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Winter Ecology of Ringed Seals (*Phoca hispida*) In Alaska

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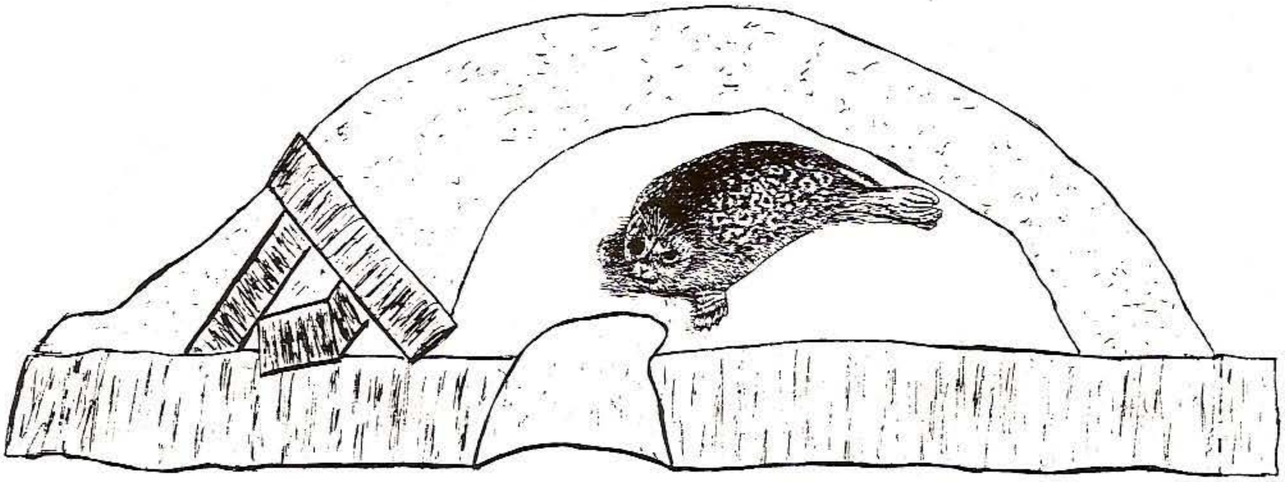

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I. Summary

During winter and spring, the highest densities of breeding ringed seals in Alaska occur along the coasts of the Chukchi and Beaufort seas in shorefast ice. Fast ice also provides a reasonably safe and convenient platform on which various phases of petroleum exploration or other human activities can be conducted. In response to concerns and preliminary indications that on-ice activity might affect the distribution and abundance of ringed seals, the Outer Continental Shelf Environmental Assessment Program funded this study, beginning in 1981, to examine and quantify potential impacts.

Aerial surveys were conducted in the central Beaufort Sea in 1981 and 1982 as part of a study to determine the effects of on-ice seismic exploratory activity on the distribution of ringed seals. Results of line-by-line and block comparisons for both years were ambiguous, but generally indicated no overall difference in density of ringed seals in seismic and in adjacent control areas. However, aerial surveys were not well-suited to detecting small-scale differences in geographically restricted areas, and consequently were not, by themselves, adequate for examining the possible effects of industrial activity.

To complement the aerial surveys, on-ice surveys were conducted in the Beaufort Sea in 1982 in seismic and control areas in order to determine the fate of subnivean structures made by ringed seals. Trained dogs were used to search 295 linear km of seismic and control lines, along which they found 157 structures. Results of the searches indicated that there was no significant difference in abandonment for structures located within or beyond 150 m of seismic or control lines. A comparison of the fates of structures in relation to times when seismic lines were vibrated suggested that disturbance from the seismic vibroseis equipment per se had no different effect than the aggregate effects of heavy equipment and other noise. Investigator activity was not indicated as a major source of disturbance in the Beaufort Sea studies since 87% of both structures that were opened by investigators and those that were only probed and re-examined at a later date remained open. For the Beaufort Sea sample as a whole, 11% of all structures were found to be abandoned when they were first detected by dogs and examined.

Following the 1982 studies of ringed seal structures in areas of intense industrial activity, we conducted more general, coast-wide studies in 1983-1984 to examine regional differences in abundance and types of seal structures; predation; natural rates of abandonment of structures; and characteristics of structures and the ice in which they were found. During these studies, the dogs searched 82 linear km along 22 lines in a coast survey extending from Norton Sound to Peard Bay, 64 km² in 7 grids in southern Kotzebue Sound and near Cape Lisburne, and 35 linear km along 12 lines on the pack ice near Cape Lisburne. They located a total of 660 seal-made structures, consisting of breathing holes and simple, complex, and pupping lairs.

Data were analyzed to assess potential biases in the number and kinds of structures detected by the 2 dogs and the effects of wind on their success. The dogs were found to be comparable in the maximum and mean distances at which they found structures, in the number of structures found per linear kilometer, and in the types of structures they located. Neither the angle of

the wind relative to the search line nor wind speed (from 0-45 km/hr) appeared to affect the dogs' performance. Multiple searches of the same lines within grids indicated that the dogs found approximately 60%-70% of the total structures within 200 m of a line on the first search. This suggests that a correction factor must be used if comparisons are to be made between densities of seal structures based on single searches of lines and those from multiple or grid searches.

The composition of 794 identified structures found during 1982-1984 was 40% breathing holes, 39% simple lairs, 10% complex lairs, and 10% pupping lairs. On fast ice, lairs made up 53% of all structures in the Beaufort Sea in 1982, 64% in Kotzebue Sound in 1983, and 75% near Cape Lisburne in 1984. Only 39% of the structures in pack ice were lairs.

The highest density of seal structures within our study grids was on the fast ice east of Cape Lisburne, where the dogs located an average of 8.6 structures/km^2. The density in southern Kotzebue Sound was somewhat lower, 7.2/km^2. Corrected values from line searches, which take into account our findings that the dogs found approximately 65% of total structures on a single search of a line, indicated high densities of structures on fast ice of the northern Bering Sea (12.8/km^2) and Peard Bay (18.2/km^2), and on pack ice off Cape Lisburne (10.0/km^2). The lowest structure densities in Alaska occurred in the Beaufort Sea (3.6/km^2).

The best pupping habitat along the Alaska coast, as indicated by the density of pupping lairs in our study areas in 1982-84, was on the fast ice of the central Chukchi Sea, east of Cape Lisburne. Pupping lairs made up 18% of all structures and occurred at a density of 1.6/km^2. This compares to the Beaufort Sea, where only 7% of all structures were pupping lairs, with a density of 0.3/km^2, and southern Kotzebue Sound where 11% of the structures were pupping lairs, occurring at a density of 0.8/km^2. The density of pupping lairs on fast ice near Cape Lisburne was higher than the total density of structures reported by Smith and Stirling (1975) for Amundsen Gulf and over twice the reported density of pupping lairs in the eastern Arctic (Smith et al. 1978).

Measurements were obtained from 577 structures located on fast ice of the Chukchi and Beaufort seas. Breathing holes in the fast ice were significantly smaller (mean diameter = 31 cm) than access holes into all types of lairs (43-52 cm). Breathing holes in pack ice were significantly smaller (mean diameter = 20 cm) than those in fast ice. Single-chambered, simple lairs were the smallest of the lair types, with a mean length of 160 cm in fast ice and 139 cm in pack ice. Multi-chambered, complex lairs were intermediate in size (mean length = 235 cm) and pupping lairs were largest of all (mean length = 277 cm). Within Alaska, there was no apparent trend in the size of lairs. By comparison, lairs in Amundsen Gulf were significantly larger, possibly because of the larger average size of the seals in that area.

Predator activity by polar bears and arctic foxes varied by geographic region, from a low in Kotzebue Sound where arctic foxes marked 3% of all structures and entered 5% of all lairs, to a high on the fast ice near Cape Lisburne where arctic foxes and polar bears combined marked 47% of all structures and entered 37% of lairs. Overall, foxes marked more structures, opened more lairs, and killed more pups than did polar bears.

Pups were killed at 7% of all pupping lairs on fast ice in southeastern Kotzebue Sound compared to 30% of all pupping lairs on fast ice of the central Chukchi and Beaufort seas. The actual rate of predation ranged from a low of 0.04 kills/km^2 in southern Kotzebue Sound to a high of 0.43 kills/km^2 on fast ice near Cape Lisburne.

Predators were apparently able to distinguish between structure types since pupping lairs made up 7%-18% of all structures on fast ice in our studies but accounted for 20%-43% of all predation attempts. Virtually all pups were killed at pupping lairs. Less than 3% of predation attempts at non-pupping structures resulted in kills, compared to 47%-100% at pupping lairs.

In our studies, some of the structures we found had been abandoned by seals (the access hole was completely frozen). The rate of abandonment was lowest (6%) in areas without much predator activity and where industrial activity did not occur. In areas with industrial activity, the rate of abandonment was 11%, almost double that in undisturbed areas. The greatest abandonment was caused by predators. For structures opened and/or entered by arctic foxes or polar bears, abandonment was 29%, or about 5 times that in undisturbed areas with no predation. Depending on the study methods, investigator examinations caused little or no additional abandonment (13% abandonment on revisits compared to 11% on first visits in the Beaufort Sea in 1982), or abandonment approaching that caused by predators (22% on Cape Lisburne grids and parts of one Kotzebue Sound grid).

Sixty-six ringed seals were collected from nearshore leads and pack ice in Norton Sound and near Cape Lisburne to compare age, size, reproductive parameters, and diet of "coastal" and "offshore" seals. Seals collected from Norton Sound were significantly longer, heavier, and older than those from the Cape Lisburne area, and many more were sexually mature (60% vs. 28%). There were no significant differences in any of these parameters for seals collected from coastal leads compared to those from pack ice, either within regions, or for both regions combined.

Between-region differences in diet were also greater than the differences between lead system and pack ice seals. In Norton Sound, invertebrates made up 41% of the total volume of stomach contents, compared to 94% near Cape Lisburne. Norton Sound seals had eaten mostly shrimps and arctic cod (*Boreogadus saida*). *Pandalus hypsinotus* was the major shrimp species in coastal samples and *Pandalus goniurus* in pack ice samples. Near Cape Lisburne, seals also had eaten mostly shrimps and lesser amounts of other invertebrates and fishes. Stomachs of seals collected in nearshore leads contained mostly *Pandalus goniurus* and sculpins. Pack ice seals had eaten the shrimps *P. goniurus* and *Eualus gaimardii*, and lesser amounts of mysids, arctic cod, and pricklebacks.

