evenly distributed brash and pan ice may cover only 20-50% of an area, but make it extremely difficult to find bowheads and to locate them as they surface. On the other hand, continuous ice may cover over 75% of an area but bowhead behavior can still be studied because the whales are concentrated into a few relatively distinct open water areas.

It is not possible to make firm statements about the amounts and types of ice, and combinations thereof, that will make behavioral observations futile. As noted above, the behavior of the whales themselves is also an important factor. However, during the LGL/MMS bowhead feeding study we were able to observe the behavior of migrating bowheads effectively under the very heavy ice conditions that prevailed north and east of Kaktovik in late September 1985. We were also able to study whale behavior in areas of 90%-100% cover by new ice. The presently proposed study will include observers with experience locating bowhead whales and studying their behavior in a variety of conditions, including whales traveling through areas of pack ice. Through use of experienced personnel, we expect to be able to acquire valid and useful behavioral data under almost any ice conditions that permit drilling.

Photographic Evaluation of Whale Size, Status and Identification

We recommend that an effort be made to measure and identify individual whales passing near the drillsite, as well as a sample of those found farther away. In 1981 and 1982, LGL developed a photogrammetric method to measure free-ranging bowhead whales. The method allows one to measure the size of the whale to an accuracy of a few percent. This, in turn, allows an evaluation of age if the whale is small, or maturity if the whale is larger. Through application of the photogrammetric method, it has been found that bowheads often segregate by age and reproductive status. Information about the occurrence or lack of occurrence of segregation by age or status is important in evaluating the effects of any disturbance or displacement of animals.

The same photographs that allow measurements of bowheads also show that many whales are individually recognizable through distinctive markings or scars. This capability for individual recognition provides a way to determine whether individual whales remain in an area of industrial activity (or any other area), or whether they are moving quickly through the area. If a recognizable bowhead is photographed near the Corona drillsite on more than one day, this would prove that the animal did not move quickly out of the area. The observation would be especially informative if the behavior of the animal was observed and a sonobuoy was dropped to determine the underwater noise to which it was exposed. In addition, in situations where bowheads are moving quickly it may be possible to rephotograph animals at intervals of a few hours. This would provide additional information on speed of movements and whether the whales are deflected by drilling operations.

Photogrammetric work would be done from the same aircraft used for behavioral observations. Photographs would be taken at the end of behavioral observation sessions. Thus, the individual identity and length (and thus age class) would be determined for a sample of the whales observed. This approach proved to be very practical and successful in the 1985 phase of the LGL/MMS feeding study, and will be applied in that study again in 1986. The amount of time spent in each photography session would be determined by the adequacy of the behavior observations, number of whales present, and aircraft fuel remaining.

Other projects in the summer and autumn of 1986 elsewhere in the Beaufort Sea will include photogrammetry and are expected to provide further comparative data at no cost to this project. Data from this project, in turn, will complement the other studies (e.g., MMS feeding study) and assist in an overall evaluation of various attributes of Western Arctic bowheads, including size and age composition, population segregation, and movements and growth of recognizable individuals.

Standard low-level photogrammetric techniques will be used (Davis et al. 1982, 1983, 1986). Calibration photographs will be acquired by applying the same procedures to photograph a target of known dimensions. By comparing the size of the calibration target as estimated from photos with its known size, any biases will be detected and a correction factor will be developed. For example, if the radar altimeter is consistently in error by 1 or 2%, raw length estimates will be similarly biased; this bias will be detected and corrected through the calibration process.

Sizes of bowheads will be determined by measuring the whale images and applying the correction factor developed by the calibration procedure. Duplicate photos of the same individual whale will be found by first categorizing the images according to the sizes and positions of white pigmentation on the whales, and then comparing all images within each category. Procedures for measuring and identifying whales will be fully consistent with those used in previous years (Davis et al. 1982, 1983, 1986) and on LGL studies in 1985 (SWEPI-Sandpiper Island; MMS eastern Alaskan feeding study; Alaskan Oil Industry-bowhead reproduction study).

Results to be acquired in 1986 will include the following:

1. Length-frequency data for correlation with behavior data in relation to distance from drilling operation and received noise levels.
2. Length-frequency data for whales near the drillsite and distant from the drillsite, subdivided by date within the migration season.
3. Data on minimum residence times for any whales re-photographed at the same location (near or distant from the drillsite).
4. Data on net speed and direction of movement for whales rephotographed at a different location, either on the same or a different day than the first photograph. Again, these data will be partitioned according to distance from drillsite.

The above types of data will be analyzed to determine whether size composition or movement patterns are detectably different close to the drillsite relative to those at more distant locations and whether the behavior of animals is a function of their age (= length).

All photographs of suitable quality for future re-identifications will be deposited in the bowhead catalog of the National Marine Mammal Laboratory in Seattle. As the accumulated number of photographs of bowheads increases, the amount of relevant information also increases. We now have 20 documented cases of whales photographed in more than one year in the Canadian Beaufort Sea, and a large number of within-year reidentifications. Any reidentifications of the same whale near the Corona operation on different dates in 1986, and in the same area in future years, would provide useful information on longer-term behavior patterns of bowheads. Reidentifications of whales photographed to the east during the LGL/MMS feeding behavior study would also provide data on rates of movement through the general Corona area.

Aerial Surveys of Bowhead Distribution, Numbers and Movements

Aerial surveys are necessary for two reasons. First, the surveys provide a systematic method of searching for whales to be used for behavioral observations. Second, the surveys provide important information on the distribution, numbers and movements of bowheads in relation to the drilling operation and in relation to natural features such as distance from shore, water depth (18 and 50 m depth contours), and ice conditions.

The available data suggest that in some years, only small numbers of bowheads would be expected near the Corona site. In such situations, it is important that a substantial proportion of these animals be found and their behavior observed. We believe that a modification of the approach we used at Sandpiper Island in 1985 would maximize the chances of finding whales in 1986. This approach involves first surveying an intensive grid centered at the Corona site. If no whales are present on the intensive grid, then the larger less intensive 'Area' grid would be surveyed.

'Intensive' Grid

Each day when weather conditions permit, the aircraft would first survey the 'Intensive Grid' beginning in the east and moving west. This would maximize the chances of finding whales as they approach the drilling operation. If whales are found, then the systematic surveys would be terminated and quantitative behavioral observations begun. The behavioral observations would continue until terminated by darkness, lack of fuel, deterioration of weather conditions, or departure of the whales from the Corona area. Photography would be attempted at the end of the observation period if sufficient behavioral data had been obtained. On subsequent flights, attempts would be made to relocate the studied animals if they were still within the potential zone of influence of the drilling operation.

The size of the 'Intensive' grid would be variable depending on ice conditions and the need for icebreaking activities to be conducted remote from the drillship. The basic grid would consist of a series of north-south transects at intervals of 4 km. Since each transect strip covers a 2 km width (see later), 50% of the area would be covered directly by the transects. In addition, bowheads are often seen off-transect beyond the transect strip. The 2 km wide off-transect zone between each pair of transect strips would be covered twice--e.g., once on a northbound line and again on the adjacent southbound line.

We propose that the 'Intensive' grid extend 28 km to the east and 16 km to the west of the drillship. The transect lines should extend 20 km to the north and south of the drillship. This design provides intensive coverage of all parts of the zone where whales might be influenced by noise from the operation. In addition, the design provides for the detection of animals sufficiently far to the east such that control observations can be conducted outside the zone of acoustic influence before the whales move into the potential zone of influence. The proposed 'Intensive' grid is mapped in Figure 12. The proposed survey design provides 'on-transect' coverage of half of the 1760 km^2 area of the grid. The remaining half of the area would be covered twice at off-transect distances of 1 to 3 km from the survey aircraft.

If no bowheads are detected on the 'Intensive' grid, then the aircraft would proceed to Barter Island to refuel. The 'Area' grid would then be surveyed.

'Area' Grid

The 'Area' grid represents a geographic expansion of the 'Intensive' grid. The 'Area' grid would extend from the coast north to 70°45' or about 30 km beyond the northern boundary of the 'Intensive' grid or 15-25 km north of the 50 m depth contour. The 'Area' grid would consist of a series of eight north-south transects (transect width 2 km) spaced at 10 km intervals (see Figure 7). The easternmost line would be about 45 km east of the drillsite and the westernmost line would be 25 km west of the site. This design increases the probability of finding whales that are approaching the drilling operation. Again, transects will be terminated and behavioral observations begun if whales are sighted.

The design of the 'Area' grid provides coverage north of the 'Intensive' grid. This is important to provide some regional perspective for comparison with migration patterns in previous years. This type of information can be very important for interpreting the results from the 'Intensive' grid if few whales are seen there in 1986. Seven of the eight transects proposed for the 'Area' grid were part of the grid surveyed by LGL for Unocal/SWEPI in conjunction with the Hammerhead/Corona studies in the fall of 1985.

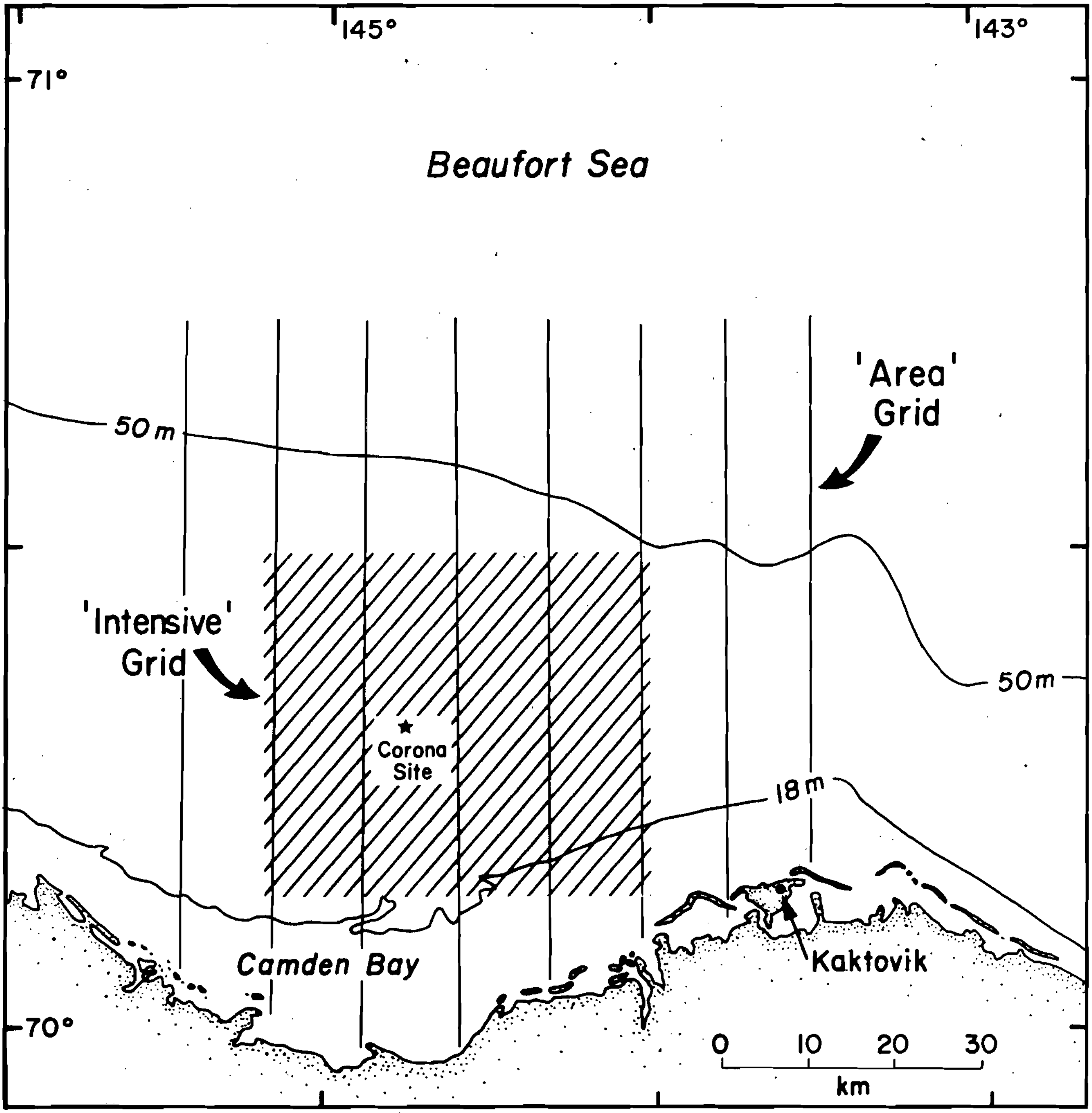

Figure 12. Study areas proposed for bowhead behavior studies in September/ October 1986. Most search efforts and behavioral observations will be made in the 'Intensive Grid'. The 'Area Grid' will only be searched when no whales are present in the 'Intensive Grid'.

Three other aspects of the design of the 'Area' grid are important. (1) The design increases our chances of finding whales at long distances from the drilling operation, thereby increasing our opportunities to sample the behavior of bowheads that are clearly undisturbed by the operation. (2) These 'control' animals can also be photographed to determine their lengths. When compared to animals near the operation, it may be possible to determine if any small-scale segregation occurs in the age of animals that approach and avoid the drilling operation. (3) Five of eight transects pass through the 'Intensive' grid. Thus, the 'Area' grid provides important additional coverage of the prime area of interest.

The design of the 'Area' grid should be considered tentative at this point. Two factors will influence the final design of the 'Area' grid. The two easternmost transects come to shore quite close to Kaktovik. It may be necessary to truncate these lines at some distance offshore or omit them entirely until the Kaktovik whalers have filled their 1986 quota. In 1985, the whalers requested that survey aircraft not pass over or near the whaling boats. The question should be discussed with the Kaktovik whalers as part of the community liaison program suggested later in this proposal.

The second potential design problem relates to fuel availability in Barter Island (Kaktovik). It is rumored that commercial fuel may not be available this summer and fall at Barter island. This question is apparently unresolved at the present time. To protect the project against this eventuality, we propose to use a specially-designed fuel system to extend the range of the Twin Otter survey aircraft (see Logistics Considerations). The extended range will also increase safety margins. Furthermore, it will increase the potential duration of behavioral observation sessions, and reduce the likelihood that observations of whales near the drillsite will have to be interrupted for refuelling. Completion of the 'Intensive' and 'Area' grids plus travel to and from Deadhorse would require about 7.9 hours of flight time if no bowheads were seen (i.e. if the surveys were not terminated in favor of behavioral observations). The extended range of the Twin Otter is about seven to eight hours. Thus, if fuel is not available at Barter Island it will be necessary to reduce the 'Area' grid from eight to six lines so that total flight time is 7.0 hours.

Methods

Standardized aerial survey procedures (Davis et al. 1982) would be used for comparability between surveys and between projects. The equipment and techniques will be the same as those that we employed for the Union studies at Hammerhead and Shell studies at Sandpiper Island in 1985. We will use a deHavilland Twin Otter equipped with bubble window for enhanced visibility. Surveys will be conducted at a ground speed of 200 km/h. Observers in the co-pilot's seat and a left rear seat will dictate all sighting data into tape recorders. For each sighting, the position, number, heading and activity of the whales will be noted, as will any calves. Lateral distance from the flightline will be determined by inclinometer. Ice cover and visibility will be recorded at 2-min intervals (every 6.7 km). Positions will be determined from a GNS 500A or other VLF/Omega system. Water depth of all sightings will be determined from hydrographic charts after the surveys. Locations and headings of whales will be mapped for each survey, and summarized for longer periods.

Bowhead surveys have been conducted at both 500 and 1000 ft altitudes. In a previous study, Davis et al. (1982) demonstrated that surveys at the two altitudes provided comparable results with each observer watching a 1 km wide transect strip. The appropriate strip is 200-1200 m from the aircraft flightlines at 1000 ft as opposed to 100-1100 m at 500 ft altitude. In previous bowhead survey programs an altitude of 500 ft has usually been used since low cloud ceilings in the Beaufort Sea often prevent surveys at 1000 ft. However, in the study proposed here it is more appropriate to conduct the surveys at 1000 ft in order to reduce potential disturbance to the whales caused by the overflight and the subsequent climb to 1500 ft to begin behavioral observations. Surveys will be flown at 500 ft on days when low ceilings prevent use of the 1000 ft altitude. In these situations behavioral observations will not be attempted when whales are found; photographic samples will be obtained and then the surveys will be resumed. It is very important that the behavioral data not be contaminated by disturbance responses to the study aircraft.

The Naval Ocean Systems Center (NOSC) will be continuing its aerial survey program in the Alaskan Beaufort Sea on behalf of the Minerals Management Service during August through October 1986. Our proposed surveys will complement rather than duplicate the NOSC effort. NOSC obtains broad regional coverage of the entire Alaskan Beaufort Sea. However, they do not obtain the detailed or frequent coverage in any one area that will be collected during this study. In addition, LGL will be conducting the second year of the MMS-feeding study in the Alaskan Beaufort Sea east of 144°W. This study includes systematic surveys to document whale numbers and distribution. The methods that we are proposing for the Corona study are identical to those to be used on the MMS study. We would also coordinate closely with the LGL-MMS crew to avoid duplication of survey effort, and more importantly, to minimize potential interactions with the Kaktovik whale hunt. Our MMS crew will be based in Kaktovik again in 1986.

The aerial survey/search program would be conducted throughout the period when whales are expected in the area. The study period should extend from 1 September until the end of migration, which is assumed to occur on 15 October for planning purposes. If the drilling operation is completed earlier and the ships move off site, then the study would be terminated at that time.

Ship-based Monitoring

We propose to monitor the moored acoustic array on a continuous basis. When bowhead calls are heard attempts will be made to localize them (see Task 1). These computations will be conducted in the field in near real-time. Information on the numbers of calls and their locations will be transmitted to the behavioral crew by radio to the aircraft or by telephone to Deadhorse. The behavior crew will redesign their plans to attempt to find and observe the animals detected by the array. The information from the array will be valuable since it will indicate that whales are relatively close to the drilling operation.

In addition to the acoustic monitoring, we propose that some visual observations be made from the drillship. As discussed under Acoustics, Subtask 2, it will be necessary to have a person on the drillship to document and log the various activities by the drillship, support vessels and helicopters. We recommend that a biologist fill this position and that he make systematic observations for bowheads on a regular basis. A system of 20 minute observation periods during periods of adequate visibility would be used. The length of each observation period must be longer than the average dive time of the whales so that whales in the area are likely to be detected. The number and timing of these observation periods should remain flexible until the field season when it will be possible to determine the design that best allows for collection of the information on industrial activities, which is the prime responsibility of this individual. The whale observations would be done when feasible.

Radio Tagging/Monitoring

As part of LGL's study of bowhead feeding in the eastern Alaskan Beaufort Sea, attempts will be made to attach radio tags to bowhead whales. The radio-tagged whales will be monitored to determine movement patterns and residence times in feeding areas east of Barter Island. Since these tagged whales will migrate through the Corona study area, and may linger there, we recommend that appropriate radio receivers be carried on board the aircraft. Since the MMS-crew will not be in the field after 30 September, it would be especially desirable to monitor the appropriate radio frequencies as part of the Corona study in October.

We propose to equip the project aircraft with a Yagi antenna and telemetry receiver. A back-up receiver will also be available. The receiver will be monitored after the LGL/MMS feeding study personnel have deployed one or more radio tags onto bowheads. The radio tags are expected to be detectable from distances up to 100 km when the whale is at the surface and the aircraft is at an altitude of 1000 ft. A range of 50-75 km is likely when the aircraft is at 500 ft.

Although detection of a tag can be done as the aircraft is engaged in its usual work, aircraft-based procedures for localizing a radio tag can be time consuming (Gilmer et al. 1981). If a tag signal is detected during an aerial survey, we propose to continue the survey while monitoring the tag.

The approximate location of the tag can be determined by circling the aircraft at several locations to determine two or more intersecting bearings. If the tagged whale is within the survey grid, its position can probably be determined quite precisely from successive bearings acquired during the survey, along with the variations in signal strength that will occur as the aircraft approaches and/or moves away from the tag. If aircraft endurance allows, the exact location of the whale will be determined during or after the formal survey. In any case, information about the probable or exact location will be relayed by radio to other aircraft equipped to monitor the tags, e.g., aircraft in use by MMS contractors.

When a tagged whale is located, at least to the point of knowing that it is one of the whales in a particular group, we will record the general activities and headings of the whales. If the whales are near the drillsite or other industrial activity, a sonobuoy will be dropped and full fledged behavioral observations will be conducted.

To search for tagged whales, one person aboard the aircraft should monitor the receiver(s) continuously as his primary duty. This is especially necessary if more than one frequency must be monitored (i.e. if >1 whale has been tagged). The aircraft will normally carry a crew of four, one of whom can monitor the receiver while the aircraft is in transit and on surveys. During behavioral observation sessions while the aircraft circles over one area, continuous radio monitoring would not be conducted.

Study Protocol

The study is designed to maximize the number of behavioral data obtained from whales that are potentially affected by the industrial operation. The protocol for determining the routing and objectives of each aircraft mission is described below.

The first step each morning will be to contact the ship-based biologist and/or acoustic crew to determine whether any whales have been seen or localized by the hydrophone array since the last flight. If no whales have been noted, then the aircraft would fly from its base at Deadhorse to the start of the easternmost transect of the 'Intensive' grid. The grid would be flown from east to west to maximize the chances of finding whales approaching the drilling operation while maximum fuel reserves remained on the aircraft. When whales are found, the intensive survey would be terminated and behavioral observations would be initiated, provided that the cloud ceiling was above 1500 ft, the minimum altitude for meaningful behavioral observations. Thus, the surveys are used as the principal systematic technique for finding whales to study. Behavioral observations would be made for as long as useful data were being obtained. Behavior sessions would be terminated if winds and waves increased above sea state 4, fog or cloud reduced ceilings below 1500 ft, or the whales moved into heavy ice cover, or were lost. Alternately, if conditions remained favorable, behavior observations would continue as long as fuel reserves were adequate. A few minutes at the end of the behavioral observations would be used to photograph the whales to determine their lengths and to document the presence of individually recognizable animals.

If no whales are found on the 'Intensive' grid, then the aircraft would return to Barter Island to refuel (if fuel is still available there in September-October). The 'Area' grid would then be flown beginning at the easternmost transect. The same procedures as on the 'Intensive' grid would then apply. That is, surveys would continue until whales are found, at which time behavioral observations would be instituted. Photography would be conducted at the end of the behavior session if adequate quantitative information about behavior had been obtained.

The protocol for the next flight would depend on the results of the previous flight. If whales were present during the previous flight or during the intervening period (as indicated by the hydrophone array or visual sightings), then the subsequent flight might attempt to relocate these whales to continue behavioral observations and to document residence times. This decision would be made at the time based on the available information. The good judgement of an experienced field team is required to determine the best specific approach for each flight.

Satellite Imagery

As part of the LGL/MMS bowhead feeding study, we will be acquiring and analyzing digital satellite imagery of the eastern Alaskan Beaufort Sea for the September 1986 period. The objective is to understand the distribution and movements of water masses that may affect zooplankton and, indirectly, bowhead whales that feed on zooplankton. The satellite imagery, when suitably processed on a digital image processor, provides information about sediment concentration, sea surface temperature, and fronts between water masses. The distribution of bowhead whales is suspected to be related to some or all of these oceanographic features (Thomson et al. 1986). Satellites can provide simultaneous and repeated measurements of these parameters over wide areas when clouds and ice are absent.

We plan to include the Camden Bay area within the zone considered during image processing. This will be done at no cost to Shell, and at no additional cost to MMS. The results may be helpful in understanding the distribution and movements of bowhead whales through the Corona area during the autumn of 1986.

Logistics Considerations

Operations Base

Two potential bases are available for use in this study: Kaktovik and Deadhorse. The principal advantage of Kaktovik is that the Barter Island airstrip is closer to the Corona study area than is Deadhorse. In addition, basing at Kaktovik would allow better communication with the community and with the LGL crew that will be based there for the MMS bowhead feeding study. On the other hand, basing the SWEPI study at Kaktovik increases the number of take-offs, landings and overflights that might interfere with the bowhead hunt or at least be perceived to cause interference. We anticipate relatively smooth relations with the whalers due to our proposed initiatives (see section on 'Native Hunt/Community Liaison') and we can guarantee close coordination with the LGL crew at Kaktovik. For a variety of reasons, however, Deadhorse is the preferred base for this study.

The airstrip at Deadhorse is better equipped and therefore safer. Fuel is definitely available at Deadhorse, whereas there is some doubt about supply in Kaktovik this year. The much lower fuel costs at Deadhorse partly counteract the increased costs of ferrying to the study area from Deadhorse. Accommodations and communications are more readily available in Deadhorse. This should assist daily communications with SWEPI. The NOSC (D. Ljungblad, S. Moore, J. Clarke, et al.) survey crew, which conducts the MMS regional surveys stays at NANA camp at Deadhorse. We propose to stay at the Prudhoe Bay Hotel, which is next door to NANA. This will facilitate the daily coordination with the NOSC crew. As in 1984 and 1985, we propose to provide daily reports of whale sightings to NOSC and, through them, to MMS.

Finally, basing at Deadhorse will allow much better routine communication with the drilling operation and with our acoustic crews at the site. In addition, in the unlikely event of a spill, coordination with SWEPI personnel and activation of standby crews would be greatly facilitated if the behavior crew is based in Deadhorse rather than Kaktovik. This question is discussed further in our companion proposal for the oil spill monitoring program.

Aircraft Type

A variety of aircraft types could be proposed for this study but the DHC-6 Twin Otter provides the best compromise of reliability, availability, payload, range, and mission suitability. The minimum requirements are for a high-winged (for sightability), twin-engined (for offshore safety) aircraft with STOL capabilities and a stall speed of less than 80 knots. The slow speed performance is essential for the slow circling flights used for behavior studies. Good single engine performance is also essential.

We assume that Alaskan oil companies are similar to Canadian companies that insist that offshore flights be made only in turbine-powered, multi-engine aircraft. This safety policy is laudable. However, it basically restricts the choice of aircraft to Twin Otters. The Rockwell Turbo Commander meets the high-winged, turbine engine criterion but lacks the capability for slow flight speeds needed for behavior observations. The most suitable (adequate payload and stall speed) alternative to the Twin Otter is the Britain-Norman Islander but this is a piston-engine aircraft. NOSC uses a Grumman Turbo-Goose for aerial surveys but switches to a Twin Otter for behavior studies. Overall, we recommend that a Twin Otter be used for the behavior study, including the survey and photography components. We have used this type of aircraft on previous Alaskan bowhead studies, including the ongoing MMS-funded feeding study.

Special Equipment

A variety of specialized equipment is required for this study. This equipment includes

- VLF navigation system (e.g., GNS 500A, LRN-70) for reliable offshore navigation and positioning,
- radar altimeter for altitude maintenance during behavior studies and, particularly, during aerial photography and associated calibration flights,
- three specialized bubble windows for improved visibility,
- AC power (110V, 60 cycle),
- marine VHF radio with external antenna,
- life raft and associated safety equipment,
- a six position intercom system with voice activated, noise cancelling microphones,
- internal, long range fuel tank (250-300 gal.), and
- belly mounted camera hatch with optical glass.

The latter requirements greatly limits the number of aircraft that are suitable for the project. In fact, none of the Alaskan-based charter operators can or will supply a Twin Otter with a suitable camera hatch. We have based our budgets on a Twin Otter with suitable equipment, including a camera hatch supplied by Empire Airways of Idaho. Empire has supplied the Twin Otters used for bowhead photography at Barrow in the spring of 1985 and 1986 by National Marine Mammal Laboratory (M. Nerini and D. Rugh), at Kaktovik in the fall of 1985 and 1986 on the LGL/MMS feeding study, and in the fall of 1985 on the LGL/SWEPI Sandpiper Island study. The costs of Empire Air compared with local carriers (Cape Smythe, ERA) are discussed in the accompanying cost proposal.

