Interim Report, April 1998-March 1999

MONITORING DISTRIBUTION AND ABUNDANCE OF RINGED SEALS IN NORTHERN ALASKA

Cooperative Agreement Number 14-35-0001-30810

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COOPERATIVE ACTIVITIES OVERVIEW

The Department of the Interior, Minerals Management Service (MMS) cooperatively agreed with the Alaska Department of Fish and Game (ADF&G) to conduct a 3-year study to monitor the distribution and abundance of ringed seals in northern Alaska. Unusual weather in 1998 resulted in an abbreviated field season. For this reason, the study was extended at no additional cost to include a fourth year of surveys. The MMS has a major role in providing significant funds to the ADF&G for study design and implementation, aerial surveys, and analysis of ringed seal observations. The ADF&G provides field operations management, and expertise for conducting aerial surveys; MMS cooperates with field activities and the planning and execution of fieldwork. The ADF&G reviews and refines previously established ringed seal protocols. Ringed seal relative abundance and observed density on fast ice will be compared between two sampling periods, 1985-1987 and 1996-1999, by ADF&G, which will also compare abundance and observed density of hauled out seals for near industrial and non-industrial areas. The MMS works in conjunction with ADF&G to ensure that all pertinent data are accessible, analyzed, and integrated as needed. The MMS also provides geographical information system information on coastlines, planning areas, and other marine resources, and integrates the information with ADF&G aerial survey coverages. ADF&G provides reports of findings resulting from the study to local residents and subsistence users.

PROJECT ORGANIZATION

This study is designed as a cooperative effort that involves the MMS Alaska Region Environmental Studies Section, the ADF&G, the National Marine Fisheries Service (NMFS), the University of Alaska (UA), and the North Slope Borough (NSB). ADF&G has primary responsibility for project management and coordination, conduct of surveys, data analysis, and reporting. The NMFS National Marine Mammal Laboratory is assisting in the conduct of surveys, data analysis, and reporting, and will coordinate this project with NMFS ringed seal research and management programs. UA Fairbanks is assisting with conduct of surveys and reporting. One UA Anchorage graduate student is working on this project as part of a Master of Science thesis in biology. The NSB Department of Wildlife Management will assist other cooperators in communicating study plans and results to people residing in the study area. All cooperators have input into project design, and have access to, and will be able to make use of, all data collected.

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EXECUTIVE SUMMARY

This is an interim report describing progress made in the third year of a four year project to examine the distribution and abundance of ringed seals (*Phoca hispida*) in northern Alaska. This is a cooperative project funded primarily by the U.S. Department of the Interior, Minerals Management Service, with additional support being contributed by the Alaska Department of Fish and Game, the National Marine Fisheries Service, the University of Alaska Fairbanks, and the North Slope Borough. Specific objectives of the project are to: 1) review and refine the previously established protocol for monitoring ringed seals by aerial surveys; 2) estimate relative abundance and density of molting ringed seals on fast ice in the Beaufort Sea during 1996-1999 and compare with data collected during 1985-1987; 3) correlate observed ringed seal densities on fast ice with environmental parameters; 4) determine abundance and observed density of molting ringed seals at and near industrial operations, and compare with otherwise comparable non-industrial areas; 5) review adequacy of ringed seal data collected by past industry site-specific monitoring programs, and make recommendations for protocols to be used in future industry studies; and 6) provide reports of findings that result from ringed seal monitoring to local residents and subsistence users.

Surveys were conducted in the Beaufort Sea from Oliktok to Barter Island on 27-28 May 1998 using previously established survey protocols. We surveyed approximately 1,200 km^2, and sighted 1,111 seals in 579 groups. Overall observed density was 0.93 seals/ km^2 (0.81 seals/km^2 in sector B3 and 1.19 seals/km^2 in sector B4). Sector B4 had the highest density of seals at cracks and at holes on both fast and pack ice.

Two sectors (B3 and B4) have been surveyed each year of this project, thus enabling between-year comparisons. In both sectors the raw densities of ringed seals on fast ice, based on standard strip transect analysis, were lowest in 1996 (sector B3 - 0.57 seals/km^2 in 1996, 0.74 seals/km^2 in 1997and 0.83 seals/km^2 in 1998; sector B4 - 0.67 seals/km^2 in 1996, 1.17 seals/km^2 in 1997, and 1.16 seals/km^2 in 1998). On pack ice, the estimated densities were similar for the three years in sector B3 (0.92 seals/km^2 in 1996; 0.81 seals/km^2 in 1997; 0.82 seals/km^2 in 1998) and quite variable in sector B4 (1.17 seals/km^2 in 1996, 2.37 seals/km^2 in 1997, 1.57 seals/km^2 in 1998). Observed densities for these two sectors during 1996-1998 surveys generally fell within the range of, but tended to be lower than estimated densities for 1985-1987. Statistical comparison of 1985-1987 and 1996-1999 surveys will be presented in the final report next year.

Preliminary covariate analyses of 1996-1998 survey data were conducted to examine the effects of weather and habitat variables on seal counts. Ice type, percent ice deformation, percent melt water, time of day, distance from shore, distance from the fast ice edge, longitude, date, and cloud cover were all found to affect the observed density. Modeled seal counts declined as ice deformation increased, and with distance away from the fast ice edge, and increased with increasing distance from shore. It is likely that the interaction of distance from shore and distance from the edge complicates this relationship.

Seal sightings and ice characteristics data for the three survey years have been entered into a geographical information system (GIS). Using the GIS, some preliminary analyses have been completed which overlay seal sightings with data layers created for ice deformation, distance from shore, and distance from the fast ice edge. Like covariate analysis, the GIS analysis indicated that observed seal density increased with distance from shore. Observed density relative to the ice edge was more complicated. In 1996 and 1998, when breakup had already begun, the observed densities were highest near the edge. In general, the edge was much closer to shore. In 1997, when surveys were clearly before breakup, the opposite was true. Observed densities increased from the edge to about 16 km south of the edge, then decreased again towards shore. The distance at which densities began to decline relative to distance from the edge is about where the 1996 and 1998 ice edges were located. This suggests that some factor other than the ice edge per se, for example water depth, may be the underlying cause for the observed patterns in density. It is clear from these preliminary analyses that the use of GIS techniques is time consuming, and that not all aspects of ringed seal distribution are equally suited to such analysis. The greatest benefit is likely for habitat variables such as bathymetry which are not already part of the survey database and lend themselves well to visual representation. During the remainder of this project, we will continue to develop and refine methods for applying GIS techniques to the analysis of ringed seal aerial survey data.

A literature search is ongoing to compile references pertaining to the distribution, abundance, and natural history of ringed seals. Over 230 references have been annotated and entered in a bibliographic computer database. The database will be distributed at the completion of this project.

We recommend that surveys in 1999 should be conducted using the standard methods described in the previous MMS-ADF&G protocol. Based on the almost identical estimates produced by line- and strip transect analyses during 1996 and 1997, and because all previous ringed seal surveys in Alaska have been conducted using strip transect methods, we recommend that future ringed seal surveys be conducted using strip transect methods. Efforts to develop methods for covariate analysis should be continued.

ACKNOWLEDGMENTS

This project is funded primarily by the U.S. Department of the Interior, Minerals Management Service, Alaska Region Environmental Studies Section. Additional support and in-kind services are being contributed by the Alaska Department of Fish and Game, the National Marine Fisheries Service, the University of Alaska Fairbanks, and the North Slope Borough. Cleve Cowles and Jane Carlson have assisted with implementation of the cooperative agreement. Valerie Elliott has provided information on industrial activities and Warren Horowitz has assisted with GIS/ARCINFO analysis of ringed seal survey data.

We thank Tom Blaesing, Commander Northwest, for providing the aircraft used for 1996 -1998 surveys and for his expert piloting. Doug DeMaster, Casey Hessinger, Sue Hills, Debbie

Blaesing, Grey Pendleton, John Bengston and Janice Waite served as observers and data recorders on the surveys.

Rob DeLong developed computer programs for handling aerial survey data. Casey Hessinger prepared the ringed seal bibliography, assisted with organization of historical data files, and developed a pilot project for GIS analysis to examine ringed seal distribution and density relative to habitat variables. Jeff Laake provided advice on study design and data analysis.

1. INTRODUCTION

1.1 Project Background

In 1985, the National Oceanic and Atmospheric Administration and the U.S. Minerals Management Service (MMS) awarded a contract to the Alaska Department of Fish and Game (ADF&G) to develop a program for monitoring the population of ringed seals (*Phoca hispida*) off Alaska. The general objectives of the study were to estimate the density of ringed seals in nearshore regions of the Chukchi and Beaufort seas, to develop a better understanding of factors affecting ringed seal distribution and abundance, and to evaluate potential effects of industrial activities that were being conducted. Of particular concern were potential conflicts on the shorefast ice, which is used by seals for pupping and molting and which also provides a convenient platform for a variety of human activities. A monitoring protocol was developed, and aerial surveys were flown in the Chukchi and Beaufort seas using that protocol during May-June 1985, 1986, and 1987. A final report describing the design of the monitoring program and the results of the three years of surveys was submitted to MMS in 1988 (Frost et al. 1988). One of the recommendations in that report was that another three-year series of ringed seal surveys should be conducted in 1991-1993.

Relatively little industrial activity occurred in the Beaufort and Chukchi seas during 1988-1995, although some exploration was conducted mostly during the open water season. No surveys designed to monitor ringed seals were flown during that period. That situation changed in 1995 with the announcement that development would begin on the Northstar prospect, in offshore waters of the Beaufort Sea west of Prudhoe Bay. As a result, early in 1996 MMS and ADF&G negotiated a Cooperative Agreement (Number 14-35-0001-30810) to resume a program of monitoring ringed seals in the Beaufort Sea. Other cooperators in this project are the University of Alaska (UA), the National Marine Fisheries Service, and the North Slope Borough Department of Wildlife Management.

This is an interim report describing activities conducted under Cooperative Agreement Number 14-35-0001-30810 during the period April 1998 through March 1999. The third year of surveys under the cooperative agreement was conducted during this period.

1.2 Ringed Seal Biology

Ringed seals are small phocid seals. Adult animals in Alaska average 115 cm in nose-tail length and 49 kg in weight (Frost and Lowry 1981). They are a widespread, circumpolar species, that in Alaskan waters occur in the Beaufort, Chukchi, and Bering seas, usually in association with sea ice (Burns 1970). Seasonal shifts in distribution occur due to changes in sea ice characteristics, but the dynamics of these and other movements are poorly known.

Although they also occur in pack ice, ringed seals are the only species of seal in Alaska that normally lives in and under the extensive, largely unbroken, shorefast ice (Burns 1970). Shorefast ice begins to form in October-November, and persists until May-July, depending on location. At its maximum extent the shorefast ice extends seaward to about the 20 m isobath, which may be 40 km or more offshore (Stringer et al. 1980). Using strong claws on their foreflippers, ringed seals make breathing holes in the newly formed ice and maintain the holes as the ice thickens (Smith and Stirling 1975; Smith and Hammill 1981). Later in the season some holes are enlarged to provide access to the ice surface on which seals excavate lairs in the accumulated snow. Pregnant females give birth to and nurture their single pup in the lairs during March-May (Smith and Stirling 1975).

As day length and temperature increase in the spring, increasing numbers of ringed seals haul out on the surface of the ice near breathing holes or lairs. This hauling-out or basking is associated with the annual molt, which occurs in May-July (McLaren 1958) when increased skin temperatures are needed to promote epidermal growth (Feltz and Fay 1966). It is during this time that seals are most readily observed and counted.

1.3 Industrial Activity in Ringed Seal Habitat

In addition to being an important habitat for ringed seals, the shorefast ice also provides a reasonably safe and convenient surface on which various human activities may be conducted. Coastal residents have traditionally used the shorefast ice to hunt for seals and polar bears (*Ursus maritimus*), trap for arctic foxes (*Alopex lagopus*), and to travel between villages and camps. More recently the oil and gas industry has used the shorefast ice for conducting certain phases of petroleum exploration. Activities that might affect ringed seals and their habitat include principally seismic profiling and exploratory drilling, which requires deployment of camps and heavy equipment, and construction of ice roads and airstrips.

The Outer Continental Shelf (OCS) Lands Act of 1953 began the process of leasing Federal OCS areas for oil and gas development. The U.S. Department of the Interior, MMS, is charged with administering the program. Industry interest in exploring for oil and gas off Alaska has been high. In the decade following the first Federal lease sale in ringed seal habitat in December 1979, over 1.2 million hectares were leased in the Beaufort Sea, on which 21 exploratory wells were drilled. Leasing began in the Chukchi Sea in 1988, and as of October 1990, 775,000 hectares had been leased and four exploratory wells drilled (Gould et al. 1991). Many thousands of km of seismic profiling have been conducted in preparation for lease sales and exploratory drilling.

During the 1980s, industrial activity in the Beaufort Sea consisted primarily of seismic exploration and the construction of artificial islands. After 1985, a year in which both seismic exploration and island construction took place, industrial activity in the area declined during winter although there were several summer operations in open water.