II. Introduction and Background

Ringed seals, *Phoca hispida*, are a widespread, circumpolar species which, in waters adjacent to Alaska, occur in the Beaufort, Chukchi, and Bering seas. They are the most abundant of the phocid seals found in seasonally ice-covered seas of northern Alaska.

Of the northern phocids, ringed seals are the best adapted to life in thick pack ice and landfast ice (McLaren 1958; Smith and Stirling 1975). In Alaskan waters, ringed seals are the only species that normally lives in and under the extensive, unbroken fast ice (Burns 1970). Using strong claws on their foreflippers, they make breathing holes in newly formed ice and maintain these holes as the ice thickens (Smith and Stirling 1975; Smith and Hammill 1981). During the course of a freezing season, ice thickens, becomes deformed, and accumulates an increasingly thicker snow cover. Some breathing holes are enlarged to provide access to the ice surface on which seals excavate snow lairs (Smith and Stirling 1975). Lairs include single-chambered cavities (simple lairs), multi-chambered cavities (complex lairs), and cavities with 1 or more small tunnels radiating from the main chamber(s). The latter are usually complex lairs in which a pup was born or cared for; the tunnelling is done by the pup. Subnivean lairs are used for resting, birthing, and caring for the single pup.

Compared to other pinnipeds, ringed seals are small. Neonates average 65 cm long and weigh 4-5 kg (McLaren 1958; Fedoseev 1975). At the end of the 4- to 6-week nursing period pups weigh 9-12 kg (Tikhomirov 1968). Growth continues through the first 8-10 years, at which time seals have reached about 96% of their final length. Ringed seals in Alaskan waters are much smaller than those in eastern Canada. Mean standard length of seals older than 10 years collected in the Bering, Chukchi, and Beaufort seas was 114.6 cm and mean weight was 49 kg (Frost and Lowry 1981). Corresponding measurements for Canadian seals were 128.2 cm and 62 kg (McLaren 1958). Males are, on average, slightly longer than females. Weight and girth vary throughout the year due to seasonal changes in blubber thickness (McLaren 1958; Johnson et al. 1966).

Most ringed seals become sexually mature at 5-7 years of age. Mature males (and perhaps females) begin to establish breeding territories as early as February. Females give birth to a pup in a subnivean lair between late March and mid-April. Birth lairs have been described by McLaren (1958), Smith and Stirling (1975), Lukin and Potelov (1978), Lukin (1980), and Burns and Kelly (1982). Pups are born with a dense, white-hair covering called lanugo. Mating occurs at and immediately after the time when pups are weaned, usually during late April and May. Most females mate every year, although the frequency of successful pregnancy has shown considerable annual variation (Stirling et al. 1977; Smith and Stirling 1978; Burns and Frost, unpubl.). The period of pregnancy, including a period of delayed implantation which lasts until late August or early September, is about 10.5 months (Burns, unpubl.) Based on sightings of small, white-coated pups in the Bering Sea, some births occur on exposed ice floes where snow accumulation is insufficient for excavating lairs. Such pups are usually considerably smaller than those seen in more optimum habitat at the same time of year. It is hypothesized that most such instances involve young, inexperienced females that are unable to successfully compete with older animals for more optimum habitat in which to bear pups (McLaren 1958). Subadult animals may also be excluded from the optimum pupping and breeding habitat (McLaren 1958).

Some investigators are of the opinion that ringed seals of the fast ice and pack ice may represent different ecomorphs (Fedoseev 1975; Finley et al. 1983). It is well documented that ringed seals in offshore waters tend to be smaller than those near the coast (McLaren 1958; Fedoseev 1975). This can, to some extent, be explained by differences in age structure (i.e., smaller, immature seals occurring primarily in pack ice). Finley et al. (1983), working in Baffin Bay, found a breeding "population" of ringed seals occupying the pack ice. These offshore seals were generally smaller and less robust than seals occupying landfast ice. Such size differences may be due to differences in the length of nursing periods, with optimum conditions occurring on the more stable, landfast ice (McLaren 1958).

After the end of lactation and mating, seals haul out to molt near enlarged breathing holes, collapsed lairs, along cracks, and around larger holes in the deteriorating ice sheet. At this time of the year (May-July) they spend long periods of time basking, especially on relatively calm, warm days (Burns and Harbo 1972; Finley 1979; Smith and Hammill 1981). During this period, a large portion of the population is visible on the ice and can be counted by means of aerial surveys. Such surveys, which have been conducted over much of the ringed seal's range, have documented substantial regional and annual variations in abundance (Burns and Harbo 1972; Smith 1975; Stirling et al. 1977; Frost et al. 1985, 1987). Highest densities have been found on stable shorefast ice along complex coastlines, with intermediate densities on shorefast ice along simple coastlines, and lower densities on offshore pack ice (Smith 1973, 1975; Burns and Eley 1978; Frost et al. 1985, 1987). In the Alaskan Beaufort Sea, highest densities of seals have been found on ice with 40% or less deformation (Burns and Kelly 1982; Frost et al. 1985, 1987).

Factors influencing local and regional abundance of ringed seals are poorly known. In some areas, seasonal movements of seals may be primarily onshore-offshore, which results in an increased abundance in coastal waters during the open-water period (McLaren 1958; Finley et al. 1983). Although some investigators consider them to be non-migratory, most ringed seals in the Bering Sea make long, annual movements northward to summer in the pack ice of the Chukchi and Beaufort seas (Frost and Lowry 1981). Patterns of distribution, especially during summer, may most likely be influenced by distribution and movements of prey (Lowry et al. 1980). Densities during winter and spring may be influenced by a combination of ice conditions and prey availability (Stirling et al. 1977; Smith and Hammill 1981). Long-term variations in abundance may result from the interaction of a variety of factors, including ice conditions, food availability, predation, and hunting (Smith 1975; Stirling et al. 1977; Smith 1980). In Alaska, ringed seals are harvested in greater numbers than any other seal species by subsistence-oriented coastal residents living from Kuskokwim Bay to Barter Island (ADF&G, unpubl.).

Since the highest densities of breeding ringed seals occur in fast ice areas, this type of habitat is very important to the population. In the northern Chukchi and Beaufort seas, fast ice also provides a reasonably safe, convenient, and efficient platform on which certain phases of petroleum exploration can be conducted. In the Beaufort Sea, seismic exploration has been conducted during late winter-spring since the late 1960's to identify areas most likely to have large sub-surface petroleum reserves. Energy sources utilized to generate seismic waves necessary for recording subsurface geological profiles have included buried explosive charges during the late 1960's and early 1970's; air guns in the mid- and late 1970's; and a vibroseis technique in the 1980's. During late winter when fast ice becomes thick and stable enough to support heavy equipment and allow extensive mobility, a variety of machinery is deployed. Main ice roads, connecting roads, seismic shot lines, ice runways (for aircraft), and temporary camp sites are prepared. Each self-contained crew and its equipment moves over the fast ice, eventually covering as much of the area of interest as possible. The activities of such a crew in a given area may last for more than a week. Operations of seismic crews are constrained by ice topography. They mainly operate in regions of relatively flat ice or where the surface relief is neither too high nor deformation too extensive in areal coverage.

The first indications that on-ice activity might have affected the distribution of ringed seals occurred in Norton Sound during the middle 1960's. In 2 consecutive years, an intensive shallow-core drilling program to locate marine deposits of placer gold was undertaken from fast ice between Sledge Island and Cape Nome. Subsistence hunting for ringed seals during winter by Native inhabitants of Nome was, during that time, still of major importance to the local economy. Many Nome hunters consistently reported declines in the availability of ringed seals in the area subject to exploration, both during and continuing after the activities ceased, until the ice began to deteriorate and migrating seals moved in. No studies of this potential disturbance were undertaken at that time.

The first extensive aerial surveys of ringed seals in fast-ice areas of the northern Chukchi and Beaufort seas were made between 8 and 15 June 1970 (Burns and Harbo 1972). These surveys were not designed to test differences in seal density, if any, between areas subjected to seismic exploratory activity and adjacent areas in which such exploration did not occur. However, a general test was made after the fact by comparing 2 adjacent blocks, one that included ice roads and seismic shot lines and one that did not. Structure of the aerial surveys and size of the areas compared were considered inadequate, and results of the comparisons were inconclusive (Burns and Harbo 1972).

Extensive aerial surveys were again undertaken in June 1975 to 1977, mainly to investigate the magnitude of annual variation in ringed seal abundance along the north coast. No specific tests of the possible effects of seismic exploration were included in the survey design as the objective was an extensive, broad-scale assessment of abundance rather than intensive comparisons among relatively small areas. However, a substantial increase in on-ice seismic activity had occurred since 1970, and permitting agencies requested that the data be used to compare ringed seal densities in areas with and without extensive seismic exploratory activity. The 1975-77 survey data indicated a consistently lower density of seals in areas where seismic exploratory activity had occurred. Magnitude of the differences ranged from 22% to 88%, with a combined average difference for 3 years of 51%.

In 1981, at the urging of many interested parties, the Outer Continental Shelf Environmental Assessment Program initiated and funded more rigorous studies to verify and quantify the perceived impacts of on-ice seismic exploration on the distribution and abundance of ringed seals. Aerial surveys of ringed seals on the fast ice of the Beaufort Sea were conducted during June 1981 and 1982 to compare the observed densities of seals in areas with and without on-ice seismic exploration. Results of those surveys were reported in Burns et al. (1981); Burns and Kelly (1982); Frost et al. (1985); Frost and Lowry (1988); and Kelly et al. (1988) and will be summarized in this report.

The effects of seismic activity on ringed seals were also investigated by monitoring the use, by seals, of breathing holes and lairs in industrially impacted areas. Such structures are beneath the snow and not visible. However, hunting dogs can be trained to locate seal holes and lairs (Smith and Stirling 1975; Lukin and Potelov 1978). In 1982, we used trained dogs to investigate the effect of on-ice seismic exploration on the alteration and abandonment of seal-made structures. Results have been reported in Burns and Kelly (1982) and Kelly et al. (1988).

Beginning in 1983, as a follow-up to the 1982 study of ringed seals in seismic areas, we initiated a broader study of various aspects of the winter ecology of ringed seals in the Bering, Chukchi, and Beaufort seas. Trained dogs were used to detect breathing holes and lairs of ringed seals in different regions and habitats along the Alaska coast in order to describe structure characteristics, the density and proportion of structures in different habitats, predation, and rates of abandonment of structures in areas with and without disturbance by humans. This final report covers the results of those studies.