PERMITS

The proposed research on bowhead whales requires permits under the Marine Mammal Protection Act (MMPA) and the Endangered Species Act (ESA). The National Marine Fisheries Service (NMFS) in Washington, D.C., is the agency responsible for issuance of a combined research permit under the two acts. At SWEPI's request we recently contacted the appropriate NMFS office to verify that permit requirements and application procedures had not changed in the past year. We were informed that no changes had been made and that, on average, it takes about 90 days to process a permit application from receipt to date of issuance. Applications can take longer if formal objections are filed.

LGL Ltd. has the required MMPA/ESA permit to conduct all aspects of the research in this proposal. This permit (No. 518) was issued on 23 August, 1985 and is valid until 31 December, 1987. The studies conducted by LGL for SWEPI and Unocal in 1985 were covered by this permit. Studies in 1986 are subject to consultation with the Regional director of NMFS in Juneau at least "two weeks prior to the initiation of the field activities, at which time the desirability of a NMFS designated observer will be determined by the Regional Director". This is a standard clause in bowhead permits. A NMFS observer was not considered necessary in 1984 or 1985.

NATIVE HUNT/COMMUNITY LIAISON

The Corona drillsite is only about 50 km northwest of the village of Kaktovik. Although the site is west and north of the normal bowhead hunting areas used by the Kaktovik whalers, there will be concern about potential effects of the distant noise and the associated shipping and aircraft activities. We propose several initiatives to attempt to minimize real and perceived interactions between the bowhead studies and the Kaktovik whaling activities. The principal thrust of the initiatives is to establish regular communications with the whalers. This will be facilitated by the fact that we (LGL) will have a biological crew stationed in Kaktovik throughout September 1986. This crew will be conducting behavioral, photographic, tagging, marine sampling, and aerial survey programs in the area east of

Kaktovik as part of the MMS-funded study of bowhead feeding. This crew under the direction of Dr. W. John Richardson of LGL conducted similar studies in 1985 when regular communication with Kaktovik whalers occurred. Although we propose to establish independent community contacts for the SWEPI study in 1986, close coordination with the MMS-feeding study will be necessary since problems caused by one study will affect all studies. The full-time presence of an LGL crew in Kaktovik will provide important backup for our proposed initiatives for SWEPI.

If we are awarded this contract, we would schedule an information meeting with the whalers and other interested residents in Kaktovik during July. A senior representative from LGL and from Greeneridge Sciences would travel to the community to explain the proposed program and to outline measures proposed to minimize interactions with whaling. It would be advantageous to conduct this meeting in conjunction with SWEPI personnel so that all aspects of the drilling operation can be discussed with the whalers. (We have not proposed meetings with Nuiqsut since their whaling activities occur well to the west of Corona. However, if Nuiqsut wishes to have such a meeting, we would certainly schedule one.)

To ensure that regular communication occurs after the preliminary meeting in Kaktovik, we suggest that a 'liaison officer' be hired in Kaktovik. This person would be a native resident of Kaktovik who would be hired for the duration of the field program (approximately two months). The duties of the 'liaison officer' would be to communicate with the whaling crews on a regular (daily) basis to determine whether any interactions with industrial or biological study activities occur. In 1985, the Kaktovik whalers were interested in receiving daily reports of the activities of the LGL/MMS feeding study crews, and about their plans for the next day. We expect that there will be similar interest in the activity of Shell's biological and acoustical contractor in 1986. If Kaktovik residents have concerns about any of our activities, the concerns would be reported immediately to the LGL project director (Dr. R.A. Davis) in Deadhorse. If a serious situation developed, then we would report the details to SWEPI and arrange a meeting with the whalers.

On a routine basis, we would report our findings and sightings to the 'liaison officer' for transmission to the whalers. Hopefully, sighting data from the whalers would be passed on to us. In addition, information on areas being used by the whalers would also be obtained to help us avoid overflying such areas.

Surveys and other aerial activities would not be conducted in areas where active whaling is underway. To this end, the southern ends of the easternmost two transects in the 'Area' grid will be truncated about 10 km offshore to avoid potential whaling areas. The full transects would be reinstated after the Kaktovik whalers have filled their bowhead quota. To further reduce inadvertent interactions with whaling activities, we propose to carry a CB radio on the aircraft so that direct communication with whaling crews is possible. The Kaktovik whaling boats carry CB radios. This would allow the whaling crews to contact the aircraft if they felt that we were interfering with their activities. This approach was suggested by some of the whalers last year. The added cost of the CB radio and aircraft antenna is relatively small.

We believe it would be useful to invite representatives of the community of Kaktovik to accompany us during our flights. This would allow people to see our techniques first hand and to watch the responses (or lack thereof) of the animals to our study techniques. Because of the need for a highly specialized four man crew and for the onboard fuel tank and camera hatch, only one or two observers could participate on a particular flight.

There may be some interest in the communities to actually visit the drilling operation. This initiative is, of course, entirely up to SWEPI. One of the positions on the proposed acoustic crew could be filled by native technicians from the North Slope Borough communities (see Task 1). This position would be filled by two people rotating on and off-duty at two week intervals. Information about the ship-based studies would be transmitted back to the communities by these two technicians.

Finally, it is important to continue the community liaison after the field program is finished. We recommend that the community be visited during the winter to present the results of the study. The lack of follow-up visits reporting on project results is a recurring complaint in Eskimo communities. We have heard this concern expressed in Nuiqsut, Kaktovik, Clyde River, Pond Inlet, and Resolute Bay. The proposed winter visit could be done by project staff, SWEPI personnel, or a combination of the two. We present this as an option for consideration; we have not included this visit in our proposed budget.

CLIENT/AGENCY LIAISON

The RFP requests that provision be made for three trips to Anchorage for meetings. Each trip would involve the Project Director (R.A. Davis, LGL) and the Principal Investigator, Acoustics (C.R. Greene, Greeneridge). The meetings mentioned in the RFP include the MMS contractor's meeting in June or July; a meeting in early December with SWEPI; and a final meeting in late winter 1987 to present the study findings to the relevant state and federal agencies, North Slope Borough, and project sponsors. In addition, we have proposed that information meetings be held in Kaktovik in July and in early 1987 to present the study design and results to interested residents.

We are prepared to accompany SWEPI personnel during early meetings with the agencies and Borough scientists during the approval phase of the project. Our presence at such meetings may help to clarify some points and help to ensure that suggestions for additions or deletions from the study are appropriate and will, in fact, achieve the desired objectives. In many cases, apparently reasonable technical modifications can founder because of the vagaries of arctic weather and ice conditions, naturally small samples of animals available for study, and difficulties associated with studying animals that are below the water surface 75% of the time. We have not made budget provisions for these early planning meetings with the agencies since they were not part of the RFP. However, we can accompany SWEPI personnel at these meetings, if SWEPI considers our presence to be helpful.

As noted above, Dr. R.A. Davis would represent LGL at meetings with agencies. If for some unexpected reason he is not available, then Dr. W.J. Richardson would be available. Both Davis and Richardson have extensive experience with these types of meetings and are well-known to agency and Borough personnel.

COORDINATION WITH OTHER STUDIES

Because of the high cost of conducting arctic marine research, it is important that all studies be closely coordinated to reduce overlap and maximize results per dollar expended. As noted in the Introduction to this proposal, a serious problem will be caused if Amoco is drilling at the 'Eric' site which is only 17 n. mi. east of Corona. Major changes to the design of the Corona study will be necessary because the Eric site is in the major control area where undisturbed behavior observations would be made on whales approaching Corona. For the purposes of this proposal, we have assumed that drilling will not be occurring at Amoco's Eric site in the fall of 1986.

Ongoing Studies

Three other bowhead-related studies are probable for 1986. These include the MMS-funded regional surveys and feeding study which have funding in place and the site-specific acoustics study which will probably be funded. The regional aerial surveys are directed by Don Ljungblad of Naval Ocean Systems Center (NOSC) with Janet Clarke and Sue Moore of SEACO acting as field leaders. We have worked closely with the NOSC team for several years. In 1984 and 1985, we provided daily reports of our survey coverage and whale sightings to NOSC. These data were transmitted, with the NOSC sightings, to MMS and NMFS in Anchorage on a daily basis. We propose to stay at the Prudhoe Bay Hotel which is next door to NANA Camp where the NOSC crew is quartered. This will assist communications between the two field crews.

The second year of the MMS-funded feeding study will be conducted by an LGL team under the direction of Dr. W. John Richardson. The study will be based at Kaktovik and covers the area from there to Herschel Island by aircraft and boat. This study area is directly adjacent to the proposed Corona study area. Close coordination of activities between this study and the Corona study will be necessary to avoid unnecessary activity near the whaling activities in the Kaktovik area. Very good communications can be expected between LGL crews on the proposed Corona study and on the MMS feeding study.

It is expected that the MMS site-specific noise study will be funded again in 1986. Bolt Beranak and Newman Inc. (BBN) is the prime contractor on this study. LGL is the biological subcontractor to BBN on this study. Hence, we again expect close coordination with the BBN study team. As an example of this close coordination, the LGL/Greeneridge team provided BBN with tapes of sounds from Sandpiper Island and the offshore drilling operation that we studied for Unocal and SWEPI in 1985.

Other SWEPI Studies

The RFP mentions the possibility of two other studies that might be funded by SWEPI in 1986. The first of these involves testing the feasibility of infrared scanners to detect whale blows. The preliminary tests of this technique were conducted by Greeneridge Sciences Inc. The results suggested that blows could be detected only at relatively short distances. Thus, further testing of the technique is not warranted at this time.

The other possible SWEPI study involves the establishment of an elaborate hydrophone array for tracking bowhead calls. The array was designed by Honeywell Marine Systems. We are not aware whether this study will be funded in 1986. If the Honeywell array is deployed, then close coordination with the acoustic studies suggested in this proposal will be necessary. We anticipate that such coordination will be feasible. Dr. C.R. Greene of our study team has been a consultant to Honeywell during the design of the array.

Oil Spill Contingency Study

A companion proposal addresses the design and conduct of a scientific study to document the potential effects of an oil spill on bowheads and their behavior and migrations. If a spill occurred, then it is obvious that very close coordination would be required among all researchers in the area. A major concern is that study activities may interfere with each other, making it difficult to distinguish between the effects of the spill event and the effects of the study efforts.

Since most of the pre-spill control data will be collected as part of the main Corona bowhead study, it is necessary that similar methods and techniques be used on spill-related behavioral studies. The bowhead contractor for the main Corona project should have input to the design (Phase I) of the bowhead/oil spill contingency program.

Finally, the initial response to an oil spill should be made by the main Corona bowhead behavior study team. This is the most efficient means of obtaining important early post-spill data. Use of this crew ensures a fast response and compatible study techniques. In addition, the Twin Otter chartered by the behavior crew is likely to be the only available camera hatch-equipped aircraft in Alaska apart from the Twin Otter being used on the LGL/MMS feeding study.

SCHEDULE AND TIMING

Details of the timing of many of the major activities of the proposed study are presented in other sections. The relevant sections are 'Permits', 'Client/Agency Liaison', and 'Reporting Requirements'. These sections discuss meeting dates and reporting deadlines. The 'Permits' section is only relevant in that it indicates that a potential limiting factor is not applicable in our case since we already have the appropriate MMPA/ESA permit.

We propose to conduct the acoustical field work from 15 August to 15 October. The end date will be determined by the end of the bowhead migration and/or the termination of drilling activities and removal of the ships from the area. We propose to begin the bowhead behavior studies on 1 September. This start date was selected based on the seven years of migration data summarized in the 'Background' section. Bowheads are not expected near the Corona site before September. Behavior studies would continue until the end of migration or the end of the drilling operation, whichever comes first. For budget purposes, we have assumed that fieldwork will end on 15 October.

REPORTING REQUIREMENTS

Progress Reports

Monthly progress reports will be submitted in five copies to the SWEPI project manager. These reports will be submitted during the final week of each month. Each report will include a review of the status of the budget and the amounts remaining to be spent. On the technical side, the report will very briefly describe work performed during the month and any problems encountered. Deviations from the proposal schedules will be identified.

Draft and Final Reports

Ten copies of the draft final report will be submitted to SWEPI on 16 February 1987.

The RFP calls for a draft final report to be available for the regulatory agencies by 1 March 1987. This deadline may be unrealistic since it is entirely dependent upon the timely receipt of comments from SWEPI. We prefer to undertake to produce a draft final report for the agencies within 10 (calendar) days of receipt of comments from SWEPI.

The final report would be prepared after receipt of comments from the regulatory agencies and other outside reviewers. Depending on the extent and validity of the comments it may take some time to revise the report and have 100 copies printed and shipped. Assuming a reasonable number of comments, the revision, printing and shipping process would probably take about three weeks from receipt of agency comments.

The RFP specifically requests that the report be of 'high scientific quality' or peer review quality. It also specifically requests that the report not be in brief, cryptic journal style. We agree with this approach since all data should be presented in enough detail to permit reanalysis and/or reinterpretation by other workers. Thus, the final report will be quite detailed and complicated. We propose to write an overview report of the entire study that would provide management personnel and non-technical personnel with a concise summary of the study and the significance of its findings.

Research Papers

One of the criticisms that has been voiced at recent interagency meetings is the lack of peer review of the recent studies of the potential effects of industry activities on bowheads in the Beaufort Sea. We believe that this criticism is not really justified. As evidence, we have included a list of 10 journal papers resulting from our study of bowhead behavior conducted for MMS (see Appendix 1). The preparation of these papers was funded by MMS.

As a further response to criticism about lack of peer review, we recommend that SWEPI consider the possibility of funding a series of papers based on the results of this study (Corona 1986) and the other industry-funded bowhead monitoring projects (Seal Island 1982, 1984; Hammerhead 1985; Sandpiper Island 1985). The four previous studies were all conducted by the team of LGL and Greeneridge. Publication of the results of the five studies would lend credibility to the industry-funded monitoring program.

We have not proposed a budget for these papers pending an expression of interest by SWEPI. Because publication of journal papers is beneficial to LGL and Greeneridge, and to our scientists, we are prepared to partially subsidize these papers in conjunction with SWEPI.

Bowhead Conference

If the present policy is adhered to, the North Slope Borough will again be sponsoring a conference on bowhead biology in Anchorage in early 1987. We propose to make two presentations of Corona results at this conference, if SWEPI agrees. The papers would cover the main acoustical and biological results of the study. The costs of these presentations are included in the proposed budget assuming that one of the three client/agency meetings in Anchorage is scheduled at the same time as the North Slope Borough's conference.

PERSONNEL

We have assembled a highly experienced team of specialists to conduct the proposed research. An important addition to the impressive experience of the individual scientists is the fact that most of the team has worked together on previous studies of bowhead whales and arctic acoustics. The group has an excellent record of producing credible results in spite of the many vagaries of arctic logistics in ice-covered waters. Much of the learning curve involved in successfully conducting complicated integrated behavior/acoustic studies of arctic whales has been covered. Thus, our team will not be subject to problems associated with inexperience or with lack of integration associated with a crew whose members have not previously worked together.

Capsule resumes of the personnel that we would assign to this project are presented below with details of each individual's role on the project. Full professional resumes of the key personnel are including in Appendix 3.

Dr. Rolph A. Davis will serve as Project Director for the proposed study. Dr. Davis is a Director of LGL Ecological Research Associates and President of LGL Limited. he has been involved with studies of bowhead whales since 1976 and has directed and managed many of LGL's large-scale arctic marine projects since 1974. Recently, he directed the 1980, 1981 and 1983 systematic survey programs for bowheads in the Beaufort Sea. He also directed the development of the vertical photography method for studying bowheads during 1981 and LGL's three studies (1982, 1984 and 1985) using the technique and was senior author of the reports on this work. Dr. Davis conducted and directed LGL's industry-funded bowhead studies in the Alaskan Beaufort Sea in the fall of 1982, 1984 and 1985. He has been an invited expert concerning bowheads and other marine mammals at several meetings of the Scientific Committee of the International Whaling Commission. In 1983 he was invited to present to the IWC the results of LGL's 1981 and 1982 vertical photography studies, and in 1986 he has been invited to present the results of LGL's study of bowhead reproductive rates conducted in 1985. He is the author of numerous reports and papers concerning bowheads and other marine mammals. Dr. Davis will participate in the final design and conduct of the field program. He will be responsible for all client and agency liason and will supervise the production of the final report.

Dr. W. John Richardson will assist the project director with the design, analysis and management of the project. He will provide senior review of the final report and ensure that the results of the Corona study are integrated with the results of the LGL/MMS feeding study for which he is project director. His presence in Kaktovik in September will be beneficial for the very important communications with the Kaktovik whalers that are required. Dr. Richardson is, by academic training, an animal behaviorist and specialist in application of quantitative procedures to biological field problems. Since joining LGL in 1973, he has been responsible for or assisted with the design, management, conduct, analysis and reporting of many of LGL's major field projects in Alaska and Canada. From 1980 to 1985, he was project director for LGL's study for MMS of the behavior, feeding, and disturbance responses of bowhead whales summering in the eastern Beaufort Sea; he was involved in all aspects of that project, including planning, logistics coordination, field leader, data analysis, reporting, client liason, participation in meetings, and preparation of publications in the refereed literature. Dr. Richardson will be directing the second year of the LGL/MMS feeding study in the Alaskan Beaufort Sea in 1986. He is also the principal LGL subcontractor to BBN on the MMS-funded study of site-specific industrial noise in the Alaskan Beaufort Sea. Dr. Richardson provides a senior, highly qualified back-up to the Project Director for the proposed project. This is a good example of the depth of experience available to this project. Dr. Richardson is a Vice-President and director of LGL.

William R. Koski will make behavioral observations and will act as the photographer when vertical aerial photographs of bowheads are taken. He participated in LGL's study of the behavioral reactions of bowheads to industrial activities in the Beaufort Sea for MMS in 1983. He also conducted behavioral observations during some of LGL's studies of bowheads that used photographic techniques. These studies require quantitative information on dive profiles. The studies were conducted in 1981, 1982, 1984 and 1985 in the Beaufort Sea for a variety of government and industry clients in both Alaska and Canada. Mr. Koski has an M.Sc and joined LGL in 1973. Since 1977 he has been field supervisor and/or participant in many of LGL's major mammal studies. His studies in the eastern Canadian High Arctic from 1978-80 involved bowhead whales and several other species of marine mammals. He has authored many reports on arctic mammals, including a paper on the status of the Baffin Bay population of the bowhead.

Dr. Peter L. McLaren, senior scientist with LGL, will act as an aerial behaviorist/surveyor during the proposed field work, and will also be involved in the subsequent data analysis and report write-up. Dr. McLaren has been with LGL Ltd. for 11 years and has conducted many field studies involving arctic marine mammals. He has extensive experience with bowhead whales, both in Canadian waters and in the Alaskan Beaufort Sea. He was the project field leader for LGL's bowhead monitoring study for Unocal/SWEPI/AOGA at the Hammerhead/Corona sites in the Camden Bay-Flaxman Island area of the Alaskan Beaufort Sea in 1985. Dr. McLaren also participated in a study of bowhead whales near Seal Island for SWEPI in 1984 and in LGL's study of bowhead behavior and acoustics in the Canadian Beaufort Sea for U.S. Minerals Management Service. Also in 1985, he was field leader on LGL's study of bowhead reproductive behavior funded by the Alaskan oil industry. In previous years he was project director for major marine aerial survey programs in Baffin Bay (1978-80), the Labrador Sea (1981-82), and bowhead wintering areas in the pack ice of Davis Strait and west Greenland waters.

Randall S. Wells will serve as the senior behavioral observer on the aircraft crew. He completed his Ph.D program on cetacean behavior at the University of California Santa Cruz during the spring of 1986. Dr. Wells wa a behavioral observer throughout the 1981-83 phases of the LGL/MMS study of bowhead behavior and disturbance responses. During that study Dr. Wells participated in the development of the standardized behavioral observation techniques to be used during the present study. He was co-author of several of the reports and journal papers that were prepared based on the LGL/MMS study. Dr. Wells has also conducted behavioral observations of summering gray whales in the Bering Sea. He is well-known for his long-term study (1979 to date) of a population of individually identified bottlenose dolphins. Techniques used during that study include radio-telemetry; monitoring for bowhead whales radio tagged during other 1986 studies will be one of his tasks during this study.

Dr. Steven L. Swartz will be a behavioral observer on the aircraft crew. His doctorate was obtained at the University of California Santa Cruz, based on field research in 1977-82 on the behavior and other aspects of the biology of gray whales wintering in Baja California. In 1983 and 1984, he conducted aerial observations of the behavior of bowhead whales in the Alaskan Beaufort Sea during autumn, on behalf of the Naval Ocean Systems Center and MMS. The observation techniques used in that study were those developed in the 1980-84 LGL/MMS study; these are the same techniques to be used in the present study. Dr. Swartz is one of the editors of a technical book on gray whales, and he has recently conducted radio-telemetry work on gray whales using the same types of radio tags that we hope to monitor during this study.

Michael S.W. Bradstreet, a biologist with LGL since 1974, will act as whale observer and industrial activity monitor on board the drillship. Mr. Bradstreet has extensive ship-based experience in the Bering Sea, Beaufort Sea, Lancaster Sound-Baffin Bay and Labrador Sea. He monitored industrial activity and its effects on wildlife at Thetis island, Alaska, for Sohio during construction of Mukluk Island. He also participated in monitoring industrial activity at Seal Island in 1984 for Shell. Mr. Bradstreet has had extensive experience studying bowhead whales from land, ship/boat and aircraft platforms. He monitored bowhead whale migration past Cape Adair, Baffin Island, for two monthly periods in 1978 and 1979. Speed of migration was determined through theodolite tracking. Mr. Bradstreet is principal investigator for LGL's study of feeding bowhead whales for DIAND in the Canadian Beaufort Sea in 1985/86. This study is closely coordinated with the LGL/MMS study of feeding bowhead whales in Alaska. Mr. Bradstreet has monitored the fall migration of bowhead whales through the Alaskan Beaufort Sea during 1984 and 1985 for Amoco and SWEPI; these studies included behavioral observations, photogrammetry and monitoring of underwater noise from Seal and Sandpiper Islands. This extensive monitoring (both real-time and <u>post-facto</u>) demonstrates the importance of accurate determination of the types and locations of industrial activities for interpreting variations in the sound field. Bradstreet's experience on ships and in industrial camps suggests that he will be able to gather the required industry data with minimal interference.

C.R. Evans, a biologist with LGL since 1979, will be the fourth observer on the behavioral observation team. He has extensive experience in field studies of bowhead whales, including participation in our aerial quantitative studies of bowhead behavior at Sandpiper Island for SWEPI in 1985. He also anticipated in the field aspects of our bowhead study at Seal Island for SWEPI in 1984. Mr. Evans recently completed his third season (1983-85) on LGL's study of undisturbed bowhead behavior in the eastern Canadian Arctic at Isabella Bay. This study involved shore-based (theodolite-tracking) and kayak-based observations of behavior of up to 75 bowheads in a coastal fiord system on Baffin Island. In 1982, Mr. Evans was a member of the field crew on LGL's aerial photogrammetric studies of bowheads for NMFS. In July-September 1981, he was a surveyor in our major aerial surveys of bowheads in the Canadian Beaufort Sea and Amundsen Gulf for the Alaskan and Canadian oil industry and the State of Alaska. The latter study involved quantitative aerial behavioral observations (about 50 hr) to determine dive times and surface times for the calculation of correction factors to account for submerged animals during the surveys. In addition to his experience with bowheads, Mr. Evans participated in other LGL studies of arctic marine mammals in Hudson Bay, Hudson Strait, Baffin bay and Lancaster Sound.

Dr. Charles R. Greene will act as senior acoustician. He will supervise the moored buoy array design, procurement, and testing; he will be present at Corona for the entire field season; he will direct the acoustic data analysis and prepare the report on the acoustics study task. Dr. Greene has been performing underwater sound data collection and analysis during the arctic summer/fall for the past six years, most recently at Hammerhead, Sandpiper Island, and Corona in 1985. His graduate degrees are in electrical engineering from the Massachusetts Institute of Technology and the University of California at Santa Barbara. Under-ice acoustic research has been his primary interest since 1962, with U.S. Navy sponsorship until the bowhead whale-related work began in 1980. His work on marine mammal related acoustics has included spring, summer and autumn studies in the Alaskan and Canadian Beaufort Sea, and spring work on the pack ice and fast ice of the Canadian High Arctic. He has worked closely with LGL since 1980 leading to close coordination between acoustic and biological studies.

Gary W. Miller, a wildlife biologist with LGL since 1977, will be responsible for analysis of aerial photographs. He will classify and identify the whales on the photographs, and will search for matches with other photographs obtained in 1986 and previous years. Mr. Miller was a member of the field crew for LGL's 1981, 1982, 1984 and 1985 bowhead photography projects, and was the photographer for part of the 1982 and the 1985 season. He developed the method for categorizing, filing, retrieving, and matching bowhead photographs. His procedure is now used for the comprehensive National Marine Fisheries Service catalog of bowhead photos, which we will use to determine whether any whales identified in 1986 were also identified in earlier years. Besides his work on bowheads, Mr. Miller has also conducted numerous other studies of marine mammals in arctic areas ranging from the Bering Sea to western Greenland. In 1983 and 1984 he participated in LGL's study of behavioral reactions of bowheads to industrial activities in the Beaufort Sea. In 1984, he was also involved in our aerial surveys of bowheads in Alaska for Shell Western and Amoco. In 1985 and 1985, he is a member of LGL's crew on the MMS feeding study.

Dr. Christopher W. Clark will act as a consultant regarding optimal design of the acoustic array. After the field season, he will also use his custom-designed computer system to localize bowhead sounds (and calibration data) recorded via the array. Dr. Clark has graduate degrees in both electrical engineering and biology. He is presently an assistant professor at Rockefeller University, where he specializes in quantitative studies of animal vocalizations, with emphasis on computerized processing of animal sounds. He developed a localization system for underwater sounds of right whales during his graduate research program. He has subsequently been one of the principal investigators for the acoustic localization and census study of bowheads passing Point Barrow in spring. This study is entering its third year in spring 1986; it is funded by the North Slope Borough. Dr. Clark worked as a consultant to LGL in 1980-85, when he was responsible for analyses of bowhead calls recorded by LGL via air-dropped sonobuoy techniques in the Canadian Beaufort Sea.

Dr. Wm. T. Ellison, chief scientist with Marine Acoustics of Clinton, Mass., will act as a consultant to LGL and Greeneridge regarding the optima design of the acoustic array. He will also provide external independent review of other aspects of the project plan and the draft report. He is a graduate of the U.S. Naval Academy and M.I.T. Dr. Ellison specializes in studies of underwater acoustics in the arctic, where he has conducted research on physical acoustics for the U.S. Navy and biological acoustics for various agencies. He is one of the principal investigators for the acoustic localization and census study of bowhead whales passing Barrow in spring.

LGL is aware that Drs. Clark and Ellison are also participants in another proposal to SWEPI for this project. They have both agreed to work with LGL if the project is awarded to us. We have included them on our proposal because of their experience with the North Slope Borough-funded localization study. Their inclusion on this project will allow important comparisons between the spring study and the fall Corona study.

CORPORATE STRUCTURE AND PRIME SUBCONTRACTOR

LGL Group

The LGL Group consists of three employee-owned research companies. Ownership of the three companies is interlocking and the Boards of Directors of the three companies are also interlocking. The three firms each maintain particular fields and areas of expertise; this expertise is readily available to the other companies. The three companies are

- LGL Ecological Research Associates, Inc., Bryan, Texas
- LGL Limited, King City, Ontario
- LGL Alaska Research Associates, Inc., Anchorage, Alaska

LGL Ecological Research Associates, Inc., of Bryan, Texas is the corporate entity submitting this bid. The study team has been assembled from the three component companies.

LGL has been conducting arctic research in Alaska and northern Canada since 1971. The group has conducted research for a wide variety of government and industry clients, many of them repeat customers. LGL has been able to build-up a stable work force of experienced staff biologists who have conducted several arctic studies of similar size and complexity.