Recent exploratory drilling in the Beaufort Sea has resulted in prospects near Prudhoe Bay and increased pre-industrial activity in the study area (Valerie Elliott, Minerals Management Service, pers. commun.). Seismic-vibroseis activity occurred in the central Beaufort (our survey sector B3, lines 14-24) during late March to mid-April 1996. Pre-industrial activities during

1996-1997 included seismic-vibroseis activity during January to May off the Colville River delta (survey sector B2 - lines 24-34; sector B3 - lines 1-6.5) and in the western Beaufort (sector B1; sector B2 - lines 1-13). Activity around the Liberty exploration project (near the south end of line 24 in sector B3) included ice island and ice road construction (December-April), drilling of an exploratory/delineation well (February-April), and bore hole geotechnical and seismic surveys (February-March). On-ice seismic data acquisition was planned for March-April 1997 in Mikkelsen Bay (B3, lines 27-30) but specifics are not yet available. The Warthog exploratory well (sector B4, near south end of line 12) was spudded in November 1997. It was then plugged and abandoned in December 1997. Details of activities occurring in the contract year covered by this report are reported in Appendix A.

In addition to leasing tracts of land and regulating activities on those leases, the MMS supports environmental studies needed to provide the information required for planning lease sales and monitoring their impacts on marine resources. Due to the possible impacts of OCS activities on ringed seals, especially the possible conflicts on the shorefast ice, MMS has supported a variety of studies on ringed seals (e.g., Frost et al. 1988; Frost and Burns 1989; Kelly et al. 1986).

1.4 Development of Ringed Seal Survey Methods

Development of a method to estimate the number of ringed seals in an area using aerial surveys requires that we determine when the largest and most stable proportion of the seals is hauled out basking on the surface of the ice so that they can be seen and counted. To do this, and thereby standardize the conditions under which aerial surveys for ringed seals can be considered comparable, we have incorporated the results of previous ringed seal surveys and other studies of ringed seal behavior into our survey methods (Burns and Harbo 1972; Smith 1975; Finley 1979; Burns et al. 1981; Smith and Hammill 1981; Stirling et al. 1982; Frost et al. 1988; and Kelly and Quakenbush 1990). Based on these studies and the recommendations of Frost et al. (1988), we decided upon a survey protocol in which surveys would be flown under the following conditions: in late May or June before the fast ice begins to break up and melt water has not flooded the ice surface; between 1000 and 1600 hrs true local time; winds reported to be 37 km/hr or less; cloud ceilings above 91 m; survey altitude of 91 m; and survey strip width of 0.41 km on each side of the aircraft with a 134 m centerline offset. Brief descriptions of some of the important factors affecting ringed seal surveys follows.

Season and Time of Day

In the Beaufort Sea optimal survey conditions generally occur in late May to early June (Burns et al. 1981). The shorefast ice has not yet begun to fracture and break up significantly and surface water from melt and overflow of rivers is usually not yet extensive (Burns and Harbo 1972; Frost and Hills unpubl. obs.). This is also the time of the year when ringed seals begin to haul out on the surface of the ice in large numbers. Thirteen seals radio-tagged in the Beaufort Sea hauled out significantly more frequently and for longer periods of time as spring progressed (Kelly and Quakenbush 1990). The proportion of time spent out of the water increased from 12.1% in March to 21.9% in May and 42.9% in early June.

Most ringed seal surveys have been conducted between 1000 and 1600 hrs true local time (i.e., from 2 hours before to 4 hours after local mid-day) to coincide with the time of day when maximal numbers of seals haul out (Burns and Harbo 1972; Smith 1975; Finley 1979; Smith and Hammill 1981). Kelly and Quakenbush (1990) monitored haulout bouts of radio-tagged ringed seals when they were inside the lair and when they were basking on the surface of the ice. During May and June, mean hours of haulouts were between 1030 and 1630 hrs.

Weather Conditions

Although more ringed seals generally are seen basking on warm, sunny days with relatively light winds, the magnitude of the effects of wind speed, air temperature and cloud cover on the observed number of basking ringed seals is unclear. During aerial surveys weather reports usually are available from a limited number of coastal stations which may not accurately represent the conditions in the survey area or at the surface of the ice (Frost et al. 1988). Stirling et al. (1982) found a negative association of ringed seal densities with wind speed > 9.3 km/hr and for cloud cover. Finley (1979) found a similar negative coefficient with wind speed but said that ringed seals retreated to the water on sunny windless days. Kelly and Quakenbush (1990) saw few of their radio-tagged ringed seals basking outside of lairs before 7 May when air temperatures rose above -5° C. Frost et al. (1988) did not survey during extreme weather conditions but found significantly lower densities when wind speeds were > 45 km/hr, air temperatures were < -5° C, and wind chills were < -20° C.

Altitudes and Strip Widths

Caughley (1974) found that the three factors that most affected sightability of terrestrial animals during aerial surveys were ground speed, altitude, and strip width. Ground speed has been reasonably constant in previous ringed seal surveys, but altitude has often been either 152 m or 91 m without consideration given to possible differences in counts. Frost et al. (1988) analyzed observed densities of seals on replicate transects flown at those two altitudes and concluded that significantly fewer seals were observed on transects flown at 152 m. However, in that dataset the effects of strip width and survey altitude were confounded because the angles defining strip boundaries were kept constant when altitude changed.

In previous studies, the width of the transect surveyed has varied from 400 m to 914 m on each side of the aircraft. In addition, some investigators have subdivided each transect into inner and outer sectors. When a 400 m wide transect was subdivided with no offset from the center line, more seals were consistently recorded in the outer portion (Stirling et al. 1982; Kingsley et al. 1985). This difference may have been due to seals near the transect centerline diving more quickly as the aircraft approached, the shorter period of time that areas near the aircraft were in view, the difficulty in looking downward as compared to outward, or other factors. Stirling et al. (1982) found that when the inner strip was offset from the centerline, densities in the inner and outer strips were not significantly different. Frost et al. (1988) analyzed data from 914 m wide transects that were subdivided into inner and outer halves. Overall, densities were lower in the outer strips; the difference was 20% for surveys flown at 91 m altitude, and 31% for surveys at 152 m. This was interpreted to mean that fewer seals were missed in the inner strips, and that the actual distance between the observer and the animal, as well as the transect width itself, affected the counts.

Observer Effects

The possibility of observer bias has been tested by comparing the number of seals counted by observers on the left and right sides of the aircraft during simultaneous transects, and by using backup observers on the same side of the aircraft. In a comparison of counts made during 1974-1979, Stirling et al. (1982) found differences in counts ranging from 2.2% to 24.9%, but none of the differences was statistically significant. Burns and Harbo (1972) added additional observers to test the effectiveness of primary observers and concluded that the primary observers were adequate. Frost et al. (1988) found no significant difference between left and right side observers: total counts of the left observer ranged from 7% less to 8% more than those of the right observer. They also tested the effectiveness of inexperienced observers and found that the experienced observers counted significantly more seals.

2. STUDY OBJECTIVES AND RATIONALE

The extensive surveys and analysis conducted by Frost et al. (1988) resulted in a recommended monitoring protocol for ringed seals in Alaska. Increased industry interest and activity on Alaska's North Slope and in the Beaufort Sea, as well as development of analytical methods that may be applicable to aerial surveys for ringed seals, have made additional research on monitoring methods and reanalysis of historical data timely.

Specific objectives of this project identified in the Cooperative Agreement are as follows:

1. Review and refine the established protocol for monitoring ringed seals by aerial surveys.

2. Estimate relative abundance and density of molting ringed seals on fast ice in the Beaufort Sea during 1996-1999 and compare with data collected during 1985-1987.

3. Correlate ringed seal densities on fast ice with environmental variables.

4. Determine abundance and density of molting ringed seals at and near industrial operations, and compare with otherwise comparable non-industrial areas.

5. Review adequacy of ringed seal data collected by past industry site-specific monitoring programs, and make recommendations for protocols to be used in future industry studies.

6. Provide reports of findings that result from ringed seal monitoring to local residents and subsistence users.

This project was designed as a three-year study. In 1998, due to unusual weather and ice conditions, a joint decision was made by ADF&G and MMS to extend the surveys for an additional year. Progress made on study objectives during year three of the study is described in this interim report. A full statistical analysis of all the density estimates for all years will not be undertaken until all of the data (including survey data from 1999) are available.

3. METHODS

3.1 Coordination and Workshops

Project cooperators held a teleconference on 5 May 1998 to discuss details of 1998 surveys. Participating were Kathy Frost (ADF&G), Cleve Cowles and Valerie Elliott (MMS), and John Bengston (NMFS). Frost described the proposed survey procedures and options for the 1998 survey. Per a 30 March 1998 memo from ADF&G to MMS, the decision was made to conduct abbreviated surveys in 1998 due to unusually warm weather and thin fast ice along the Beaufort Sea coast. It was decided that Sectors B1 and B2 would not be surveyed in 1998, and coverage in sectors B3 and B4 would be limited to primary survey lines flown at 2-nm intervals, entailing about 30 hours of flying. To offset reduced coverage in 1998, ADF&G proposed that the cooperative agreement be extended for an additional year, and surveys be flown again in 1999 at no extra cost to MMS. Sectors B1 through B4 will be surveyed in 1999.

Final decisions were made during the teleconference about the survey protocol. For the 1998 surveys, it was agreed that two observer/recorder pairs would take data using the standard strip transect protocol. Based on analysis of line transect data collected during the first two years of this study, it was decided that line transect data would not be collected in 1998. The third "back-up" observer/recorder pair would be used to train people for future surveys and expand the pool of reliable ringed seal survey observers. Responsibilities and involvement of the various personnel are listed in Table 1.

During May 1998, Ms. Casey Hessinger attended an ArcView training class held by Biological Resources Division of the U.S. Geological Survey. She found the class to be very practical and useful, and the instructor was able to assist her with problems specific to her ringed seal data files.

A data analysis coordination meeting was held on 19 August 1998 at the Department of Fish and Game office in Anchorage. Grey Pendleton and Casey Hessinger met to exchange results from the 1996 and 1997 surveys and discuss analysis procedures for using the GIS to plot the results from the predictive regression analysis model.

Grey Pendleton attended the Wildlife Society meetings in Buffalo, NY during 22-26 September 1998 and delivered an oral paper presenting preliminary results from this ringed seal aerial survey project. Meeting participants expressed interest in our analyses that use generalized linear models, which are becoming more widely used. Copies of the slides for his paper were included with the September quarterly report for this project.

Principal investigator Kathryn Frost attended the annual MMS Information Transfer meeting in Anchorage on 20 January 1999. She made two slide presentations, one on the preliminary results of this ringed seal aerial survey project and another on the results a beluga satellite tagging project conducted by ADF&G in cooperation with the North Slope Borough and the Alaska Beluga Whale Committee.

Another data analysis coordination meeting was held at ADF&G in Anchorage on 3-4 February 1999 to discuss analysis of the 1998 survey data. Hessinger, Frost and Pendleton attended. Pendleton and Hessinger continued work on integrating the GIS analysis with the regression analysis model.

3.2 1998 Beaufort Sea Surveys

The survey aircraft was a twin-engine high-wing Aero Commander (N7UP) chartered from Commander Northwest. Two experienced primary observers (Frost and Lowry) counted seals using previously established ADF&G-MMS strip transect protocols (see Frost et al. 1988; Frost et al. 1997 and 1998). An additional observer (Hessinger, Pendleton, or Bengston) seated behind the right primary observer also counted seals using standard protocols. Each observer was paired with a data recorder who entered all sightings directly into a laptop computer. Data recorders also entered information on ice and weather conditions, evidence of on-ice industrial activity, and sightings of other animals. During the survey every recorder/observer pair had direct open-microphone communication, but was isolated from other observer/recorder pairs. A Global Positioning Unit (GPS) interfaced with all three computers such that start and end points for survey lines, positions of seal sightings, and positions of all changes in ice conditions were recorded directly from the GPS.

In the evening following survey flights, all data entries were checked by hand and edited as necessary. Approximate edge of the fast ice was reconciled by left and right side observers to ensure consistent coding of data. Resolution of the ice edge was not straight-forward in 1998 for the western part of sector B3. Position of the ice edge for these lines required the use of satellite photographs of the ice edge to classify ice near the edge as fast or pack.

Aerial surveys were conducted in the central Beaufort Sea during 27-28 May (Table 2). Transect lines were surveyed in sector B4 on 27 May and B3 on 28 May (Figure 1). On 28 May, Cleve Cowles, MMS Project Coordinator, made an on-site visit to the project.

3.3 Raw Density Estimates - Strip Transects

The density of observed ringed seals was calculated separately for each survey line as the number of seals observed divided by the area surveyed. The area surveyed was computed from the latitude and longitude of the first and last survey points on each line. The width of the surveyed strip was 0.41 km on each side of the plane for all transects in 1998. Areas were computed separately for each side of the plane, although these were very close in all cases. Mean density and its standard error were computed for each sector using the Jackknife procedure (Manly 1991). Approximate 95% confidence intervals were computed as the mean density plus or minus the standard error multiplied by the appropriate t-statistic with n-1 degrees of freedom, where n is the number of survey lines in a sector.

Observed density estimates were computed for all combinations of ice types (entire line, fast ice, pack ice) and seals (all seals, seals at holes, seals at cracks). For the fast and pack ice estimates, the portion of the strip covered by the two ice types was computed for each line.