III. Objectives

Dogs were trained to detect seal-made structures in 1981. In 1982, this study focused on evaluating the possible effects of on-ice seismic exploration on distribution, density, and fate of structures made by ringed seals in the central Beaufort Sea. In 1983, emphasis shifted to the identification of geographical areas of the shorefast ice which are important as pupping habitat, and to description of the characteristics of those areas and the subnivean structures found in them. In 1984, studies of subnivean structures on the shorefast ice were continued. In addition, research was expanded to include an investigation of the characteristics of seals and seal structures in the drifting pack ice. Principal objectives were as follows:

<u>1981-1982</u>

1. To train dogs to detect seal holes and lairs and test the efficiency with which structures can be located.

2. To determine relative abundance and distribution of ringed seals inhabiting the fast ice in the nearshore central Beaufort Sea region, as determined by presence of seal holes and lairs.

3. To determine effects, if any, of on-ice seismic exploratory activity on distribution and density of ringed seals, as indicated by continued use of subnivean structures at various distances from seismic lines and as indicated by aerial surveys conducted in May-June.

4. To investigate the relationship of seal density and type of seal-made subnivean structure with ice characteristics.

5. To integrate results of objectives 1-4 as a basis for formulation of recommendations.

<u>1983</u>

1. To determine geographic areas important as whelping habitat for ringed seals, based on preliminary surveys of subnivean seal structures in pre-selected areas along the Bering and Chukchi sea coasts, from Norton Sound to near Point Barrow.

2. To determine the densities and proportions of different kinds of subnivean structures, especially pupping lairs, in 2 or 3 regions of high seal abundance as indicated during the preliminary surveys.

3. To determine the physical parameters of subnivean structures and the characteristics of fast ice within which they occur at relatively high densities.

<u>1984</u>

1. To compare age, reproductive condition, physical characteristics, and food habits of ringed seals in offshore and coastal waters of the northern Bering and central Chukchi seas.

2. To compare relative abundance, density, and composition of subnivean structures in the drifting pack ice and in adjacent landfast ice of the central Chukchi Sea.

3. To determine, through aerial surveys conducted in May, the number of ringed seals associated with a known number of subnivean structures located within measured grids on fast ice of the central Chukchi Sea.

4. To determine, through aerial survey procedures, the relative abundance of ringed seals in fast ice areas from Kotzebue Sound to Point Lay and, if possible, in selected areas of drifting ice.

5. To prepare and submit a final report encompassing work undertaken from 1982 to 1984.

IV. Study Area

Studies during 1981-84 were conducted at a number of locations along the coast of the Bering, Chukchi, and Beaufort seas between southern Norton Sound and Barter Island. Most of the work was done in regions of shorefast ice, the average maximum extent of which is shown in Figure 1. Some work was done in the flaw zone and moving pack ice, particularly in 1984.

The time when shorefast ice begins to form varies depending on latitude. The rapidity with which ice forms at any given location is dependent on seasonal temperatures and wind conditions as well as proximity to rivers (water with reduced salinity freezes more quickly).

On average, ice forms along the shores of Norton Sound in mid-November, along the Chukchi Sea coast in mid- to late October (except in Kotzebue Sound where it normally begins to form in early to mid-October), and along the Beaufort Sea coast usually in late September to mid-October. In years of

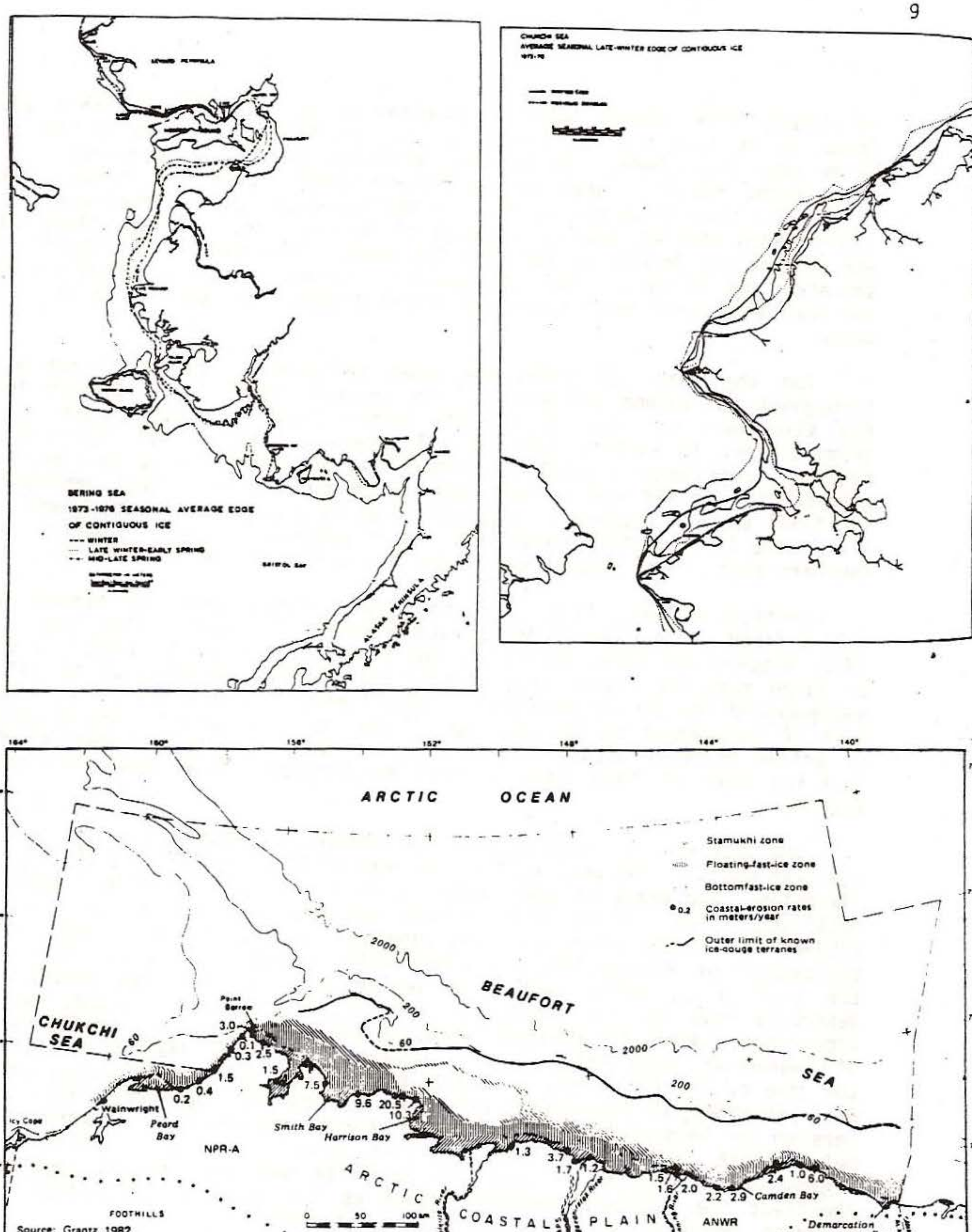


Figure 1. Average extent of fast ice in the Bering, Chukchi, and Beaufort seas. Data are from Stringer et al. 1980 and Minerals Management Service 1988.

relatively warm autumn weather accompanied by periodic offshore winds, formation of fast ice is delayed as the developing ice sheet is repeatedly blown away from shore. In autumns dominated by cold temperatures the ice sheet forms rapidly. When strong onshore winds prevail in northern areas, thick multi-year floes are driven into shallow water, become grounded, and are incorporated into the developing sheet of landfast ice. Grounded floes anchor and protect the developing landfast ice sheet. According to Stringer (1974), shorefast ice in the Beaufort Sea generally includes numerous pressure ridges, the most seaward of which characteristically become grounded in about 18 m of water.

The shorefast ice sheet continues to grow in thickness and extent throughout the autumn and winter. Its seaward extent varies greatly from a few kilometers or less in eastern Norton Sound and near major western promontories, to several tens of kilometers in the central Beaufort Sea. Kotzebue Sound becomes completely covered by shorefast ice as do other large embayments. By the end of the freezing period (April to May, depending on latitude) the ice reaches a thickness of up to 1 m in Norton Sound and up to 2 m in the Beaufort Sea. Shorefast ice is present for about 7 months in the southern part of the study area and up to 9 months in the Beaufort Sea.

Contact between fast ice and the drifting pack is marked by a well-defined shear line (Reimnitz and Barnes 1974) and/or flaw zone (Burns 1970; Shapiro and Burns 1975). In our experience, there is usually a series of large pressure ridges roughly parallel to and beginning at or slightly shoreward of the active shear zone. Each line of ridges probably represents a zone of impingement by the pack ice on the fast ice during repeated episodes of active movement during winter/early spring. Usually deformation of the fast ice sheet is least close to shore and becomes greater toward the seaward margin.

The pack ice is a more dynamic environment, in which the ice is in nearly constant motion. The pack ice is a mixture of floes of variable thickness and dimensions, and areas of open water. Pack ice is made up of both annual and multi-year floes. Floes in first-year ice tend to be flat, though they are subject to extreme deformation and ridging. Sheets of annual ice formed by coalescence of multiple floes may be heavily ridged. Multi-year floes within the study area, while usually of lesser areal extent than annual floes, generally have several meters of vertical relief and a rounded, weathered appearance. Winds and currents keep the pack ice in motion, producing areas of open-water leads and polynyas. Depending on local weather conditions at the time of its formation, a lead or polynya may remain open, close as floes are rearranged, or freeze over with newly formed ice. Open-water features may persist for long periods in areas with certain geographic, oceanographic, and meteorologic conditions. The term flaw zone is generally applied to the region of interaction between the pack ice and the seaward edge of the shorefast ice. Dynamic processes such as the formation of ridges, leads, polynyas, and new ice are very common in this zone.

Presence of a snow cover is of great importance to ringed seals. Deformation of the ice usually results in greater accumulation of wind-drifted snow, particularly on the lee sides of irregular ice features such as grounded floes and ridges. Obviously, depth of snow and size of drifts continue to increase over the winter and spring. The minimum snow depth in which seals excavate lairs is 20 cm, and the maximum is greater than 150 cm. Areas of flat ice with little or no snow contain breathing holes but no subnivean structures (Smith and Stirling 1978).

V. Methods

Field activities, including the initial training of dogs, were conducted during late winter and spring of 4 years, 1981-84. The schedule of activities as they were conducted is given in Table 1.

A. Training of Dogs

Trained Labrador retrievers were used to locate subnivean seal structures. Initial training of 2 dogs was conducted at a field location on the ice of Prince Albert Sound in the western Canadian Arctic from 1-20 April 1981. Ringed seals are very abundant in Prince Albert Sound, thus affording numerous opportunities for the dogs to learn how to locate structures and to reinforce that learning by experiencing a high frequency of success. Field facilities and direction in training were provided by Dr. Thomas G. Smith (Arctic Biological Station, Ste Anne de Bellevue, Quebec), who had used a trained Labrador bitch for locating seal structures since 1971 (Smith and Stirling 1975).