Greeneridge Sciences, Inc.

The principal subcontractor to be used on the proposed study is Greeneridge Sciences, Inc. of Santa Barbara, California. Greeneridge will be responsible for the acoustic phase (Task 1) of the study. Although Greeneridge is a relatively new company (formed in 1983), its president and senior scientist, Dr. C.R. Greene, has conducted arctic acoustic research since the 1960's. He has been closely associated with LGL studies of whales and acoustics since 1980. Major joint field research projects have been conducted during each of the six years beginning in 1980.

CORPORATE EXPERIENCE

LGL has a long history of studies of bowhead whales ad of integrated behavior/acoustical studies of offshore industrial activities. LGL first began studying bowhead whales in 1974 and has been actively involved with this species for the past 12 years. The majority of our work has been related to the status of the populations and the potential effects of offshore oil and gas exploration, production and transportation. We have conducted many of the major government-sponsored research projects on bowheads and most of the oil-industry funded monitoring studies of bowheads. Most of our joint biological/acoustical studies have been conducted in association with Dr. C.R. Greene and Greeneridge Sciences Inc. We have conducted joint studies since 1980. This experience has allowed us to achieve fully integrated studies in which the acoustical results are directly relevant to the biological questions of interest.

The following sections present lists of studies that we have conducted that are relevant to the present proposal. More detailed descriptions of these and other projects are presented in Appendix 2.

Alaskan Bowhead Monitoring Studies

LGL and Greeneridge have conducted most of the industry-funded bowhead monitoring studies to date. These include

- construction of an artificial gravel island (Seal Island) in 1982 for Shell Oil Company, Houston (with C.R. Greene).
- exploration-related activities on an artificial island (Seal Island) in 1984 for Shell Western E & P Inc. (SWEPI), Anchorage (with Greeneridge Sciences Inc.).
- seismic exploration in the eastern Alaskan Beaufort Sea for Amoco Production Company, Denver.
- exploratory drilling from a drillship at the Hammerhead site in Camden Bay in 1985 for Union Oil of California. Part of this study was funded by the Alaska Oil and Gas Association (AOGA) (with Greeneridge Sciences Inc.).
- icebreaking noise measurements using a drillship at the Corona site for SWEPI in 1985 (with Greeneridge Sciences Inc.).
- exploratory drilling from an artificial island (Sandpiper Island) in 1985 for SWEPI, Anchorage (with Greeneridge Sciences Inc.).

In addition to these field studies, we prepared environmental reports on the potential effects of exploratory drilling on bowheads for Global Marine Inc. for their CIDS sites off Harrison Bay; for Sohio Alaska Petroleum Company for their Mukluk artificial island; and for Placid Oil for several potential drilling sites in the Alaskan Beaufort Sea.

Government-funded Research Programs

LGL has conducted several relevant research programs for government agencies. These include

- A major five year (1980-84) study of the potential short-term effects of offshore exploration and underwater noise on bowheads. This study was funded by the U.S. Minerals Management Service (MMS) but conducted in the Canadian Beaufort Sea where offshore exploration has been conducted since 1976 (with Greeneridge Sciences Inc.).
- An intensive two-year (1985-86) study of the importance of the eastern Alaskan Beaufort Sea for feeding bowhead whales is being conducted for Minerals Management Service (with Greeneridge Sciences Inc.)

- As the biological subcontractor to BBN Inc., we are participating in the MMS-funded study (1985-86) of industrial sources of underwater noise in the Alaskan Beaufort Sea.

- An integrated study of the feeding ecology of the gray whale was conducted in the Bering Sea for the OCSEAP program of NOAA.

- A study of the length distribution and reproductive biology of the bowhead whale was conducted in 1982 for the National Marine Mammal Laboratory (NMFS), Seattle.

- An experimental study of the long-term effects of offshore exploration on bowhead whales was conducted for Canada Department of Indian and Northern Affairs (DIAND) in the Canadian Beaufort Sea in 1984.

- A study of feeding ecology of bowheads and the oceanography of Yukon coastal waters was conducted for DIAND in 1985.

- LGL is the principal contractor for the Beaufort Environmental Monitoring Project (BEMP) which has focussed on the potential effects on bowhead whales of offshore production in the Canadian Beaufort Sea. Funded by the Canadian Departments of Environment, Fisheries and Oceans, and Northern Affairs.

Industry-funded Studies

We have conducted a variety of additional studies of bowheads that have been funded by the Alaskan and/or Canadian oil industries. These include

- A major two-month, two aircraft census of the Western Arctic bowhead population on its summering grounds in the eastern Beaufort Sea and Amundsen Gulf in 1981. This study was funded by a consortium of seven Alaskan and three Canadian oil companies and the State of Alaska.

- A major field study (two aircraft) of the reproductive rate of the bowhead whale for a group of ten Alaskan oil companies and three government agencies in 1985.

- Studies of the distribution of bowheads in relation to offshore exploration in the Canadian Beaufort Sea in 1980 and 1983 for Dome Petroleum, Gulf Canada Resources and Esso Resources.

- Surveys of the distribution and fall migration of bowheads out of the Canadian Beaufort Sea in October 1985 for Shell Western E & P Inc., Anchorage.

- A major literature review of the effects of offshore oil and gas activities on cold water marine mammals for the American Petroleum Institute, Washington (with C.R. Greene).

Eastern Arctic Bowhead Population

LGL has also conducted a variety of studies on the distribution and behavior of bowheads in the waters of the Canadian eastern arctic and Greenland. Studies were conducted in all but one of the 12 years from 1974 to 1985 and covered the full species range from the pack ice of the wintering grounds in Hudson Strait to summering areas in Baffin Bay and the High Arctic. Sponsors of these studies have included industrial consortia such as the Polar Gas Project, Arctic Pilot Project, Norlands Lancaster Sound group, and Petro-Canada EAMES project. Other clients in this area have included DIAND, Fisheries and Oceans, and World Wildlife Fund (Canada).

Acoustical Studies - Greeneridge Sciences Inc.

Greeneridge Sciences has conducted several field experiments for underwater sound data collection and analysis involving the influence of industrial sounds on marine mammals.

The first field trip was a month-long effort in two places: in Baffin Bay to record the sounds of the Canadian Coast Guard Ship John A. MacDonald breaking ice at various ranges, and in Lancaster sound recording sounds of narwhals, white whales, and ships breaking ice in the vicinity. At the same time biologists monitored whale activity. The work was funded by the Canadian Government and several industrial concerns through the Department of Indian Affairs and Northern Development. The data collection was successfully completed and the resulting reports submitted. LGL Ltd. in Toronto was the prime contractor and performed the biological work.

Field trips to the Canadian Beaufort Sea were conducted in August every year from 1980-1984. The project was funded by the U.S. Department of the Interior, Minerals Management Service, with the objective of learning how industrial activities affect bowhead whales. Greeneridge was responsible for collecting underwater sound data from industrial sources and for projecting previously recorded industrial sounds in the presence of whales while biologists observed whale reactions, if any. The data collection effort was successful. Data analysis and reporting have been completed. LGL was the prime contractor on this five year study.

Greeneridge participated in the NOSC study of seismic noise and bowhead whales in the Alaskan Beaufort Sea in September 1983. The sounds from a seismic exploration airgun array at various distances were recorded.

In 1984, Greeneridge conducted the acoustic portions of the Seal Island monitoring program for Shell Western E and P. The study included the use of an acoustic array and boat- and aircraft-deployed hydrophones.

In 1985, Greeneridge undertook several acoustic studies in the Alaskan Beaufort Sea in conjunction with LGL Ltd. These studies involved the drilling operation at Hammerhead which used the Canmar Explorer II, Robert Lemeur, and Canmar Supplier I. This study was funded by Unocal and the Alaska Oil and Gas Association (AOGA). In addition, acoustic measurements were made of the icebreaker Robert Lemeur at Corona for SWEPI and drilling from an artificial island (Sandpiper) also for SWEPI.

In all of these projects, tape recordings from the field tests were analyzed to determine the frequency spectrum distribution of the noise power, separating the tonal and random components of the noise quantitatively. Sound levels in standard 1/3-octave bands and in other, wider bands were computed. Natural and industrial sounds alike have been analyzed in this way. All equipment has been calibrated to permit referring all sound levels to a standard unit of sound pressure.

Transient sounds, like airgun array signals and bowhead calls, have been analyzed to determine their sound pressure levels. Such signals have been analyzed into their frequency components as a function of time and displayed as waterfall spectrograms. These displays present the variation of a signal's power vs. time and frequency.

For many industrial noise sources, sound levels have been measured vs. distance from the source. From the data, equations have been derived to moedl the received sound levels as a function of range, permitting sound levels to be predicted for other ranges than those measured. This technique has been useful in providing information on ranges at which bowheads might be influenced by sound from a specific source.

Dr. Charles Greene is the President and Principal Scientist at Greeneridge Sciences. His personal experience with passive acoustic ranging systems began while he was with the U.S. Navy, where he worked on data display, automatic tracking of passive sonar targets, and a system for tracking torpedos using only the noise made by the running torpedo. He has worked on underwater acoustics research problems in the arctic since 1962, addressing problems including ambient noise and sound transmission loss, absorption at high frequencies, the coherence of ambient noise, sound levels from industrial sources including aircraft, drillships, semisubmersibles, boats, and dredges, as well as sounds from bowhead whales.

LITERATURE CITED

Beeman, K., C.W. Clark and W.T. Ellison. 1985. Acoustic tracking of migrating whales. Horizon, Vol. 9, Sippican Ocean Systems, Inc.

Braham, H., B.D. Krogman and G.M. Carroll. 1984. Bowhead and white whale migration, distribution, and abundance in the Bering, Chukchi, and Beaufort seas, 1975-78. NOAA Tech. Rep. NMFS SSRF-778. Nat. Oceanic & Atmos. Admin., Rockville, MD. 39 p.

Cubbage, J.C., J. Calambokidis and D.J. Rugh. 1984. Bowhead whale length measured through stereophotogrammetry. Rep. from Cascadia Res. Collective, Olympia, WA, for Nat. Mar. Mamm. Lab., Seattle, WA. 71 p.

Cummings, W.C. an D.V. Holliday. 1985. Passive acoustic location of bowhead whales in a population census off Point Barrow, Alaska. J. Acoust. Soc. Am. 78(4):1163-1169.

Davis, R.A., C.R. Greene and P.L. McLaren. 1985. Studies of the potential for drilling activities on Seal Island to influence fall migration of bowhead whales through Alaskan nearshore waters. Rep. by LGL Ltd., King City, for Shell Western E & P Inc., Anchorage, AK. 69 p.

Davis, R.A., W.R. Koski and G.W. Miller. 1983. Preliminary assessment of the length-frequency distribution and gross annual reproductive rate of the western arctic bowhead whale as determined with low-level aerial photography, with comments on life history. Unpubl. Rep. from LGL Ltd., Toronto, for Nat. Mar. Mamm. Lab., Seattle, WA. 91 p.

Davis, R.A., W.R. Koski and G.W. Miller. 1986. Experimental use of aerial photogrammetry to assess the long-term responses of bowhead whales to offshore industrial activities in the Canadian Beaufort Sea. Rep. by LGL Ltd., King City, to Canada Dept. Indian and Northern Affairs, Ottawa. 155 p.

Davis, R.A., W.R. Koski, W.J. Richardson, C.R. Evans and W.G. Alliston. 1982. Distribution, numbers and productivity of the western arctic stock of bowhead whales in the eastern Beaufort Sea and Amundsen Gulf, summer 1981. Unpubl. Rep. from LGL Ltd., Toronto, for Sohio Alaska Petrol. Co. and Dome Petrol. Ltd. (co-managers). 134 p. Summarized as Int. Whal. Comm. document SC/34/PS20.

Finley, K.J., C.R. Greene and R.A. Davis. 1983. A study of ambient noise, ship noise, and the reactions of narwhals and belugas to the MV _Arctic_ breaking ice in Admiralty Inlet, N.W.T. - 1982. Rep. by LGL Limited for Canada Department of Indian Affairs and Northern Development, Ottawa. 108 p.

Finley K.J., G.W. Miller, R.A. Davis and C.R. Greene. 1984. Responses of narwhals (_Monodon monoceros_) and belugas (_Delphinapterus leucas_) to icebreaking ships in Lancaster Sound - 1983. Rep. by LGL Ltd., to Canada Dept. of Indian Affairs and Northern Development, Ottawa. 117 p.

Gilmer, D.S., L.M. Cowardin, R.L. Duval, L.M. Mechlin, C.W. Shaiffer and V.B. Kuechle. 1981. Procedures for the use of aircraft in wildlife biotelemetry studies. U.S.F. & W.S. Resour. Publ. 140. 19 p.

Greene, C.R. 1982. Characteristics of waterborne industrial noise. p. 249-346 In: W.J. Richardson (ed.), Behavior, disturbance responses and feeding of bowhead whales *Balaena mysticetus* in the Beaufort Sea, 1980-81. Chapter by Polar Research Laboratory, Inc., in Unpubl. Rep. from LGL Ecol. Res. Assoc., Inc., Bryan, TX, for U.S. Bureau of Land Management, Washington, DC. 456 p.

Greene, C.R. 1985. Characteristics of waterborne industrial noise, 1980-84. p. 197-253 In: W.J. Richardson (ed.), Behavior, disturbance responses and distribution of bowhead whales *Balaena mysticetus* in the eastern Beaufort Sea, 1980-84. Unpubl. Rep. from LGL Ecol. Res. Assoc., Inc. Bryan, TX, for U.S. Minerals Management Service, Reston, VA. 306 p.

Greene, C.R. and B.M. Buck. 1964. Arctic Ocean ambient noise. J. Acoust. Soc. Am. 36:1218-1220.

Hickie, J. and R.A. Davis. 1983. Distribution and movements of bowhead whales and other marine mammals in the Prudhoe Bay region, Alaska, 26 September to 13 October 1982. p. 84-117. In: B.J. Gallaway (ed.), Biological studies and monitoring at Seal Island, Beaufort Sea, Alaska, 1982. Rep. by LGL Ecol. Res. Assoc., Inc., Bryan, TX, for Shell Oil Co. Inc., Houston, Texas. 150 p.

Johnson, S.R. 1983. Birds and marine mammals. p. 115-175 In: Environmental characterization and biological use of lagoons in the eastern Beaufort Sea. Rep. by LGL Ecol. Res. Assoc. Inc., Bryan, TX, to NOAA/OCSEAP, Juneau, AK.

Ljungblad, D.K. 1981. Aerial surveys of endangered whales in the Beaufort Sea, Chukchi Sea and northern Bering Sea. NOSC Tech. Doc. 449, Naval Ocean Systems Center, San Diego, CA. 302 p.

Ljungblad, D.K., S.E. Moore, J.T. Clarke, D.R. Van Schoik and J.C. Bennett. 1985a. Aerial surveys of endangered whales in the northern Bering, eastern Chukchi and Alaskan Beaufort Seas, 1983: with a six year review, 1979-1984. NOSC Tech. Rep. 1046, Naval Ocean Systems Center, San Diego, CA. 301 p.

Ljungblad, D.K., S.E. Moore and D.R. Van Schoik. 1983. Aerial surveys of endangered whales in the Beaufort, eastern Chukchi, and northern Bering Seas, 1982. NOSC Tech. Doc. 605, Naval Ocean Systems Center, San Diego, CA. 382 p.

Ljungblad, D.K., S.E. Moore and D.R. Van Schoik. 1984. Aerial surveys of endangered whales in the northern Bering, eastern Chukchi and Alaskan Beaufort Seas, 1983: with a five year review, 1979-1983. NOSC Tech. Rep. 955, Naval Ocean Systems Center, San Diego, CA. 356 p.

Ljungblad, D.K., S.E. Moore, D.R. Van Schoik and C.S. Winchell. 1982. Aerial surveys of endangered whales in the Beaufort, Chukchi, and northern Bering Sea. NOSC Tech. Doc. 486, Naval Ocean Systems Center, San Diego, CA. 406 p.

Ljungblad, D.K., M.F. Platter-Rieger and F.S. Shipp, Jr. 1980. Aerial surveys of bowhead whales, North Slope, Alaska. NOSC Tech. Doc. 314, Naval Ocean Systems Center, San Diego, CA. 181 p.

Richardson, W.J., M.A. Fraker, B. Würsig and R.S. Wells. 1985a. Behaviour of bowhead whales Balaena mysticetus summering in the Beaufort Sea: reactions to industrial activities. Biol. Conserv. 32(3):195-230.

Richardson, W.J., R.S. Wells and B. Würsig. 1985b. Disturbance responses of bowheads, 1980-84. p. 89-196 In: W.J. Richardson (ed.), Behavior, disturbance responses and distribution of bowhead whales Balaena mysticetus in the eastern Beaufort Sea, 1980-84. Unpubl. Rep. from LGL Ecol. Res. Assoc., Inc., Bryan, TX, for U.S. Minerals Management Service, Reston, VA. 306 p.

Thiele, L. 1981. Underwater noise from the icebreaker M/S "Voima". Rep. No. 81.42, Ødegaard & Danneskiold-Samsøe K/S, Copenhagen, Denmark. 35 p.

Thiele, L. 1984. Preliminary results of underwater noise measurements on the icebreaker "John A. MacDonald". Note No. 84-108, Ødegaard & Danneskiold-Samsøe K/S, Copenhagen, Denmark. 21 p.

Thomson, D.H., D.B. Fissel, J.R. Marko, R.A. Davis and G.A. Borstad. 1986. Distribution of bowhead whales in relation to hydrometeorological events in the Beaufort Sea. Environmental Studies Revolving Funds Report No. 028. Ottawa. 119 p.

Urick, R.J. 1972. Noise signature of an aircraft in level flight over a hydrophone in the sea. J. Acoust. Soc. Am. 52:993-999.

Urick, R.J. 1975. Priciples of underwater sound. 2nd Ed. McGraw-Hill Co., New York. 384 p.

Wenz, G.M. 1962. Acoustic ambient noise in the ocean: spectra and sources. J. Acoust. Soc. Am. 34:1936-1956.

Würsig, B., C.W. Clark, E.M. Dorsey, M.A. Fraker and R.S. Payne. 1982. Normal behavior of bowheads. p. 33-143 In: W.J. Richardson (ed.). Behavior, disturbance responses and feeding of bowhead whales Balaena mysticetus in the Beaufort Sea, 1980-81. Rep. from LGL Ecol. Res. Assoc., Inc., Bryan, TX, for U.S. Bureau of Land Management, Washington, DC. 456 p.

Würsig, B., C.W. Clark, E.M. Dorsey, W.J. Richardson and R.S. Wells. 1983. Normal behavior of bowheads, 1982. p. 25-115 In: W.J. Richardson (ed.), Behavior, disturbance responses and distribution of bowhead whales Balaena mysticetus in the eastern Beaufort Sea, 1982. Unpubl. Rep. from LGL Ecol. Res. Assoc., Inc., Bryan, TX, for U.S. Minerals Management Service, Reston, VA. 357 p.

Würsig, B., E.M. Dorsey, M.A. Fraker, R.S. Payne, W.J. Richardson and R.S. Wells. 1984. Behavior of bowhead whales, Balaena mysticetus, summering in the Beaufort Sea: surfacing, respiration, and dive characteristics. Can. J. Zool. 62(10):1910-1921.

Würsig, B., E.M. Dorsey, W.J. Richardson, C.W. Clark and R. Payne. 1985. Normal behavior of bowheads, 1980-84. p. 13-88 In: W.J. Richardson (ed.), Behavior, disturbance responses and distribution of bowhead whales, Balaena mysticetus, in the eastern Beaufort Sea, 1980-84. Rep. from LGL Ecol. Res. Assoc., Inc., Bryan, TX, for U.S. Minerals Management Service, Reston, VA. 306 p.

APPENDIX 1

This list shows the journal papers that have been prepared based on the LGL/MMS study of the behavior and disturbance responses of bowhead whales.

Normal Behavior Papers

Würsig, B., E.M. Dorsey, M.A. Fraker, R.S. Payne, W.J. Richardson and R.S. Wells. 1984. Behavior of bowhead whales, Balaena mysticetus, summering in the Beaufort Sea: surfacing, respiration, and dive characteristics. Can. J. Zool. 62(10):1910-1921.

Würsig, B., E.M. Dorsey, M.A. Fraker, R.S. Payne and W.J. Richardson. 1985. Behavior of bowhead whales, Balaena mysticetus, summering in the Beaufort Sea: a description. Fish. Bull. U.S. 83(3):357-377.

Würsig, B., E.M. Dorsey, M.A. Fraker, R.S. Payne and W.J. Richardson. in press. Behaviour of bowhead whales, Balaena mysticetus, summering in the Beaufort Sea: a summary. Rep. Int. Whal. Comm. (Spec. Issue 8).

Würsig, B., E.M. Dorsey, W.J. Richardson and R.S. Wells. MS. Feeding, aerial and play behavior of the bowhead whale, Balaena mysticetus, summering in the Beaufort Sea. Submitted to 'Arctic'

Dorsey, E.M., W.J. Richardson and B. Würsig. MS. Factors affecting respiration, surfacing and dive characteristics of bowhead whales, Balaena mysticetus, summering in the Beaufort Sea. In revision.

Disturbance Papers

Richardson, W.J., M.A. Fraker, B. Würsig and R.S. Wells. 1985. Behaviour of bowhead whales, Balaena mysticetus, summering in the Beaufort Sea: reactions to industrial activities. Biol. Conserv. 32(3): 195-230.

Richardson, W.J., B. Würsig and C.R. Greene, Jr. In press. Reactions of bowhead whales, Balaena mysticetus, to seismic exploration in the Canadian Beaufort Sea. J. Acoust. Soc. Am. 79(4). To appear in April 1986 issue.

Industrial Noise Papers

Greene, C.R., Jr. MS. Characteristics of oil industry dredge and drilling sounds in the Beaufort Sea. Submitted to 'J. Acoust. Soc. Am.'

Greene, C.R., Jr., and W.J. Richardson. MS. Characteristics of marine seismic survey sounds in the Beaufort Sea. Submitted to 'J. Acoust. Soc. Am.'

Distribution Paper

Richardson, W.J., R.A. Davis, C.R. Evans, D.K. Ljungblad and P. Norton. MS. Summer distribution of bowhead whales, *Balaena mysticetus*, relative to oil industry activities in the Canadian Beaufort Sea, 1980-84. In revision for 'Arctic'.

APPENDIX 2. RELEVANT CORPORATE EXPERIENCE OF LGL LIMITED AND GREENERIDGE SCIENCES INC.

LGL Limited has conducted a large number of studies of bowhead whales and other arctic marine mammals. This attachment contains brief descriptions of some of the more relevant of these studies. Many of these studies were conducted in association with Greeneridge Sciences Inc., Santa Barbara, CA.

Monitoring the Responses of Bowhead Whales to Drilling from Sandpiper Island during the Fall Migration. This study was conducted by LGL in 1985 for Shell Western E & P Inc. This was the first case where active drilling from an artificial island was permitted during the fall migration. The levels of underwater noise associated with the operation were measured. The responses of whales were studied using a combination of systematic aerial surveys and behavioral observations. The approximate age of the animals and their individual identity were examined using aerial photography. In addition, hydrophones were monitored continuously to determine if bowheads were present near the island during periods when aerial surveys were not being conducted. Underwater acoustic measurements were made by Greeneridge Sciences Inc.

Evaluation of Underwater Noise Levels Associated with Offshore Drillship Operations and the Migration Patterns of Bowheads at Hammerhead Site, Camden Bay, Alaska. Detailed measurements of underwater noise levels associated with offshore drilling operations were made by Greeneridge Sciences Inc. as a subcontract to LGL. A five hydrophone moored array was tested to assess its efficiency for monitoring bowhead whale travel routes. The array also provided data to assess the variability of noise emanating from the drillship operation. The array was designed and operated by Greeneridge Sciences Inc.

Bowhead whales were monitored using systematic aerial surveys to determine the routes used by migrating whales. Emphasis was placed on the distribution patterns near the several potential drillsites. Drilling was not permitted at the Hammerhead site during the bowhead migration. This study was funded by Unocal and the Alaska Oil and Gas Association (AOGA).

Assessment of the Effects of Actual Drillship Operations on Bowhead Migration in Ice-infested Waters. Shell Western E & P Inc. obtained a permit to drill from a drillship (Canmar Explorer II) at the Corona site in the Alaskan Beaufort Sea during the fall bowhead migration. Associated research was designed and conducted by LGL. The research included detailed aerial behavioral observations, systematic aerial surveys, and aerial photography. The program was curtailed by heavy ice and the resultant cancellation of the drilling program. Efforts were made to document levels of underwater sound from icebreakers operating in the area. Preliminary measurements of ice-breaker noise were made by Greeneridge Sciences Inc.

Studies of the Potential for Drilling Activities at Seal Island to Influence Fall Migration of Bowheads Through Alaskan Nearshore Waters. This study was conducted in the fall of 1984 for Shell Western E & P. It involved systematic aerial surveys of bowhead distribution and acoustic monitoring of industrial noise and bowhead calls. Acoustic studies included the use of arrays to localize whale positions as well as documenting levels of industrial and ambient noise. The acoustics phase was conducted by Greeneridge Sciences Inc.

Effects of Island Construction in the Alaskan Beaufort Sea. This study was conducted by LGL for Shell Oil in 1982. The study was designed to determine the responses of marine mammals and birds to various activities associated with construction of a gravel island. The study included monitoring the underwater sounds resulting from various construction activities as well as underwater vocalizations of seals and whales during and after island construction. Acoustic monitoring of the fall bowhead migration was conducted, and aerial surveys were used to document the timing and proximity of bowhead migration past the artificial island. The acoustic monitoring was conducted by Dr. C.R. Greene, then of Polar Research Lab.

Behavior of Bowhead Whales in the Presence of Offshore Oil and Gas Industry Activities. In 1980-84, on behalf of the U.S. Minerals Management Service, LGL performed a five-year study of the behavior of bowheads and the possible disturbance effects of offshore oil and gas industry activities, particularly offshore drilling, seismic exploration, and other activities that produce underwater sounds. The aim was to study short-term behavioral reactions to industrial activities, although distributional data from 1980-84 were also analyzed as a first attempt to determine if there is long-term displacement. A comprehensive review of available information concerning these topics was prepared early in the study.

The types of activities studied in the field included aircraft and marine traffic, construction of artificial islands, drilling, and underwater seismic exploration. LGL's approach was to apply both experimental and observational techniques. Controlled experiments involved observation of bowhead behavior before, during and after disturbance by boats, aircraft, etc. Considerable effort was also expended in determining the normal behavior patterns of bowheads, and in measuring the characteristics and propagation of industrial noises present in the water near ongoing exploratory operations. LGL has submitted several papers based on this study for publication in scientific journals. Greeneridge Sciences Inc. conducted the acoustic portions of this five year study.

Site-Specific Study of Industrial Noise Sources in the Alaskan Beaufort Sea. LGL is acting as a subcontractor to BBN Inc. in this MMS-funded study. The study conducted in 1985-86 is designed to document noise levels of various industry activities and the patterns of transmission loss of these sounds. LGL is providing expertise related to the potential zones of influence of these activities on bowhead whales.

Importance of the Eastern Alaskan Beaufort Sea to Feeding Bowheads. This two-year study, which began in 1985 on behalf of U.S. Minerals Management Service, is designed to quantify the proportion of the energy requirements of the Western Arctic bowhead whale stock that is provided by food resources located in the eastern Alaskan Beaufort Sea. The study is addressing both the feeding activities of bowheads in the eastern Alaskan Beaufort Sea and also the availability, distribution, patchiness and energy content of prey. Activities and residence times of bowheads in the area are being studied through the use of (1) aerial and boat surveys of distribution, numbers and movements; (2) observations of feeding behavior and other activities; (3) photogrammetric work to study population composition and recurrence of identifiable individuals in feeding areas; and (4) radio-tagging of individuals to assess detailed activity patterns.