3.4 Covariate analyses

Often the data available in wildlife studies are counts of animals. Usually, these counts are used as indicators of the actual population of animals using a particular habitat, area, or site. The observed count is less than or equal to the true population and can be expressed as follows:

$$C = N * p \qquad (1)$$

where C is the observed count, N is the population of interest, and p is the probability that an animal in N is included in C ($p \leq 1$). The inclusion probability, p, can take on a variety of forms including constants, probability functions (e.g., binomial), and functions of covariates such as date, time of day, weather conditions, etc. Excluding the unlikely event that p is a constant (a constant fraction of the population is counted on all occasions and under all circumstances), analyses involving C as a surrogate for N will be imprecise and often biased (Barker and Sauer 1992, 1995).

In this study, we are interested in the relationship between the abundance of ringed seals and characteristics of their environment in the Beaufort Sea. Because we are basing our investigations on counts, we accommodated the effects of incomplete counts by modeling the inclusion probability as a function of environmental covariates. We have modeled the factors that affect the actual local abundance of seals (e.g., ice deformation) simultaneously with factors that likely affect only the availability of seals for observation (e.g., weather variables).

We used Poisson regression (McCullagh and Nelder 1989) to model the relationship between seal counts and the covariates. Poisson regression is appropriate for these analyses because the Poisson distribution is a positive discrete distribution in which only positive integers are acceptable values. This is more suitable for count data, especially where there are zero counts, than the normal distribution where non-integers and negative values are also permissible. This approach is very similar to that of Manly et al. (1993) except that they use logistic regression to predict the probability that an animal is present rather than predicting the number of animals present. To obtain input for the regression analyses, each survey transect (data from left and right side observers were treated as separate transects) was divided in segments based on ice type (pack or fast), ice deformation, melt water category, distance from shore (in 2-km zones starting at the inshore end of the each transect, or approximately the 3-m contour), and distance from the fast ice edge (in 2-km zones). When any of these variables changed, a new segment was defined such that each segment was uniform with respect to the explanatory variables. The number of seals observed and the area surveyed (segment length in km multiplied by strip width = 0.41 km) were determined for each segment.

The response variable in the regression was the number of seals in a segment. The explanatory variables were ice type (pack or fast), ice deformation, percent of surface covered by melt water, distance from shore, distance from the fast ice edge (separate parameters for distance into the fast ice and distance into the pack ice), longitude, time of day, Julian date, year, wind chill, and percent cloud cover. Distance from shore, distance from the fast ice edge, and longitude were included to account for large-scale patterns of seal abundance that were independent of local ice or weather conditions. Time, date, and year were included to examine daily, seasonal, and yearly changes abundance or visibility. As in index of wind chill, we used the following formula (Siple and Passel 1945) of heat loss adjusted to give results in currently used units

$$H = (12.1452 + 11.6222*\mathrm{sqrt}(v) - 1.16222*v) * (33 - t) \qquad (2),$$

where H is the heat loss in W/m^2, v is the wind velocity in m/s, and t is the temperature in °C.

The ln(area) of each segment was included in the regressions as an offset variable (Agresti 1990) to account for the fact that, all other variables being equal, larger segments have more seals than smaller segment (adjusts analyses to a density basis). Quadratic terms and interactions were included for some variables or combinations of variables when we believed that relationships were not linear (on the log scale). Based on preliminary analyses, the models did not explain all of the variation in the response variable (i.e., the models did not 'fit' the data) probably because of the presence of larger groups of seals. To accommodate this lack of fit in the regression analyses, segments <0.01 km^2 were eliminated because of their extreme influence on results. We also adjusted tests and standard errors using the Pearson chi-square statistic as an overdispersion parameter (i.e., quasi-likelihood approach, Agresti 1990). The importance of each variable in the regression was evaluated using Wald chi-square statistics.

3.6 GIS Project - Seal Distribution and Ice Characteristics

Both on-ice studies and many previous aerial survey analyses have described various habitat factors that are related to ringed seal distribution and abundance (Burns 1970; Burns et al. 1981; Finley 1979; Frost et al. 1988; Kelly et al. 1986; Kingsley et al. 1985; McLaren 1958; Smith and Stirling 1975; Smith and Hammill 1981; Stirling et al. 1982). However, habitat factors have not previously been used to stratify survey areas, post-stratify survey data, match control and treatment areas, or determine spatial patterns based on habitat features. Use of Geographic Information System (GIS) technology has made it possible to use survey data to combine spatial and attribute information about the features or resources present. For this project, we have used this technology to build spatial data layers of habitat variables and compare observed densities of ringed seals to these factors. The GIS analysis of ringed seal survey data has been conducted primarily by Ms. Casey Hessinger as part of her Master of Science thesis project.

Ringed seal distribution and habitat maps were generated for shorefast ice in the study area. GIS analyses did not include the pack ice. Habitat maps include observed seal density in relation to ice deformation, distance from shore and distance from fast/pack ice edge shoreward. In the future, maps will be added for seal distribution relative to depth using 5-m increment bathymetry, and effects of industrial activity on density of seals, contingent on the acquisition of detailed industrial activity information.

Seal sightings and data on habitat variables were entered into the vector-based GIS software "InfoCAD" to analyze ringed seal distribution in relation to ice characteristics and other factors. Attribute data from surveys was used to create spatial data layers for comparison with ringed seal distribution and abundance. Areas of high observed seal density, and the habitat variables associated with these areas, were determined. For these analyses, the database files were shifted 350 meters to center the records in the middle of the survey strips. All habitat maps were exported into ArcView for presentation mapping.

A spatial data layer for ice deformation was built manually for 1996 surveys. This process was automated for the 1997 and 1998 data. The survey strips were built along each transect and then divided into polygons based on the ice deformation category. Deformation categories were: 0-10%, 10%-20%, 20%-30%, and >30%. Estimates of seal density were then calculated for each ice deformation category.

Spatial data layers for distance from shore and distance from the fast ice edge were created for sectors 1996-1998 survey data. Distance from the shore begins at the start of the survey lines or approximately the 3-m depth contour and uses 2-km increments. Distance from the fast/pack edge is also by 2-km increments. An estimate of seal density was calculated for each 2-km increment.

3.7 Ringed Seal Bibliography

Various literature searches have been conducted by Casey Hessinger to compile references pertaining to the distribution, abundance, and natural history of ringed seals. When a reference is located, it is annotated and entered into "Papyrus", a computer software developed for managing bibliographic data.

Computerized databases as well as files at ADF&G, UA, and ARLISS (Alaska Resources Library Information Services) have been searched. The bibliography includes both published and gray literature. Computerized databases that have been searched include: Aquatic Biology, Aquaculture and Fisheries; Wildlife Worldwide; SLED (Statewide Library Electronic Doorway); Online Bibliographic Database Natural History Book Service Web Site; Academic Abstracts;

PolarPac; and Arctic and Antarctic Regions. The meta-database Arctic and Antarctic Regions is composed of a multidisciplinary collection of major databases on polar and cold regions with coverage spanning from 1800 to present (December 1998). The following databases are included: The Arctic Instate of North America, Cold Regions Bibliography; U.S. Army Corps of Engineers Cold Regions Research and Engineering Laboratory; U.S. National Science Foundation, Center for Cold Ocean Resources Engineering, World Data Center for Glaciology; Scott Polar Research Institute; Canadian Circumpolar Library; and Department of Indian and Northern Affairs.

4. RESULTS AND DISCUSSION

4.1 1998 Aerial Surveys

Ringed seal surveys were conducted in the central Beaufort Sea on 27-28 May. Transect lines were surveyed in sector B3 on 27 May and B3 and B4 on 28 May (Table 2, Figure 1). In total, we surveyed 39 lines covering an area of about 1,196 km^2 (Table 3). The onboard computer data acquisition worked well in 1998. Problems encountered in 1997 with the GIS-computer interface were remedied in 1998 by ADF&G programmer Rob DeLong.

Weather was good, with relatively warm (above freezing) sunny conditions or high overcast on both flights. However, the fast ice was covered with extensive melt water. Near shore as much as 80%-90% of the ice surface was covered by water, resulting in very poor survey conditions. Farther off shore, much of the ice was completely bare of snow. Because of the advanced stage of melt on the fast ice, we flew only abbreviated surveys of the study area. Instead of surveying 100% of all surveys lines spaced at 2-nm intervals, we flew just over 50% of these lines. The unused aircraft hours will be saved for next year's survey effort.

Ringed seals were seen throughout the study area (Figure 2). Most of the ice we surveyed (66%), and consequently most of the seals we counted, were on fast ice.

4.2 Strip Transect Analysis

During the 1998 surveys, we sighted 1,111 seals in 579 groups (Table 4). Sixty-five percent of the seals we counted were on fast ice and 35% on pack. Overall, 62% of the seals we observed were at holes. The average unadjusted density estimate for ringed seals during 1998 was 0.93 seals/km^2 (Table 5).

Our estimate of observed density was higher in Sector B4 than it was in B3 (Table 5). The total observed density (seals at holes and at cracks) for fast and pack ice combined in sector B3 was approximately 30% lower than the total density in sector B4 (0.81 seals/km^2 compared to 1.19 seals/km^2). This difference was true for both seals at holes and at cracks, and for seals on pack as well as fast ice. For both sectors, the observed density of seals at holes was greater than the density of seals at cracks on both fast and pack ice.

The average group size for sectors B3-B4 combined was 1.9 seals (Table 4). Group size for seals at cracks was approximately double the group size for seals at holes (3.4 seals/group at cracks vs. 1.5 seals/group at holes). Group size, like estimated density, was greater in sector B4 than in sector B3. In sector B3, average group size was 1.4 for seals at holes and 2.9 for seals at cracks. In sector B4, group size was 1.6 for seals at holes and 4.5 for seals at cracks.

Sectors B3 and B4 have now been surveyed in 1996-1998 as part of this study (Table 6). In both sectors, observed densities of ringed seals on fast ice, and for all ice combined, were lowest in 1996. In sector B3, the density estimates for 1997 and 1998 were similar. In sector B4, the observed densities were higher in 1997 than in 1998, due mostly to more seals in pack ice in 1997.

Comparisons of our data with surveys in 1985-1987 indicate that the densities observed during 1996-1998 were generally within the range of densities observed ten years ago. On fast ice, the observed densities in 1996-1998 tended to be lower than densities in the 1980s, especially than in 1986 and 1987 (Table 7). On pack ice, our estimate of total density was substantially higher in sector B4 in 1996-1998 than in the 1980's (Table 8). Statistical comparisons of surveys conducted in the 1980's and the 1990's will be included with the final report for this project.

Some of the annual variability in observed seal densities is likely due to differences in ice conditions at the time surveys were flown. Even though surveys occurred on approximately the same calendar dates in all years, they represented different stages of breakup. In 1997, survey dates coincided with the time when maximal numbers of seals hauled out but when the ice had not yet begun to breakup and crack. In 1996, breakup began somewhat earlier than in 1997, and seals had already begun to redistribute and aggregate around newly formed cracks by the time our surveys began. In 1998, lack of snow and unusually warm conditions also resulted in an apparently earlier onset of breakup. It is difficult to predict when breakup will begin and how long the survey window might be in a particular year.

One of the objectives of this project in the final year will be to investigate ways to make survey data more comparable from year to year. This may include analysis of a particular subsample of the ice (for example only fast ice within some distance from land), or might involve adjusting data to some standard set of conditions based on the effects of covariates such as weather, ice characteristics, and/or date.

4.3 Sightability Covariate Analysis

Covariate analyses were conducted for all seals and all ice types combined using data from sectors B3 and B4 in 1996-1998. These were the only two sectors that were surveyed in all three years. We initially used a model with the categorical variable ice type (shorefast or pack) and the continuous variables year (i.e., "trend"), percent ice deformation, percent melt water, time, date, distance from shore, distance from the fast ice edge, and longitude, wind chill, and cloud cover. Quadratic terms were also tested for all variables. Interactions between year and ice type, longitude and year, and date and year were also used. The ice type term is the regression intercept for each ice type and the ice type * year interaction is the "trend" coefficient for each ice type. Unimportant variables were deleted sequentially. In our analysis of the 1996-1998 surveys, 13 of 29 explanatory variables were significant at $p \leq 0.001$ (Table 9). These included regular or quadratic terms for ice type, ice deformation, meltwater, time of day, distance from shore, longitude (1997 only), date, and cloud cover.

The covariate analysis indicated that seal counts declined as ice deformation increased (Figure 3a; graph shows the response of observed density to ice deformation with all other variables at their mean levels). Intermediate levels of melt water added the most to predicted density with less added for high melt water (Figure 3b). Note that melt water occurs only at the lowest levels of ice deformation, so the influence of melt water on observed density is not as extensive as it might seem. Predicted density was greatest when our surveys began at 10 am "sun time" and declined throughout the day (Figure 3c). Observed seal density was fairly constant within about 30 km of shore, and increased beyond that (Figure 3d) to the edge of the fast ice, where it once again decreased with distance into the pack ice. (Figure 3e). These two variables, to some extent, change together so their combined effect could be complex. The model predicted that seal abundance increased with date (Figure 3f) and generally increased from west to east within the survey area (Figure 3g). Predicted density was highest with moderate cloud cover (Figure 3h).