Brendan Kelly took 2 dogs to Prince Albert Sound; a male Labrador retriever (Clyde) and a male springer spaniel (Henry). Dr. Smith's experienced dog was important, if not central, to the training and reinforcing process. That dog located lairs while the trainee dogs participated in the search and received encouragement at each lair that was found. The dogs were periodically exposed to dead ringed seals, a stimulus that caused great excitement. In this manner they were able to make the connection between the seals and the lairs from which the smell of seals emanated.

At first the inexperienced dogs worked with the experienced female, then in pairs without the female, and finally alone. Dr. Smith's dog occasionally reworked an area previously searched by the dogs being trained, as a check on efficiency of the latter. The objective was to provide the maximum opportunity for each dog to become proficient and confident of its ability to locate holes and lairs.

Both the Labrador retriever and the springer spaniel developed the ability to locate lairs. However, because the springer was less responsive to unfamiliar people, was not social in the presence of other dogs, and was generally less tractable, it was not used in future work.

As a follow-up to the training and reinforcing efforts in Prince Albert Sound, Kelly took Clyde to Port Clarence, Alaska from 26 April to 4 May 1981 in order to provide the dog with additional experience and to conduct tests of its efficiency. Ringed seals are moderately abundant in that area, and arctic foxes, Alopex lagopus, were rare there in spring 1981. Because foxes were common in Prince Albert Sound, and had opened or marked many of the seal structures, there was a chance that the dog could have keyed on the scent of foxes rather than or in addition to that of seals, thus restricting its search

Table 1. Schedule of field activities and scientific personnel for Research Unit 232 during 1981-1984.

Date	Location	Activity	Personnel
1981			
1-20 Apr	Holman, NWT	Training of dogs	B. Kelly
26 Apr-4 May	Port Clarence, AK	Training of dogs	B. Kelly
2-9 Jun	Beaufort Sea	Aerial surveys	K. Frost, B. Kelly, S. Moore, J. Burns J. Venable
1982			
5 Mar-26 May	Beaufort Sea	Ringed seal/seismic work using dogs	J. Burns, B. Kelly, L. Aumiller, R. Nelson, S. Hills
25 May-4 Jun	Beaufort Sea	Aerial surveys	J. Burns, B. Kelly, K. Frost
1983			
22 Feb-16 Mar	Norton Sound to Barrow	Ringed seal structure survey using dogs	J. Burns
27 Mar-1 May	Kotzebue Sound	Ringed seal structure work using dogs	K. Frost, S. Hills, R. Nelson, J. Burns
1984			
3-16 Mar	Norton Sound/ northern Bering Sea	Pack ice/fast ice ringed seal collections	J. Burns, A. Adams, R. Zarnke
28 Mar-15 May	Central Chukchi Sea	Pack ice/fast ice ringed seal collections	J. Burns, L. Lowry, K. Frost, A. Adams
3 Apr-15 May	Central Chukchi Sea	Ringed seal structure work using dogs	J. Burns, K. Frost, L. Lowry, S. Hills, A. Adams, R. Tuzroyluk Jr.
16 May	Cape Thompson-Kotzebue Sound	Aerial survey	J. Burns, K. Frost

to seal lairs previously marked by foxes. Since only 1 set of fox tracks was seen in the Port Clarence study area, and no fox-marked lairs were found, this potential problem was resolved.

The dog's efficiency at locating seal structures was tested visually by the handler. Many seals were hauled out on the ice at Port Clarence during the study period. The basking seals could be seen by a person standing on pressure ridges or other high places, but not from the dog's eye level. In this manner, the handler worked the dog toward known seal holes and recorded its success in finding them. In most cases the seal entered the water through its hole before the dog approached close enough to see it. The dog's success in these tests was 100%. On 2 of the most productive days of testing, the dog found 10 of 10 seal holes known to the observer through the presence of a hauled-out seal, plus an additional 18 holes.

In 1983, another young male Labrador (Charlie) was trained to serve as a back-up for Clyde and to increase the amount of territory that could be searched during a limited field season. The younger dog was worked alongside Clyde for a period of approximately 1 month, during which he learned to run a "line" in front of a snow machine, detect the scent of a seal, run to the seal structure, and indicate its location by digging directly above it. At the end of a month, Charlie had developed the necessary proficiency and confidence to act independently, and was subsequently worked alone. Periodically, our 2 dogs were worked together as a check on their performance and to intensify, through competition, their desire to find structures. In addition, some search lines were worked more than once by the same dog, or on different days by different dogs, also in order to check their efficiency at detecting structures.

B. Location and Fate of Seal Structures

Searches for subnivean ringed seal structures were made along previously established lines. Depending on year and location these lines were either trails made during the course of seismic exploration or snow machine trails made by the investigators. Dogs working singly or in pairs ran or trotted along those lines in front of a slow-moving snow machine. When the dogs detected a scent, they turned and ran upwind to its source, which they indicated by digging in the snow. The area indicated by the dog was probed with a wooden-handled aluminum rod (approximately 1 cm in diameter and marked in 10 centimeter increments to a length of 150 cm) until the lair or an open hole to the water was located. Presence of a lair was indicated either by a void under the snow or by a thin layer of ice which forms on the ceiling as a result of the warmth and breathing of the seal. This could be felt as the probe was pushed first through snow, then the thin ice layer, and finally into the open space of the lair. Depending on objectives of the field program, structures were dug open by the investigators so they could be classified and measured. In the Beaufort Sea (1982), most structures were opened at the end of the study period after 2 or more visits. During coastal and pack ice line surveys, as well as the intensive searches in grids (1983 and 1984), structures were partially opened at the time each was located. All structures that were opened were subsequently reconstructed.

Structures were classified into 3 major types: breathing holes maintained by seals but not used for hauling out of the water; simple lairs which were single-chambered cavities excavated in the snow above an enlarged breathing hole (referred to as an access hole); and complex lairs which were multi-chambered, excavated cavities. Complex lairs were further classified as pupping lairs if there was positive evidence of a pup's presence. Evidence included actual presence of a pup, the remains of a dead pup, blood or afterbirth, lanugo, pup tunnels or chambers (small excavations off the main chamber that were too small to accommodate seals larger than pups), and pup claw marks on the chamber walls.

Measurements of subnivean structures included length and width of the breathing or access hole and length, width, and height of the lairs. For those lairs with more than a single chamber, measurements were of the total length of the contiguous chambers. (In 1982 this was not the case. In that year, the largest chamber was measured, not total lair dimensions.) Snow depth to the ice surface was measured at approximately the center of the lair.

Additional notations for each structure included the extent (0% to 100%) and average height of ice deformation within a radius of 200 m; any indications that the structure had been marked (urine or feces), entered (tunnel), or a seal pup killed by arctic foxes or polar bears (Ursus maritimus); any indications of the presence of a pup; and whether the breathing hole was open, open but altered (e.g., a haul-out lair being used only as a breathing hole), or refrozen. A marker stake was placed in the snow immediately over the access hole of each active structure and over inactive structures. Distance (determined by pacing or by a hand-held range finder) and magnetic heading from the search trail to the structure were noted, and each structure was assigned a number for record-keeping purposes. In this manner it was possible to keep track of individual structures and also to measure the dogs' efficiency on multiple searches of the same survey line.

Efficiency of search effort by the dogs was mostly influenced by weather. Optimum wind velocity was about 9-27 km/hr. Other limiting factors included very rough ice, soft snow (particularly in late spring as temperatures warmed up and the snow became soft), blowing snow or falling wet snow, and the physical endurance of the dogs.

Variations in the way lines were selected and laid out, as well as differences in structure work-up, occurred in response to the particular objectives of a field season as follows.

1982--Emphasis was on determining the fate of structures before and after seismic exploratory activity. To test the effects of such activity, a trained dog was run along lines that had been laid out and cleared for purposes of seismic exploration, as well as on adjacent "control" lines laid out with snow machines. In order to minimize disturbance caused by the investigators, structures were usually not opened on the initial visit. When a new structure was indicated by the digging activity of the dog, it was probed until an open hole to the water was located. Open access or breathing holes indicated that a seal was periodically using the hole and preventing it from freezing closed, and such holes were classified as active. The small probe holes were closed with snow, lairs were marked with a stake, and no additional disturbance of the area was caused by the investigators.

When an open access or breathing hole was not located by probing, the structure was exposed by digging down to the sea ice. Usually, an abandoned lair with a frozen access or breathing hole was found. However, there were instances when an active hole was present, but could not be probed from the snow surface because it was under a shelf of upthrust ice or otherwise situated such that vertical probing did not detect it. Some structures indicated by the dog could not be confirmed because they were in ice pressure ridges or ice piles. Normally when an open hole was not found, the area was excavated until the refrozen hole was located, or until it was clear that there was probably a structure covered by ice through which we could not dig.

So far as possible, each active structure was revisited at approximately 2-week intervals, up to a maximum of 7 times. At each revisit, the access hole was probed to determine if it was still open. At the time of the last revisit, each structure that had not previously been examined was opened, its type (breathing hole, simple lair, or complex lair) confirmed, and its dimensions measured. Starting in April, some access holes to the snow surface were found. These were treated in a manner similar to subnivean structures.

A preliminary study of haul-out patterns of radio-tagged ringed seals was initiated during the 1982 field season. Based on the success of that effort a separate research project, directed by Brendan Kelly (University of Alaska, Fairbanks), was continued through 1984. Results of radio-tagging efforts have been reported separately (Kelly et al. 1986).

1983--Emphasis during this field season was on determining the types, densities, and physical characteristics of structures in different geographic areas. The field effort included 2 phases. The first phase involved search lines at 23 different locations along the Bering and Chukchi sea coasts. A helicopter was used to transport a dog, an investigator, and a snow machine to the search area. Once an area with suitable ice conditions was found, a search line was laid out by snow machine. The line was oriented perpendicular to the wind. The dog was then worked back along that line. Width of the strip effectively searched by the dog varied with wind speed. The primary dog on all coastal surveys was Clyde. Based on findings during phase one, 2 areas in Kotzebue Sound were chosen for intensive study during phase two.