Studies of bowhead prey include (1) hydroacoustic surveys to determine zooplankton distribution and relative biomass in various areas and positions in the water column; (2) net sampling at selected stations and depths to determine actual numbers, biomasses and species composition, and to provide zooplankton samples for size-frequency, calorimetry, and other analyses; (3) boat-based measurements of water temperature, salinity and chlorophyll content; (4) aerial remote sensing of water temperature, chlorophyll and sediment content on a near-synoptic basis; and (5) digital processing of satellite imagery to acquire synoptic data on sea surface temperature and water color on the few cloud-free days.

The final report for this study will include an estimation of the total energy needs of the Western Arctic bowhead stock and an assessment of the contribution of the eastern Alaskan Beaufort Sea to that total.

<u>Reproductive Parameters of the Bowhead Whale and the Status of the Western Arctic Bowhead Population</u>. This project, conducted in 1985, was designed to provide an estimate of Gross Annual Recruitment Rate (GARR), defined as the number of calves as a proportion of the population, for the Western Arctic stock of bowheads and to provide other information about population status (proportion of yearlings, calving interval, etc.). A subsidiary objective of the study was to assess geographic segregation on the summer range of animals of different age and reproductive classes.

The study was conducted by means of extensive systematic aerial surveys in both Amundsen Gulf and the Beaufort Sea. Bowheads were photographed whenever they were encountered with the objective of photographing as large a proportion of the population, and especially the adult population, as possible. Age classes will be assessed through length measurements, and it is hope that calving interval can be estimated through repeat identifications of females photographed with calves in previous years. Data analysis for this project is ongoing.

This project is funded by a consortium of ten Alaskan oil companies (managed by Standard Alaska Production Co.) and three government departments (U.S. National Marine Fisheries Service, Canada Dept. Fisheries and Oceans, and Canada Dept. Northern Affairs).

<u>Food Availability Characteristics of the Offshore Yukon Coast to the Bowhead Whale</u>. The primary objective of this study conducted in 1985, was to gain a better understanding of the importance of the Yukon nearshore and adjacent marine areas in the annual energy budget of the bowhead whale. Data collection techniques included sampling of zooplankton by means of both oblique and surface bongo net tows, hydroacoustic sampling to assess the

extent of zooplankton patches, and collection of physical oceanographic data both by satellite and directly. Samples were collected in a systematic grid off the Yukon coast. In addition to the samples taken in this grid, horizontal bongo tows were made in areas where the echosounder indicated zooplankton patches, and also when feeding bowhead were encountered. Data analysis for this project is nearing completion. The results of this study were compared with the results of other studies of bowhead whale distribution in the area. The study was funded by Canada Department of Northern Affairs.

Studies of Length-Frequency Distribution and Individual Identification of Bowhead Whales Using Low-level Aerial Photography in 1982. This study was conducted in the Beaufort Sea for the U.S. National Marine Fisheries Service during August 1982. The project involved the use of vertical aerial photography from precisely measured altitudes to obtain photographs from which the lengths of animals could be measured and animals could be identified based on color and scar patterns. Photographs were taken using a 6x7 cm camera shooting through a floor camera hatch. A total of 728 whale images were obtained from which 436 measurements were made; 206 individual whales would be identifiable in future years. Average errors associated with the measurements using this technique were estimated to be less than 1.5%. Additional information obtained from the photographs included an estimate of percent calves in the population and the distances travelled by individual animals between resightings. Application of this remote sensing technique to this endangered species over a period of years could provide additional information such as the calving interval for individual females, estimation of population size via mark-recapture methods, and analysis of the tendency to return to the same site in later years. The results of this pilot study were encouraging. Results were presented to, and defended at, the Scientific Committee of International Whaling Commission.

Distribution, Numbers and Productivity of Western Arctic Bowhead Whales in 1981. In 1981 an extensive aerial census program was conducted in the Canadian Beaufort Sea. The purpose of this census program was (1) to determine the distribution and movements of bowhead whales in the Beaufort Sea and Amundsen Gulf, and (2) to obtain information from which a population estimate could be derived for comparison with estimates derived from counts of bowheads migrating past Point Barrow, Alaska. The study area extended from the Alaska-Yukon border to the east end of Amundsen Gulf and from the coast north to 72°N, an area of approximately 210,000 km^2. Four complete censuses of this area were attempted using 10% or 20% coverage in different portions of the study area. Two aircraft and eight aerial surveyors conducted these strip transect censuses from mid July to mid September.

Total numbers of whales present in the study area were estimated for each survey period using mathematical and statistical procedures derived specifically for the study. Correction factors were derived (1) to estimate the numbers of whales at the surface that were missed by the observers, and (2) for the proportion of whales that were below the surface (and hence not visible) at the time of the census. Estimates of bowhead population size using these methods suggested that the population was probably larger than 3842 animals. Results were presented to International Whaling Commission in 1982.

In addition to meeting the main objectives, vertical photographs of bowheads were taken. These proved usable for measurements of animal lengths and for individual identification of bowheads. Preliminary length-frequency histograms were constructed. This was the first attempt to develop a method to study individually recognizable, free-ranging bowheads.

This study was funded by Sohio Alaska Petroleum Co., Dome Petroleum, ARCO Alaska, BP Alaska Exploration, Chevron U.S.A., Exxon, Phillips Petroleum, Shell Oil, Esso Resources Canada, Gulf Canada, and the State of Alaska.

<u>Long-term Effects of Offshore Industrial Activity on the Bowhead Whale in the Canadian Beaufort Sea</u>. This study involved intensive use of aerial photography to determine the distribution, behavior, movements and residence times of bowheads near industrial activities and in unaffected control areas. The study focused on a small part of the Beaufort Sea yet over 1000 images of bowhead whales were obtained. The 1984 study was funded by three departments of the Canadian government.

<u>Distribution of Bowheads Around Seismic Exporation Vessels in the Alaskan Beaufort Sea</u>. In September 1984, as part of an operating permit, Amoco was required to monitor the presence of bowhead whales near operating seismic boats. LGL conducted daily intensive aerial surveys around and east of the boats. When whales were detected east of a boat, an estimate was made of the time that would elapse before the whale would be within 5 n.mi. of the vessel, and this information was relayed by radio to the vessel.

<u>Aerial Surveys of Bowheads in the Southeastern Beaufort Sea in 1980</u>. During the period from early August to early September 1980, LGL conducted three aerial surveys of the numbers and distribution of bowheads off the Tuktoyaktuk Peninsula and Mackenzie Delta for Dome Petroleum and Esso Resources Canada Ltd. Calf counts were conducted, and potential biases discussed. Very large numbers of bowheads were found close to shore, including many near industrial sites, during this study in 1980.

<u>Factors Determining Bowhead Whale Distribution in the Beaufort Sea: A Feasibility Study</u>. This study involved a retrospective analysis of data from 1980-83. We attempted to determine whether the observed variable distribution of bowheads in the Canadian Beaufort Sea can be correlated with easily measurable physical oceanographic features. The study examined data on winds, hydrology of the Mackenzie River, temperature and salinity measurements taken from drillships, and satellite imagery. The study was funded by the Environmental Studies Revolving Fund.

<u>Aerial Surveys of Bowheads in the Southeastern Beaufort Sea in 1983</u>. This study was conducted by LGL in 1983. These systematic surveys were part of an ongoing industry-funded attempt to monitor the distribution patterns of bowheads in the areas of the Canadian Beaufort Sea where high levels of offshore oil and gas exploration activities are occurring. Two aerial surveys of the area from the Alaska-Yukon border east to Cape Bathurst, and from the shore north beyond the edge of the continental shelf, were conducted in late August and early September. The distribution and movements of whales were evaluated, and numbers in the main area of offshore oil exploration were compared with those elsewhere in the study area.

Review of Effects of Offshore Operations of the Petroleum Industry on Cold Water Marine Mammals. On behalf of the American Petroleum Institute, LGL completed a critical review of the literature relevant to effects of (1) waterborne noise and (2) other aspects of offshore industrial operations on marine mammals. Topics reviewed in detail included characteristics and propagation of industrial noise, hearing capabilities of marine mammals, production and use of sound by marine mammals, noise masking, documented reactions of marine mammals to noise and other human-related activities, habituation to ongoing industrial activities, and effects of oilspills on marine mammals. This study was oriented toward Alaskan species and operations, but the worldwide literature was used whenever relevant (e.g., in documenting characteristics of sounds from offshore drilling rigs and hearing capabilities of marine mammals). Special efforts were made to include information from current studies and from earlier studies that were not widely known or not published in the primary literature.

Distribution of Feeding Bowheads in the Eastern U.S. Beaufort Sea. Bowheads move west from Canadian to Alaskan waters in September, and continue to feed near the border. Bowheads in this area were studied by LGL in September 1982 as part of a larger interdisciplinary study of the eastern Alaskan Beaufort Sea sponsored by the U.S. government (NOAA/OCSEAP). Very high numbers of bowheads were documented in the coastal and nearshore waters of this area.

Environmental Effects of Gas Shipment Via Icebreaking LNG Carriers. In 1977-1978, LGL began field studies of the potential environmental effects of a plan to ship liquefied natural gas from Melville Island to an east coast port via icebreaking LNG ships (the Arctic Pilot Project). More recently, existing information about the physical and biological systems along the transportation route south to the Gulf of St. Lawrence was also reviewed, with emphasis on evaluating the zone of influence and consequences of year-round icebreaking on bowheads and other marine mammals plus seabirds. Effects of noise and other forms of disturbance on pinnipeds and whales were one of the main subjects evaluated. In early 1981, a workshop to assess the potential effects of noise from the LNG carriers on marine mammals was held, with major participation by Dr. R. Davis of LGL. Dr. Davis has subsequently participated in the Canadian-Danish working group established to deal with the international aspects of this potential problem.

In March of 1981 and 1982, large-scale systematic aerial survey programs were undertaken to document the distribution of overwintering marine mammals (mainly bowheads, white whales, narwhals and walruses) in pack ice habitat between Greenland and Baffin Island where the LNG carriers would pass. With supplementary funding from Petro-Canada and the Dept. of Fisheries and Oceans, the surveys were extended south to Labrador, and west through Hudson Strait and across northern Hudson Bay. These studies revealed a major wintering area in Hudson Strait and a wintering area south of Disko Island, Greenland.

Marine Ecology of Northwest Baffin Bay and Lancaster Sound. In 1978 and 1979, LGL Ltd. conducted systematic studies of marine mammals, seabirds, fish, benthos and plankton in the northern part of Baffin Bay for Petro-Canada Exploration as part of the EAMES project. The marine mammals components of this study included extensive aerial surveys of coastal and offshore waters (total survey length over 150,000 km) and shore-based migration watches to provide systematic information about the distributions, numbers, wintering areas, migration routes and timing, summering areas, and habitat dependencies of whales and other marine mammals. Population estimates were made for all important species by determining the extent of available habitat from satellite imagery and by incorporating into the aerial survey results correction factors for animals present but not recorded within the survey area. Bowheads were censused by counting them from shore during their autumn migration along the coast of Baffin Island. Extensive habitat analyses were conducted using appropriate statistical techniques for all marine mammal species identifying types of habitat (i.e. coastal, ice edge, pack ice edge, or offshore) and ice cover categories that were selectively used by each species. Preliminary results on bowheads and white whales were presented to the International Whaling Commission. Overall, about 20 scientific papers from these biological studies have been published in the primary literature.

Studies of Bowheads at Isabella Bay, Baffin Island. LGL completed a three year study of bowheads at this important summer concentration area in 1985. This study was funded by the World Wildlife Fund of Canada and involved studies of the behavior of bowheads including acoustic studies designed to determine why this area is apparently so important to eastern arctic bowheads.

Effects of Underwater Noise and Icebreakers on Belugas, Narwhals and Bowheads. This study was conducted in the eastern Canadian high arctic in spring in 1982, 1983 and 1984 for Canada Department of Indian Affairs and Northern Development. The acoustic portion of the study involved measurements of ship noise, transmission loss, ambient noise and whale and seal vocalizations. The studies of whale behavior and responses were directed by Dr. R.A. Davis of LGL Ltd. and the acoustics studies were conducted by Dr. C.R. Greene of Greeneridge Sciences Inc.

Scientific Committee, International Whaling Commission. Three members of LGL's staff were asked to participate as Invited Experts in the June 1979 meeting of the International Whaling Commission. Dr. R.A. Davis of LGL attended, and LGL submitted four invited papers. These included one paper on bowhead whales in the eastern arctic, two papers on white whales (in the Canadian high arctic and in the Beaufort Sea), and one paper on the narwhal harvest in the Canadian arctic. Three of these papers have since been published by the IWC. Similarly, K.J. Finley participated in the 1981 meeting and presented papers on narwhals and white whales. Invited papers on western arctic bowheads were presented in 1982 and 1983. In the latter year, R.A. Davis attended to present the results of LGL's 1982 photographic study of individually identifiable bowheads. Another invited paper, based on LGL's aerial survey work and subsequent analyses of the size of the eastern arctic narwhal population, was published previously by the IWC.

Environmental Review of Harrison Bay, Alaska. In 1983, on behalf of Sohio Alaska Petroleum Company, LGL prepared an environmental report to supplement the Mukluk Island Exploration Plan, a proposal for exploratory drilling in Harrison Bay, Alaska. This report included a description of the proposed action, a comprehensive discussion of the affected environment, and an evaluation of the environmental consequences and impacts on the environmental components. Marine mammal populations in the area were included in the discussion and evaluation.

Other Studies of Marine Mammals

LGL has also conducted several other studies of arctic and subarctic marine mammals aside from the bowhead studies. Several of these studies have been in the Beaufort Sea/Amundsen Gulf area, and several have involved studies of industrial effects on marine mammals.

--studies of white whales in relation to oil exploration in the Mackenzie estuary region, 1979-82, on behalf of Esso Resources Canada Ltd. and associated companies;

--studies of the carrying capacity of the northern Bering Sea for gray whales, conducted for the U.S. National Oceanic and Atmospheric Administration (NOAA/OCSEAP);

--effects of winter ice-breaking traffic on ringed seals in the Beaufort Sea for Dome Petroleum;

--effects of winter ice-breaking traffic on ringed seals in Labrador for Arctic Pilot Project;

--four years of studies (1974-77) of marine mammals in the central Canadian high arctic for Polar Gas Project, including extensive aerial surveys and behavioral studies of ringed seals and walruses;

--studies of ringed seals in Amundsen Gulf and Prince of Wales Strait for Polar Gas in 1980;

--studies of numbers, distribution and stock identity of white whales in eastern Hudson Bay and Hudson Strait for Department of Fisheries and Oceans;

--comprehensive review of the status and management of arctic marine mammals for the Northwest Territories Science Advisory Board;

--organization of a workshop on research needs relating to management of and industrial impacts on Canadian arctic marine mammals, for Department of Fisheries and Oceans;

--studies of birds and marine mammals (including several species of baleen whales) off Labrador coast in 1980-81 for OLABS;

--studies of numbers and distribution of marine mammals in relation to seismic exploration in central Hudson Bay, for Canadian Occidental Petroleum;

--aerial surveys of seabirds and marine mammals, including bowheads, in Lancaster Sound, for Norlands Petroleums in 1976.

In addition to the above studies of arctic marine mammals, the LGL group of companies have conducted many studies of arctic birds, freshwater and marine fish, and arctic marine systems for a variety of government agencies, industrial concerns, and native groups such as the North Slope Borough and Makivik Corp. (Northern Quebec Inuit Association).

APPENDIX 3

RESUMES OF KEY PERSONNEL

R.A. Davis
W.J. Richardson
C.R. Greene
R.S. Wells
S.L. Swartz
P.L. McLaren
W.R. Koski
C.W. Clark
W.T. Ellison
C.R. Evans
M.S.W. Bradstreet
G.W. Miller

DR. ROLPH A. DAVIS
President, LGL Ltd.
Director, LGL Ecological Research Associates, Inc., Bryan, Texas
Director, LGL Alaska Research Associates, Inc., Anchorage, Alaska

---

EDUCATION

1972	Ph.D. Animal Ecology, University of Western Ontario.
1964	Graduate courses in Wildlife Biology, University of Guelph.
1963	B.A. Geography, University of Toronto.

PROFESSIONAL EXPERIENCE

1979 to present — President of LGL Ltd.

1974-79 — Vice-President, Operations, and Director, Eastern Region, LGL Ltd.

1974 to present — Responsible for all LGL projects in the central and eastern Arctic and the High Arctic. Senior supervisor of most of LGL's bowhead studies in the western Arctic. Studies supervised have included LGL's work on

- -assessment of underwater noise characteristics of an operating drillship and patterns of bowhead migration at the Hammerhead and Corona drilling sites in Camden Bay, Alaska, for Unocal, SWEPI, and the Alaska Oil and Gas Association.

- -evaluation of the responses of migrating bowhead whales to an active drilling operation at an artificial island (Sandpiper Island) in the Alaskan Beaufort Sea.

- -major study of the reproductive biology of bowhead whales in the summering range in 1985 for ten Alaskan oil companies and three government agencies.

- -evaluation of the potential for offshore drilling from Seal Island to influence fall bowhead migration through nearshore Alaskan waters (1984) for Shell Western E & P Inc.

- -retrospective analyses of the relationships of bowhead distribution and oceanographic and hydrographic features in the Canadian Beaufort Sea from 1980-83 for ESRF.

- -aerial photography study of bowheads to determine distribution, movements, behaviour and residence times in relation to offshore industrial activities in the Canadian Beaufort Sea (1984) for DIAND, DFO and DSS.

-major participant in the Beaufort Environmental Monitoring Project (BEMP) for DIAND (1983-85).

-chairman of NOAA/OCSEAP workshop on marine mammals and offshore oil exploration in the Chukchi Sea.

-aerial surveys of bowhead whales and other mammals in the SE Beaufort Sea for ESRF in 1983.

-length distribution and photographic identification of bowhead whales in the Beaufort Sea for U.S. National Marine Fisheries Service (1982).

-winter distribution of marine mammals in west Greenland, Baffin Bay and Davis Strait for Arctic Pilot Project (1981-82).

-birds and marine mammals in the Labrador Sea, Strait of Belle Isle, and NE Newfoundland for OLABS (Petro-Canada operator) (1981-83).

-bowhead whales in the Beaufort Sea and Amundsen Gulf for a consortium of Canadian and Alaskan oil companies (1981);

-bowhead whales and ringed seals in the SE Beaufort Sea for Dome Petroleum Ltd. (1980);

-white whales in Hudson Strait and eastern Hudson Bay for Canadian Department of Fisheries and Oceans (1980-81);

-marine mammals, birds and resource harvesting in Baffin Bay, Jones Sound, Lancaster Sound, Prince Regent Inlet and Gulf of Boothia for Petro-Canada EAMES Project (1978-80);

-birds and marine mammals in Lancaster Sound for Norlands Petroleums Ltd. (1976);

-marine mammals and birds in the central and High Arctic (1973-1977) and Victoria Island (1980) for Polar Gas Project;

Senior author of a comprehensive review of the status and management of arctic marine mammals for NWT Science Advisory Board, and chairman of an international workshop on management of arctic marine mammals for DFO. Invited expert at Scientific Committee of the International Whaling Commission (1979, 1982, 1983) to present papers on the behaviour and status of populations of bowhead whales, narwhals and white whales. Prepared several Environmental Impact Statements for arctic projects and testified at EARP and National Energy Board hearings.

1972-74 Ornithological research for LGL Ltd. at the site of the proposed new Toronto International Airport and in Alaska, Yukon and N.W.T. along proposed gas pipeline routes.

1969-71 Teaching Assistant at University of Western Ontario (Department of Zoology) in introductory biology, ecology and bio-statistics.

1970 Research on the distribution and ecology of Red-throated Loons on offshore islands along the coast of the Labrador peninsula.

1967-69 Research on the comparative ecology of Arctic Loons and Red-throated Loons on the coastal tundra of the west shore of Hudson Bay. Cooperated on studies of the nesting ecology, population dynamics, social and feeding behaviour, and migration of geese.

1965-67 Technician, Department of Ornithology, Royal Ontario Museum. Involved field work on distribution of birds in southern Ontario, Lake Superior, James Bay and Central America.

REPORTS AND PUBLICATIONS

Reports and publications deal mainly with distribution and abundance of marine mammals and birds in the North American arctic and the impacts of development upon arctic ecosystems.

Reports and Publications on Marine Mammals

1986 Davis, R.A., W.R. Koski and G.W. Miller. Experimental use of aerial photogrammetry to assess the long-term responses of bowhead whales to offshore industrial activities in the Canadian Beaufort Sea. Rep. by LGL Ltd., King City, to Canada Dept. Indian and Northern Affairs, Ottawa. 155 p.

1986 Thomson, D.H., D.B. Fissel, J.R. Marko, R.A. Davis and G.A. Borstad. Distribution of bowhead whales in relation to hydro-meteorological events in the Beaufort Sea. Environmental Studies Revolving Funds Report No. 028. Ottawa. 119 p.

1985 Davis, R.A., C.R. Greene and P.L. McLaren. Studies of the potential for drilling activities on Seal Island to influence fall migration of bowhead whales through Alaskan nearshore waters. Rep. by LGL Ltd., King City, for Shell Western E & P Inc., Anchorage, AK. 69 p.

1985 Davis, R.A. and W.J. Richardson. Observations on the variable distribution of bowhead whales, Balaena mysticetus, in the vicinity of the 'industrial area' of the Canadian Beaufort Sea, 1976-1984. Extended abstract of paper presented at Third Conference on the biology of the bowhead whale, Balaena mysticetus, January 21-23, 1985. Anchorage, Alaska.

1985 Richardson, W.J., R.A. Davis, C.R. Evans and P. Norton. Distribution of bowheads and industrial activity, 1980-84. p. 255-306. In: W.J. Richardson (ed.), Behavior, disturbance responses and distribution of bowhead whales Balaena mysticetus in the eastern Beaufort Sea, 1980-84. Rep. by LGL Ecol. Res. Assoc., Inc., Bryan, TX, for U.S. Minerals Management Service, Reston, VA. 306 p.

1984 Davis, R.A. Fall migration of the bowhead whale through the Alaskan Beaufort Sea: implications for exploratory drilling. Rep. by LGL Limited, King City, Ontario, for D.F. Dickins Associates Ltd., Vancouver, B.C. 18 p.

1984 Miller, G.W. and R.A. Davis. Distribution and movements of narwhals and beluga whales in response to ship traffic at the Lancaster Sound ice edge - 1984. Rep. by LGL Limited, King City, Ontario, for Canada Dept. of Indian Affairs and Northern Development, Ottawa. 34 p.

1984 Finley, K.J., G.W. Miller, R.A. Davis and C.R. Greene. Responses of narwhals (Monodon monoceros) and belugas, (Delphinapterus leucas) to ice-breaking ships in Lancaster Sound - 1983. Rep. by LGL Limited,King City, Ontario, to Canada Dept. Indian Affairs and Northern Development, Ottawa. 118 p.

1984 Finley, K.J. and R.A. Davis. Reactions of beluga whales and narwhals to ship traffic and ice-breaking along ice edges in the eastern Canadian high arctic: 1982-1984. An overview. Rep. by LGL Limited, King City, Ontario, for Canada Dept. Indian Affairs and Northern Development, Ottawa. 41 p.

1984 Finley, K.J., C.R. Evans and R.A. Davis. Evaluation of the importance of Isabella Bay, Baffin Island, as summer habitat for the endangered bowhead whale. Progress report of 1984 studies. Rep. by LGL Limited, King City, Ontario, for World Wildlife Fund (Canada), Toronto, Ontario. 30 p.

1984 McLaren, P.L. and R.A. Davis. Distribution of bowhead whales and other marine mammals in the southeast Beaufort Sea, August-September 1983. Rep. by LGL Ltd., Toronto, to the Environmental Studies Revolving Funds, Ottawa. 63 p.

1984 Davis, R.A. and D.H. Thomson. Marine Mammals. 76 p. In: J. Truett (ed.). Barrow Arch environment and possible consequences of planned offshore oil and gas development. Rep. by LGL Ecological Research Associates, Texas, to U.S. NOAA, Juneau, Alaska.

1983 Davis, R.A., P.L. McLaren and R.A. Buchanan. Environmental issues and impacts associated with exploratory drilling in Lancaster Sound. Rep. by LGL Ltd., Toronto to The Consolidex Magnorth Oakwood Lancaster Sound Joint Venture and Pallister Resource Management Ltd., Calgary. 171 p.

1983 Davis, R.A., W.R. Koski and G.W. Miller. Preliminary assessment of the length-frequency distribution, life history and gross annual reproductive rate of the western arctic bowhead whale as determined with low-level aerial photography. Rep. by LGL Limited to U.S. National Marine Mammal Laboratory, Seattle, Wash. 93 p. (Paper SC/35/PS5 at Scientific Committee, International Whaling Commission, Cambridge, July 1983.)

1983 Davis, R.A. and W.J. Richardson. Bowhead whale population estimates and distribution from aerial survey efforts in the Canadian Beaufort Sea. Extended Abstract. 2nd Conference on Biology of the Bowhead Whale, Anchorage. 5 p.

1983 Finley, K.J., C.R. Evans and R.A. Davis. Evaluation of the importance of Isabella Bay, Baffin Island, as summer habitat for the endangered bowhead whale. Rep. by LGL Ltd., Toronto, to World Wildlife Fund, Toronto. 72 p.

1983 Finley, K.J., P. Norton and R.A. Davis. Status report on the white whale in the Beaufort Sea. Rep. by LGL Ltd., Toronto, to Canada Dept. of Fisheries and Ocean, Ottawa. 25 p.

1983 Finley K.J., C.R. Greene, and R.A. Davis. A study of ambient noise, ship noise, and the reactions of narwhals and belugas to the MV Arctic breaking ice in Admiralty Inlet, N.W.T. Rep. by LGL Ltd., to Canada Dept. of Indian Affairs and Northern Development, Ottawa. 95 p.

1983 Finley, K.J., J.P. Hickie and R.A. Davis. Status report on the white whale in the Beaufort Sea. Rep. by LGL Ltd., Toronto for Comm. on status of endangered wildlife in Canada. Dept. Fisheries and Oceans, Ottawa. 25 p.

1983 Richardson, W.J., R.A. Davis, C.R. Evans and P. Norton. Distribution of bowheads and industrial activity, 1980-82. In: W.J. Richardson (ed.), Behavior, disturbance responses and distribution of bowhead whales *Balaena mysticetus* in the eastern Beaufort Sea, 1982. Rep. for U.S. Minerals Management Service, Reston, VA.

1983 Hickie, J. and R.A. Davis. Distribution and movements of bowhead whales and other marine mammals in the Prudhoe Bay region, Alaska, 26 September-13 October 1982. Rep. by LGL Ecological Research Associates Inc. to Shell Oil Company Inc., Houston, Texas.

1983 McLaren, P.L. and R.A. Davis. Marine mammal distribution off West Greenland and in southern Baffin Bay and northern Davis Strait, March 1982. Rep. by LGL Limited, Toronto, to Arctic Pilot Project, Calgary. 98 p.

1983 Finley, K.J., G.W. Miller, R.A. Davis and W.R. Koski. A distinctive large breeding population of ringed seals (Phoca hispida) inhabiting the Baffin Bay pack ice. Arctic 36:162-173.

1983 Finley, K.J., C.R. Greene and R.A. Davis. A study of ambient noise, ship noise and the reactions of narwhals and belugas to the MV Arctic breaking ice in Admiralty Inlet, N.W.T. Rep. by LGL Limited, Toronto, to Can. Dept. Indian Affairs and Northern Development, Ottawa. 142 p.

1983 Richardson, W.J., C.R. Greene, J.P. Hickie and R.A. Davis. Review of the effects of offshore petroleum operations on cold water marine mammals. Rep. by LGL Limited, to American Petroleum Institute, Washington. 248 p.