Examination of year and ice type effects indicated that, after accounting for differences in other variables, the estimate of density on fast ice was 22% (95% C.I. of -47% to -18%) higher in 1998 than in 1996 (Figure 4). There was no significant trend in the modeled density of seals on pack ice. The wide confidence intervals indicate that these yearly changes are imprecisely estimated. They also should be interpreted with caution because factors not accounted for by the model (e.g., seasonal progression of ice break-up) can affect the availability of seals within the survey area. This could be especially pronounced with only three years of data.

The use of covariates in the analysis of ringed seal densities is complicated, and should become more robust with the inclusion of additional years of data spanning a broader array of survey conditions. Several factors that were not significant with only two years of data (e.g. cloud cover and date) became significant with the addition of a third year.

It was our hope at the beginning of this project that we might be able to develop parameter estimates for the different covariates and use them to "correct" the data to standard conditions, thus making our estimated index of density more accurate. After our initial analysis of 1996-1998 data, this does not appear to be a simple task. For harbor seal surveys where we used covariates to correct count estimates (Frost et al. 1999), the counts were made at the same sites every year. Seal habitat did not change, only the conditions under which the seals were counted. In contrast, ringed seal habitat (the sea ice) in the same geographic location is not necessarily the same from year to year, nor is it uniform along a survey line or within a sector. Surveys may be flown over the same exact lines in different years, but the ice (and therefore suitability as ringed seal habitat) may be quite different. Furthermore, this underlying difference in habitat is then confounded by differences in weather. As discussed earlier in this report, there may be differences in the actual number (N) of animals living in an area (which are likely affected by ice conditions) and/or in the proportion (P) of the animals we count on a particular day (which are likely affected by weather).

Based on our preliminary analyses, we think that the best approach will be to conduct surveys only under the best survey conditions, thus eliminating weather (to the greatest extent possible) as a significant factor affecting observed densities. Once weather has been minimized as a factor, we can then use covariate analysis to examine how habitat factors affect the actual number (N) of animals living in an area.

4.4 Seal Distribution and GIS Habitat Analysis

GIS analysis of changes in ringed seal density with distance from shore indicated that estimates of seal density were lowest near shore and increased as distance from shore increased in 1996 and 1997 (Table 10; Figure 5a). In both years, observed densities on fast ice more than 10 km from shore were more than 50% higher than densities within 10 km from shore. For the 1998 GIS analysis, there was no clear trend with distance from shore, perhaps due to some large groups of seals found close to shore in an area where the ice edge approached the coastline. This was in contrast to the covariate analysis, which combined all three survey years and considered additional variables, and demonstrated a clear relationship between observed density and distance form shore.

When we used the GIS to examine density with distance from the fast ice edge, we found considerable annual variability (Table 11, Figure 5b). In 1996 and 1998, estimated density was highest near the edge and decreased steadily south of the edge. In contrast, observed densities in 1997 increased from near the edge to about 16 km south of the edge, then decreased towards shore. The distance at which densities began to decline relative to distance from the edge is about where the 1996 and 1998 ice edges were located. This suggests that some factor other than the ice edge per se, for example water depth, may be the underlying cause for the observed patterns in density.

GIS analysis of changes in ringed seal density with ice deformation in 1996-1998 indicate that observed seal densities were lowest in >30% deformed ice and highest in 0%-10% ice deformation categories (Figure 6). This is consistent with the covariate analysis which indicated that observed densities decreased as ice deformation increased.

The GIS analyses presented in this annual report are preliminary. However, it is clear from the preliminary analyses that not all habitat variables are equally suited to GIS analysis. For example, ice deformation changes tend to occur in a highly variable patchwork of deformation categories. GIS maps of ice deformation are visually complex and difficult to interpret. Ultimately the most readily understood presentation is one that shows density by deformation categories in tabular or graphic form. Such tables are more efficiently produced directly from a database using conventional methods. In contrast, bathymetric data - which are not already part of the data set - are highly suitable to GIS analysis. Depths appear as smooth contours, and visual patterns are more readily discerned. In the final stages of this project, decisions and recommendations will be made about which analytical techniques (or combination of techniques) are best suited to particular variables.

4.5 Ringed Seal Bibliography

Over 230 references have been annotated and entered in the bibliographic computer database for ringed seals. Both hard copy and a computer database version of the annotated bibliography will be submitted with the final report. Interim versions on diskette or as hard copy are available at any time upon request. This bibliography is being compiled by Casey Hessinger using the computer software "Papyrus." The literature search is current through December 1998.

5. CONCLUSIONS AND RECOMMENDATIONS

1) Estimates of density calculated by standard strip transect methods for ringed seals on fast ice were higher in 1997 and 1998 than in 1996. For the three-year period, they were generally lower than estimates of density made in the 1980s. On pack ice in 1996-1998, observed densities were lower than in the 1980's in sector B3 and higher in sector B4. The estimated average overall observed density for sectors B2-B3 in 1998 was 0.93 seals/km^2.

2) Covariate analysis indicated that survey conditions were sufficiently standardized in 1996-1998 so that wind chill had no significant effect on seal counts. In contrast, habitat variables including ice deformation, melt water, distance from shore and from the fast ice edge, and longitude did significantly affect seal counts. Counts decreased as ice deformation increased. They increased with distance from shore, and decreased with distance away from the fast ice edge. After accounting for differences in other variables, covariate analysis indicated that estimated density on fast ice was higher in 1998 than in 1996. This is consistent with results of standard strip transect analysis.

It is apparent from these and previous surveys that the observed distribution and abundance of ringed seals in the study area may change during the selected survey period. It is unclear whether such changes represent immigration from the pack ice or areas to the west and south as breakup begins, a change in hauling out behavior, or a combination of these factors. In the future, refinement of survey methods and interpretation of data could be greatly facilitated by a telemetric study which began to identify and quantify the factors responsible for these observed changes. Quantification of movements in terms of the proportion of seals moving and distances moved could significantly improve our ability to relate the observed distribution of ringed seals during June surveys to industrial activities the previous winter. Development of a correction factor using data collected by such a study could also help in the interpretation of aerial survey data, particularly when making interannual comparisons. It would be particularly valuable if telemetric studies and aerial surveys were conducted simultaneously in one or more years.

6. LITERATURE CITED

Agresti, A. 1990. Categorical data analysis. Wiley-Interscience, New York, NY.

Barker, R. J., and J. R. Sauer. 1992. Modeling population change from time series data. Pages 182-194 *in*, D. R. McCullough and R. H. Barrett, eds. Wildlife 2001: Populations. Elsevier, London, UK.

Barker, R. J., and J. R. Sauer. 1995. Statistical aspects of point count sampling. Pages 125-130 in, C. J. Ralph, J. R. Sauer, and S. Droege, eds. Monitoring Bird Populations by Point Counts. USDA Forest Service, General Technical Report PSW-GTR-149.

Burns, J. J. 1970. Remarks on the distribution and natural history of pagophilic pinnipeds in the Bering and Chukchi seas. J. Mammal. 51:445-54.

Burns, J. J. and S. J. Harbo, Jr. 1972. An aerial census of ringed seals, northern coast of Alaska. Arctic 25:279-90.

Burns, J. J., L. F. Lowry, and K. J. Frost. 1981. Trophic relationships, habitat use, and winter ecology of ice-inhabiting phocid seals and functionally related marine mammals in the Arctic. Annual Rep. U.S. Dep. Commer., NOAA, Outer Continental Shelf Environmental Assessment Program, Juneau, AK.

Caughley, G. 1974. Bias in aerial survey. J. Wildl. Manage. 38:921-933.

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

Feltz, E. T. and F. H. Fay. 1966. Thermal requirements in vitro of epidermal cells from seals. Cryobiol. 3:261-264.

Frost, K. J. and J. J. Burns. 1989. Winter ecology of ringed seals (*Phoca hispida*) in Alaska. Final Rep. U.S. Dep. Commer., NOAA, Outer Continental Shelf Environmental Assessment Program, Anchorage, AK.

Frost, K. J. and L. F. Lowry. 1981. Ringed, Baikal, and Caspian seals. In Handbook of Marine Mammals, ed. by S. H. Ridgway and R. J. Harrison, 29-53. London, Academic Press.

Frost, K. J., L. F. Lowry, J. R. Gilbert, and J. J. Burns. 1988. Ringed seal monitoring: Relationships of distribution and abundance to habitat attributes and industrial activities. U.S. Dep. Commer. NOAA, OCSEAP Final Rep. 61 (1989):345-445.

Frost, K. J., L. F. Lowry, S. Hills, G. Pendleton, and D. DeMaster. 1997. Monitoring distribution and abundance of ringed seals in northern Alaska. Interim Rept. May 1996-

March 1997, U.S. Dept. Interior Minerals Management Service, Cooperative Agreement 14-35-0001-30810, 42 p.

Frost, K. J., L. F. Lowry, S. Hills, G. Pendleton, and D. DeMaster. 1998. Monitoring distribution and abundance of ringed seals in northern Alaska. Interim Rept. April 1997-March 1998, U.S. Dept. Interior Minerals Management Service, Cooperative Agreement 14-35-0001-30810, 48 p.

Frost, K. J., L. F. Lowry, and J. M. Ver Hoef. 1999. Monitoring the trend of harbor seals in Prince William Sound, Alaska, after the Exxon Valdez oil spill. Marine Mammal Science 15(2):000-000. In press.

Gould, G. J., R. M. Karpas, and D. L. Slitor. 1991. OCS National Compendium. U.S. Dep. Interior, OCS Information Rep. MMS 91-0032.

Kelly, B. P. and L. T. Quakenbush. 1990. Spatiotemporal use of lairs by ringed seals (*Phoca hispida*). Canadian Journal of Zoology. 68:2503-2512.

Kelly, B. P., L. T. Quakenbush, and J. R. Rose. 1986. Ringed seal winter ecology and effects of noise disturbance. U.S. Dep. Commer., NOAA, OCSEAP Final Rep. 61(1989):447-536.

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

Manly, B. J. F. 1991. Randomization and Monte Carlo methods in biology. Chapman and Hall, New York, NY. 281pp.

Manly, B. J. F., L. L. McDonald, and D. L. Thomas. 1993. Resource selection by animals: statistical design and analysis for field studies. Chapman and Hall, London, UK.

McCullagh, P. and J. A. Nelder. 1989. Generalized linear models. Second edition. Chapman and Hall, London, England. 511 pp.

McLaren, I. A. 1958. The biology of the ringed seal, *Phoca hispida*, in the eastern Canadian Arctic. Bull. Fish. Res. Board Can. No. 118.

Siple, P. A, and C. F. Passel. 1945. Measurements of dry atmospheric cooling in subfreezing temperatures. Proc. Amer. Phil. Soc. 89:177-199.

Smith, T. G. 1975. Ringed seals in James Bay and Hudson Bay: Population estimates and catch statistics. Arctic 28:170-182.

Smith, T. G. and I. Stirling. 1975. The breeding habitat of the ringed seal (*Phoca hispida*). The birth lair and associated structures. Can. J. Zool. 53:1297-305.

Smith, T. G. and M. O. Hammill. 1981. Ecology of the ringed seal, *Phoca hispida*, in its fast ice breeding habitat. Can. J. Zool. 59:966-81.

Stirling, I., M. Kingsley and W. Calvert. 1982. The distribution and abundance of seals in the eastern Beaufort Sea, 1974-79. Occasional Paper No. 47, Canadian Wildlife Service, Edmonton, Alberta.

Stringer, W., S. Barrett, and L. Schreurs. 1980. Nearshore ice conditions and hazards in the Beaufort, Chukchi, and Bering seas. Rep. UAGR #274. University of Alaska Fairbanks.

Table 1. Principal personnel participating in the ringed seal monitoring project from April 1998 through March 1999.

Name	Affiliation	Activities
Kathryn Frost	ADF&G	Project coordination, data analysis, report writing, survey observer, logistics, data quality control
Lloyd Lowry	ADF&G	Survey design, survey observer, GIS and data analysis
Grey Pendleton	ADF&G	Data analysis, survey observer
Susan Hills	UA	Survey recorder, report writing, data quality control
Casey Hessinger	UA	Ringed seal bibliography, survey recorder/observer, ringed seal GIS habitat analysis
Doug DeMaster	NMFS	Survey design, coordination with NMFS
John Bengston	NMFS	Survey recorder, training as observer
Cleve Cowles	MMS	MMS project coordinator, single-variate statistical analysis, site visit
Valerie Elliott	MMS	Project tracker, industrial information
Warren Horowitz	MMS	GIS data layers (bathymetry)

Table 2. Transects flown during aerial surveys of ringed seals in the Beaufort Sea, 27-28 May 1998.

Date	Activity	Hours	# Lines	Sector	Lines flown
26 May	Transit	3.4			
27 May	Survey	6.1	21	B3	1, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34, 36, 38
				B4	2
28 May	Survey	6.3	20	B4	4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24
				B3	4, 6, 7, 9, 11, 21, 23, 25, 27
29 May	Transit	4.1			
Totals		19.9	41		

Table 3. Area surveyed in each sector for each ice type during May/June 1996 – 1998 aerial surveys of ringed seals in the Alaskan Beaufort Sea.