In phase two, survey grids (as opposed to single lines) were established, with a basic search unit of approximately 2.6 km^2 (1 square statute mile). When a larger grid was desired, it was made up of adjacent gridded blocks. Each grid consisted of parallel search lines spaced approximately 400 m apart and connected by at least 1 perpendicular "base line." The baseline of a grid was generally along some extensive flat ice feature such as a refrozen lead or a large flat pan of ice which facilitated easy travel from one part of the grid to another. Lines were laid out with the aid of a surveyor's transit. One person measured angles with the transit and with hand signals or two-way radio gave directions to a second person on a snow machine who put in the straightest possible trail. Line lengths were measured by snow machine odometer. Length of lines was checked with the Global Navigation System of the helicopter and by periodically running the snow machines over courses of known length (e.g., air fields) on shore. Trails were marked every 400 m with brightly painted, coded surveyor's stakes. These fixed points provided the means for mapping structures in the grid, as the distance and angle to each structure, in relation to a stake, were recorded.

Two hundred meters on the windward side of the line was considered a conservative estimate of the strip width searched by a dog. Consequently, the goal was to run every grid line at least twice, once with the wind to the left of the line, and once with the wind to the right. Most lines were run additional times to check the efficiency of the dogs. If the wind conditions during the period a grid was worked precluded searching one side of some lines, intermediate lines were established at 200-m intervals. Similarly, lines perpendicular to the surveyed grid lines and connecting the marker stakes were sometimes run to ensure adequate coverage. Two dogs, Clyde and Charlie, were used in searches of the grids. Tests of their efficiency on the same lines were made throughout the study.

1984--There were 2 primary goals during the 1984 field season. The first was a continuation of the intensive efforts begun in Kotzebue Sound in 1983 to determine the kinds, densities, and physical characteristics of subnivean structures. Work was conducted within grids established on fast ice in the vicinity of Cape Lisburne. Two dogs were used to search grids. The second goal was to obtain comparative data from the offshore pack ice. Offshore searches on the pack ice were conducted in the same manner as the coastal surveys of 1983. The dog, investigator, and snow machine were transported by helicopter to areas of pack ice where there were large, unbroken pans that could be safely worked. Searches of the pack ice were primarily done by Charlie. A black Labrador retriever bitch, Lil (owned by Brendan Kelly), was used on some of the searches.

C. Aerial Surveys

Aerial surveys were flown in 1981 and 1982 in order to compare the densities of ringed seals in areas where on-ice seismic exploration had occurred with densities in adjacent control areas. In 1981, 12 survey flights were flown between 2 and 9 June in a turbine-engine Grumman Goose. In 1982, 11 flights were flown between 25 May and 4 June using a Bell 204 helicopter. Both aircraft were equipped with GNS-500 Global Navigation Systems. Survey altitude was 91 m at an average speed of 240 km/hr in 1981 and 152 m at 120-170 km/hr in 1982. Most surveys were flown between 1000 and 1600 hours local time, the period at this time of year when maximum number of seals haul out. In addition to the pilot and co-pilot, the survey crew consisted of 2 experienced observers (1 left and 1 right) and a navigator. Except for the first 2 flights on 2 June 1981, the same observers occupied the same sides of the aircraft throughout the surveys.

For each minute of flight time, all seals visible within 0.9 km of each side of the aircraft were recorded as within either the inner or outer half of the track. Thus, seal numbers were recorded for 4, 0.45-km-wide tracks. Boundaries of the strips were maintained through use of inclinometers. When discernible, it was noted whether a seal was situated next to a natural crack or next to a hole in the ice made by the seal. During analysis of the data it became apparent that densities for the outer tracks were substantially and consistently lower than those for the inner tracks. Consequently, further density calculations and comparisons were based on the inner tracks only.

One observer recorded ice conditions for each minute of flight. The ice records included type (shorefast or pack), coverage in oktas, and percent deformity of the surface. Hourly weather reports from Lonely, Oliktok, Deadhorse, and Barter Island were obtained from FAA Flight Service.

On 2 June 1981, surveys were flown parallel to the coastline from Prudhoe Bay to Cape Halkett and from Prudhoe Bay to Barter Island. Survey flights on 3, 5, and 9 June were directly over seismic shot lines and parallel to and midway between those lines. Survey lines between adjacent seismic lines were designated as "controls." An area of numerous, closely spaced seismic lines east of Prudhoe Bay and an adjacent undisturbed area were surveyed on 4 June. On that date, the survey lines extended northward approximately 37 km from shore and were spaced 5.6 km apart. On both 7 and 8 June, surveys covered the area from Smith Bay to Camden Bay. North-south lines approximately 28 km long and 22 km apart were surveyed, as well as the connecting east-west lines. The north-south lines were offset approximately 11 km between 7 and 8 June such that, in total, the surveys from the 2 days covered the study area with lines spaced 11 km apart. A survey flight on 6 June was aborted due to inadequate visibility.

Three types of transect lines were surveyed in 1982: (1) those along seismic trails or access roads; (2) those between or away from lines or ice roads; and (3) duplicates of transects flown in June 1981. The latter transects were surveyed to provide a comparison of overall relative abundance of seals between 1981 and 1982.

In 1984, we planned to survey seals in areas where on-ice studies of seal structures had been conducted. However, because of an unusually cold spring, seals did not begin to haul out on the ice as early in May as they usually do, and thus could not be satisfactorily surveyed then. By mid-May when the weather was more conducive to hauling out, a shortage of helicopter fuel at Cape Lisburne in combination with other scheduled use for the aircraft precluded survey flights in areas where study grids were previously established and searched. A fixed-wing survey was flown instead along the coast from Kotzebue to Cape Thompson on 16 May. The survey aircraft was a Cessna 185 flown at a 152 m altitude with a transect strip of 0.9 km on either side of the plane. Survey coverage was approximately 943 km². Results of this survey were incorporated in another OCSEAP study being undertaken by the same principal investigators entitled "Ringed Seal Monitoring: Relationships of Distribution, Abundance, and Reproductive Success to Habitat Attributes and Industrial Activities" (Frost et al. 1985, 1987, 1988).

D. Collection of Seals

In 1984, we collected ringed seals in 2 broad geographic areas: Norton Sound near Nome, and the eastern Chukchi Sea near Cape Lisburne. Within each geographic area seals were taken primarily from the nearshore lead systems adjacent to the fast ice, and from the more distant (seaward) pack ice. Specimens from the fast ice were also desired but opportunity to obtain them was very limited in 1984. The actual locations where seals were collected in 1984 were determined by the availability of seals and ice conditions. Suitable ice conditions were those where ice floes were thick enough on which to land a helicopter and where seals could surface in small leads or other openings in the ice cover.

A Bell 204 helicopter was used to fly over leads and look for seals and seal holes in thin ice. When seals or evidence of seals were detected, the helicopter landed and the engine was usually shut down. As seals appeared they were shot, retrieved with the aid of the helicopter, and tagged. The date, time, and location (from GNS-500) of the collection were recorded. Seals were transported to laboratory facilities at Nome or Cape Lisburne for examination and necropsy.

A series of standard weights and measurements was taken from each seal. A sample of approximately 30 ml of blood was taken from the extradural vein. The blood sample was allowed to clot, and was then centrifuged and the serum removed, labeled, and frozen. The exterior of the seal was examined for wounds, scars, and external parasites. The body cavity was opened and all organs removed. The skull, 2 claws from a foreflipper, and the reproductive organs were also removed, labeled, and frozen. Two sets of samples of approximately 100 g of tissue were taken from the liver, kidney, blubber, skeletal muscle, and heart. One set was wrapped in foil and the other put in whirl-packs. Both were labeled and frozen. Stomachs were slit open and the contents were put in plastic bags, labeled, and frozen. All organs were examined for parasites (by Ann Adams, University of Washington, Seattle, WA) and samples of parasites and affected tissues were preserved.

Specimens were shipped frozen to the ADF&G laboratory in Fairbanks. In the laboratory, stomach contents were sorted, identified, and quantified. Claws were soaked in water and the number of annual rings on them was counted. A canine tooth was removed from the lower jaw, thin-sectioned in a cryostat, stained, and mounted on a slide. Ages were determined from counts of annuli in dentine. Tissue samples were sent to Mr. Robin West (U.S. Fish and Wildlife Service, Anchorage, AK) and to Dr. James Clayton (Department of Fisheries and Oceans, Winnipeg, Manitoba, Canada). Serum samples were provided to Dr. Clayton and to Dr. R. L. Rausch (University of Washington, Seattle). Subsamples of sera were also archived at ADF&G, Fairbanks. Parasites were retained and examined by Ms. Ann Adams (Adams 1986, 1987).

VI. Results

A. Aerial Surveys in Beaufort Sea Seismic Exploration Areas, 1981 and 1982

In 1981 a total of 5,334 km of survey lines was flown, including 480 km along seismic lines and 333 km along adjacent control transects (Figure 2). The remaining flights were generally north-south or east-west legs flown to determine regional densities of seals. Those results were incorporated into the 1985 interim report by ADF&G for the NOAA/MMS-funded project (RU #667) entitled "Ringed seal monitoring: Relationships of distribution, abundance, and reproductive success to habitat attributes and industrial activities" (Frost et al. 1985, 1987, 1988).

The 1981 surveys were complicated by early and rapid deterioration of shorefast ice. Surveys were terminated on 9 June due to unfavorable conditions (breakup, surface water, snow melt, and the presence of open water near shore and around the barrier islands). As the survey period progressed, more extensive cracks in the fast ice cover appeared, more seals moved in along those cracks (or redistributed themselves from other areas), and consequently a progressively higher proportion of seals was encountered along cracks (Table 2). Based on our previous experiences, the conditions which existed by 9 June 1981 were not normally encountered until after 15 June.