1982 Davis, R.A. and C.R. Evans. Offshore distribution and numbers of white whales in the eastern Beaufort Sea and Amundsen Gulf, summer 1981. Rep. by LGL Limited, Toronto, to Sohio Alaska Petroleum Company, Anchorage, and Dome Petroleum Ltd., Calgary. 78 p.

1982 McLaren, P.L. and R.A. Davis. Winter distribution of arctic marine mammals in ice-covered waters of eastern North Amercia. Rep. by LGL Limited, Toronto, to Petro-Canada Exploration, Inc., Calgary. 151 p.

1982 Miller, G.W., R.A. Davis and K.J. Finley. Ringed seals in the Baffin Bay region: habitat use, population dynamics and harvest levels. Rep. by LGL Limited, Toronto, to Arctic Pilot Project, Calgary. 93 p.

1982 Finley, K.J., G.W. Miller, R.A. Davis and W.R. Koski. Status of ringed seals (Phoca hispida) of the Baffin Bay pack ice. Rep. by LGL Limited, Toronto, to Petro-Canada Exploration, Inc., Calgary. 39 p.

1982 Finley, K.J., G.W. Miller, M. Allard, R.A. Davis and C.R. Evans. The belugas (Delphinapterus leucas) of northern Quebec: distribution, abundance, stock identity, catch history and management. Can. Tech. Rep. Fish. Aquat. Sci. 1123. 57 p.

1982 Davis, R.A., W.R. Koski, W.J. Richardson, C.R. Evans and W.G. Alliston. Distribution, numbers and productivity of the Western Arctic stock of bowhead whales in the eastern Beaufort Sea and Amundsen Gulf, summer 1981. Rep. by LGL Ltd., Toronto, to Sohio Alaska Petroleum Co. and Dome Petroleum Ltd. (Co-managers). 134 p.

1981 Davis, R.A. Environmental research in frontier regions. In: Frontier oil and gas development--The decade ahead. Montebello, P.Q. (in press).

1981 Davis, R.A. Summary of marine mammal distribution in arctic portions of the proposed Arctic Pilot Project shipping route. p. 78-89. In: N.M. Peterson (ed.). The question of sound from icebreaker operations: Proceedings of a workshop. Arctic Pilot Project/Petro-Canada, Calgary. 350 p.

1981 Davis, R.A. Report of a workshop on arctic marine mammals. Can. Tech. Rep. Fish. Aquatic Sci. 1005:iv + 13 p.

1981 McLaren, P.L. and R.A. Davis. Distribution of wintering marine mammals in southern Baffin Bay and northern Davis Strait, March 1981. Rep. by LGL Limited, to Arctic Pilot Project, Calgary. 92 p.

1981 Renaud, W.E. and R.A. Davis. Aerial surveys of bowhead whales and other marine mammals off the Tuktoyaktuk Peninsula, N.W.T., August-September 1980. Rep. by LGL Limited, to Dome Petroleum Ltd., Calgary. 55 p.

1980 Davis, R.A. Issues in arctic marine mammal management. Paper presented to Can. Soc. Environmental Biologists. Ottawa, Jan. 1980.

1980 Koski, W.R. and R.A. Davis. Studies of the late summer distribution and fall migration of marine mammals in NW Baffin Bay and E Lancaster Sound, 1979. Rep. by LGL Limited, to Petro-Canada Exploration, Inc., Calgary. 214 p.

1980 Davis, R.A., K.J. Finley and W.J. Richardson. The present status and future management of arctic marine mammals in Canada. Sci. Advis. Board of the Northwest Territories Rep. No. 3. 93 p.

1980 Davis, R.A. and W.R. Koski. Recent observations of the bowhead whale in the eastern Canadian high arctic. Rep. int. Whal. Commn 30:439-444.

1980 Finley, K.J., R.A. Davis and H.B. Silverman. Aspects of the narwhal hunt in the eastern Canadian arctic. Rep. int. Whal. Commn 30:459-464.

1979 Davis, R.A. and K.J. Finley. Distribution, migrations, abundance and stock identity of eastern arctic white whales. Working paper SC/31/SM10, 31st Ann. Meeting, International Whaling Commission, Cambridge, England, June 1979. 49 p.

1979 Koski, W.R. and R.A. Davis. Distribution of marine mammals in northwest Baffin Bay and adjacent waters, May-October 1978. Rep. by LGL Ltd. to Petro-Canada, Calgary. 305 p. + Map Appendix (223 p.).

1979 Davis, R.A. and A.D. Sekerak. Notes on birds, marine mammals and marine ecology made during reconnaissance flights over Polar Gas Project's Y-Line and associated route options, July 1979. Rep. by LGL Ltd. to Polar Gas Project, Toronto. 11 p.

1978 Davis, R.A., W.R. Koski and K.J. Finley. Numbers and distribution of walruses in the central Canadian high arctic. Rep. by LGL Limited, to Polar Gas Project, Toronto. 50 p.

1978 Davis, R.A., W.J. Richardson, S.R. Johnson and W.E. Renaud. Status of the Lancaster Sound narwhal population in 1976. Rep. int. Whal. Commn 28:209-215.

1977 Davis, R.A. and A.D. Sekerak. 1977. Ecological significance of northwest Baffin Bay and Lancaster Sound. An overview report. Rep. by LGL Limited, to Petro-Canada, Calgary. 25 p.

1977 McLaren, M.A., W.E. Renaud, R.A. Davis and J.C. Treutt. 1977. Studies of terrestrial mammals on eastern Melville Island, July-August 1977. Rep. by LGL Limited, to Petro-Canada, Calgary. 111 p.

1976 Johnson, S.R., W.E. Renaud, R.A. Davis and W.J. Richardson. Marine mammals recorded during aerial surveys of birds in eastern Lancaster Sound, 1976. Rep. by LGL Limited, to Norlands Petroleums Ltd., Calgary. 180 p.

1975 Davis, R.A., K.J. Finley, M.S.W. Bradstreet, C. Holdsworth and M. McLaren. Studies of the numbers and distribution of birds and marine mammals in the central Canadian arctic, 1974: A supplement. Rep. by LGL Limited, to Polar Gas Project, Toronto. 205 p.

1974 Finley, K.J., R.A. Davis and W.J. Richardson. Preliminary studies of the numbers and distribution of marine mammals in the central Canadian arctic, 1974. Rep. by LGL Limited, to Polar Gas Project, Toronto. 68 p.

DR. W. JOHN RICHARDSON
Vice-President - Research, LGL Limited

EDUCATION

1975	Ph.D. Animal Behaviour, Cornell University, Ithaca, N.Y.
1968	B.Sc. Biology, McMaster University, Hamilton, Ontario.

PROFESSIONAL EXPERIENCE

1973 to present

LGL Limited, environmental research associates, Toronto. Generally responsible for research design, statistical analysis, computing and report quality for LGL's projects.

Research specialties: behavioural responses of marine mammals to industrial disturbance; radar and visual studies of migratory and local movements of birds; bird hazards to aircraft; multivariate and other statistical analyses of biological data.

Major activities at LGL have included the following:

- Project Director for study of effects on bowhead whales of acoustic and other disturbances associated with offshore oil and gas activities (1980-85).
- Supervised studies of the feeding ecology of bowhead whales, and of their reactions to drillsites and seismic boats, in the Alaskan Beaufort Sea (1984-85).
- Studies of migratory and local movements of birds in Ontario, Manitoba, Alberta, B.C., N.W.T., Yukon, Alaska and New York; these projects involved either biological or 'bird hazard to aircraft' objectives.
- Design and analysis of surveys and experiments concerning birds, mammals and marine ecology in the Canadian and Alaskan arctic.
- Developed multivariate forecasting models for biological variables (birds, mammals, plankton, benthos).
- Computer programming for analysis of aerial and ground surveys of birds and mammals, and for analysis of behavioural, oceanographic and marine benthic data; computer graphics; statistical programming in FORTRAN and BASIC.
- Reviewer of many draft reports and manuscripts produced by LGL; referee for several journals; reviewer of NSF grant proposals.

1969-73

Studied bird migration in eastern Canada and West Indies as thesis research (sponsored by Assoc. Comm. on Bird Hazards to Aircraft, Nat. Res. Counc. Can.). Documented non-stop flights from eastern North America over the Atlantic to the West Indies and South America. Developed standardized radar techniques and new applications of statistical methods.

Assisted in Cornell University projects involving radiotelemetry and radar; experimental design, computer programming, statistics.

1965-68 Contract research on bird movements in Ontario and prairies (four summers; sponsored by Can. Wildl. Serv.): radar studies, data analysis, computing, preparation of reports and papers.

MEMBERSHIPS

Ecological Society of America; Animal Behavior Society
Arctic Institute of North America; Society for Marine Mammalogy
American (Elective Member) and British Ornithologists' Unions
Cooper and Wilson Ornithological Societies
International Ornithological Committee; Sigma Xi
Amer. Assoc. for the Advancement of Science, etc.

REPORTS AND PUBLICATIONS

About 30 publications and 35 unpublished reports concerning

- bird migration
- multivariate analysis
- avian habitat preferences
- marine mammals
- bird hazards to aircraft
- census techniques

Publications are in Rep. Intern. Whal. Comm., Arctic, Biol. Conserv., Fish. Bull. U.S., Can. J. Zool., Can. Wildl. Serv. Rep. Ser., Oikos, Behav. Ecol. Sociobiol., Am. Birds, Auk, Ibis, Wilson Bull., several conference proceedings, etc.

PUBLICATIONS AND REPORTS ON MARINE MAMMALS
(excludes about 25 published papers and 20 reports on birds)

Sub-mitted — Richardson, W.J., R.A. Davis, C.R. Evans, D.K. Ljungblad and P. Norton. Summer distribution of bowhead whales, Balaena mysticetus, relative to oil industry activities in the Canadian Beaufort Sea, 1980-84.

In Press — Richardson, W.J., B. Würsig and C.R. Greene. Reactions of bowhead whales, Balaena mysticetus, to seismic exploration in the Canadian Beaufort Sea. **J. Acoust. Soc. Am.**

Sub-mitted — Greene, C.R. and W.J. Richardson. Characteristics of marine seismic survey sounds in the Beaufort Sea.

Sub-mitted — Dorsey, E.M., W.J. Richardson and B. Würsig. Factors affecting respiration, surfacing and dive characteristics of bowhead whales, Balaena mysticetus, summering in the Beaufort Sea.

Sub-mitted — Würsig, B., E.M. Dorsey, W.J. Richardson and R.S. Wells. Feeding, aerial and play behavior of the bowhead whale, Balaena mysticetus, summering in the Beaufort Sea.

In Press — Richardson, W.J. and C.R. Greene. Issue 3--Noise and marine mammals. In: Environmental synthesis, Beaufort Sea Sale 87. Nat. Oceanic & Atmos. Admin., Juneau, AK.

1985 — Wursig, B., E.M. Dorsey, M.A. Fraker, R.S. Payne and W.J. Richardson. Behavior of bowhead whales, Balaena mysticetus, summering in the Beaufort Sea: a description. **Fish. Bull., U.S.** 83(3):357-377.

In press — Würsig, B., E.M. Dorsey, M.A. Fraker, R.S. Payne and W.J. Richardson. Behaviour of bowhead whales, Balaena mysticetus, summering in the Beaufort Sea: a summary. **Rep. Int. Whal. Comm.** (Special Issue).

1985/1984/1983 — Richardson, W.J., R.S. Wells and B. Würsig. Disturbance responses of bowheads, 1980-84/1983/1982. In: W.J. Richardson (ed.), Behavior, disturbance responses and distribution of bowhead whales Balaena mysticetus in the eastern Beaufort Sea, 1980-84/1983/1982. Three reports to U.S. Minerals Management Service, Reston, VA.

1985/1984/1983 — Würsig, B., E.M. Dorsey, W.J. Richardson, C.W. Clark, R. Payne and R.S. Wells. Normal behavior of bowheads, 1980-84/1983/1982. In: W.J. Richardson (ed.) Ibid. [Coauthors vary among three reports.]

1985/1984/1983 — Richardson, W.J., R.A. Davis, C.R. Evans and P. Norton. Distribution of bowheads and industrial activity, 1980-84/1983/1980-82. In: W.J. Richardson (ed.) Ibid. [Coauthors vary among three reports.]

1985 Richardson, W.J., C.R. Greene and B. Würsig. Behavior, disturbance responses and distribution of bowhead whales Balaena mysticetus in the eastern Beaufort Sea, 1980-84: a summary. Rep. MMS 85-0034 for U.S. Minerals Management Service, Reston, VA. 30 p.

1985 Fraker, M.A., D.K. Ljungblad, W.J. Richardson and D.R. Van Schoik. Bowhead whale behavior in relation to seismic exploration, Alaskan Beaufort Sea, autumn 1981. Rep. MMS 85-0077 for U.S. Minerals Management Service, Reston, VA. 40 p.

1985 Richardson, W.J., M.A. Fraker, B. Würsig and R.S. Wells. Behaviour of bowhead whales Balaena mysticetus summering in the Beaufort Sea: reactions to industrial activities. Biol. Conserv. 32:195-230.

1984 Würsig, B., E.M. Dorsey, M.A. Fraker, R.S. Payne, W.J. Richardson and R.S. Wells. Behavior of bowhead whales, Balaena mysticetus, summering in the Beaufort Sea: respiration, surfacing, and dive characteristics. **Can. J. Zool.** 62(10):1910-1921.

1983 Richardson, W.J., C.R. Greene, J.P. Hickie and R.A. Davis. Review of the effects of offshore petroleum operations on cold water marine mammals. Am. Petrol. Inst. Rep. No. 4370, Washington, D.C. 248 p.

1982 Davis, R.A., W.R. Koski, W.J. Richardson, C.R. Evans and W.G. Alliston. Distribution, numbers and productivity of the Western Arctic stock of bowhead whales in the eastern Beaufort Sea and Amundsen Gulf, summer 1981. Rep. for Sohio Alaska Petrol. Co. and Dome Petrol. Ltd. (Co-managers). 134 p.

1982 Fraker, M.A., W.J. Richardson and B. Würsig. Disturbance responses of bowheads. p. 145-248 In: W.J. Richardson (ed.), Behavior, disturbance responses and feeding of bowhead whales Balaena mysticetus in the Beaufort Sea, 1980-81. Rep. to U.S. Bureau of Land Management, Washington. 456 p.

1980 Fraker, M.A. and W.J. Richardson. Bowhead whales in the Beaufort Sea: a summary of their seasonal distributions and activities, and potential disturbance by offshore development. Rep. to U.S. Bureau of Land Management, Washington. 86 p.

1980 Davis, R.A., K.J. Finley and W.J. Richardson. The present status and future management of arctic marine mammals in Canada. Sci. Adv. Board N.W.T. Rep. No. 3, Dept. of Information, Yellowknife, N.W.T. 93 p.

1978 Sekerak, A.D. and W.J. Richardson. The importance of fast-ice-edges to seabirds and marine mammals. Rep. for Polar Gas Environmental Program, Toronto. 92 p.

1978 Davis, R.A., W.J. Richardson, S.R. Johnson and W.E. Renaud. Status of the Lancaster Sound Narwhal population in 1976. **Rep. Int. Whal. Comm.** 28:209-215.

1974 Finley, K.J., R.A. Davis and W.J. Richardson. Preliminary studies of the numbers and distribution of marine mammals in the central Canadian arctic - 1974. Polar Gas Environmental Program, Toronto. 68 p.

DR. CHARLES R. GREENE
President and Principal Scientist, Greeneridge Sciences, Inc.

EDUCATION

1978	Ph.D. Electrical Engineering, University of California, Santa Barbara
1957	B.S. and M.S., Electrical Engineering, Massachusetts Institute of Technology.

PROFESSIONAL INTERESTS:

Underwater sound research, including studies of man-made and natural noises, transmission loss, and signal and noise coherency. Design and development of sensing and processing systems to detect, identify and localize underwater sounds, including systems for remote data collection.

SOCIETIES AND MEMBERSHIPS

Acoustical Society of America
Eta Kappa Nu, Electrical Engineering Honorary Fraternity
Sigma Xi, National Society for Scientific Research
Institute of Electrical and Electronics Engineers

PROFESSIONAL EXPERIENCE

1983 to present

Principal Scientist, Greeneridge Sciences, Inc., Santa Barbara, CA. During fall 1985, directed acoustics research involving bowhead call monitoring and industrial noise measurement at the drillship site Hammerhead for Unocal, and at an artificial gravel island (Sandpiper) for Shell Western. The Hammerhead project also involved sound source localization using a five- hydrophone moored array. Measured icebreaking sounds from "Robert Lemeur" at Corona in October 1985.

In spring 1985, completed a project for the U.S. Minerals Management Service involving studies of bowhead whales and offshore industrial noise in the Canadian Beaufort Sea, 1980-85. This project included studies of underwater sounds from bowheads, boats, aircraft, geophysical surveys using airgun arrays, dredges, and island construction activities.

In September to October 1984, conducted the acoustics phase of the LGL/Greeneridge study of Seal Island and bowhead whales for Shell Western E & P. The study included measurements of ambient noise, industrial noise and bowhead locations using a directional array.

During June and July 1983, measured sounds of the Canadian Coast Guard icebreaker "John A. MacDonald" breaking ice in Baffin Bay and Lancaster Sound. The research was for the Canadian Government and various Canadian industrial concerns.

1974-83 Senior Scientist, Polar Research Laboratory, Inc., Santa Barbara, CA. Dr. Greene's work involved scientific data analysis, engineering analysis and design, and technical management. He was concerned with the incorporation of seismic, meteorological, oceanographic, and acoustic sensors in data acquisition systems. Much of Dr. Greene's work at PRL involved studies of arctic underwater acoustics, including work based in arctic Alaska, Canada and Greenland. Much of this work was for the U.S. Navy.

From 1980 to 1982, Dr. Greene was responsible for PRL's work (through LGL for the Bureau of Land Management) concerning reactions of bowhead whales to industrial sounds associated with offshore oil and gas activities. This work included field recording and computer-assisted analysis of waterborne sounds from bowhead whales, boats, aircraft, seismic exploration, dredging, drillships, etc.

In 1982, Dr. Greene also conducted three other studies on arctic underwater acoustics as related to marine mammals. On behalf of Shell Oil Co., he measured underwater sounds from construction of an artificial island in the Alaskan Beaufort Sea. On behalf of the Canadian Government and a number of industrial concerns, he measured sounds from an icebreaking ore carrier that was breaking ice in the high arctic (Admiralty Inlet). On behalf of the Environmental Affairs Department of the American Petroleum Institute, he analyzed sounds of the semisubmersible drilling rig "Sedco 708" recorded near the Aleutian Islands.

1971-74 Senior Scientist, Anacapa Sciences, Inc., Santa Barbara, CA. Worked on sonar data displays and training devices under U.S. Navy sponsorship.

1963-71 Senior Research Engineer, General Motors Corp., Santa Barbara, CA. Designed and evaluated a digital multibeam passive sonar for arctic installation. Conceived and demonstrated an effective analysis and display technique for bearing, frequency and time information from passive sonars. Developed specialized signal processors for passive sonars. Conducted arctic field experiments on low and high frequency underice acoustics, including ambient noise, absorption loss, propagation loss, and coherency.

1959-63 Instrumentation Engineer, Acoustics Division, U.S. Naval Ordinance Laboratory, Silver Spring MD. Tested a system for acoustical communications to submarines. Developed techniques for tracking passive sonar targets. Developed a one-bit hybrid crosscorrelator; patent award for this invention was shared with C.N. Pryor.

1957-59 Electronics Engineer, National Bureau of Standards, Boulder, CO. Maintained and operated the ionospheric physics research equipment for one year at the Amundsen-Scott IGY South Pole Station.

Curriculum Vitae of
Randall S. Wells
April 1986

Born: 18 November 1953; Peoria, Illinois.

Affiliation: Institute of Marine Sciences
Long Marine Laboratory
University of California
Santa Cruz, CA 95064
(Phone (408) 458-2062).

Education:

1975	B.A.,	University of South Florida, Tampa
1978	M.S.,	University of Florida, Gainesville
1986	Ph.D.,	University of California, Santa Cruz

Professional Experience:

1984-	Coordinator, Long Marine Laboratory Dolphin Research Facility and Field Operations.
1984-	Adjunct Scientist, Mote Marine Laboratory, Sarasota, Florida.
1982-	Vice President, Dolphin Biology Research Associates, Inc., Sarasota, Florida, engaged in long-term studies of the behavior and ecology of free-ranging bottlenose dolphins.
1981-	Biological Consultant for LGL Ecological Research Associates, Bryan, Texas, engaged in research on the behavior of bowhead and gray whales.
1984	Biological Consultant for Chambers Consultants and Planners, for report on potential impact of offshore oil development on cetaceans.
1978-83	Research and Teaching Assistant, Biology Board, University of California, Santa Cruz, engaged in research on the behavior of Hawaiian spinner dolphins
1978	Research Assistant, Dept. of Psychology, University of Hawaii, engaged in research on behavior of humpback whales.
1977	Teaching Assistant, College of Veterinary Medicine, University of Florida.
1974-77	Research and Teaching Assistant, Zoology Dept., University of Florida, engaged in research on the behavior and ecology of bottlenose dolphins.
1972-74	Research Assistant, Dept. of Chemistry, University of South Florida, engaged in study of control of aquatic weeds.
1970-74	Research Assistant, Mote Marine Laboratory, Sarasota, Florida, engaged in research on behavior of bottlenose dolphins and sharks, also on red tide.

Publications:

1. Irvine, B. and R.S. Wells. 1972. Results of attempts to tag Atlantic bottlenose dolphins (Tursiops truncatus) Cetology 13:1-5.

2. Irvine, B., R.S. Wells and P.W. Gilbert. 1973. Conditioning an Atlantic bottlenose dolphin, Tursiops truncatus, to repel various species of sharks. J. Mammal. 54:503-505.

3. Fehring, W.K. and R.S. Wells. 1976. A series of strandings by a single herd of pilot whales on the west coast of Florida. J. Mammal. 57:191-194.

4. Wells, R.S. 1978. Home range characteristics and group composition of Atlantic bottlenose dolphins, Tursiops truncatus, on the west coast of Florida. M.S. thesis, Univ. of Florida, 91 p.

5. Irvine, A.B., M.D. Scott, R.S. Wells and J.G. Mead. 1979. Stranding of the pilot whale, Globicephala macrorhynchus, in Florida and South Carolina. Fish. Bull. U.S. 77:511-513.

6. Irvine, A.B., M.D. Scott, R.S. Wells, J.H. Kaufmann and W.E. Evans. 1979. A study of the activities and movements of the Atlantic bottlenose dolphin, Tursiops truncatus, including an evaluation of tagging techniques. NTIS PB-298-042, 54 p.

7. Mead, J.G., D.K. Odell, R.S. Wells and M.D. Scott. 1980. Observations on a mass stranding of spinner dolphins, Stenella longirostris, from the west coast of Florida. Fish. Bill. U.S. 78:353-360.

8. Wells, R.S., A.B. Irvine and M.D. Scott. 1980. The social ecology of inshore odontocetes, p. 263-317. In: Herman, L.M. (ed.) Cetacean Behavior: Mechanisms and Functions. New York: J. Wiley and Sons, 463 p.

9. Nichols, G. Jr., A. Nichols, J. Hickie, J. Norris and R.S. Wells. 1980. Report on whales in the waters of Nova Scotia, Newfoundland, and Labrador. Cruise report of R/V "Regina Maris" Expedition #1, Boston-Newfoundland, 20 July-15 September 1976.

10. Irvine, A.B., M.D. Scott, R.S. Wells and J.H. Kaufmann. 1981. Movements and activities of the Atlantic bottlenose dolphin, Tursiops truncatus, near Sarasota, Florida. Fish. Bull. U.S. 79:671-688.

11. Wells, R.S., B.G. Wursig and K.S. Norris. 1981. A survey of the marine mammals, including Phocoena sinus, of the upper Gulf of California. NTIS PB-81-168-791, 51 p.

12. Wells, R.S., M.D. Scott, A.B. Irvine and P.T. Page. 1981. Observations during 1980 of bottlenose dolphins, Tursiops truncatus, marked during 1970-1976, on the west coast of Florida. Unpubl. Rept. to National Marine Fisheries Service for Contr. No. NA-80-GA-A-196, 29 p.

13. Irvine, A.B., R.S. Wells and M.D. Scott. 1982. An evaluation of techniques for tagging small odontocete cetaceans. Fish. Bull. U.S. 80:135-143.

14. Shane, S.H., R.S. Wells, B. Wursig and D.K. Odell. 1982. Behavior and ecology of the bottlenose dolphin: a review. Contr. Rept. to Univ. of So. Miss., Gulf Park, Miss., 71 p.

15. Wursig, B., C.W. Clark, E.M. Dorsey, W.J. Richardson and R.S. Wells. 1983. Normal behavior of bowheads, 1982. p. 25-115. In: Richardson, W.J. (ed.), Behavior, disturbance responses, and distribution of bowhead whales *Balaena mysticetus* in the eastern Beaufort Sea, 1982. Unpubl. Rept. from LGL Ecol. Res. Assoc., Inc., Bryan, Texas, for U.S. Minerals Management Service, Reston, Virginia, 357 p.

16. Richardson, W.J., R.S. Wells and B. Wursig. 1983. Disturbance responses of bowheads, 1982. p. 117-215. In: Richardson, W.J. (ed.), Behavior, disturbance responses, and distribution of bowhead whales *Balaena mysticetus* in the eastern Beaufort Sea, 1982. Unpubl. Rept. from LGL Ecol. Res. Assoc., Inc., Bryan, Texas, for U.S. Minerals Management Service, Reston, Virginia, 357 p.

17. Wursig, B., R.S. Wells and D.A. Croll. 1983. Behavior of summering gray whales. p. 109-143. In: Thomson, D.H. (ed.), Feeding ecology of gray whales (*Eschrichtius robustus*) in the Chirikof Basin, summer 1982. Unpubl. Rept. from LGL Alaska Res. Assoc., Inc., Anchorage, Alaska, for Nat. Oceanic and Atmos. Admin., Juneau, AK., 222 p.

18. Richardson, W.J., M.A. Fraker, B. Wursig and R.S. Wells. 1983. Observations on the behavior of bowhead whales in the Canadian Beaufort Sea in the presence of marine industrial activities. Anchorage: Second Conference on the Biology of the Bowhead Whale, *Balaena mysticetus*, 5 p.

19. Wursig, B., E.M. Dorsey, W.J. Richardson, C.W. Clark, R. Payne and R.S. Wells. 1984. Normal behavior of bowheads, 1983. p. 23-99. In: Richardson, W.J. (ed.), Behavior, disturbance responses and distribution of bowhead whales *Balaena mysticetus* in the eastern Beaufort Sea, 1983. Unpubl. Rept. from LGL Ecol. Res. Assoc., Inc., Bryan, Texas, for U.S. Minerals Management Service, Reston, Virginia, 361 p.

20. Richardson, W.J., R.S. Wells and B. Wursig. 1984. Disturbance responses of bowheads, 1983. p. 101-215. In: Richardson, W.J. (ed.), Behavior, disturbance responses and distribution of bowhead whales *Balaena mysticetus* in the eastern Beaufort Sea, 1983. Unpubl. Rept. from LGL Ecol. Res. Assoc., Inc., Bryan, Texas, for U.S. Minerals Management Service, Reston, Virginia, 361 p.

21. Wursig, B., E.M. Dorsey, M.A. Fraker, R.S. Payne, W.J. Richardson and R.S. Wells. 1984. Behavior of bowhead whales *Balaena mysticetus*, summering in the Beaufort Sea: surfacing, respiration, and dive characteristics. Can. J. Zool. 62:1910-1921.

22. Wells, R.S. 1984. Reproductive behavior and hormonal correlates in Hawaiian spinner dolphins, Stenella longirostris. p. 465-472. In: Perrin, W.F., R.L. Brownell, Jr. and D.P. DeMaster (eds.), Reproduction in Whales, Dolphins and Porpoises. Cambridge:Reports of the International Whaling Commission, Special Issue 6, 495 p.