Sector	Fast Ice		Pack Ice	
	number of lines	area (km^2)	number of lines	area (km^2)
1996				
B2	3	67.2	3	25.1
B3	43	653.2	43	656.6
B4	18	131.0	18	426.9
1997				
B1[a]	20	513.2	11	123.3
B1[b]	10	292.6	2	12.1
B2	21	639.1	--	--
B3	57	1487.4	49	260.7
B4	31	580.2	31	367.5
1998				
B3	27	551.8	27	276.2
B4	12	236.6	12	131.3

[a] Data from 31 May 1997 only.
[b] Data from 2 June 1997.

Table 4. Number of groups and average group size, by sector, for ringed seals counted during aerial surveys of the Alaskan Beaufort Sea, 27-28 May 1998.

	All Ice			Fast Ice			Pack Ice		
	Hole	Crack	All	Hole	Crack	All	Hole	Crack	All
Sector B3									
Number of seals	420	254	674	273	192	465	147	62	209
Number of groups	291	88	379	182	75	257	109	13	122
Average group size	1.44	2.89	1.78	1.50	2.56	1.81	1.35	4.77	1.71
Sector B4									
Number of seals	269	168	437	149	109	258	120	59	179
Number of groups	163	37	200	93	33	126	70	4	74
Average group size	1.65	4.54	2.19	1.60	3.30	2.05	1.71	14.75	2.42
All sectors									
Number of seals	689	422	1111	422	301	723	267	121	388
Number of groups	454	125	579	275	108	383	179	17	196
Average group size	1.52	3.38	1.92	1.53	2.79	1.89	1.49	7.12	1.98

Table 5. Unadjusted density estimates of ringed seals, by sector, for fast ice, pack ice, and all ice combined during May 1998 aerial surveys.

	Fast Ice			Pack Ice			All		
	Hole	Crack	All	Hole	Crack	All	Hole	Crack	All
Sector B3									
Density/km^2	0.484	0.347	0.831	0.495	0.327	0.822	0.506	0.308	0.814
SE	0.012	0.013	0.016	0.012	0.053	0.057	0.008	0.016	0.017
LCL	0.463	0.323	0.801	0.472	0.229	0.717	0.490	0.279	0.783
UCL	0.505	0.372	0.861	0.517	0.425	0.926	0.522	0.337	0.845
Sector B4									
Density/km^2	0.687	0.476	1.163	0.858	0.713	1.571	0.730	0.456	1.186
SE	0.046	0.041	0.055	0.071	0.174	0.169	0.037	0.041	0.059
LCL	0.597	0.395	1.054	0.719	0.370	1.238	0.656	0.376	1.069
UCL	0.777	0.557	1.271	0.997	1.057	1.904	0.803	0.537	1.303
All Sectors									
Density/km^2	0.546	0.387	0.933	0.607	0.446	1.052	0.575	0.354	0.929
SE	0.010	0.010	0.013	0.014	0.040	0.043	0.008	0.011	0.014
LCL	0.528	0.368	0.909	0.582	0.371	0.974	0.560	0.334	0.903
UCL	0.565	0.405	0.957	0.632	0.520	1.130	0.589	0.374	0.954

Table 6. Observed densities of ringed seals for fast ice, pack ice, and all ice combined for 1996 - 1998 aerial surveys. The number of lines (n) and number of km^2 flown per sector are given in parentheses.

	Fast Ice			Pack Ice			All		
	Hole	Crack	All	Hole	Crack	All	Hole	Crack	All
Sector B3									
1996	(n=43; 653 km^2)			(n=43; 657 km^2)			(n=43; 1,310 km^2)		
Density/km^2	0.52	0.06	0.57	0.74	0.18	0.92	0.57	0.13	0.70
SE	0.01	0.01	0.01	0.03	0.01	0.03	0.01	0.00	0.01
LCL	0.50	0.05	0.56	0.69	0.17	0.87	0.55	0.12	0.67
UCL	0.54	0.07	0.59	0.79	0.20	0.98	0.59	0.14	0.72
1997	(n=57; 1,487 km^2)			(n=49; 261 km^2)			(n=57; 1,748 km^2)		
Density/km^2	0.73	0.01	0.74	0.508	0.30	0.81	0.73	0.07	0.80
SE	0.01	0.00	0.01	0.018	0.01	0.02	0.01	0.00	0.01
LCL	0.72	0.01	0.73	0.474	0.28	0.77	0.71	0.07	0.78
UCL	0.75	0.01	0.76	0.541	0.32	0.85	0.74	0.08	0.82
1998	(n=27; 552 km^2)			(n=27; 237 km^2)			(n=27; 789 km^2)		
Density/km^2	0.48	0.35	0.83	0.50	0.33	0.82	0.51	0.31	0.81
SE	0.01	0.01	0.02	0.01	0.05	0.06	0.01	0.02	0.02
LCL	0.46	0.32	0.80	0.47	0.23	0.72	0.49	0.28	0.78
UCL	0.51	0.37	0.86	0.52	0.43	0.93	0.52	0.34	0.85
Sector B4									
1996	(n=18; 131 km^2)			(n=18; 427 km^2)			(n=18; 558 km^2)		
Density/km^2	0.59	0.08	0.67	0.53	0.64	1.17	0.55	0.52	1.07
SE	0.02	0.01	0.02	0.03	0.04	0.06	0.03	0.03	0.05
LCL	0.54	0.06	0.62	0.46	0.57	1.05	0.50	0.46	0.98
UCL	0.63	0.10	0.71	0.60	0.72	1.29	0.60	0.58	1.16
1997	(n=31; 580 km^2)			(n=31; 367 km^2)			(n=31; 947 km^2)		
Density/km^2	1.15	0.03	1.17	0.69	1.68	2.37	0.92	0.47	1.39
SE	0.02	0.00	0.02	0.04	0.09	0.11	0.02	0.02	0.03
LCL	1.11	0.02	1.13	0.62	1.52	2.15	0.88	0.44	1.33
UCL	1.19	0.03	1.21	0.75	1.85	2.58	0.95	0.51	1.45
1998	(n=12; 237 km^2)			(n=12; 131 km^2)			(n=12; 368 km^2)		
Density/km^2	0.69	0.48	1.16	0.86	0.71	1.57	0.73	0.46	1.19
SE	0.05	0.04	0.06	0.07	0.17	0.17	0.04	0.04	0.06
LCL	0.60	0.40	1.05	0.72	0.37	1.24	0.66	0.38	1.07
UCL	0.78	0.56	1.27	1.00	1.06	1.90	0.80	0.54	1.30

Table 7. Observed densities of ringed seals at holes and cracks on fast ice, based on aerial surveys in 1985-1987 and 1996-1998.

	Seals at holes						Seals at cracks						All seals					
	1985	1986	1987	1996	1997	1998	1985	1986	1987	1996	1997	1998	1985	1986	1987	1996	1997	1998
Sector B1																		
Density/km^2	0.58	0.54	0.82	-	0.40	-	0.05	0.00	0.03	-	0.00	-	0.62	0.54	0.86	-	0.40	-
SE	0.01	0.01	0.01	-	0.01	-	0.01	0.00	<0.01	-	0.00	-	0.02	0.01	0.02	-	0.01	-
L95%CL	0.55	0.51	0.80	-	0.37	-	0.04	0.00	0.02	-	0.00	-	0.59	0.51	0.83	-	0.37	-
U95%CL	0.60	0.57	0.85	-	0.42	-	0.06	0.00	0.04	-	0.00	-	0.66	0.57	0.88	-	0.42	-
Sector B2																		
Density/km^2	0.65	1.09	1.06	-	0.61	-	0.19	0.01	0.05	-	0.00	-	0.85	1.09	1.11	-	0.61	-
SE	0.03	0.01	0.05	-	0.02	-	0.02	0.00	0.02	-	0.00	-	0.03	0.02	0.06	-	0.02	-
L95%CL	0.60	1.06	0.97	-	0.58	-	0.16	0.01	0.02	-	0.00	-	0.78	1.07	0.98	-	0.58	-
U95%CL	0.70	1.11	1.15	-	0.63	-	0.23	0.01	0.09	-	0.00	-	0.91	1.12	1.17	-	0.63	-
Sector B3																		
Density/km^2	0.47	1.16	1.05	0.52	0.73	0.48	0.54	0.08	1.89	0.06	0.01	0.35	1.01	1.24	2.94	0.57	0.74	0.83
SE	0.01	0.02	0.02	0.01	0.01	0.01	0.02	0.01	0.13	0.01	<0.01	0.01	0.02	0.03	0.13	0.01	0.01	0.02
L95%CL	0.46	1.13	1.01	0.50	0.72	0.46	0.50	0.05	1.66	0.05	0.01	0.32	0.97	1.20	2.70	0.56	0.73	0.80
U95%CL	0.48	1.21	1.10	0.54	0.75	0.51	0.57	0.10	2.12	0.07	0.01	0.37	1.05	1.29	3.18	0.59	0.76	0.86
Sector B4																		
Density/km^2	0.49	1.28	1.07	0.59	1.15	0.69	0.10	1.43	2.92	0.08	0.03	0.48	0.59	2.71	3.99	0.66	1.17	1.16
SE	0.01	0.06	0.04	0.02	0.02	0.05	0.01	0.17	0.51	0.01	<0.01	0.04	0.01	0.14	0.52	0.02	0.02	0.06
L95%CL	0.47	1.17	0.99	0.54	1.11	0.60	0.08	1.12	1.96	0.06	0.02	0.40	0.57	2.46	3.01	0.62	1.13	1.05
U95%CL	0.51	1.39	1.14	0.63	1.19	0.78	0.12	1.74	3.88	0.10	0.03	0.56	0.62	2.97	4.97	0.72	1.21	1.27

Table 8. Observed densities of ringed seals at holes and cracks in pack ice based on aerial surveys in 1985-1987 and 1996-1998.

	Seals at holes						Seals at cracks						All seals					
	1985	1986	1987	1996	1997	1998	1985	1986	1987	1996	1997	1998	1985	1986	1987	1996	1997	1998
Sector B1																		
Density/km^2	1.01	0.05	0.39	-	0.11	-	0.12	<0.01	0.07	-	0.01	-	1.13	0.05	0.46	-	0.12	-
SE	0.92	<0.01	0.04	-	0.02	-	0.18	<0.01	0.03	-	<0.01	-	1.10	0.01	0.05	-	0.02	-
L95%CL	0.00	0.04	0.32	-	0.08	-	0.00	<0.01	0.03	-	0.01	-	0.00	0.04	0.38	-	0.09	-
U95%CL	2.58	0.06	0.45	-	0.14	-	0.43	<0.01	0.12	-	0.02	-	3.01	0.06	0.54	-	0.15	-
Sector B2																		
Density/km^2	-	0.08	0.55	-	-	-	-	0.07	0.29	-	-	-		-	0.15	0.84	-	-
SE	-	0.02	0.67	-	-	-	-	0.03	0.41	-	-	-	-	0.03	1.07	-	-	-
L95%CL	-	0.04	0.00	-	-	-	-	0.01	0.00	-	-	-	-	0.09	0.00	-	-	-
U95%CL	-	0.11	1.68	-	-	-	-	0.13	0.97	-	-	-	-	0.21	2.66	-	-	-
Sector B3																		
Density/km^2	0.16	0.10	0.45	0.74	0.51	0.50	0.27	1.10	0.77	0.18	0.30	0.33	0.43	1.20	1.23	0.92	0.81	0.82
SE	0.01	0.03	0.02	0.03	0.02	0.01	0.02	0.27	0.04	0.01	0.01	0.05	0.03	0.27	0.05	0.03	0.02	0.06
L95%CL	0.13	0.05	0.42	0.69	0.47	0.47	0.24	0.63	0.71	0.17	0.28	0.23	0.39	0.72	1.13	0.87	0.77	0.72
U95%CL	0.18	0.15	0.49	0.79	0.54	0.52	0.31	1.58	0.84	0.20	0.32	0.43	0.48	1.69	1.32	0.982	0.85	0.93
Sector B4																		
Density/km^2	0.55	0.18	0.31	0.53	0.69	0.86	0.15	0.30	0.63	0.64	1.68	0.71	0.70	0.48	0.94	1.17	2.37	1.57
SE	0.09	0.01	0.01	0.03	0.04	0.07	0.04	0.02	0.06	0.04	0.09	0.17	0.12	0.02	0.06	0.06	0.11	0.17
L95%CL	0.36	0.16	0.28	0.46	0.62	0.72	0.07	0.27	0.52	0.57	1.52	0.37	0.44	0.45	0.82	1.05	2.15	1.24
U95%CL	0.74	0.19	0.36	0.60	0.75	1.00	0.23	0.34	0.73	0.72	1.85	1.06	0.96	0.51	1.06	1.29	2.58	1.90

Table 9. Parameter estimates and analyses for all ringed seal observations (shorefast and pack ice, seals at holes and cracks) for the 1996 - 1998 surveys.