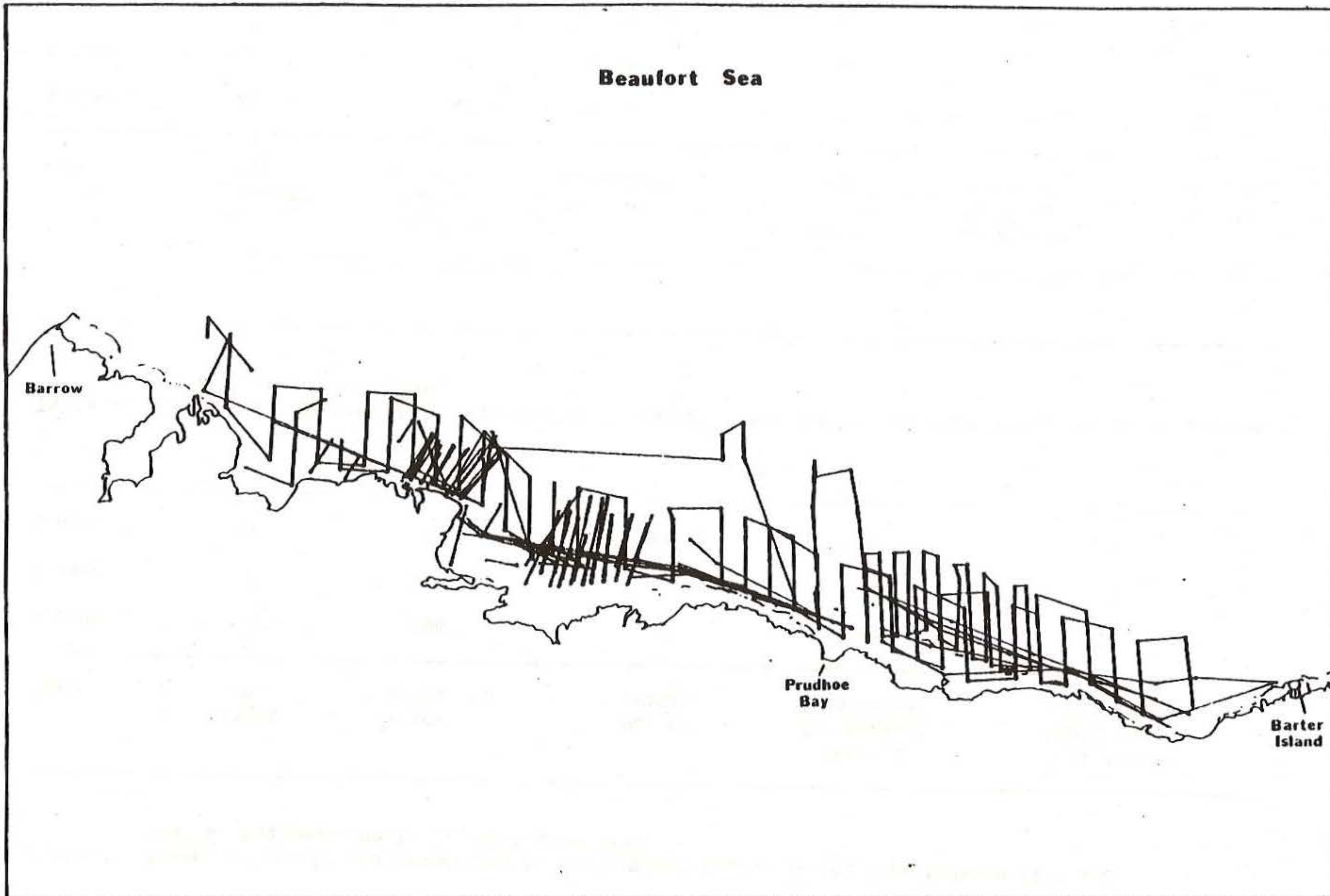

Beaufort Sea
Barrow
Prudhoe Bay
Barter Island

Table 2. Number of cracks and proportion of seals along cracks in the area between 145° and 148° W longitude, on 4, 7, and 8 June 1981.

Date	Flight no.	Track miles (km)	No. of cracks	Density for surveys (seals/km²)	% of total seals seen along cracks
4 June	5	506	8	0.43	14
7 June	8	459	19	0.60	16
8 June	11	493	21	0.37	23

Table 3. Comparisons of ringed seal density on "seismic" lines and on "control" lines, based on surveys of 3, 5, and 9 June 1981.

	Seismic transects			Control transects		
Date	No. of transect legs	Length of combined tracks (km)	Density (seals/km²)	No. of transect legs	Length of combined tracks (km)	Density (seals/km²)
3 June	5	88	0.24	4	76	0.41
5 June	6	151	0.40	4	89	0.50
9 June	10	241	0.33	6	169	0.26

Results of the earliest surveys, those up to 5 June, were considered to be more representative of normal late spring conditions than were subsequent surveys.

Specific surveys to test the difference in abundance of ringed seals along seismic lines and in the less "disturbed" areas between seismic lines were made on 3, 5, and 9 June. Ice roads or trails were highly visible from the survey aircraft and, whenever encountered, were used as the centerline of strip transects referred to as "seismics." It was not possible to distinguish which roads or trails were transport corridors and which were actual shot lines, but in all cases the trails had been used as routes traversed by heavy equipment utilized in seismic exploration. With the aid of the Global Navigation System "control" lines parallel to and midway between the seismic lines were also surveyed.

Results of these surveys (Table 3) showed a statistically significant difference in seal density between seismic and control transects flown on 3 June ($x^2 = 7.01$, df = 1, $p < 0.01$). The density of seals on seismic lines was 58% of that on control transects. On 5 June, the density of seals on seismic lines was slightly but not significantly less than on control transects ($x^2 = 2.21$, df = 1, $p > 0.05$). On 9 June, the density of seals was higher on seismic lines than on control lines, but the difference was not statistically significant ($x^2 = 2.45$, df = 1, $p > 0.05$).

Comparisons were also made between blocks of area within which seismic exploration occurred and adjacent non-disturbed control areas (Table 4). Densities of seals were similar in seismic and control blocks.

The relationship between ringed seal density and ice deformation was examined (Table 5). Densities of seals on ice with less than 40% deformation ($0.5/km^2$) were almost double the densities ($0.3/km^2$) on ice with greater than 40% deformation.

All survey flights in 1982 were flown with a Bell 204 helicopter. This was unlike previous years in which fixed-wing aircraft were used. The helicopter proved to be very satisfactory, having the advantages of slow flying speed (120 to 170 km/hr) and excellent forward and lateral visibility. Basking seals did not seem especially bothered by the turbine-engine, rotor-wing aircraft and seals usually stayed on the ice during the survey period unless the helicopter passed very close to them. This was in contrast to the response of seals in early May when temperatures were cooler and the molt period was just beginning. In early May it was difficult to land within 1000 m of a basking seal without it fleeing, but during the survey periods it was possible to land within 200 to 300 m. These seasonal differences in tolerance may be due to behavioral changes associated with the molt. Also there may have been some modification of the noise from the helicopter resulting from a combination of warmer temperatures and low cloud cover which prevailed during the survey period.

Survey flights were made on 25, 26, 29, 30, and 31 May and 1, 3, and 4 June. The total length of all transects combined was 2,006 km. This included 409 km along a transect which replicated one flown in 1981 (Figure 3), 752 km along seismic lines, and 706 km along control transects (Figure 4). An additional 3 legs of one flight were over drifting ice for a total distance of

Table 4. Comparison of ringed seal densities in blocks within which seismic exploration was and was not conducted. Nonseismic blocks are designated as controls.

Block	Date	Number legs	Number miles (km²)	Seals/km²
Control A	7-8 June	8	361	0.49
Seismic A	7-8 June	5	256	0.48
Control B	7-8 June	5	250	0.45
Seismic B	7-8 June	7	326	0.46

Table 5. Distribution of ringed seals in relation to deformation of fast ice in the study area, based on 1981 surveys.

Percent ice deformation	Length of tracks (km)	Percent of transect area of designated deformation	Number of seals seen within inner strip	Density (seals/km²)
0-10	2,011	37	822	0.41
> 10-20	1,641	31	759	0.46
> 20-30	406	8	193	0.48
> 30-40	246	5	83	0.34
> 40-50	146	3	45	0.31
> 50-60	224	4	50	0.22
> 60-70	332	6	73	0.22
> 70-80	178	3	37	0.21
> 80	150	3	34 (55)[1]	0.23 (0.37)[1]
Totals	5,334	100	2,096	0.39

[1] Highly deformed ice (>80%) was limited in extent and occurred next to the flaw lead. Values in parentheses represent observed number of seals and the resulting density in this ice deformation category. They are considered anomalous because of a single sighting of 22 seals along a crack extending to the lead. This crack was a corridor along which seals from the lead could penetrate the adjacent fast ice. The actual trend of seal density in relation to deformation is more clearly obvious by either disregarding areas of 80% or more deformation, or by adjusting the observed number of seals to represent the single sighting of 22 seals as a sighting of 1. Values not in parentheses represent the latter adjustment.

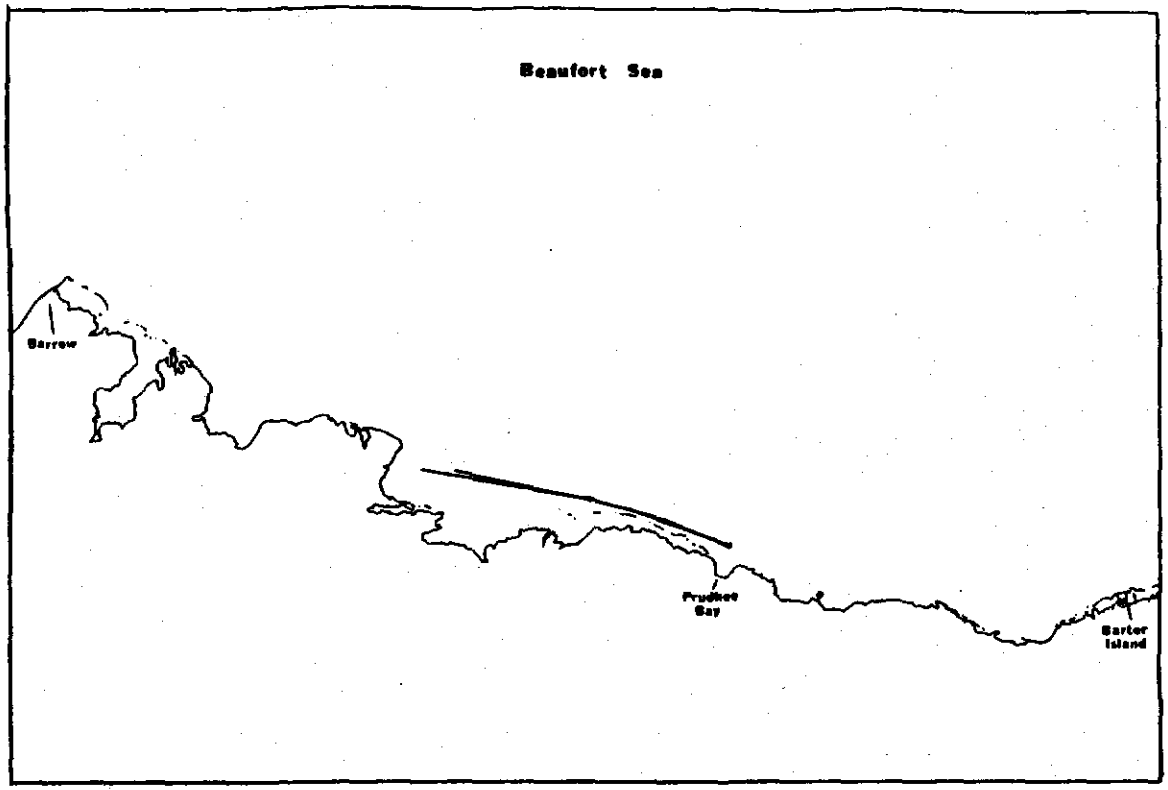


Figure 3. Location of the 1981-82 replicate line flown for purposes of comparing seal densities in both years.