23. Richardson, W.J., M.A. Fraker, B. Wursig and R.S. Wells. 1985. Behaviour of bowhead whales, Balaena mysticetus, summering in the Beaufort Sea: reactions to industrial activities. Biological Conservation 32(1985):195-230.

24. Norris, K.S., B. Wursig, R.S. Wells, M. Wursig, S. Brownlee, C. Johnson and J. Solow. 1985. Behavior of the Hawaiian spinner dolphin, Stenella longirostris. National Mar. Fish. Serv. Admin. Rept. LJ-85-06C, 213 p.

25. Wells, R.S., B.G. Wursig and K.S. Norris. 1981. Un reconocimiento de los mamiferos marinos en el alto Golfo de California, Mexico. Proc. 6th International Meeting for the Study of Marine Mammals of the Peninsula of Baja California; La Paz, Baja Cal. Sur, Mexico, 10-12 Feb. 1981.

26. Richardson, W.J., R.S. Wells and B. Wursig. 1985. Disturbance responses of bowheads. p.89-106. In: W.J. Richardson (ed.), Behavior, disturbance responses and distribution of bowhead whales Balaena mysticetus in the eastern Beaufort Sea, 1980-84. Unpubl. Rep. from LGL Ecol. Res. Assoc., Inc., Bryan, TX for U.S. Minerals Management Service, Reston, VA. 306 p.

27. Wells, R.S. 1982. Dolphins in the wild. Earthwatch, Fall Edition:14-15.

28. Wursig, B. and R.S. Wells. 1984. School life of the spinner dolphin. p. 192-193 In: D. Macdonald (ed.), The Encyclopedia of Mammals, London:Equinox-Oxford Ltd., 895 p.

29. Wursig, B., R.S. Wells and D.A. Croll. In press. Behavior of gray whales summering near St. Lawrence Island, Bering Sea. Can. J. Zool.

30. Wursig, B., E.M. Dorsey, W.J. Richardson and R.S. Wells. In press. Feeding, aerial, and play behavior of the bowhead whale, Balaena mysticetus, summering in the Beaufort Sea. Arctic.

31. Wells, R.S. 1985. Bottlenose dolphin social behavior: Longterm research in a natural laboratory. J. Amer. Cet. Soc. Whalewatcher, 19(4):3-6.

32. Wells, R.S. In press. Population structure of bottlenose dolphins: (1) Behavioral studies along the central west coast of Florida. Contract Rept. to National Marine Fisheries Service, Southeast Fisheries Center. Contract No. 45-WCNF-5-00366. 70 pp.

33. Duffield, D.A. and R.S. Wells. In press. Population structure of bottlenose dolphins: (2) Genetic studies of bottlenose dolphins along the central west coast of Florida. Contract Rept. to National Marine Fisheries Service, Southeast Fisheries Center. Contract No. 45-WCNF-5-00366. 10 pp.

34. Shane, S.H., R.S. Wells and B. Wursig. 1986. Ecology, behavior and social organization of the bottlenose dolphin: A review. Marine Mammal Science, 2(1):34-63.

35. Wells, R.S., M.D. Scott and A.B. Irvine. In press. The social structure of free-ranging bottlenose dolphins. In: Genoways, H. (ed.), Current Mammalogy, Vol. 1. Plenum Press:New York.

36. Wells, R.S. 1986. Structural aspects of dolphin societies. Ph.D. Dissertation, U. of California, Santa Cruz. 234 pp.

Grants and Awards:

1986-1987	Center for Field Research, Belmont, MA. $31,700. Wild dolphin societies.
1985	National Marine Fisheries Service, Miami, FL. $3,225. Bottlenose dolphin population discreteness.
1984-1985	Center for Field Research, Belmont, MA. $35,000. Population biology and social behavior of Atlantic bottlenose dolphins.
1983	Center for Field Research, Belmont, MA. $14,700. Population biology and social behavior of Atlantic bottlenose dolphins.
1982	Center for Field Research, Belmont, MA. $14,300. Population biology and social behavior of Atlantic bottlenose dolphins.
1980-1981	National Marine Fisheries Service, Pascagoula, MS. $3,000 (with K.S. Norris). Observations of a population of bottlenose dolphins marked during 1970-1976, on the west coast of Florida.
1980-1981	U.C.S.C. Biomedical Research Support Grants. $3,000. Reproductive hormone levels and social behavior of Hawaiian spinner dolphins.

Presentations at Professional Meetings:

1985 Odontocete social organization: Mammalian strategies in an aquatic environment. Invited Plenary Paper, Sixth Biennial Conference on the Biology of Marine Mammals, Vancouver, B.C.

1985 Population structure of bottlenose dolphins: behavioral studies of bottlenose dolphins along the central west coast of Florida. Natl. Mar. Fish. Serv. Bottlenose Dolphin Workshop: Problems in Defining Populations and Management Units with Emphasis on the N. Gulf of Mexico, Pascagoula, MI.

1983 Reproductive and social patterns of free-ranging female bottlenose dolphins, Tursiops truncatus. Fifth Biennial Conference on the Biology of Marine Mammals, Boston, MA.

1983 Patterns of daily movements and distribution of Hawaiian spinner dolphins, Stenella longirostris. Fifth Biennial Conference on the Biology of Marine Mammals, Boston, MA.

1981 Repeated patterns of occurrence, distribution, and social associations of marked bottlenose dolphins, Tursiops truncatus, observed from 1970-1981. Fourth Biennial Conference on the Biology of Marine Mammals, San Francisco, CA.

1981 Reproductive seasonality and social behavior of Hawaiian spinner dolphins, Stenella longirostris. International Whaling Commission Conference on Cetacean Reproduction, La Jolla, CA.

1979 Behavior of "escort" accompanying mother-calf pairs of humpback whales. Third Biennial Conference on the Biology of Marine Mammals, Seattle, WA.

1979 Group and home range characteristics of bottlenose dolphins, Tursiops truncatus. Fifty-ninth Annual Meeting, Amer. Society of Mammalogists, Corvallis, OR.

1977 Home range characteristics and group structure of Atlantic bottlenose dolphins, Tursiops truncatus, on the west coast of Florida. Second Biennial Conference on the Biology of Marine Mammals, San Diego, CA.

STEVEN LINDSAY SWARTZ
Soc. Sec. No.
Birth Date:

POSITION: Senior Scientist / Field Biologist / Marine Project Manager/ Quantitative Marine Mammal Ecologist and Population Biologist

SUMMARY: Ten years experience with all aspects of marine field research, specializing on whales and dolphins but including fish, manatees and sea turtles; proposal writing and submission, quantitative experimental design, management of field programs, data acquisition, analysis and statistical testing, technical report writing and editing, and final publication of findings in peer reviewed professional journals. My experience includes selection and management of field personnel, aerial and vessel census surveys, behavioral studies, and fund raising. I've worked as a contract biologist and consultant for government and private agencies such as the International Union for the Conservation of Nature, International Whaling Commission, National Marine Fisheries Service/Marine Mammal Laboratory, Marine Mammal Commission, World Wildlife Fund-US and Netherlands, Hubbs-Sea World Research Institute, National Geographic Society, American Cetacean Society, and others.

RESEARCH EXPERIENCE:

1984 to present: Senior Scientist and Program Manager for SEACO, Inc., on contract to the Naval Ocean Systems Center, Code 514, San Diego, California. Served as a field biologist and analyst for studies on the effects of seismic exploration on the behavior of bowhead whales (Balaena mysticetus), and aerial surveys for marine mammals in the Beaufort, Chukchi and Bering Seas.

1982-84: Graduate Student/Teaching Assistant/Research Assistant at the University of California, Center for Marine Studies, Santa Cruz, California.

1977-82: Principal Investigator for Demographic Studies, Behavior, and Habitat Assessment of Breeding Gray Whales (Eschrichtius robustus) In Laguna San Ignacio, Baja California Sur, Mexico. Senior Biologist and Project Manager for Cetacean Research Associates, San Diego, California.

1981: Senior Research Biologist for the National Marine Mammal Laboratory, National Marine Fisheries Service, Seattle, Washington. Field Biologist and Senior Scientist for the study of the impact of the pelagic drift-net fishery for salmon on the north Pacific population of Dall's porpoise (Phocoenoides dalli), US-Japanese Cooperative Fisheries Agreement.

1979: Co-Investigator for Aerial Surveys to Estimate Sizes of Populations of Bottlenose Dolphins (Tursiops truncatus) in Three Selected U.S. Coastal Areas in Florida and Texas. Principal Investigator J. Stephen Leatherwood, Hubbs-Sea World Research Institute, San Diego, California and Orlando, Florida. Contract for the National Marine Fisheries Service, SEFC.

1976: Research Assistant for behavioral fish study in the Gulf of California. Principal Investigator Steven Hoffman, Ph.D., University of California, Santa Barbara, California.

EDUCATION:

1980-85: University of California at Santa Cruz. Ph.D. degree in Biology. Major Professor: Kenneth S. Norris, Ph.D. Major area of interest: Marine Mammal Biology, Ecology, Behavior and Population Dynamics. Dissertation research: Population Dynamics, Behavior, and Biology of Gray Whales (*Eschrichtius robustus*).

1972-74: University of the Pacific, Pacific Marine Station, Dillon Beach, California. Master of Science program in Marine Ecology. Thesis research: Feeding Biology of Embiotocids.

1969-71: University of California, Santa Barbara, California. B.A. Degree in Biology with a major in Marine Science.

1967-69: California Western University, USIU, San Diego, California. Undergraduate major in Biology.

RELATED SKILLS:

Computer Experience:
Languages: Basic and Fortran 77.
Statistics: SAS, SPSS, Stat-Pac.
Word Processing: UNIX-nroff -me, Edit-Vi, Multimate, Word-Star.
Systems: Bell Labs UNIX, DEC PDP111, VAX-60, IBM 360, IBM XT-PC, COMPAQ Portable.

S.C.U.B.A. Naui 100 hr Certification 1971.
Small Vessel Operator (50 ton).
Spanish Speaker.

PROFESSIONAL MEMBERSHIPS:

1983-present: Charter Member in the Society for Marine Mammals.
1981-present: President and Board Member of Cetacean Research Associates, San Diego, California.
1981-present: American Society of Mammalogists.
1979-present: Charter Member in Sociedad Mexicana Para El Estudio de Los Mamiferos Marinos, Baja California Sur, Mexico.
1979-1980: Research Associate, Hubbs-Sea World Research Institute, San Diego, California.
1977-1979: Research Associate, San Diego Society of Natural History.

CONSULTING AND SCIENTIFIC MEETINGS

1985: Workshop to evaluate future gray whale research needs. Sponsored by the U.S. Marine mammal Commission. June, Monterey, CA. Convener and participant.

1983: "The Oceanic Society Field Guide to the Gray Whale", Legacy Publishing Company, San Francisco. Technical Advisor.

1982: "Whales", Zoo-books, Wildlife Education, Ltd. San Diego, CA. Technical Advisor.

1982: Workshop on the behavior of large whales. Sponsored by the International Whaling Commission, Scientific Committee. National Marine Mammal Laboratory, Seattle, WA. Invited Participant.

1981: "The Whale Primer". T.J. Walker, Ph.D. Cabrillo Historical Association, San Diego, CA. Technical Advisor.

1981: Meeting to review and plan scientific research programs for the Indian Ocean Whale Sanctuary. Sponsored by the International Whaling Commission, World Wildlife Fund Netherlands, and the International Union for the Conservation of Nature, Zeist, Netherlands. Invited Participant.

1981: Meeting on cetacean behavior and intelligence and the ethics of killing whales. Sponsored by the International Whaling Commission, World Wildlife Fund International, Washington, D.C. Invited Participant.

1980: "The Whales that Would Not Die". Emmy award winning KPBS-American Cetacean Society television special. Technical Advisor and Participant.

1979-83: Biennial Meeting on the Biology of Marine Mammals. Sponsored by the Society for Marine Mammals. Presented papers at the III and IV meetings.

1979-84: International Reunion for the Study of Marine Mammals. Sponsored by the Sociedad Mexicana Para El Estudio de los Mamiferos Marinos, La Paz, Baja California Sur, Mexico. Participant each year.

1977: "The Great Whales". WQED-National Geographic Society. Emmy award winning documentary on whales and whaling. Technical Advisor and Participant.

PUBLICATIONS

Swartz, S.L. and Cummings, W.C. 1978. Gray Whales (Eschrichtius robustus) in Laguna San Ignacio, Baja California, Mexico. U.S. Dept. Commerce N.T.I.S. Publ. PB288 636, 38 pp.

Swartz, S.L. and Jones, M.L. 1979. The evaluation of human activities on gray whales (Eschrichtius robustus) in Laguna San Ignacio, Baja California Sur, Mexico. U.S. Dept. Commerce N.T.I.S. Publ. PB289 737, 42 pp.

Swartz, S.L. and Bursk, M.K. 1979. The gray whales of Laguna San Ignacio: after two years. Whalewatcher, J. Amer. Cetacean Soc. 13(1):7-9.

Swartz, S.L. and Jones, M.L. 1980. Preliminary report on gray whales (Eschrichtius robustus) during the 1980 winter in Laguna San Ignacio, Baja California Sur, Mexico. Rep. Intl. Whal. Comm. SC 31.

Swartz, S.L. and Jones, M.L. 1980. Gray whales (Eschrichtius robustus)during the 1977-1978 and 1978-1979 winter seasons in Laguna San Ignacio, Baja California Sur, Mexico. U.S. Dept. Commerce N.T.I.S. Publ. PB80 202989, 35 pp.

Swartz, S.L. and Jones, M.L. 1981. Demographic Studies and habitat assessment of gray whales (Eschrichtius robustus) in Laguna San Ignacio, Baja California Sur, Mexico. U.S. Dept. Commerce N.T.I.S. Publ. PB82 123373. 56 pp.

Swartz, S.L. 1981. Cleaning symbiosis between topsmelt (Atherinops affinis) and gray whale (Eschrichtius robustus) in Laguna San Ignacio, Baja California Sur, Mexico. Fish. Bull. 79(2):360.

Swartz, S.L. and Jones, M.L. 1983. Gray whale (Eschrichtius robustus) calf production and mortality in the winter range. Rep. Intl. Whal. Comm. SC/34/PS4.

Swartz, S.L. and Jones, M.L. 1984. Gray whale mothers and their calves. Oceans 17(2):47-55.

Swartz, S.L. and Jones. M.L. 1985. Gray whales (Eschrichtius robustus) in Laguna San Ignacio, Baja California Sur, Mexico: 1978-1982. Natl. Geog. Soc. Res. Reports: 1978 Projects. p. 543-551.

Jones, M.L. and Swartz, S.L. 1984. Demography and phenology of breeding gray whales in Laguna San Ignacio, Baja California Sur, Mexico: 1978 to 1982. In: Jones, et al. (Eds.) The Gray Whale. Academic Press, Inc., New York. 602 pp.

Jones, M.L. and Swartz, S.L. 1984. Demography, behavior, and habitat studies of gray whales (Eschrichtius robustus) in Laguna San Ignacio, Baja California Sur, Mexico between 1978 and 1982. U.S. Dept. Commerce N.T.I.S. Publ. (in press), Spanish Version (in press).

Jones, M.L. Swartz, S.L., and Leatherwood, J.S. (Eds.) 1984. The Gray Whale. Academic Press, Inc., New York. 602 pp.

Ljungblad, D., Wursig, B. and Swartz, S.L. 1985. Observations on the behavior of bowhead whales (Balaena mysticetus) in the presence of operating seismic exploration vessels in the Alaskan Beaufort Sea. Unpublished Contract Report to the U.S. Minnerals Management Service, Anchorage, AK.

Swartz, S.L. and Harvey, J.T. 1985. The use of radio-tags to determine the nighttime behavior of migrating gray whales off Monterey, California. Unpublished Contract Report to the National Marine Fisheries Service, Seattle, WA. 35 p.

DR. PETER L. McLAREN
Biologist, LGL Limited

EDUCATION

1975 Ph.D. Zoology, University of Toronto.

1972 M.Sc. Zoology, University of Toronto.

1966 B.Sc. Biology, Mount Allison University, Sackville, N.B.

PROFESSIONAL EXPERIENCE

1985 Project leader of a series of systematic aerial surveys conducted for Union Oil Co. to document the distribution and numbers of bowhead whales in the Alaskan Beaufort Sea during autumn migration. Responsibilities included conduct of the studies, data analysis and report preparation.

1985 Participated in a comprehensive study of the reproductive biology of the bowhead whale on its summering grounds in the Canadian Beaufort Sea. Activities included crew leader during a extensive systematic aerial survey program and primary observer and navigator during an aerial photography program. Responsible for data compilation, data base management, and analysis of results of the survey and photography programs.

1984 Project director of a program of ornithological research conducted for Syncrude Canada Ltd. in northeastern Alberta. The study involved an investigation of the numbers and distributions of the summer waterbird and terrestrial bird communities and of fall bird migration in the region. Responsibilities included planning and conduct of the field work, data analysis and report preparation.

1983-84 On behalf of Mobil Oil Canada Ltd., prepared a comprehensive review of the seabird and marine mammal communities on the Grand Banks of Newfoundland, including the coastal waters of the Avalon Peninsula. Included in the review were assessments of the population size, breeding status (seabirds), temporal and spatial distribution and feeding habits for each species occurring in the region.

1983 Project leader of a study, using aerial surveys, of the distribution of bowhead whales and other marine mammals in the southeast Beaufort Sea, conducted for Dome Petroleum and Gulf Canada. Responsibilities included planning and conduct of the study, data analysis and report preparation.

1981-83 Project manager for, and participated in the preparation of, an environmental impact assessment of exploratory drilling in Lancaster Sound for the Consolidex-Magnorth-Oakwood Lancaster Sound Joint Venture. Provided input for the Dome Petroleum et al. Beaufort Sea-Mackenzie Delta Environmental Impact Statement. Also involved in the preparation of a preliminary version of an environmental impact statement for the eastern Lancaster Sound-western Baffin Bay region for Petro-Canada Exploration Inc.

1981-82 Project leader of a study, using aerial surveys, of the winter distribution of marine mammals in southern Baffin Bay and Davis Strait--an LGL project for the Arctic Pilot Project and Petro-Canada Exploration Inc. Responsibilities included planning and conduct of the study, data analysis and preparation of the final report.

1981-82 Project leader, responsible for planning, supervision and conduct of an extensive aerial survey program, involving field work, data analysis and report preparation, on the distribution and relative abundances of seabirds and marine mammals in the southern Labrador Sea. The study included more than 700 hours of aerial surveys.

1980 On behalf of Arctic Pilot Project, prepared a report documenting the biology and quantitative distribution of all seabirds and marine mammals occurring in marine shipping routes from Viscount Melville Sound in the central high arctic south to the estuary of the St. Lawrence River. Also participated in LGL's systematic aerial surveys of bowhead whales in the Canadian Beaufort Sea for Dome Petroleum.

1978-79 Project leader, responsible for planning, supervision and conduct of a large scale aerial survey program, involving field work, data analysis and preparation of reports, on the seasonal distributions and habitat relationships of seabirds and marine mammals in eastern Lancaster Sound and Baffin Bay--an LGL project for Petro-Canada.

1975-77 Project leader in LGL's studies of the numbers, distributions and habitat preferences of birds throughout the District of Keewatin, northern Manitoba and northwestern Ontario for the Polar Gas Project. Field work involved extensive systematic aerial and ground surveys. Project also included marine surveys over Chesterfield Inlet and southwest coast of Hudson Bay. Provided ornithological input to the environmental statement (environmental overview and impact assessment) of the Polar Gas Project.

1969-75 Teaching assistant at University of Toronto involved with courses in biology, zoology, animal behaviour and animal ecology.

Graduate research involved the foraging and ecological relationships of songbirds in Algonquin Provincial Park, Ontario. Multivariate techniques were used in the analyses.

1967-69 Research officer for the East African Community (Nairobi, Kenya); involved in forest entomology.

1966-67 Technician in the Federal Department of Forestry; involved in planning and establishment of a laboratory for the study of soil micro-organisms.

REPORTS AND PUBLICATIONS

Dr. McLaren has written numerous reports and papers concerning the distribution, abundance and ecology of birds and marine mammals in all regions of Canada.

Reports

1985 McLaren, P.L. and J.A. Smith. Ornithological studies on and near Crown Lease 17, northeastern Alberta, June-October 1984. Rep. by LGL Ltd., Calgary, and Dabbs Environmental Service, Calgary, to Syncrude Ltd., Edmonton. 175 p.

1985 Davis, R.A., C.R. Greene and P.L. McLaren. Studies of the potential for drilling activities on Seal Island to influence fall migration of bowhead whales through Alaskan nearshore waters. Rep. by LGL Ltd., King City, for Shell Western E & P Inc., Anchorage, AK. 69 p.

1985 McLaren, M.A. and P.L. McLaren. Bird migration watches on Crown Lease 17, northeastern Alberta, Fall 1984. Rep. by LGL Ltd., Calgary, for Syncrude Canada Ltd., Edmonton. 57 p.

1984 McLaren, P.L. and R.A. Davis. Distribution of bowhead whales and other marine mammals in the southeast Beaufort Sea, August-September 1983. Rep. by LGL Ltd., Toronto, to the Environmental Studies Revolving Fund, Ottawa. 63 p.

1983 Davis, R.A., P.L. McLaren and R.A. Buchanan. Environmental issues and impacts associated with exploratory drilling in Lancaster Sound. Rep. by LGL Ltd., Toronto for The Consolidex Magnorth Oakwood Lancaster Sound Joint Venture and Pallister Resource Management Ltd., Calgary. 171 p.

1983 McLaren, P.L., R.E. Harris and I.R. Kirkham. Distribution of marine birds in the southern Labrador Sea, April 1981-April 1982. Rep. by LGL Ltd., Toronto, to Petro-Canada Exploration Inc., Calgary. 274 p.

1983 McLaren, P.L. and R.A. Davis. Marine mammal distribution off West Greenland and in southern Baffin Bay and northern Davis Strait, March 1982. Rep. by LGL Ltd., Toronto, to Arctic Pilot Project, Calgary. 75 p.

1982 McLaren, P.L., R.E. Harris and I.R. Kirkham. Distribution of marine mammals in the southern Labrador Sea, April 1981-April 1982. Rep. by LGL Ltd., Toronto, for Petro-Canada Exploration Inc., Calgary. 78 p.

1982 McLaren, P.L. and R.A. Davis. Winter distribution of arctic marine mammals in ice-covered waters of eastern North America. Rep. by LGL Ltd., Toronto, to Petro-Canada Exploration Inc., Calgary. 151 p.

1981 McLaren, P.L. and R.A. Davis. Distribution of wintering marine mammals in southern Baffin Bay and northern Davis Strait, March 1981. Rep. by LGL Ltd. for Arctic Pilot Project. 85 p.

1980 McLaren, P.L. Distribution of sea-associated birds in eastern Lancaster Sound and Baffin Bay, May-July 1979. Rep. by LGL Ltd. for Petro-Canada. 231 p. + appendices.

1979 McLaren, P.L. and W.E. Renaud. Distribution of sea-associated birds in northwest Baffin Bay and adjacent waters, May-October 1978. Rep. by LGL Ltd. for Petro-Canada. 324 p. + appendices.

1978 McLaren, P.L. Summer bird populations in Chesterfield Inlet, District of Keewatin, N.W.T. Rep. by LGL Ltd. for the Polar Gas Project. 75 p.

1978 McLaren, P.L. and C. Holdsworth. Summer bird populations in the Pitz Lake-Baker Lake area, District of Keewatin, N.W.T. Rep. by LGL Ltd. for the Polar Gas Project.

1978 McLaren, P.L. and M.A. McLaren. Studies of terrestrial bird population in northwestern Ontario and northern Manitoba, June 1977. Rep. by LGL Ltd. for the Polar Gas Project. 159 p.

1977 McLaren, M.A., P.L. McLaren and W.G. Alliston. Bird populations in the Rasmussen Basin lowlands, N.W.T., June-September 1976. Rep. by LGL Ltd. for the Polar Gas Project. 350 p.

1977 McLaren, P.L., M.A. McLaren and L.A. Patterson. Numbers and distribution of birds during migration in the District of Keewatin, northern Manitoba and northwestern Ontario, 1976. Rep. by LGL Ltd. for the Polar Gas Project. 284 p.

1976 McLaren, P.L., R.A. Davis, W.E. Renaud and C. Holdsworth. Studies of the numbers and distribution of birds in the District of Keewatin, N.W.T. June-August 1975. Rep. by LGL Ltd. for the Polar Gas Project. 591 p.

Publications

1984 McLaren, M.A. and P.L. McLaren. Tundra swans nesting in northeastern Keewatin District, N.W.T. Wilson Bull. 96:6-11.

1982 McLaren, P.L. and M.A. McLaren. Migration and summer distribution of lesser snow geese in interior Keewatin. Wilson Bull. 94(4): 494-504.

1982 McLaren, P.L. Spring migration and habitat use by seabirds in eastern Lancaster Sound and western Baffin Bay. Arctic 35:88-111.

1982 McLaren, P.L. and M.A. McLaren. Waterfowl populations in eastern Lancaster Sound and western Baffin Bay. Arctic 35:149-157.

1982 McLaren, P.L. and W.E. Renaud. Seabird concentrations in late summer along the coasts of Devon and Ellesmere islands, N.W.T. Arctic 35:112-117.

1982 Renaud, W.E. and P.L. McLaren. Ivory gull (Pagophila eburnea) distribution in late summer and autumn in eastern Lancaster Sound and western Baffin Bay. Arctic 35:141-148.

1982 Renaud, W.E., P.L. McLaren and S.R. Johnson. The dovekie, Alle alle, as a spring migrant in eastern Lancaster Sound and western Baffin Bay. Arctic 35:118-125.

1981 McLaren, P.L. and M.A. McLaren. Bird observations in northwestern Ontario, 1976-1977. Ont. Field Biol. 35:141-148.

1981 McLaren, M.A. and P.L. McLaren. Relative abundances of birds in boreal and subarctic habitats of northwestern Ontario and northeastern Manitoba. Can. Field-Nat. 95:418-427.

1976 James, R.D., P.L. McLaren and J.C. Barlow. An annotated checklist of the birds of Ontario. Life Sci. Misc. Pub., R. Ont. Mus. 75 p.

1975 McLaren, P.L. Habitat selection and resource utilization in four species of wood warblers. (Aves: Parulidae). Ph.D. Thesis, University of Toronto. 168 p.

1973 McLaren, P.L. and M.A. McLaren. A sight record of the ferruginous hawk in British Columbia. Blue Jay 31:59.

1973 McLaren, P.L. Physical combat in the brown-headed cowbird. Wilson Bull. 85:342-343.

1972 McLaren, P.L. An analysis of morphological variation in the starling (Sturnus vulgaris L.) (Aves: Sturnidae) in North America. M.Sc. thesis, University of Toronto. 126 p.

WILLIAM R. KOSKI
Wildlife Biologist, LGL Limited

EDUCATION

1974 M.Sc. Biology, Laurentian University.

1970 B.Sc. Biology, Laurentian University.

PROFESSIONAL EXPERIENCE

1985 Field leader on LGL's aerial survey program to document the late autumn migration of bowhead whales from the Canadian Beaufort Sea.

Field leader on LGL's bowhead aerial photography program to determine reproductive parameters of the western Arctic bowhead whale population.

Conducted aerial surveys of moose, bison, and furbearers in northern alberta for LGL in connection with a study to assess the impact of a proposed hydroelectric project on the Slave River.

1984 Field leader on LGL's bowhead aerial photography program in the Canadian Beaufort Sea in 1984 for Canadian government with supplemental funding from NMFS. Analysis and write-up of measurement data.

Assisted in the preparation of a document pertaining to the classification and evaluation of wetland habitats for wildlife in Alberta.