Parameter	Estimate	Standard Error	Chi square	P
Ice type = pack	-251.24	152.37	2.72	0.099
Ice type = fast	-1158.54	137.5561	70.94	<0.001
Year * Ice type pack	0.1265	0.0763	2.75	0.098
Year * Ice type fast	0.5812	0.0689	71.19	<0.001
Ice deformation	-0.0123	0.0023	27.75	<0.001
Ice deformation ^{2}			0.83	0.361
Melt water	0.0191	0.0046	17.41	<0.001
Melt water ^{2}	-0.0003	0.0001	32.23	<0.001
Time of day			0.89	0.345
Time of day ^{2}	-0.0041	0.0006	46.89	<0.001
Distance from shore	0.0313	0.0093	11.31	0.001
Distance from shore ^{2}	0.0010	0.0002	19.17	<0.001
Distance from shear zone (fast)	0.0381	0.0051	55.97	<0.001
Distance from shear zone (fast) ^{2}			0.31	0.580
Distance from shear zone (pack)	-0.0104	0.0055	3.58	0.059
Distance from shear zone (pack) ^{2}			2.17	0.141
Longitude			2.64	0.104
Longitude * year			0.01	0.941a
Longitude (1997)	-0.964	0.0254	14.35	<0.001
Longitude ^{2}			1.24	0.266
Longitude ^{2} * year			0.10	0.749b
Julian Date	0.1759	0.0293	35.97	<0.001
Julian Date * year			1.61	0.205b
Julian Date ^{2}			0.28	0.597
Julian Date ^{2} * year			0.46	0.499b
Wind chill			3.22	0.073
Wind chill ^{2}	-0.0024	0.0008	9.55	0.002
Cloud cover	0.0140	0.0028	25.83	<0.001
Cloud cover ^{2}	-0.0002	0.0000	44.63	<0.001

[a]Two parameters estimated for this effect, only 1997 retained as a separate variable.
[b]Two parameters estimated for this effect, the larger X^2 (smaller p-value) is reported.

Table 10. Ringed seal density on fast ice in the Beaufort Sea relative to distance from shore, 1996-1998.

Distance from Shore (km)	1996 # seals	1996 area	1996 observed density (seals/km^2)	1997 # seals	1997 area	1997 observed density (seals/km^2)	1998 # seals	1998 area	1998 observed density (seals/km^2)
0 –2	21	103.6	0.20	65	144.7	0.45	26	64.1	0.41
2-4	37	101.9	0.36	79	144.7	0.55	87	64.1	1.36
4-6	55	93.7	0.59	119	144.7	0.82	50	59.2	0.85
6-8	63	88.8	0.71	117	144.7	0.81	90	55.9	1.61
8-10	59	78.9	0.75	165	143.0	1.15	47	44.4	1.06
10-12	46	72.3	0.64	163	138.1	1.18	48	39.5	1.22
12-14	59	64.1	0.92	154	134.8	1.14	19	29.6	0.64
14-16	43	60.8	0.71	161	128.2	1.26	9	14.8	0.61
16-18	33	42.7	0.77	158	124.9	1.27	13	9.9	1.31
18-20	40	24.7	1.62	116	116.7	0.99	2	3.3	0.61
Total	456	731.5	0.62	1297	1364.5	0.95	391	384.8	1.02

Table 11. Ringed seal density on fast ice in the Beaufort Sea relative to distance from the fast ice edge, 1996-1998.

Distance from Shore (km)	1996 # seals	1996 area	1996 observed density (seals/km^2)	1997 # seals	1997 area	1997 observed density (seals/km^2)	1998 # seals	1998 area	1998 observed density (seals/km^2)
0 –2	104	103.6	1.00	90	144.7	0.62	100	64.1	1.56
2-4	120	101.9	1.18	160	144.7	1.11	97	64.1	1.51
4-6	66	93.7	0.70	151	144.7	1.04	31	59.2	0.52
6-8	56	85.5	0.65	165	144.7	1.14	64	54.2	1.18
8-10	48	78.9	0.61	128	144.7	0.89	48	47.7	1.01
10-12	36	74.0	0.49	175	139.7	1.25	19	41.1	0.46
12-14	22	65.8	0.33	181	134.8	1.34	13	32.9	0.40
14-16	12	60.8	0.20	183	131.5	1.39	10	21.4	0.47
16-18	11	36.2	0.30	118	126.6	0.93	5	13.2	0.38
18-20	4	16.4	0.24	119	115.1	1.03	5	9.9	0.51
Total	479	716.8	0.69	1470	1371.2	1.07	392	407.8	0.96

Table 12. Observed ringed seal density on all ice relative to ice deformation, based on aerial surveys flown in the Beaufort Sea during late May-June, 1998.

Ice deformation	Number of seals	Area (km^2)	Density ($seals/km^2$)
0-10	660	666.1	0.99
10-20	224	256.5	0.87
20-30	132	159.9	0.82
>30	94	120.2	0.78
Total	1110	1202.7	0.92

FIGURES

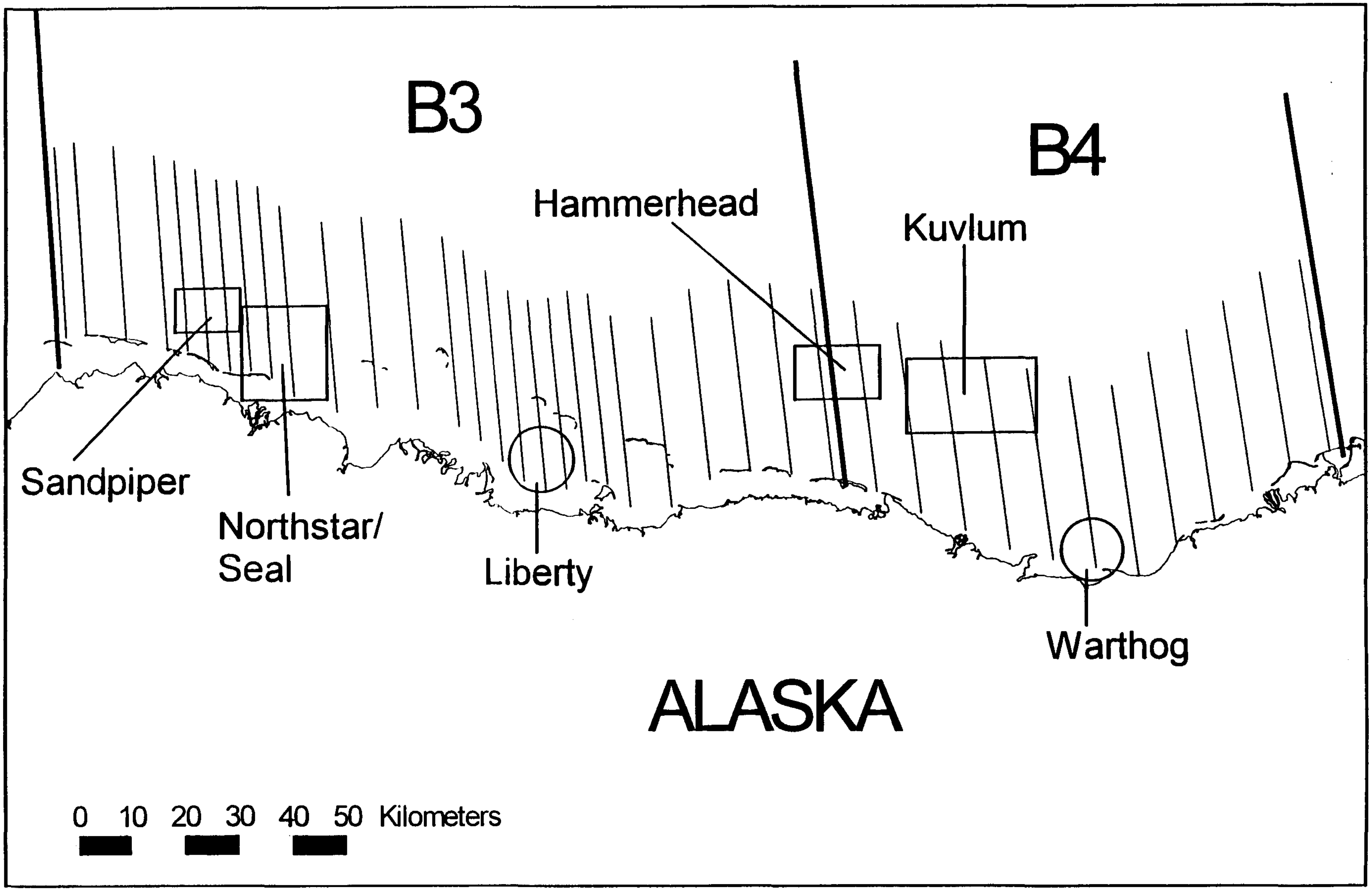


Figure 1. Map of the Beaufort Sea study area showing transect lines flown during 27-28 May 1998, and potential areas of industrial activity.

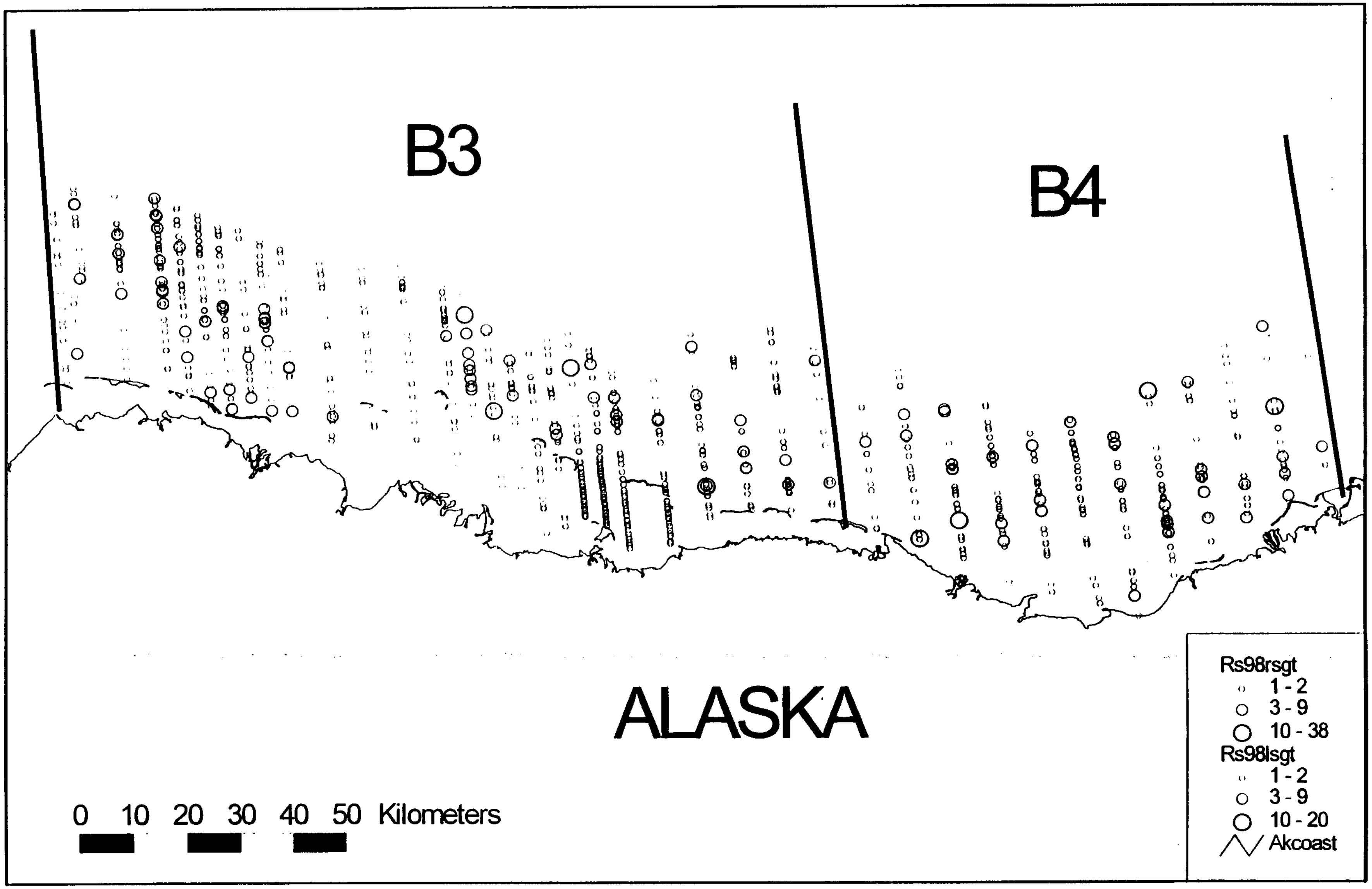


Figure 2. Map of the Beaufort Sea showing sightings of ringed seals made during 27-28 May 1998.

Figure 3. Effects of covariates on density estimates for ringed seals in the Beaufort Sea, May-June 1996-1998.