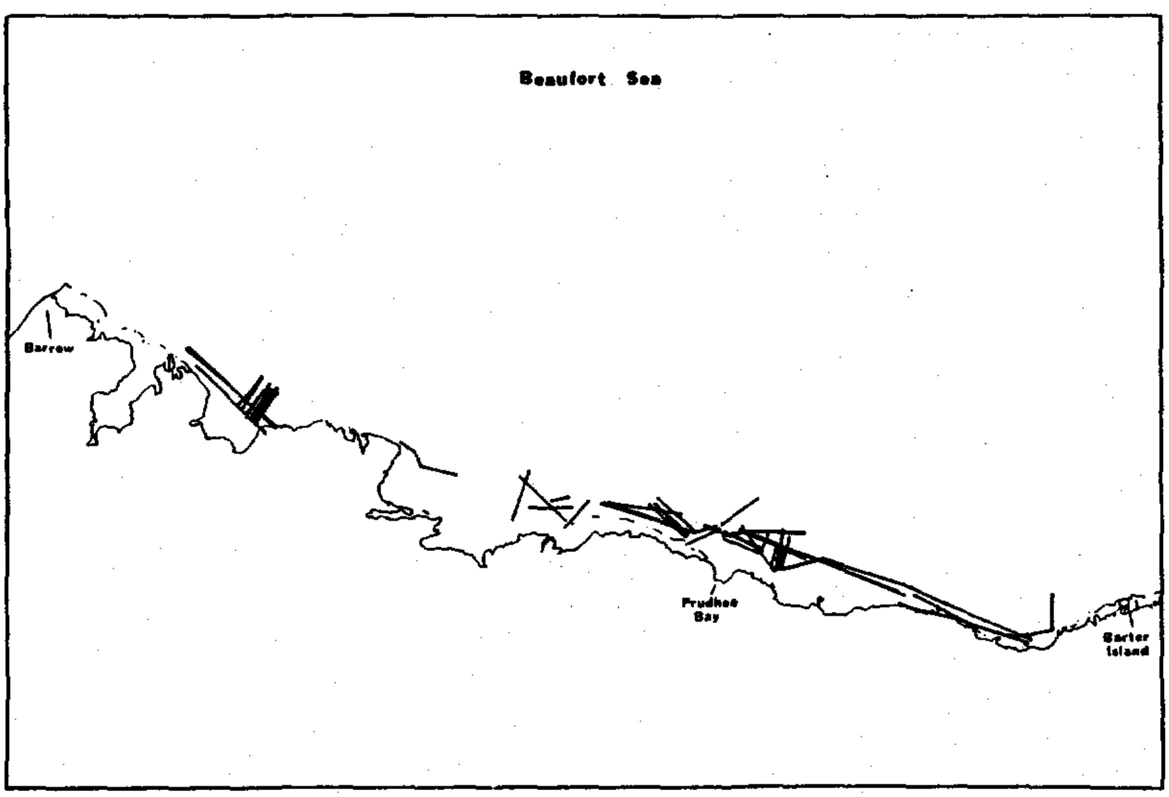


Figure 4. Map of the Beaufort Sea coast showing location of all seismic and control aerial survey transects flown in May-June 1982.

137 km. The 1981-82 replicate transect was over a course having the following waypoints: (1) 70°25.7'N, 148°15.1'W; (2) 70°34.4'N, 149°24.5'W; (3) 70°37.2'N, 149°55.2'W; and (4) 70°43.8'N, 151°56.1'W. Total length of this line was 141 km.

Replicate flights along the reference transects indicated a mean density (all legs combined) of 0.54 ringed seals/km^2 in 1982 (Table 6), compared to a mean density in 1981 of 0.37 seals/km^2 in a combined total of 702 km of transects. The higher density observed in 1982 was not significantly different than that recorded in 1981 ($t = 1.029$, $df = 32$, $p > 0.05$).

For a single flight, comparisons of seismic and control transects are valid since both types of transects were adjacent to each other and were usually flown as alternating legs which were temporally and spatially close and affected by the same weather conditions. Such similarities did not necessarily prevail among days or between 2 flights in a single day. Comparison of densities of seals on seismic and control lines for individual flights during which both types of transects were flown indicated a significant difference in only 1 instance (Table 7). On 26 May, the density of seals was greater on seismic lines (0.29 seals/km^2) than on control lines (0.14 seals/km^2). Based on a comparison of the pooled results for all seismic and control transects flown in 1982, the results were not significantly different ($t = 1.029$, $df = 32$, $p > 0.05$).

On transect legs flown over drifting ice in the region between Flaxman Island and Barter Island on 29 May the observed density of ringed seals was 0.11/km^2. This was considerably lower than the density observed on most transects over the fast ice.

The relationship between seal density and extent of deformation of fast ice in 1982 is presented in Table 8. As in 1981, the highest densities of basking seals occurred in areas where deformation was less than 40%.

B. Seal Structures in Beaufort Sea Seismic Exploration Areas, 1982

Seal structures were located by searching with a dog along 267 km of seismic and control lines (Figure 5) and along approximately 28 km of non-systematic search lines. In total, 157 structures were found: 105 along seismic trails, 36 along control lines, and 16 during non-systematic searches. It was possible to determine the type of structure in 148 cases. This sample included 70 breathing holes (47% of all identified structures), 62 simple lairs (42%), 5 complex lairs (3%), and 11 pupping lairs (7%). Two access holes to the snow surface were found and are included as breathing holes. Few of these were found because our sampling effort was terminated prior to the beginning of the main molt period, when seals haul out in large numbers.

Of the 78 lairs examined, 62 were single-chambered simple lairs (79% of all lairs), and 16 were multi-chambered (21%). (Note: complex lairs as defined in this report are not to be confused with "lair complexes" as used by Smith and Stirling (1975). The latter refers to a group of several lairs in close proximity to one another.) Eleven of the complex lairs were confirmed pupping lairs. Therefore pupping lairs made up a minimum of 7% of all structures examined, or 14% of all lairs.

Table 6. Results of aerial surveys of ringed seals along replicate reference transects, 1981 and 1982.

Date	Number of legs	Transect length (km)	Density (seals/km^2)
2 June 1981	2	100	0.59
3 June 1981	10	239	0.35
4 June 1981	1	71	0.44
7 June 1981	5	144	0.34
9 June 1981	4	149	0.25
Combined 1981	22	703	0.37
25 May 1982	2	65	0.58
26 May 1982	2	150	0.20
1 June 1982	4	129	0.69
3 June 1982	3	65	0.96
Combined 1982	11	410	0.54

Table 7. Densities and statistical comparisons of ringed seal abundance along adjacent seismic and control transects surveyed in 1982.

Date and flight	Seismic transects: number of legs	Seismic transects: transect length (km)	Seismic transects: $\bar{x}$ density (seals/km^2)	Seismic transects: s.d.	Control transects: number of legs	Control transects: transect length (km)	Control transects: $\bar{x}$ density (seals/km^2)	Control transects: s.d.	Student's t test
26 May, Flt. 1	7	155	0.29	0.12	8	132	0.14	0.14	$t = 2.238$, df = 13, $p < 0.05$
29 May, Flt. 1	4	91	0.12	0.14	4	97	0.22	0.22	$t = 0.774$, df = 6, $p > 0.1$
30 May, Flt. 1	9	102	0.40	0.43	2	31	0.14	0.29	$t = 1.051$, df = 9, $p > 0.1$
31 May, Flt. 1	2	29	0.37	0.40	3	55	0.38	0.25	$t = 0.0183$, df = 3, $p > 0.1$
Flt. 2	2	26	0.34	0.29	2	26	0.41	0.03	$t = 0.348$, df = 2, $p > 0.1$
1 June, Flt. 2	5	94	0.57	0.10	5	104	0.58	0.24	$t = 0.511$, df = 8, $p > 0.1$
3 June, Flt. 1	4	75	0.47	0.35	6	192	0.62	0.50	$t = 0.563$, df = 8, $p > 0.1$
4 June, Flt. 1	4	70	0.49	0.33	1	22	0.49	0	$t = 0.00$, df = 3, $p > 0.1$

Table 8. Distribution of ringed seals in relation to deformation of fast ice in the study area, based on 1982 aerial surveys.

Percent ice deformation	Length of tracks (km)	Percent of transect area of designated deformation	Number of seals seen within inner strip	Density (seals/km^2)
0-10	935	50	423	0.45
> 10-20	276	20	211	0.56
> 20-30	239	13	88	0.37
> 30-40	143	8	40	0.28
> 40-50	59	3	11	0.19
> 50-60	91	5	21	0.23
> 60-70	20	1	5	0.25
> 70-80	6	<1	0	0
> 80	0	0	0	-
Totals	1,869	100	799	0.43