Developed land management plans for several properties obtained by Alberta Fish and Wildlife Division under their habitat maintenance and acquisition program.

1983 Conducted aerial surveys and vertical photography of bowhead whales in the eastern Beaufort Sea. Deployed sonobuoys and monitored sound recording equipment in order to record bowhead whale vocalizations and to determine the sound levels produced byindustrial activities in areas inhabited by whales.

Conducted studies of breeding waterfowl populations in the Mackenzie Delta for LGL.

Assisted in the preparation of documents summarizing the existing literature on the distribution, numbers and use by birds of the Mackenzie Valley and parts of northern Alberta.

Assisted in the preparation of draft environmental guidelines for birds in the Mackenzie Delta.

1982	Conducted aerial surveys and vertical photography of bowhead whales for LGL in the eastern Beaufort Sea. Analysed and reported the results of the photography.
	Conducted aerial surveys and ground-based studies of breeding waterfowl in the central Mackenzie Delta.
	Conducted LGL aerial surveys and vertical aerial photography of bowhead whales in western Hudson Strait in late winter.
1981	Participated in LGL's aerial surveys, behavioural observations and vertical photography of bowhead whales and other marine mammals in the Beaufort Sea. Analyzed and reported the vertical photography results.
	Prepared summary documents concerning the distribution and numbers of birds of the Beaufort Sea region and Mackenzie Valley.
	Conducted LGL aerial surveys of marine mammals and birds in N Hudson Bay, Hudson Strait and along the Labrador Coast in late winter.
1980	Conducted LGL aerial surveys of moose and caribou in northern British Columbia.
1978-80	Responsible for conducting LGL studies of the distribution, abundance and habitat use of marine mammals in the Canadian high arctic. Supervised and conducted extensive aerial surveys in the Baffin Bay area; senior author of resultant reports.
1978	On behalf of LGL, conducted winter track counts and aerial surveys of ungulates and furbearers on the IOL Cold Lake Lease.
1977	Conducted LGL aerial surveys of birds and marine mammals in the Canadian High Arctic. Conducted vertical aerial photography of fast ice areas for ringed seals and seal holes, walrus haul-out sites and white whales.
	Conducted LGL investigations of impacts of development on the wildlife of the Cold Lake area of Alberta including aerial and boat surveys of waterfowl.
1976	Conducted an LGL review of the methods of deterring and dispersing waterbirds from oil spills.
	Conducted an evaluation of aerial photography as a method of censusing snow geese.

1974-77 Conducted aerial and ground-based investigations on the Yukon and Alaska North Slope and in the Mackenzie Delta for LGL of the impact on avifauna of the proposed Mackenzie Valley gas pipeline. Research included autumn distribution of snow geese, distribution of breeding birds relative to various habitats, distribution of nesting peregrine falcons and distribution and use of nest sites by overwintering gyrfalcons in the northern Yukon.

1975 Assisted in the establishment of census plots for breeding seabirds on St. Lawrence Island, Alaska, in early spring.

1973 On behalf of LGL, conducted studies of snow goose energetics relevant to a proposed Mackenzie Valley gas pipeline.

Research concerning regeneration of deer browse in winter-logged areas in Ontario. Conducted deer pellet group surveys to estimate winter deer populations and conducted dead deer surveys to estimate winter mortality of deer in winter yards.

1970 Consultant biologist to Ontario Water Resources Commission. Research concerning water pollution.

1969 Identified plants and incorporated them into the National Herbarium in Ottawa.

REPORTS AND PUBLICATIONS

Numerous reports and papers concerning the numbers and distributions of marine mammals in the Canadian arctic, and bird distribution and habitat use on the North Slope of Alaska and the Yukon Territory.

Reports and Publications on Marine Mammals

In prep. Koski, W.R., R.A. Davis and G.W. Miller. Remote sensing of bowhead whales using low-level aerial photography.

In prep. Koski, W.R. and R.A. Davis. Fall migration of bowhead whales along NE Baffin Island.

1986 Davis, R.A., W.R. Koski and G.W. Miller. Experimental use of aerial photogrammetry to assess the long-term responses of bowhead whales to offshore industrial activities in the Canadian Beaufort Sea. Rep. by LGL Ltd., King City, to Canada Dept. Indian and Northern Affairs, Ottawa. 155 p.

1985 Nerini, M., J. Cubbage, R. Davis, J. Calambokidis, W. Koski and D. Rugh. 1985. Length frequency distribution of bowhead whales in the Canadian Beaufort Sea, 1982-1984. International Whaling Commission Working Paper SC/37/PS23.

1983 Davis, R.A., W.R. Koski and G.W. Miller. Preliminary assessment of the length-frequency distribution and gross annual reproductive rate of the western arctic bowhead whale as determined with low-level aerial photography, with comments on life history. Rep. by LGL Ltd., for National Marine Mammal Laboratory, Seattle, Wash. 91 p.

1983 Finley, K.J., G.W. Miller, R.A. Davis and W.R. Koski. A distinctive large breeding population of ringed seals (Phoca hispida) inhabiting the Baffin Bay pack ice. Arctic 36:162-173.

1982 Davis, R.A., W.R. Koski, W.J. Richardson, C.R. Evans and W.G. Alliston. Distribution, numbers and productivity of the Western Arctic stock of bowhead whales in the eastern Beaufort Sea and Amundsen Gulf, summer 1981. Rep. by LGL Ltd., Toronto, for Sohio Alaska Petroleum Co. and Dome Petroleum Ltd. (Co-managers). 134 p.

1980 Koski, W.R. Distribution and migration of marine mammals in Baffin Bay and eastern Lancaster Sound, May-July 1979. Rep. by LGL Ltd. for Petro-Canada Exploration Inc. 317 p.

1980 Koski, W.R. Distribution of marine mammals in the Canadian Central High Arctic, July-September 1979. Rep. by LGL Ltd. for Petro-Canada and Arctic Biological Station. 107 p.

1980 Koski, W.R. and R.A. Davis. Studies of the late summer distribution and fall migration of marine mammals in NW Baffin Bay and E Lancaster Sound, 1979. Rep. by LGL Ltd. for Petro-Canada Exploration Inc., Calgary. 214 p.

1980 Davis, R.A. and W.R. Koski. Recent observations of the bowhead whale in the eastern Canadian high arctic. Rep. int. Whal. Commn 30:439-444.

1979 Koski, W.R. and R.A. Davis. Distribution of marine mammals in northwest Baffin Bay and adjacent waters, May-October 1978. Rep. by LGL Ltd. for Petro-Canada Exploration Inc., Calgary. 305 p.

1978 Davis, R.A., W.R. Koski and K.J. Finley. Numbers and distribution of walruses in the central Canadian high arctic. Rep. by LGL Ltd. for Polar Gas Project, Toronto. 50 p.

Dr. CHRISTOPHER W. CLARK
Assistant Professor, The Rockefeller University Field Research Center

BIOGRAPHICAL SKETCH

Christopher W. Clark
Rockefeller University
Field Research Center
Tyrrel Road
Millbrook, New York 12545

Date of Birth:
Married, 2 children
SS#

Present position

Assistant Professor, The Rockefeller University Field Research Center

Education

State Univ. of New York, Stony Brook	B.Sc.	1972	Biology
State Univ. of New York, Stony Brook	B.E.	1972	Engineering
State Univ. of New York, Stony Brook	M.S.	1974	Elect. Eng.
State Univ. of New York, Stony Brook	Ph.D.	1980	Biology
The Rockefeller University, New York, NY	Post.Doc.	81-83	Bio/Anim.Comm.

Honors

Member, Tau Beta Pi, 1969-
President, Tau Beta Pi, Stony Brook Chapter, 1971-1972
National Fellow, Tau Beta Pi, 1972-1973
Biomedical Research Fellowship, 1978, 1979
NIH Postdoctoral Fellow, 1981-1983

Teaching Experience

Teaching Assistant, Electrical Engineering, 1972-1974
Teaching Assistant, Biology, 1975, 1978, 1980
Invited guest lecturer, Woods Hole Boston University Marine Biology course, January 1978, 1980, 1981.
Invited guest lecturer, Cornell University Shoals Marine Laboratory, Marine Vertebrate course, July 1985.

Research Experience

1972 Assistant to Dr. Ronald Hoy in his research on the neurophysiological basis of species recognition in crickets.

1972-1973 (Summers) - Assisted Dr. Charles Walcott with his research on homing pigeon navigation.

1972-1972 (Falls) - Assisted Dr. Roger Payne during his expedition to the Gulfo San Jose, Argentina, studying the acoustics and behavior of Southern Right Whales.

1974-1975 (Summers) -I designed, built and tested a small, portable computer. This system, best described as a real time underwater sound direction finder, determined in less than a second an unambiguous direction to a vocalizing whale.

1976-1980 Doctoral research on the coast of southern Argentina studying the sounds and behaviors of Southern Right Whales.

1979-1980 (Spring) - Contracted by the National Marine Fisheries Service's Bowhead Whale Research Project to install my sound direction finding system off Pt. Barrow, Alaska and acoustically census the Bowhead whales.

1981-1983 Postdoctoral research, developing an acoustic telemetry system for remotely recording animal vocalizations, investigating correlations between variability in acoustic signals and behaviors and developing a computer based system for feature detection and recognition of animal acoustic signals.

1983-1984 Behavioral co-principle investigator and consultant to Bolt Beranek and Newman Inc. during their investigations on the potential effects of underwater noise from oil and gas development and exploration activities on the behavior of migrating gray whales.

1984-1986 Co-principle investigator for an Arctic research project studying the acoustic behavior of migrating bowhead whales. For this project I helped design and develope a customedized computer-based signal processing system. This system accepts up to four channels of acoustic input and displays them as spectrographs on a video terminal. The user can then edit, filter and compare sounds with standard analytical methods. In the case of the bowhead whale project, the analysis computed time delays between the same signal arriving at an array of hydrophones in order to determine the exact position of the vocalizing animal. By this process I am able to acoustically track whales out to distances of 15 km and accurately measure the characteristics of calls and songs including note morphology, directivity pattern and source level.

1985-1987 NSF grant for the quantitative analysis of animal vocalizations with particular emphasis on the ontogeny of song development in song birds as a function of early experiencial and physiological environment. I have developed a highly flexible acoustic processing software program in order to quantify and automate the analytical process of describing and comparing birdsong notes and syllables. This includes the high speed acquisition of songs, the ability to rapidly splice out pieces of song and describe and compare any two utterances.

Publications

Clark, C.W. 1980. A real-time direction finding device for determining the bearing to the underwater sounds of Southern Right Whales, Eubalaena australis .J. Acoust. Soc. Am. 68:508-511.

Clark, C.W. & J.M. Clark. 1980. Sound playback experiments with southern right whales, Eubalaena australis . Science 207: 663-664.

Clark, C.W. 1982. The acoustic repertoire of the southern right whale: a quantitative analysis. Anim. Behav. 30: 1060-1071.

Dooling, R.J., C.W. Clark, R. Miller & T. Bunnell. 1983. Program package for the analysis and synthesis of animal vocalizations. Behav. Res. Methods and Instr. 14: 487.

Clark, C.W. 1983. Acoustic communication and behavior of the southern right whale. In: R.S. Payne (ed.), Behavior and Communication of Whales . Westview Press: Boulder, CO.

Clark, C.W., R.J. Dooling & T. Bunnell. 1983. Analysis and synthesis of bird vocalizations: An FFT-based software system. Behav. Res. Methods and Instr. 15: 251-253.

Clark, C.W. and J.H. Johnson. 1984. The sounds of the bowhead whale, Balaena mysticetus, during the spring migrations of 1979 and 1980. Can. J. Zoo. 62:1436-1441.

Clark, C.W. 1984. Acoustic Communication and Behavior of Southern Right Whales, Eubalaena australis. In: National Geographic Society Research Reports, Vol. 17: 897-908.

Wursig, B., C.W. Clark, E.M. Dorsey, M.A. Fraker and R.S. Payne. 1982. Normal behavior of bowheads, 1980-81. In: W.J. Richardson (ed.), Behavior, disturbance responses and distribution of bowhead whales Balaena mysticetus in the eastern Beaufort Sea, 1980-81, p. 33-144. Report prepared by LGL Ecological Research Associates, Inc., Bryan, TX, for the Minerals Management Service, Reston, VA, 456 p.

Malme, C.I., P.R. Miles, C.W. Clark, P. Tyack, and J.E. Bird. 1983. Investigations of the potential effects of underwater noise from petroleum industry activities on migrating gray whale behavior. Report No. 5366, report prepared by Bolt, Beranek and Newman Inc. Cambridge, MA, for the minerals Management service, Anchorage, AK, 325 p.

Malme, C.I., P.R. Miles, C.W. Clark, P. Tyack, and J.E. Bird. 1984. Investigations of the potential effects of underwater noise from petroleum industry activities on migrating gray whale behavior-Phase 2: January 1984 migration. Report No. 5586, report prepared by Bolt, Beranek and Newman Inc., Cambridge, MA, for the minerals Management service, Anchorage, AK, 297 p.

Malme, C.I., P.R. Miles, P. Tyack, C.W. Clark, and J.E. Bird. 1984. Investigations of the potential effects of underwater noise from petroleum industry activities on feeding humpback whale behavior. Report No. 5851, report prepared by Bolt, Beranek and Newman Inc., Cambridge, MA, for the minerals Management service, Anchorage, AK, 205 p.

Clark, C.W., W.T. Ellison, K. Beeman. In press. A preliminary account of the acoustic study conducted during the 1985 apring bowhead whale, Balaena mysticetus, migration off Point Barrow, Alaska. Rep. Int. Whal. Commn. 1986, 19 p.

Ko, D., J.E. Zeh, C.W. Clark, W.T. Ellison, B.D. Krogman, and R. Sonntag. In press. Utilization of acoustic location data in determining a minimum number of spring-migrating bowhead whales unaccounted for by the ice-based visual census. Rep. Int. Whal. Commn. 1986, 38 p.

Sonntag, R.M., W.T. Ellison, C.W. Clark, D.R. Corbit, and B.D. Krogman. In press. A description of the tracking algorithm and its implication to bowhead whale acoustic location data collected during the spring migration near Point Barrow, Alaska 1984-85. Rep. Int. Whal. Commn. 1986, 55 p.

Manuscripts in preparation

Clark, C.W., W.T. Ellison, and K. Beeman. ms. Acoustic censusing of migrating bowhead whales, Balaena mysticetus, in the spring of 1984 off Point Barrow, Alaska.

Clark, C.W., W.T. Ellison, and K. Beeman. ms. Acoustic location techniques and calibration methods for observing migrating bowhead whales,

Balaena mysticetus.

Clark, C.W. ms. Acoustic behavior of bowhead whales, Balaena mysticetus, in the Beaufort Sea, 1980-1981.

Recent Presentation

Acoustical Society of America. Nov. 1983. C.W. Clark, P. Tyack, J. Bird and V. Rowntree. Effects of underwater noise on migrating gray whales off the coast of California.

Acoustical Society of America. May 1984. R.J. Dooling, H.T. Bunnell and C.W. Clark. Critical band analysis of avian vocalization.

Acoustical Society of America. Oct. 1984. W.T. Ellison, C.W. Clark and K. Beeman. Real-time passive localization and spectrum analysis of transient underwater sounds using a field portable computer-based system.

Third Conference on the biology of the bowhead whale. Jan. 1985. C.W. Clark, W.T. Ellison, and K. Beeman. Variations in the rates and types of bowhead whale, *Balaena mysticetus*, vocalizations during the spring (1984) migration off Point Barrow, Alaska.

Third Conference on the biology of the bowhead whale. Jan. 1985. C.W. Clark, W.T. Ellison, and K. Beeman. Acoustic locations and distribution of migrating bowhead whales, *Balaena mysticetus*, off Point Barrow, Alaska in the spring of 1984 during good and very good visual censusing conditions.

Third Conference on the biology of the bowhead whale. Jan. 1985. C.W. Clark, W.T. Ellison, and K. Beeman. Acoustic locations and distribution of migrating bowhead whales, *Balaena mysticetus*, off Point Barrow, Alaska in the spring of 1984 during poor and unacceptable visual censusing conditions.

Third Conference on the biology of the bowhead whale. Jan. 1985. C.W. Clark and P. Tyack. Observations on the behavior of the gray whale *Eschrictius robustus*, in the presence of underwater industrial noise.

Sixth Biennial Conference on the Biology of Marine Mammals. Nov. 1985. Invited paper. Sleeping in the dark: whoops, whistle, and space cadets.

DR. WILLIAM T. ELLISON
President and Chief Scientist, Marine Acoustics

Educational Background

1963 B.S., U.S. Naval Academy, Annapolis, Maryland
1968 M.S., Mechanical Engineering; Massachusetts Institute of Technology
1968 Nav.E., Naval Architecture; Massachusetts Institute of Technology
1970 Ph.D., Acoustics; Massachusetts Institute of Technology

Honors and Recognitions

1968 Elected to Tau Beta Pi
1970 Elected to Sigma Xi
1972 Navy Commendation Medal
Listed in Marquis' Who's Who in Science
Listed in Marquis' Who's Who in Frontier Science
Fellow of the Explorers Club

Membership in Scientific or Cultural Institutions, Societies, etc.

Fellow of the Explorers Club
Acoustical Society of America
American Association for the Advancement of Science
Marine Technology Society
American Polar Society
National Maritime Historical Society

Avocations

Captain, U.S. Naval Reserve (Ret.)
Coach, Amateur Hockey Assoc. of the U.S.
Public Speaker on Arctic Affairs and the Environment

Dr. William Theodore Ellison

Present Occupation/Principal Activities

1983-1986 President and Chief Scientist of Marine Acoustics, Cotuit, Massachusetts. Presently engaged in ongoing analysis and experimental design in underwater acoustics for various agencies of the U.S. Navy, principally in the area of high frequency under-ice acoustic scattering in the Arctic. Expert witness on behalf of the National Resources Defense Council (plaintiffs) in the case of Village of False Pass, et al. vs. James G. Watt, et al. In 1983 Marine Acoustics won a major competitive contract from the North Slope Borough, Alaska to design, develop, and implement an acoustical detection system for assisting in the census of the bowhead whale population during its spring migration past Point Barrow, Alaska. In 1984 Marine Acoustics was selected by the Canadian Government Department of Freshwater Fisheries to design and develop an acoustical recording system for multichannel array recordings of migrating beluga and narwhal in Baffin Bay. In 1985 Marine Acoustics continued its bioacoustic research role in the Arctic with a second contract with the NSB covering the Spring 1985 bowead migration. In recognition of the advances made by the Marine Acoustics team in the development of new methods of studying whale behavior and estimating whale population size, Dr. Ellison was appointed as a member of the U.S. Delegation to the scientific committee of the International Whaling Commission.

Previous Positions Held

1963-1974 Officer, U.S.Navy including qualification as Sonar Officer in Destroyer Class Vessels; Technical Director of the AN/SQS-26 Project Office (PMS-387), NAVSEA Headquarters, Washington, D.C.; and Quality Assurance Officer for Submarines and SUBSAFE Program Officer at the Supervisor of Shipbuilding, Groton, CT. Currently hold the rank of Captain, U.S. Naval Reserve (Ret.).

1974-1983 Vice President, Principal, and Senior Scientist at Cambridge Acoustical Associates, Inc., Cambridge, Massachusetts. Principal investigator on over fifty major research contracts including analysis, experiment, and equipment design in the fields of underwater acoustics, naval architecture, and hydrodynamics. Expert witness for the Inuit Tapirisat of Canada and the Baffin Region Inuit Association on the Arctic Pilot Project Application before the National Energy Board of Canada. Member of the Scientific Advisory Committee to the North Slope Borough, Alaska.

Expeditions, Research, Field Work

1978 - Participated as a visiting scientist on the Naval Arctic Research Laboratory's floating ice station, ARLIS VII, for a period of two weeks conducting feasibility studies on the use of both active and passive underwater acoustic devices for studying Arctic marine wildlife. This station was established on a free floating ice floe, located roughly 100 Nmi north of Point Barrow in the Beaufort Sea.

1978-1979 - Acoustical consultant to Project Whales. This project was conducted by NARL for the Bureau of Land Management on the subject of the impact of offshore petrochemical exploitation on Arctic marine mammals, particularly the bowhead whale.

1978-1981 - Member of the U.S. Naval Reserve Arctic Contingency Team including active duty for training at the Naval Arctic Research Laboratory, Barrow, Alaska, and as a member of the advance logistic support team in Thule, Greenland responsible for the initial setup of communications and logistic support for the U.S. Navy's East Arctic 80 and 81 expeditions.

1978-1981 - Principal investigator on two scientific research contracts with the Office of Naval Research in the area of Arctic underwater acoustics.

1979 - Served as a member of a special working group of The Acoustical Society of America's Coordinating Committee on Environmental Acoustics charged with reviewing the current status of knowledge on the effects of manmade noise on Arctic marine wildlife. Based on the group's recommendations a major workshop was conducted in Feb 1979, at which I served as an invited speaker and wrote the section in the proceedings on Arctic ambient noise.

1980 - Under contract to the Alaska Eskimo Whaling Commission undertook with Dr. W.C. Cummings and Dr. D.V. Holliday an Arctic ambient noise research project. This field project was conducted at a number of sites on the shorefast ice offshore of Point Barrow and Prudhoe Bay Alaska during the months of May and June, 1980.

1981 - Under contract to the North Slope Borough, Alaska participated with Dr. W.C. Cummings and Dr. D.V. Holliday in a feasibility study to determine if passive acoustic localization techniques could be used to determine the location of bowhead whales during their spring migration past Point Barrow, Alaska. This was a major field expedition stationed on the shorefast ice at the edge of the spring lead system throughout most of the month of May, 1981.

1982-1983 - Expert witness on various judicial and civil proceedings in Canada and the U.S. on the subject of the impact of manmade noise on marine wildlife.

1983 - Founded Marine Acoustics as a sole proprietorship.

1983 - Awarded a research contract to continue acoustic localization studies of bowhead whales off Point Barrow during the Spring, 1984 migration period. This contract also culminated in the design and construction of the first successful field portable marine mammal passive localization system ever developed.

1984 - Awarded contract by Canadian Government to develop a custom system for receiving and recording multichannel marine mammal vocalizations. System successfully demonstrated and delivered in December 1984.

1984 - Project leader of two field expeditions to perform acoustic studies on migrating bowhead whales off the North Slope of Alaska. April/May 1984 off Point Barrow, Alaska, and Sept 1984 off Beaufort Lagoon, Alaska.

1985 - Project leader of field expedition to continue passive acoustic location studies of bowhead whales off Point Barrow, Alaska.

1985 - Appointed as a member of the United States delegation to the scientific committee of the International Whaling Commission.

(The research citations for the activities described above are included in the next section)

Publications and Symposia

"Transmission Loss Measurements of Soda-Straw Banks," J. Acoust. Soc. Am., 42, 530-531 (1967).

"An Analysis of the Response of Cylindrical Ducts to internal Zero Mean Flow, Air-Carried Acoustic Excitation," Master's Thesis, MIT, (1968).

"Variational Formulation for the Fully Coupled Problem of a Vibrating Circular Plate in a Rigid Wall," Presentation to the Annual Spring Meeting, J. Acoust. Soc. Am., 48, 83a, (1970).

"Finite Membranes and Plates Vibrating in a Dense Fluid: An Analysis of the Fully Coupled Problem," Ph.D. Thesis, MIT, ONR Report 71476-2, (1970).

"Backscattering from a Cylinder with Variable Surface Impedance," Presented at the 89th Mtg, J. Acoust. Soc. Am., 57, S59a, (1975).

"Comparison Between Plate and Shell Models for Scattering from a Framed Elastic Cylinder," Presented at the 94th Mtg, J. Acoust. Soc. Am., (With J.M. Garrelick), 62, S1, S67a, (1977).

"Acoustic Research Requirements in Support of Under-Ice Weapon Effectiveness," Proc. 32nd Navy Symposium on Underwater Acoustics, New London, 203, (1978).

"Beaufort Sea Underwater Sound Propagation," Invited Presentation, San Diego Workshop on the Interaction between Man-Made Noise and Vibration and Arctic Marine Wildlife, Acoust. Soc. Am., 25-29 February 1980.

" Environmental Noise Studies in the Arctic," The Northern Engineer (With W.C. Cummings and D.V. Holliday), 13, 1, 14-20, (1981).

"The Target Strength of a Mock Model Submarine," Proceedings of the 34th Navy Symposium on Underwater Acoustics (With F.P. Fessenden and J. Holland), San Diego, 363, (1981).

"Measurement of Man-Made Noise off North Slope, Alaska," Presented at the 102nd Mtg, J. Acoust. Soc. Am., 70, 1, S82-3a, (With W.C. Cummings and D.V. Holliday), (1981).

"Near Shore Ambient Noise off the North Slope of Alaska," Presented at the 102 Mtg, J. Acoust. Soc. Am., 70, 1, S84-5a, (With W.C. Cummings and D.V. Holliday), (1981).

"Environmental Noise Programs in the Arctic," Invited Presentation 17th Annual Awards Meeting, Narragansett Chapter, Acoust. Soc. Am., (1982).

"1983 IMSTARP Field Data Acquisition System: Documentation and an Example of Preliminary Results," CAA, Inc. Report U-845-2023, (1982).

"Using Bowhead Underwater Sounds to Determine Spatial Distribution of the Migrating Whales," Invited Presentation at the Second Conference on the Biology of the Bowhead Whale (With W.C. Cummings and D.V. Holliday), Anchorage, (1983).

"Passive Localization of Sounds from Bowhead Whales, Balaena mysticetus: Spring Migration off Point Barrow in 1982," Presented at the Annual Spring Meeting, J. Acoust. Soc. Am., 73, S1, S56a, (1983).

"Feasibility of Passive Acoustic Location of Bowhead Whales in Population Studies off Point Barrow, Alaska: A Report to the North Slope Borough," (with W.C.Cummings and D.V. Holliday)(1983).

"An Under-Ice Scattering Model; Comparison with Measured Results," Proceedings of the 35th Navy Symposium on Underwater Acoustics,(with C.J. Albanese), Wash. D.C., Nov 1983.

"Real-Time Passive Localization and Spectrum Analysis of Transient Underwater Sounds Using a Field Portable Computer Based System," (with C.W.Clark and K.Beeman), 108th mtg Acoustical Society of America, Oct 84.

"Low ka Target Strengths of Naval Mines," (with E.G.McLeroy), U.S. Navy Journal of Underwater Acoustics, July 1984.

"An Acoustic Study of Bowhead Whales, Balaena mysticetus, off Point Barrow, Alaska during the Spring 1984 Migration," (with C.W. Clark and K. Beeman), Final Contract Report to the NSB (draft copy), Jan 1985(a).

"Objectives and Methods for the Acoustic Studies Conducted During the Spring(1984) Migration of Bowhead Whales, off Point Barrow, Alaska," (with C.W. Clark and K. Beeman), Presented to the Third Conference on the Biology of the Bowhead Whale, Anchorage, Alaska, Jan 1985(b).

"Variations in the Rates and Types of Bowhead Whale, Balaena mysticetus, Vocalizations during the Spring (1984) Migration off Point Barrow, Alaska," (with C. W. Clark and K. Beeman), Presented to the Third Conference on the Biology of the Bowhead Whale, Anchorage, Alaska, Jan 1985(a).

"Acoustic Locations and Distribution of Migrating Bowhead Whales, Balaena mysticetus, off Point Barrow, Alaska in the Spring of 1984 during Good and Very Good Visual Censusing Conditions," (with C.W. Clark and K. Beeman), Presented to the Third Conference on the Biology of the Bowhead Whale, Anchorage, Alaska, Jan 1985(b)

"Acoustic Locations and Distribution of Migrating Bowhead Whales, Balaena mysticetus, off Point Barrow, Alaska in the Spring of 1984 during Poor Visual Censusing Conditions," (with C.W. Clark and K. Beeman), Presented to the Third Conference on the Biology of the Bowhead Whale, Anchorage, Alaska, Jan 1985(c)

"Acoustic tracking and distribution of migrating bowhead whales, Balaena mysticetus off Point Barrow, Alaska in the spring of 1984." With C.W. Clark. Proceedings of the 1985 meeting of the Scientific Committee of the International Whaling Commission. Paper SC/37/PS11.