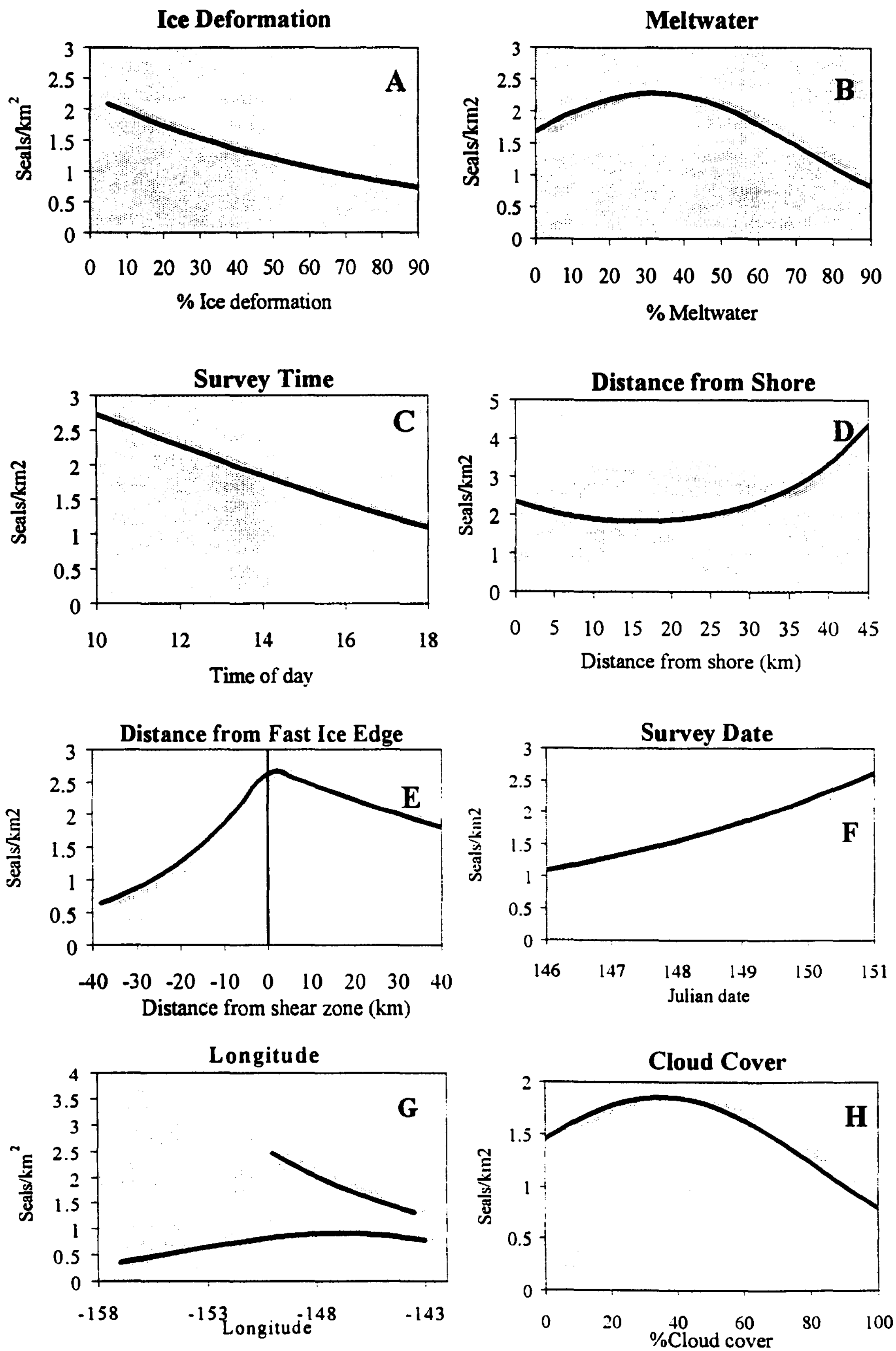
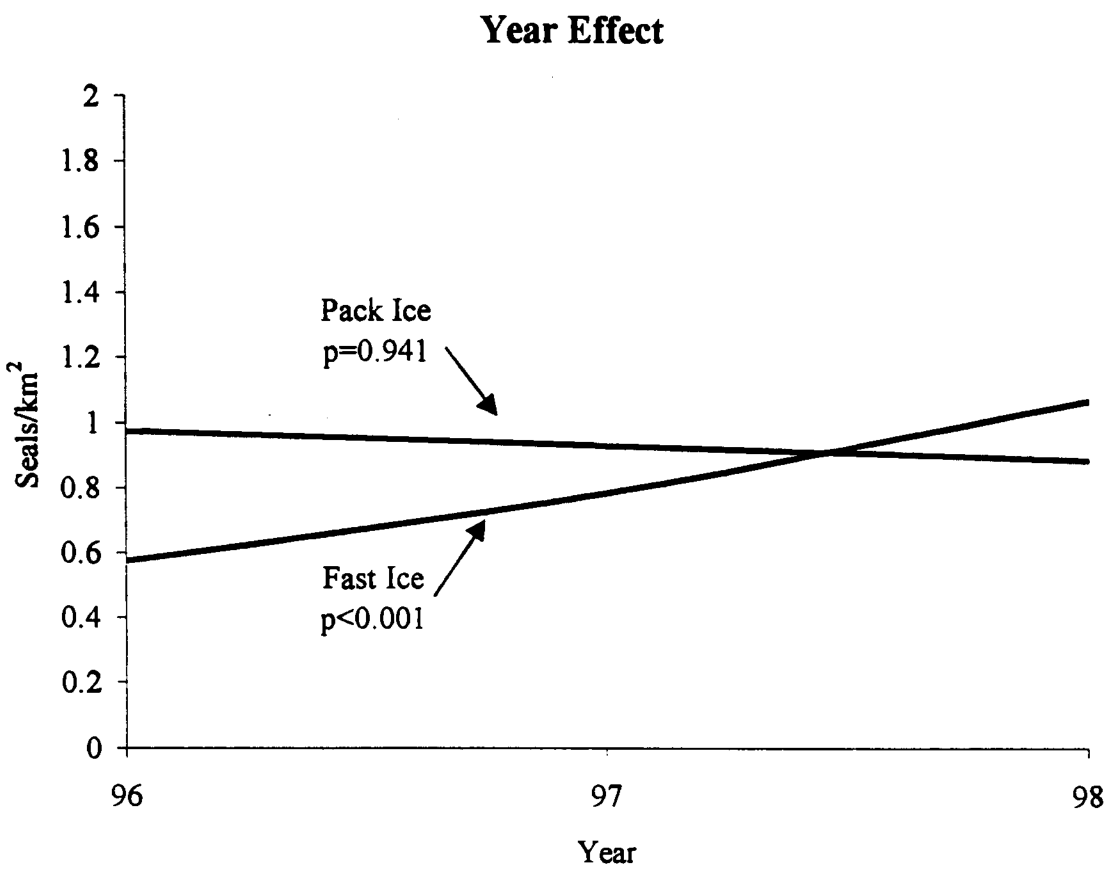
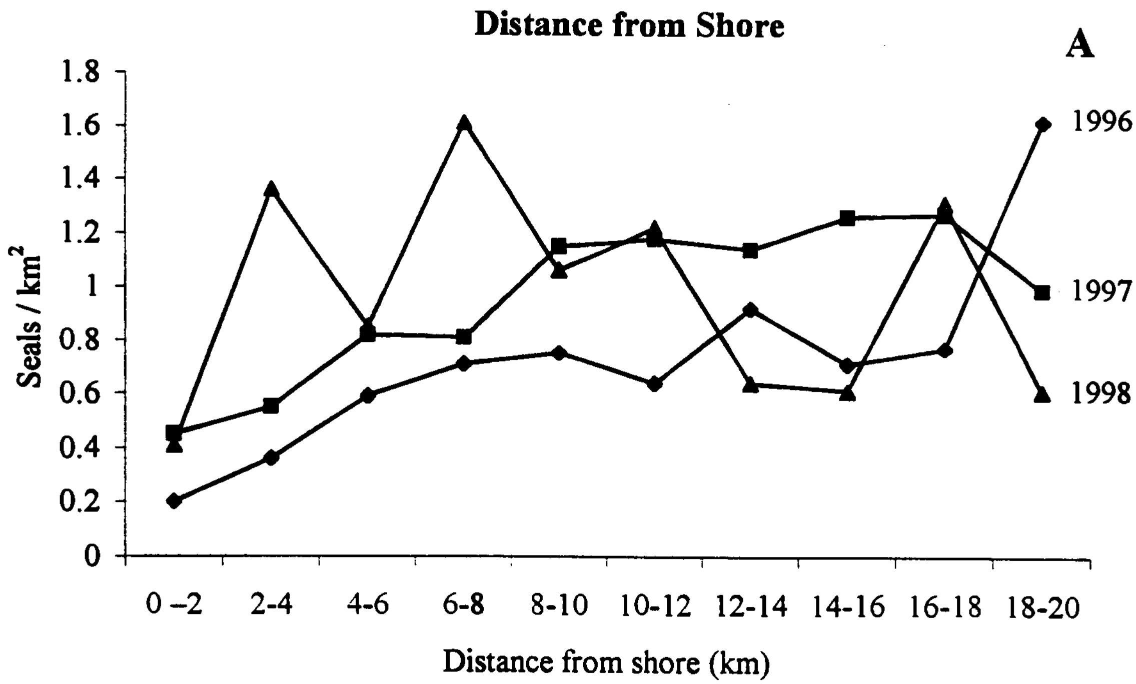


Figure 4. Effect of year in the covariate model for estimated ringed seal density in the Beaufort Sea, May-June 1996 –1998





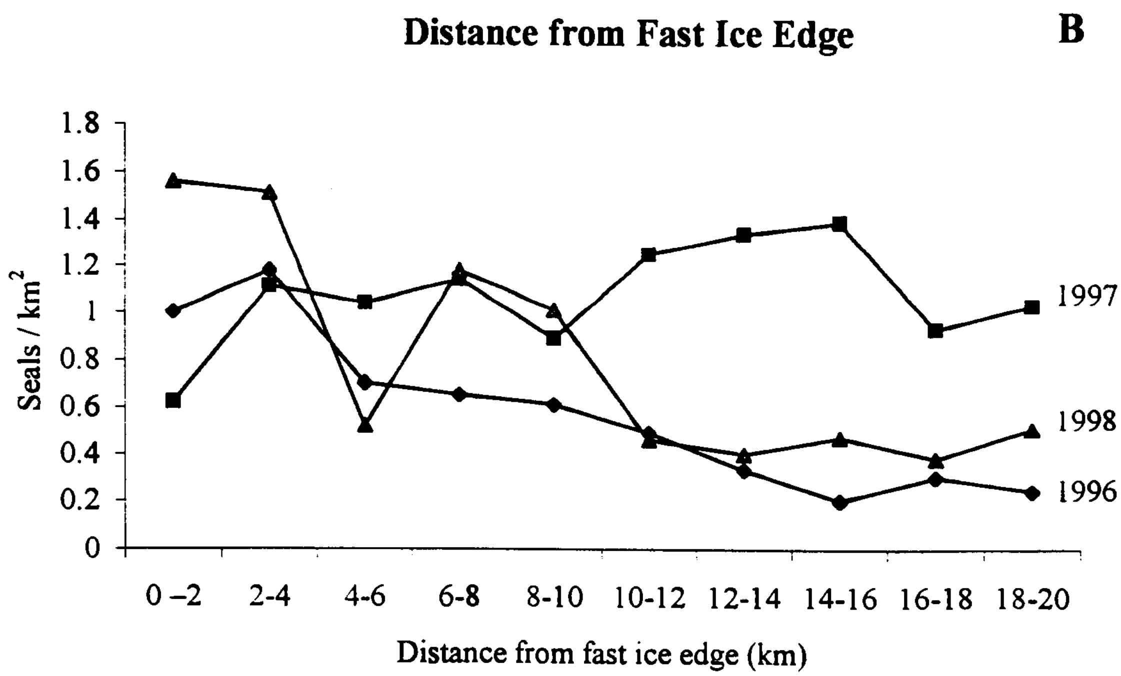


Figure 5. Observed density of ringed seals on fast ice of the Beaufort Sea, May-June 1996-1998, relative to a) distance from shore, and b) distance from the fast ice edge.