"A preliminary account of the acoustic study conducted during the 1985 spring bowhead whale, Balaena mysticetus, migration off Point Barrow, Alaska." With C.W. Clark. Proceedings of the 1985 meeting of the Scientific Committee of the International Whaling Commission. Paper SC/37/PS13.

"Acoustic Location Techniques and Calibration Methods Used During the Spring 1984 and 1985 Bowhead Whale, Balaena mysticetus, Migrations." With Clark, C.W., and Beeman, K.. Proceedings of the 1985 meeting of the Scientific Committee of the International Whaling Commission. Paper SC/37/PS10.

"A description of a tracking algorithm and its application to bowhead whale acoustic location data collected during the spring migration near Point Barrow, Alaska 1984-85." With Sonntag, R.M., Clark, C.W., Corbitt, D.R., and Krogman, B.D.. Proceedings of the 1985 meeting of the Scientific Committee of the International Whaling Commission. Paper SC/37/PS12.

"Utilization of Acoustic Location Data in Determining a Minimum Number of Spring-Migrating Bowhead Whales Unaccounted for by the Ice-Based Visual Census," (with D. Ko, J.E. Zeh, C.W. Clark, B.D. Krogman, and R. Sonntag), Proceedings of the 1985 Meeting of the Scientific Committee of the International Whaling Commission. Paper SC/37/PS15

C. ROBERT EVANS
Wildlife Biologist, LGL Limited

EDUCATION

1978 B.Sc. Renewable Resources-Wildlife Management (Honours), McGill University.

PROFESSIONAL EXPERIENCE

1985 Participated in photo-identification analyses of individual bowhead whales for LGL's studies of the reproductive parameters of bowhead whales in the Canadian Beaufort Sea and of the feeding ecology of bowhead whales in the eastern Alaskan Beaufort Sea.

Laboratory supervisor for a study of the use of predators as sampling agents for Arctic cod (*Boreogadus saida*). Examined patterns of otolith growth, regional and temporal variations in age composition and individual growth of cod. Aged over 12,000 Arctic cod otoliths.

Conducted aerial surveys of bowhead whales and other marine mammals, autumn 1985, for LGL studies of the distribution and numbers of bowhead whales migrating through areas of hydrocarbon exploration in the Alaskan Beaufort Sea.

Participated in the preparation of the final report on the distribution of bowhead whales and industrial activity in the Canadian Beaufort Sea, 1980-84, utilizing all available sources of data.

1983-1985 Participated in the assessment of the importance of a remote bay (Isabella Bay, eastern Baffin Island) to bowhead whales in 1983, 1984 and 1985. Duties included establishing and maintaining a field camp, conducting horizontal and vertical tows to determine distribution and abundance of zooplankton, profiling bathymetry with the use of a theodolite and depth sounder, maintaining watches from cliffs for marine mammals, theodolite tracking of bowhead whales, and the analysis of data obtained during these studies.

1984 Conducted aerial surveys to determine the distribution and numbers of bowhead whales and other marine mammals in the Alaskan Beaufort Sea, autumn 1984.

Participated in the aerial survey component of a study of the effects of icebreaker disturbance on arctic whales at the Lancaster Sound ice edge.

Integrated and analyzed several data sets on bowhead whale distribution in relation to offshore industrial activities in the Canadian Beaufort Sea in 1983. Participated in the laboratory analysis of benthos and zooplankton collected in the eastern high arctic.

1983 Integrated and analyzed many data sets on the distribution of bowhead whales in the Beaufort Sea, for the years 1980-82 as they related to offshore industrial activities.

Participated in the diet and morphometric analysis of high arctic benthic fishes. Participated in the laboratory analysis of benthos and zooplankton collected in the eastern high arctic.

1982 Participated in LGL's systematic aerial surveys of gray whales in the Chirikof Basin during July and September, and in aerial surveys and photogrammetric studies of bowhead whales in the Canadian Beaufort Sea. Participated in the analysis of bowhead distributional data.

1980-81 Participated in LGL projects in the central and high arctic. These included the following:

- aerial surveys of abundance, distribution and behaviour of bowhead whales in the Beaufort Sea and Amundsen Gulf and analysis of data,
- analyzed data on the distribution and abundance of white whales summering in the Canadian Beaufort Sea and Amundsen Gulf
- analysis of feeding habits of bearded seals collected in the Canadian high arctic,
- aerial surveys of seabirds and marine mammals off the Labrador coast,
- aerial surveys for marine mammals, especially white whales, in Ungava Bay, Hudson Strait and northern Hudson Bay, analysis of distribution, and historical research for catch history,
- age/morphometric analysis to determine the population status of white whales.

1976 Conducted a field study for Hydro Quebec of animal activity along a hydro right-of-way. Participated in the construction and reading of sand tracks, data compilation and analysis of vegetation. Established and resided at field camp for 3.5 months.

REPORTS AND PUBLICATIONS

1985 Bradstreet, M.S.W., K.J. Finley, A.D. Sekerak, W.B. Griffiths, C.R. Evans, M.F. Fabijan and H.E. Stallard. Aspects of the biology of Arctic cod (Boreogadus saida) and its importance in arctic marine food chains. Rep. by LGL Ltd., for Department of Fisheries and Oceans, Winnipeg. 254 p.

1985 Richardson, W.J., R.A. Davis, C.R. Evans and P. Norton. Distribution of bowheads and industrial activity, 1980-84. p. 255-306. In: W.J. Richardson (ed.), Behavior, disturbance responses and distribution of bowhead whales Balaena mysticetus in the eastern Beaufort Sea, 1980-84. Rep. by LGL Ecol. Res. Assoc., Inc., Bryan, TX, for U.S. Minerals Management Service, Reston, VA. 306 p.

1984 Finley, K.J. and C.R. Evans. First Canadian breeding record of the dovekie (Alle alle). Arctic 37:288-289.

1984 Finley, K.J., C.R. Evans and R.A. Davis. Evaluation of the importance of Isabella Bay, Baffin Island, as summer habitat for the endangered bowhead whale. Progress report of 1984 studies. Rep. by LGL Limited, King City, Ontario, for World Wildlife Fund (Canada), Toronto, Ontario. 30 p.

1984 Richardson, W.J., P. Norton and C.R. Evans. Distribution ofbowheads and industrial activity, 1983. p. 309-361. In: W.J. Richardson (ed.), Behavior, disturbance responses and distribution of bowhead whales Balaena mysticetus in the eastern Beaufort Sea, 1983. Rep. from LGL Ecol. Res. Assoc., Inc., Bryan, TX, for U.S. Minerals Management Service, Reston, VA. 361 p.

1983 Finley, K.J. and C.R. Evans. Summer diet of the bearded seal (Erignathus barbatus) in the Canadian high arctic. Arctic 36: 82-89.

1983 Finley, K.J., C.R. Evans and R.A. Davis. Evaluation of the importance of Isabella Bay, Baffin Island, as summer habitat for the endangered bowhead whale. Rep. by LGL Ltd., Toronto, to World Wildlife Fund, Toronto. 72 p.

1983 Richardson, W.J., R.A. Davis, C.R. Evans and P. Norton Fraker. Distribution of bowheads and industrial activity, 1980-82. p. 269-357. In: W.J. Richardson (ed.), Behavior, disturbance responses and distribution of bowhead whales Balaena mysticetus in the eastern Beaufort Sea, 1982. Rep. by LGL Ecol. Res. Assoc., Inc., Bryan, TX, for U.S. Minerals Management Service, Reston, VA. 357 p.

1982 Davis, R.A. and C.R. Evans. 1982. Offshore distribution and numbers of white whales in the southeastern Beaufort Sea and Amundsen Gulf, summer 1981. Rep. by LGL Limited, Toronto, to Sohio Alaska Petroleum Company, Anchorage, and Dome Petroleum Limited, Calgary. 76 p.

1982 Finley, K.J., G.W. Miller, M. Allard, R.A. Davis, and C.R Evans. The belugas (Delphinapterus leucas) of northern Quebec: distribution, abundance, stock identity, catch history and management. Can. Tech. Rep. Fish. Aquat. Sci. 1123:57 p.

1982 Davis, R.A., W.R. Koski, W.J. Richardson, C.R. Evans and W.G. Alliston. Distribution, numbers and productivity of the Western Arctic stock of bowhead whales in the eastern Beaufort Sea and Amundsen Gulf, summer 1981. Rep. by LGL Limited, Toronto, to Dome Petroleum Limited, Calgary, and to Sohio Alaska Petroleum Company, Anchorage. 135 p.

MICHAEL S.W. BRADSTREET
Biologist, LGL Limited

EDUCATION

1975 Additional courses in biology, University of Alberta.

1972 B.Sc. Zoology, University of Toronto.

PROFESSIONAL EXPERIENCE

1985 Senior investigator for a study of the use of predators as sampling agents for Arctic cod. Examined patterns of otolith growth, regional and temporal variations in age composition and individual growth of cod, mortality patterns and feeding of Y-O-Y cod. Designed a collection system that, if instituted, would permit an ongoing assessment of the life-history parameters of this important gadoid.

Senior investigator for a study of food availability to bowhead whales along the Yukon coast. Field work involved collection of physical and biological oceanographic information in areas where bowheads were, and were not, feeding. Conducted aerial surveys of bowhead whales and other marine mammals in the Alaskan and Canadian Beaufort Sea.

1984 Conducted aerial surveys of bowhead whales and other marine mammals in the Alaskan Beaufort Sea, autumn 1984.

Evaluated wetland classification and evaluation systems and established criteria for assessment of fish and wildlife habitat in Alberta by remote sensing.

1984 Principal investigator for study of the feeding ecology of sea-birds nesting at the Pribilof Islands, Alaska. Study undertaken as part of monitoring program conducted by LGL Ecological Research Associates for U.S. Minerals Management Service.

1978-83 On behalf of LGL, conducted studies of the feeding ecology of arctic seabirds in NW Baffin Bay and east Labrador for Petro-Canada.

1977 Supervised and conducted LGL's avifaunal survey of St. Lawrence Islands National Park for Parks Canada. Work included a comprehensive review and synthesis of existing information and examination of terrestrial breeding bird communities in relation to habitat variables.

1976 Conducted feeding ecology studies of northern seabirds in the Lancaster Sound and Barrow Strait areas of the Canadian arctic. Developed methods for estimating relative numbers, volumes, wet weights, dry weights and energy values of organisms represented in stomachs of arctic seabirds. This work was conducted by LGL for Polar Gas Project and Norlands Petroleums Ltd.

1975 Investigations for Polar Gas Project of the feeding ecology of shorebirds and other marine-associated birds at Creswell Bay, Somerset Island, N.W.T.

1974-75 Participated in LGL's investigations of the impact of the proposed Polar Gas Project on marine and terrestrial birds and marine mammals of the high arctic. Conducted aerial surveys, analyzed habitat variables, surveyed literature and analyzed survey techniques.

1973 Prepared, with others, the Essex Region Conservation Report for the Ontario Ministry of Natural Resources. Responsible for research and writing of biology and forestry sections.

1972-73 Warden with the Long Point Bird Observatory, Lake Erie, Ontario. Responsible for the research program. Conducted several monitoring studies of migrant and breeding birds at Long Point; work involved collecting, censusing and banding. Conducted detailed studies of the migration of shorebirds and gulls on Long Point.

REPORTS AND PUBLICATIONS

Reports and papers concerning the distribution, habitat use and feeding ecology of northern birds and mammals, and aspects of the natural history of Long Point.

Reports

1985 Bradstreet, M.S.W., K.J. Finley, A.D. Sekerak, W.B. Griffiths, C.R. Evans, M.F. Fabijan and H.E. Stallard. Aspects of the biology of Arctic cod (Boreogadus saida) and its importance in arctic marine food chains. Rep. by LGL Ltd., for Department of Fisheries and Oceans, Winnipeg. 254 p.

1985 Bradstreet, M.S.W. Food habits. p. 257-306. In: S.R. Johnson (ed.), Population estimation, productivity and food habits of nesting seabirds at Cape Peirce and the Pribilof Islands, Bering Sea, Alaska. Final Rep. by LGL Ecol. Res. Assoc., Inc., for U.S. Minerals Management Service, Anchorage, AK. 330 p.

1984 Green, J.E., W.R. Koski, M.S.W. Bradstreet, T.R. Eccles and J.A. Taylor. Wetlands habitat classification and evaluation: criteria for assessment of fish and wildlife habitat in Alberta. Rep. by LGL Ltd. for Alberta Environment. 163 p.

1983 Bradstreet, M.S.W. Feeding ecology of alcids near the Gannet Islands, Labrador. Rep. by LGL Ltd. for Petro-Canada. 117 p.

1983 Bradstreet, M.S.W. and K.J. Finley. Diet of ringed seals (Phoca hispida) in the Canadian High Arctic. Rep. by LGL Ltd. for Petro-Canada. 36 p.

1980 Bradstreet, M.S.W. Studies near the Pond Inlet ice edge: occurrence, habitat use, and behavior of seabirds, marine mammals, and arctic cod. Rep. by LGL Ltd. for Petro-Canada. 38 p.

1980 Bradstreet, M.S.W. and W.E. Cross. Studies near the Pond Inlet ice edge: trophic relationships. Rep. by LGL Ltd. for Petro-Canada. 41 p.

1980 McCracken, J.D., M.S.W. Bradstreet and G.L. Holroyd. The breeding birds of Long Point, Lake Erie. Rep. by Long Point Bird Observatory for Canadian Wildlife Service. 247 p.

1979 Bradstreet, M.S.W. Feeding ecology of seabirds in northwest Baffin Bay, 1978. Rep. by LGL Ltd. for Petro-Canada. 65 p.

1978 Bradstreet, M.S.W. and J.D. McCracken. Avifaunal survey of St. Lawrence Islands National Park. Rep. by LGL Ltd. for Parks Canada. 343 p.

1977 Bradstreet, M.S.W. The biological environment of Long Point, Lake Erie: an overview. Rep. for Nature Conservancy of Canada. 159 p.

1977 Bradstreet, M.S.W. Feeding ecology of seabirds along the fast-ice edges in Wellington Channel and Resolute Passage, N.W.T. Rep. by LGL Ltd. for Polar Gas Project. 149 p.

1977 Bradstreet, M.S.W. and K.J. Finley. Distribution of birds and marine mammals along fast-ice edges in Barrow Strait, N.W.T. Rep. by LGL Ltd. for Polar Gas Project. 315 p.

1976 Alliston, W.G., M.S.W. Bradstreet, M.A. McLaren, R.A. Davis and W.J. Richardson. Numbers an distribution of birds in the central District of Franklin, N.W.T. June-August 1975. Rep. by LGL Ltd. for Polar Gas Project. 583 p.

1976 Bradstreet, M.S.W. Summer feeding ecology of seabirds in eastern Lancaster Sound, 1976. Rep. by LGL Ltd. for Norlands Petroleums Ltd. 187 p.

1975 Davis, R.A., K. Finley, M. Bradstreet, C. Holdsworth and M. McLaren. Studies of the numbers and distribution of birds and mammals in the central Canadian arctic--1974: a supplement. Rep. by LGL Ltd. for Polar Gas Project. 205 p.

1974 Davis, R.A., M. Bradstreet, C. Holdsworth, M. McLaren and W.J. Richardson. Studies of the numbers and distribution of birds in the central Canadian arctic--1974: a preliminary report. Rep. by LGL Ltd. for Polar Gas Project. 238 p.

Publications

1985 Bradstreet, M.S.W. and R.G.B. Brown. Feeding ecology of the Atlantic alcidae. p. 263-318. In: D.N. Nettleship and T.R. Birhead (eds.), The Atlantic alcidae. Academic Press, London. 539 p.

1982 Bradstreet, M.S.W. Pelagic feeding ecology of dovekies, Alle alle, in Lancaster Sound and western Baffin Bay. Arctic 35:26-140.

1982 Bradstreet, M.S.W. Occurrence, habitat use, and behavior of seabirds, marine mammals and arctic cod at the Pond Inlet ice edge. Arctic 35:28-40.

1982 Bradstreet, M.S.W. and W.E. Cross. Trophic relationships at high arctic ice edges. Arctic 35:1-12.

1981 McCracken, J.D., M.S.W. Bradstreet and G.L. Holroyd. The breeding birds of Long Point, Lake Erie. Can. Wildl. Serv. Rep. Ser. No. 44. 72 p.

1981 Parsons, J., M. Bradstreet and G. McKeating (ed.). Seasons: special issue on Long Point. Federation of Ontario Naturalists, Don Mills. 64 p.

1980 Bradstreet, M.S.W. Thick-billed murres and black guillemots in the Barrow Strait area, N.W.T. during spring: diets and food availability along ice edges. Can. J. Zool. 58:2120-2140.

1980 Renaud, W.E. and M.S.W. Bradstreet. Late winter distribution of black guillemots in northern Baffin Bay and the Canadian high arctic. Can.Field-Nat. 94:421-425.

1979 Bradstreet, M.S.W. Thick-billed murres and black guillemots in the Barrow Strait area, N.W.T., during spring: distribution and habitat use. Can. J. Zool. 57:1789-1802.

1978 Bradstreet, M.S.W. The pelagic, summer, feeding ecology of northern fulmars in Lancaster Sound (Abstract). Ibis 120:124.

1977 Bradstreet, M.S.W., G.W. Page and W.G. Johnston. Shorebirds at Long Point, Lake Erie, 1966-1971: seasonal occurrence, habitat preference, and variation in abundance. Can. Field-Nat. 91:225-236.

1975 Reid, R.A., M.S.W. Bradstreet, W.L. Bryan, S. Scott, L.E. Clay, W.A. Mungall and I.D. Robertson. Essex Region Conservation Report. Ontario Ministry of Natural Resources. 123 + 14 p.

1975 Weseloh, D.V., R.B. Sutherland and M.S.W. Bradstreet. Movements of ring-billed gulls in the lower Great Lakes. In: E.H. Dunn (ed.). Long Point Bird Observatory 1973 Annual Report. 29 p.

1970 Bradstreet, M.S.W. and G.L. Holroyd, eds. Long Point Bird Observatory: ten-year report, 1960-69. 66 p.

1969 Bradstreet, M.S.W. Consecutive nesting of female tree swallows at Long Point, Ontario. Ontario Bird Banding 5:68-71.

1969 Hussell, D.J., R.W. Stamp, P.S. Woodford, J. Bradshaw, M.S.W. Bradstreet and W.A. Martin. Long Point Bird Observatory: 1967 report. Ontario Bird Banding 5:7-49.

1969 Hussell, D.J.T., R.W. Stamp, P.S. Woodford, M.S.W. Bradstreet, G. Page and A. Salvaderi. Long Point Bird Observatory: 1968 report. Ontario Bird Banding 5:81-121.

1968 Page, G. and M. Bradstreet. Size and composition of a fall population of least and semipalmated sandpipers at Long Point, Ontario. Ontario Bird Banding 4:50-81.

1968 Whittam, R., M. Bradstreet and G. Fairfield. Breeding bird census: Sand dunes with scattered cottonwoods. Audubon Field Notes 22:721-722.

GARY W. MILLER
Wildlife Biologist, LGL Limited

EDUCATION

1975 B.Sc. Zoology, University of Michigan.

PROFESSIONAL EXPERIENCE

1985 Participated in LGL's study of the importance of the eastern Alaskan Beaufort Sea to feeding bowhead whales: responsible for obtaining and analysing vertical aerial photographs of bowhead whales, aerial surveys of bowhead numbers and distribution, and underwater recording of bowhead and industrial sounds.

Participated in LGL's aerial photography study of the reproductive parameters of bowhead whales in the Canadian Beaufort Sea. Duties included aerial surveys to determine bowhead distribution and abundance, aerial photography and photo-identification of individual bowhead whales.

1984 Biologist in charge of ship-based marine mammal studies on the North Aleutian Shelf as part of LGL's process study for U.S. NOAA.

Conducted aerial surveys to document reactions of narwhals and belugas to icebreaker traffic at Lancaster Sound ice edge.

Participated in LGL's aerial photography study of bowhead whales in the Canadian Beaufort Sea; responsible for analysis of photographs to determine individual identifications.

Participated in LGL's aerial surveys of bowheads in the Alaskan Beaufort Sea for Shell Western and Amoco.

1983-84 Participated in boat-based study of bowhead whale behaviour in relation to industrial activity in the Beaufort Sea. Work included behavioural observations, underwater recording of bowhead and industrial sounds, and underwater playback of industrial sounds.

1983 Participated in an ice-based study of the reactions of belugas and narwhals to icebreakers in the high arctic (Lancaster Sound). The work was from a remote camp on an ice-edge over deep water, and involved underwater recording of whale and icebreaker sounds, behavioural observations from the ice, and aerial surveys.

Analysed and reported on data from shipboard and aerial wildlife surveys conducted during seismic exploration in west-central Hudson Bay.

1982 Conducted aerial surveys of gray whales summering in the Bering Sea, and wrote the project report.

Participated in LGL's systematic aerial surveys and photographic studies of bowhead whales in the Canadian Beaufort Sea. Conducted a literature review and analysis of the status of ringed seals in the Baffin Bay region. Participated in aerial surveys of marine mammal populations wintering off the west coast of Greenland.

Designed a wildlife observation program for native observers on board a seismic ship operating in Hudson Bay.

1981 Analysed and reported on the kill distribution, age structure and reproductive status of 1500 ringed seal specimens taken by Inuit hunters in the northeast Baffin Island region. Participated in field investigations of the distribution and numbers of summering bowheads in the Beaufort Sea.

1980 Participated in an investigation, in cooperation with the Inuit of northern Quebec, on the status of beluga populations inhabiting the east coast of Hudson Bay and Ungava Bay. Accompanied hunters in order to obtain morphometric data and biological specimens for hunter-killed belugas and conducted aerial surveys and migration watches. Analysed harvest statistics collected from hunters in the northeast Baffin Island region.

1979 Monitored the narwhal hunt in Pond Inlet, working with hunters to assess the effectiveness of harpoon guns as a possible means of reducing hunting losses. Collected biological samples and morphometric data from hunter-killed narwhals. Participated in morphometric and biochemical comparison of samples from offshore and nearshore populations of ringed seals in the Baffin Bay region. Conducted watches to observe the timing and numbers of narwhals and bowheads migrating past a promontory on Baffin Island.

Participated in LGL studies measuring the toxicity of oil to marine organisms in Frobisher Bay, N.W.T.

Participated in LGL analysis of stomach contents of fulmars.

1975-77 Warden at Long Point Bird Observatory. Conducted studies of bird migrations and breeding bird populations in southern Ontario.

1974 Conducted studies of breeding bird populations at Long Point for Long Point Bird Observatory.

REPORTS AND PUBLICATIONS

Reports and publications concerning:

Marine mammals
- numbers and distribution
- harvest techniques
- age structure and reproductive status
- diet analysis

Birds
- population status and breeding success of endangered species
- diet analysis

In prep. Miller, G.W. and K.J. Finley. Kill distribution, age and reproductive status of ringed seals (Phoca hispida) taken by Inuit hunters in the Canadian high arctic. Rep. by LGL Limited, to Eastern Arctic Marine Environmental Studies Program, Petro-Canada, Calgary.

In prep. Miller, G.W. Age structure and reproductive status of harp seals harvested in Pond Inlet and Grise Fiord, N.W.T.

1986 Davis, R.A., W.R. Koski and G.W. Miller. Experimental use of aerial photogrammetry to assess the long-term responses of bowhead whales to offshore industrial activities in the Canadian Beaufort Sea. Rep. by LGL Limited, King City, to Canada Dept. Indian and Northern Affairs, Ottawa. 155 p.

1986 Richardson, W.J., B. Wursig, G. Miller and G. Silber. Bowhead distribution, numbers and activities. p. 159-237. In: W.J. Richardson (ed.), Importance of the eastern Alaskan Beaufort Sea to feeding bowhead whales, 1985. Rep. by LGL Ecol. Res. Assoc., Inc., Bryan, TX, for U.S. Minerals Management Service, Reston, VA. 294 p.

1984 Miller, G.W. and R.A. Davis. Distribution and movements of narwhals and beluga whales in response to ship traffic at the Lancaster Sound ice edge - 1984. Rep. by LGL Limited, King City, Ontario, for Canada Dept. of Indian Affairs and Northern Development, Ottawa. 34 p.

1984 Miller, G.W. Shipboard and aerial wildlife observations during seismic exploration in Hudson Bay, 1983. Rep. by LGL Limited, to Canadian Occidental Petroleum Ltd., Calgary. 62 p.

1984 Miller, G.W. Distribution and abundance of gray whales (Eschrichtius robustus) in the Chirikof Basin, summer 1982. p. 75-108. In: D.H. Thomson (ed.), Feeding ecology of gray whales (Eschrichtius robustus) in the Chirikof Basin, summer 1982. Rep. for Nat. Oceanic & Atmos. Admin., Juneau, AK.

1984 Finley, K.J., G.W. Miller, R.A. Davis and C.R. Greene. Responses of narwhals (Monodon monoceros) and belugas, (Delphinapterus leucas) to ice-breaking ships in Lancaster Sound - 1983. Rep. by LGL Limited, King City, Ontario, to Canada Dept. Indian Affairs and Northern Development, Ottawa. 118 p.

1983 Finley, K.J., G.W. Miller, R.A. Davis and W.R. Koski. A distinctive large breeding population of ringed seals (Phoca hispida) inhabiting the Baffin Bay pack ice. Arctic 36:162-173.

1983 Davis, R.A., W.R. Koski and G.W. Miller. Preliminary assessment of the length-frequency distribution and gross annual reproductive rate of the western arctic bowhead whale as determined with low-level aerial photography, with comments on life history. Rep. by LGL Limited to National Marine Mammal Laboratory, Seattle, Wash. 84 p.

1983 Miller, G.W. and M.A. McLaren. Late summer wildlife observations in offshore Hudson Bay, 1982. Rep. by LGL Limited to Canadian Occidental Petroleum, Calgary. 67 p.

1982 Miller, G.W., R.A. Davis and K.J. Finley. Ringed seals in the Baffin Bay region: habitat use, population dynamics and harvest levels. Rep. by LGL Limited to Arctic Pilot Project, Calgary. 93 p.

1982 Finley, K.J., G.W. Miller, M. Allard, R.A. Davis and C.R. Evans. The belugas (Delphinapterus leucas) of northern Quebec: distribution, abundance, stock identity, catch history and management. Canadian Technical Report of Fish. Aquat. Sci. 1123. 57 p.

1982 Finley, K.J. and G.W. Miller. The 1979 hunt for narwhals (Monodon monoceros) and an examination of harpoon gun technology near Pond Inlet, northern Baffin Island. Rep. int. Whal. Comm. 32:449-460.

1980 Finley, K.J. and G.W. Miller. Wildlife harvest statistics from Clyde River, Grise Fiord and Pond Inlet, 1979. Rep. by LGL Limited to Eastern Arctic Marine Environmental Studies program, Petro-Canada, Calgary. 37 p.

1977 Bradstreet, M.S.W. and G.W. Miller. Food sample analysis of northern fulmars from Prince Leopold Island, N.W.T. Rep. by LGL Limited to the Canadian Wildlife Service, Ottawa. 17 p.

1977 Miller, G.W. The current status and breeding performance of the piping plover on Long Point--a survey of an endangered species population. Rep. by Long Point Bird Observatory for the Ontario Ministry of Natural Resources, Toronto. 28 p.

1976 Miller, G.W. The status of the piping plover on Long Point--1976. Rep. by Long Point Bird Observatory, Port Rowan, Ont. 3 p.

1974 Miller, G.W. Thirty-eighth breeding bird census. Tamarack-white cedar slough. American Birds 28:1017-18.