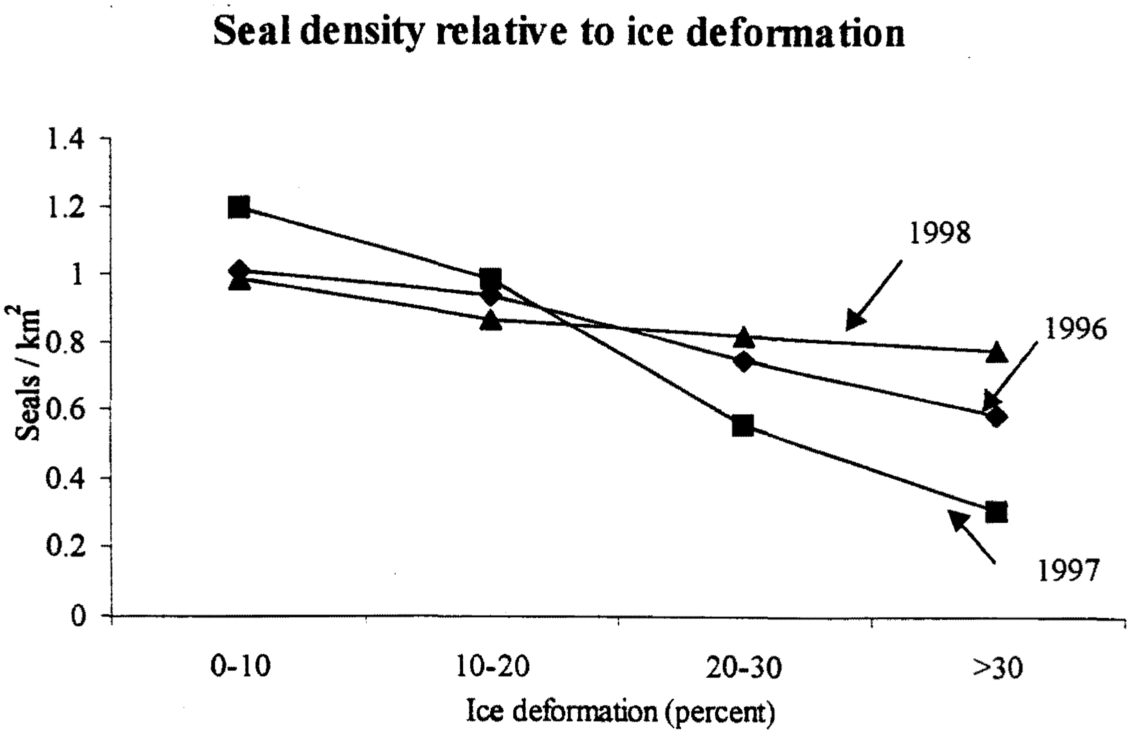


Figure 6. Observed density of ringed seals on fast ice of the Beaufort Sea, May-June 1996-1998, relative to ice deformation..

APPENDIX A

INDUSTRY SUBSECTION
of the
Annual Report March 1998 – March 1999

MONITORING DISTRIBUTION AND ABUNDANCE OF RINGED SEALS
IN NORTHERN ALASKA

Cooperative Agreement number
14-35-0001-30810

Submitted :to

Kathy Frost
Alaska Department of Fish and Game
1300 College Road
Fairbanks, AK 99701

By

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

INDUSTRIAL ACTIVITY UPDATE

This section of the annual report includes information on oil- and gas-related industrial activities in the Federal and State waters off Alaska's north slope during the winter of 1997, all 1998, or planned for the spring of 1999. Many of the details of the information are still considered propriatary and thus are not yet available for public distribution.

1.0 FEDERAL WATERS

1.1Seismic Activity

Three permits were granted for seismic-vibroseis activity in federal waters during the ice season of 1997-1998 and one for the ice season of 1998-1999 (Table 1). Figures 1 and 2 show the entire area covered by each permit. Usually, a much smaller area is actually "shot" but the location of the area of interest is not generally available to the public until the lease sale for that area has occurred. On-ice seismic data acquisition was planned for March-April 1997 in Mikkelsen Bay (B3, lines 27-30) but specifics are not yet available.

1.2 Drilling Activity

No drilling actvity took place in 1998 in the Beaufort Sea in the Federal OCS. The Warthog exploratory well (sector B4, near south end of line 12) was the last well drilled in the Beaufort Sea OCS. It was spudded in November 1997, then plugged and abandoned in December 1997.

1.3 Ice Roads and Other Structures

Winter 1999 ice roads were built by late February 1999 for Northstar and construction of a gravel production island is scheduled to start in March, 1999.

1.4 Other Information and Plans for the Future

The U.S. Army Corps of Engineers issued the final EIS on February 5, 1999 for Northstar. and plans to issue its Record of Decision in spring 1999 (Oil and Gas Update. State of Alaska Division of Governmental Coordination, March 30, 1999). A buried pipeline will be constructed there in winter 1999/2000 with first production anticipated the fourth quarter of 2001. The EIS for Liberty is scheduled to be published in March, 2000. Liberty is within the barrier islands, but in Federal waters. Construction of a Liberty artificial island and pipeline are anticipated to occur in winter 2001-2002. First production from Liberty would be in 2002.

2.0 STATE WATERS

2.1 Drilling Activity

Exploratory wells Kalubik 2 and 3, just off the east end of the Colville River delta, were drilled in February and plugged and abandoned in March 1998. In February 1998, a permit (98-0027) was granted for an additional exploratory well in the area, Kalubik 2A, but no drilling has take place there.

2.2 Ice Roads

The state does not issue permits for offshore ice roads (even those on state waters), but they do issue approvals for the onshore portions. During the winter of 1997-1998, ice roads were constructed on sea ice but very close to shore from Endicott to Badami/Point Thompson. During the winter of 1998-1999, ice roads were built from Kuparuk 3M to the mouth of the Colville Delta. Ice roads to Northstar were begun in January 1999 and are still being completed in early March 1999 (Steve Schmitz, Alaska Division of Oil and Gas, pers. comm).

2.3 Other Information and Plans for the Future

A number of changes have taken place recently among seismic companies operating in Alaska: Western Geophysical bought Northern Geophysical of America; Western Geophysical is now a subsidiary of Baker Hughes Inc.; and Western Geophysical is now the only company requesting permits to shoot seismic in Alaska (State of Alaska Division of Oil and Gas web site, March 1999).

Table 1. Recent permit activity in MMS Alaska OCS Region (MMS Alaska web page, www.mms.gov/alaska, 3/10/98). See Figures 1-2 for maps of areas covered by each permit.

Permit No.	Area	Permittee	Contractor	Type of Survey	Permit Issued	Start Date	End Date
99-01	Beaufort	WGC	WGC	CDP-3D	12/2/98	11/30/98	5/31/99
98-03	Beaufort	WAI/ Anadarko	WGC	CDP	12/08/97	12/15/97	05/31/98
98-02	Beaufort	ARCO	WGC	CDP-3D	10/09/97	11/15/97	05/31/98
98-01	Beaufort	ARCO	WGC	CDP-3D	10/09/97	11/15/97	05/15/98

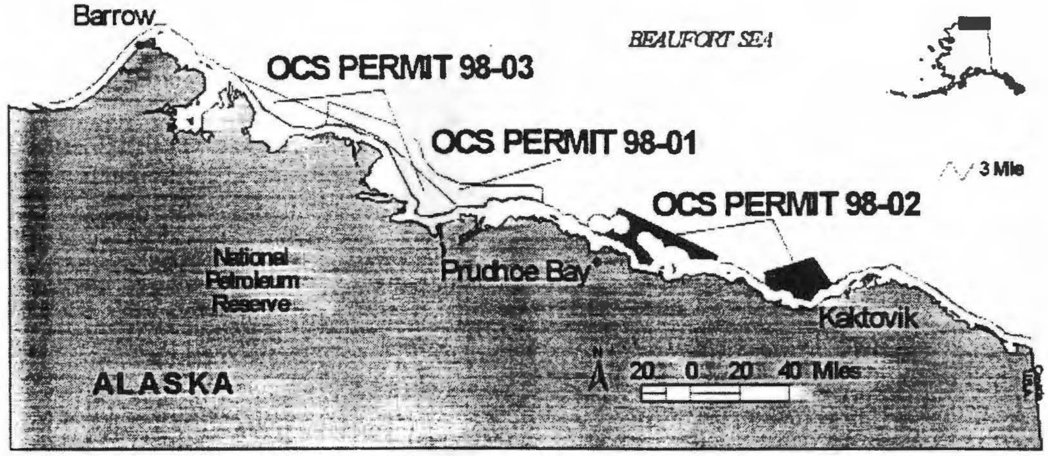


Figure 1. Areas covered by OCS permits 98-01, 98-2, and 98-03.

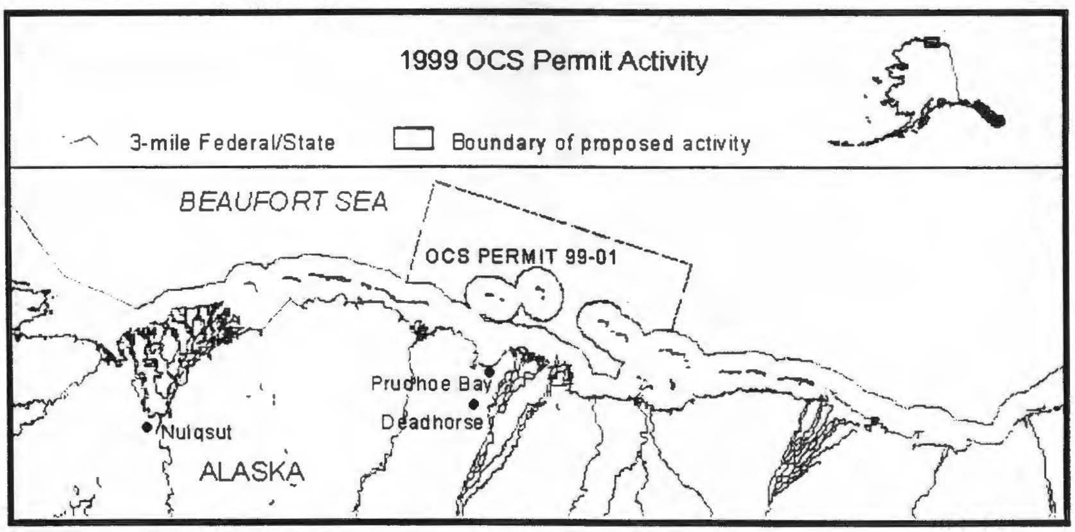


Figure 2. Area covered by permit 99-01.

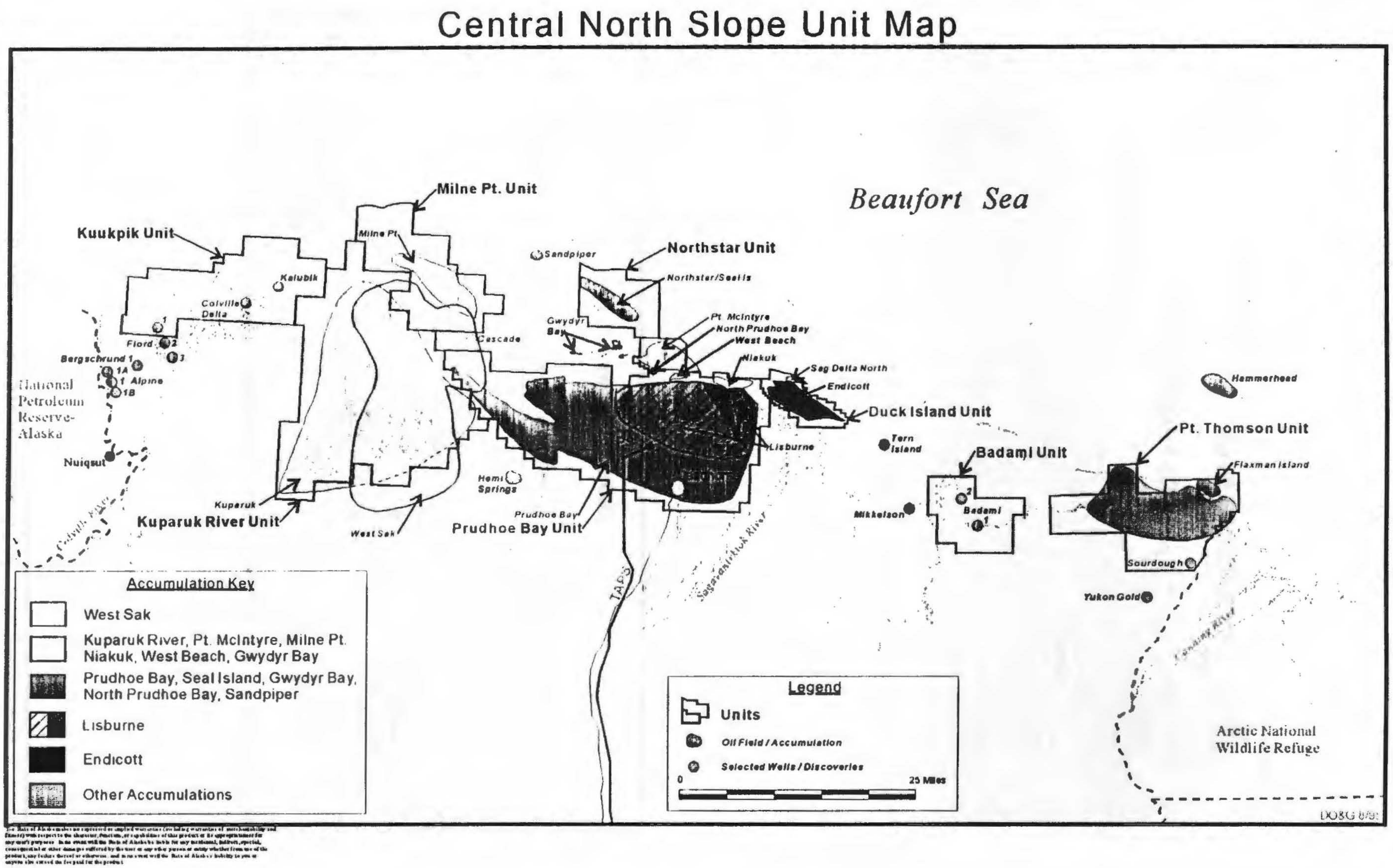


Figure 3. Map of the Central north slope of Alaska (Alaska div. Oil and Gas web site).