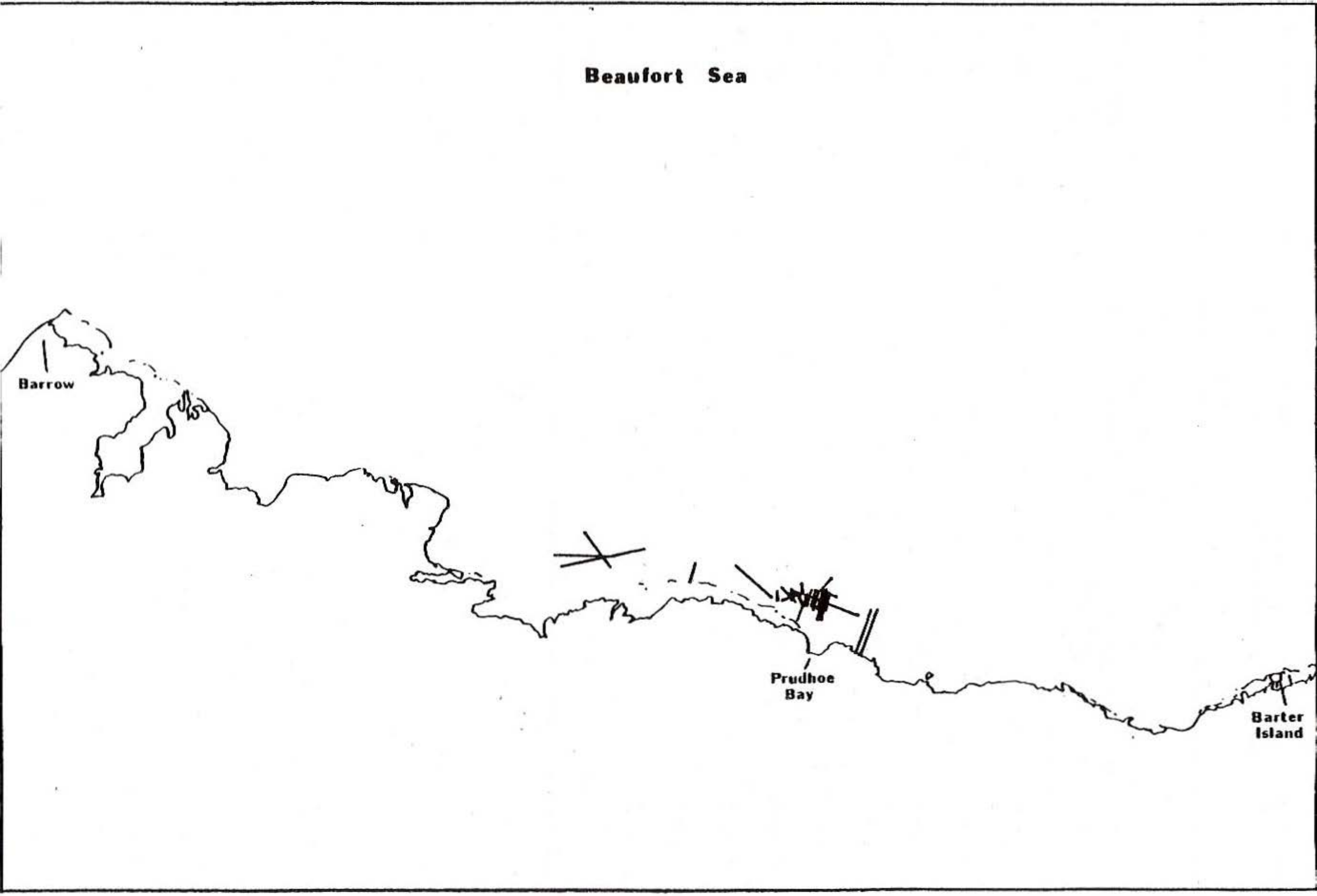


Figure 5. Map of the Beaufort Sea showing geographical location of seismic and control lines searched with the dog in 1982.

The dog was very consistent in his ability to locate subnivean seal structures. In all instances that he indicated the presence of a seal odor, we found a structure or at least were able to detect the seal odor ourselves. The dog found 2 at greater than 1500 m from search lines. The relationship between the number of structures found and distance from the search line appeared constant out to at least 50 m from the line. Unbiased searches for structures at varying distance from search lines were not a requisite of this phase of the study; the location of a large total sample of structures was.

Lairs occurred in the physical settings described by Smith and Stirling (1975) and Smith (1976): in snow drifts which form around ice hummocks, and along pressure ridges. Extent of surface deformation in which structures were situated varied from 0% (flat ice) to 75% for breathing holes and 4% to 75% for lairs. The mean ice deformation for breathing holes and all types of lairs was 26% to 28%. We did not record differences in height of deformed ice features. Our search pattern was largely dictated by the layout of seismic lines, which were ultimately limited by rough ice. Thus, our search effort was not necessarily equally distributed with respect to ice deformation. The depth of snow and dimensions of each type of structure found in the Beaufort Sea in 1982 are presented in Table 9.

We revisited structures at intervals to determine their fates. Abandonment of breathing holes and access holes into lairs was considered to have occurred if the holes became completely closed by freezing. Revisits were made to 11 structures 1 to 5 weeks after it was found that the breathing or access hole was completely frozen. In all instances the holes remained frozen. Access holes were considered altered if they froze to a smaller diameter which precluded a seal from passing through, but which still permitted access to air. In some instances the access hole was maintained unfrozen but the lair was altered when ice built up on the roof to a thickness which did not permit a seal to pass into the chamber. Of 12 structures that developed altered holes, 5 remained partially frozen (revisits 2-5 weeks after initial alteration), and 7 became completely frozen (revisits after 1-6 weeks). The fates of 4 lairs which were altered but had open access holes when found were: 1 access hole frozen within 1 week; 1 access hole partially frozen within 4 weeks; and 2 altered lairs cleared and reused for hauling out (one within 3 weeks, and one within 4 weeks).

The fates of 96 structures, active and unaltered when first found, were examined in a three-way analysis (Sokal and Rohlf 1969) that included: (1) fate of the structure; (2) the observer that found the structure; and (3) the method of initial verification of the structure (probed or partially dug into). There was no significant difference in the number of structures opened by each investigator ($G = 1.038$, $df = 2$, $p > 0.5$), nor in the fate of structures in relation to which investigators found and initially identified them ($G = 2.010$, $df = 4$, $p > 0.5$).

Approximately two thirds of the structures we located were revisited 1-5 weeks later. We compared the fates of structures that were dug into on the initial visit to those that were only probed. Based on all structures that had open breathing holes on the first visit (this includes both open and altered categories), there was no difference in the abandonment of structures that were dug into and those that were only probed (Table 10). Eighty-seven percent of all structures visited for a second time, whether dug into or

Table 9. Measurements (cm) of seal-made structures, including breathing holes, lairs, and access holes to the snow surface based on data from the Beaufort Sea, spring 1982.

		Type of structure				
Parameter	Statistic	breathing holes	simple lairs	complex lairs	pupping lairs	access holes to snow surface
Snow depth at structure	MEAN	38.4	77.2	90.8	93.0	19.5
	RANGE	0 - 116	29 - >150	70 - 123	66 - 119	15 - 24
	S.D.	20.7	26.8	22.4	17.4	6.4
	N	64	61	5	11	2
Diameter of hole	MEAN	34.9	42.6	42.0	65.0	49.5
	RANGE	10 - 62	18 - 66	41 - 43	29 - 118	39 - 60
	S.D.	12.8	11.5	1.2	32.2	14.8
	N	47	32	6	4	2
Length of lair	MEAN		165.2	268.0	245.0	
	RANGE		78 - 467	160 - 389	145 - 455	
	S.D.		66.7	90.4	81.4	
	N	-	53	5	10	-
Width of lair	MEAN		98.0	94.4	154.6	
	RANGE		52 - 165	76 - 115	84 - 250	
	S.D.		25.1	17.9	57.4	
	N	-	53	5	10	-
Greatest height of lair	MEAN		35.3	37.4	33.1	
	RANGE		12 - 55	24 - 64	25 - 53	
	S.D.		9.1	16.6	7.8	
	N	-	54	5	10	-

Table 10. Fate of seal structures in relation to initial method of examination. For 2nd and 3rd visits, only structures that were open on the previous visit are included. Open category includes structures that were completely open and those that were altered, since the two could not reliably be distinguished by probing.

Examination method (previous visit)	Sample size	Number of structures (%)	
		Open	Frozen
1st Visit	148	129 (87)	19 (13)
2nd Visit			
Dug into	46	40 (87)	6 (13)
Probed	56	49 (87)	7 (13)
All	102	89 (87)	13 (13)
3rd Visit			
Dug into	10	9 (90)	1 (10)
Probed	62	58 (93)	4 (7)
All	72	67 (93)	5 (7)

probed, remained open (x^2 = 0.007, df = 1, p > 0.9). We also compared the effect of digging into versus probing for structures that were visited a third time (Table 10). As in the previous comparison, there was no significant difference in the rate of abandonment, based on method of examination, between second and third visits (x^2 = 0.168, df = 1, p > 0.5).

Comparisons were also made of the incidence of abandonment of structures located along seismic and control lines, and relative to distance from lines. We found no significant differences in the abandonment of structures located on seismic or control lines (x^2 = 0.025, df = 1, p > 0.75), or in relation to distance from seismic or control lines (Table 11). For structures along seismic lines, 84% of those within 150 m and 95% of those beyond that distance were open (x^2 = 3.457, df = 1, p > 0.05). Along control lines these values were 86% and 91% (x^2 = 0.210, df = 1, p > 0.10). These comparisons were based on data from the first time a structure was located, before observer disturbance (if it occurred) might affect the results.

For structures found along seismic lines, we examined whether there was a relationship between fate of the structure and the time when the seismic line was worked by vibroseis equipment (i.e., vibrated). Sample groups included: (1) structures initially located after lines were laid out and cleared, but before they were vibrated; (2) those initially located within 1 week after vibration; and (3) those found 1 to 2 weeks after vibration (Table 12). There were no significant differences in fates among the 3 samples (x^2 = 4.075, df = 2, p > 0.1).

The other major source of disturbance within the study area was the construction of Seal Island, an artificial gravel island located approximately 18 km northwest of Prudhoe Bay (70° 29.5 N 148° 41.6 W). Flooding and thickening of the ice road occurred prior to February 21, 1982. Island construction began about February 23 and continued until April 8. (P. Woodson, Shell Oil Company, personal communication).

We compared the abandonment rate for 42 structures located within 10 km of Seal Island, including those found along control lines and others found during random searches. The abandonment rate within 2 km of Seal Island was found to be significantly greater than it was 2-10 km away. Within 2 km of Seal Island, 3 of 5 structures (60%) were abandoned, compared to 5 of 37 (14%) beyond 2 km (x^2 = 6.173, p > 0.025).

Arctic foxes were present in relatively low numbers on the fast ice throughout the period of our field work. In early April there was a noticeable increase in the number of fox tracks seen, indicating that more foxes were either moving closer to shore from the drifting ice or onto the fast ice from land. Our first definite evidence of the birth of a seal pup was found on 4 April. It was the remains of a pup contained in fox feces. We found the first live pup in a lair on 7 April. Remains of fox-killed pups were found near lairs on 10 and 26 April and 19 May, the latter being remains of an old kill exposed by melting snow.

Of the 78 lairs we examined, 6 pupping or complex lairs and 8 simple lairs were entered by foxes. Thus, 18% of all lairs had been entered by foxes by the time they were checked for the last time. This underestimates disturbance by foxes as there was ample time for structures to be opened by

Table 11. Fate of 132 seal structures in relation to distance from seismic and control search lines, based on first visits to structures.

Type of search line	Distance of structures from lines (m)	Sample size	Number of structures (%)	
			Open (Includes Altered)	Abandoned (Frozen)
Seismic	≤ 150	55	46 (84)	9 (16)
	> 150	44	42 (95)	2 (5)
Control	≤ 150	22	19 (86)	3 (14)
	> 150	11	10 (91)	1 (9)
All	≤ 150	77	65 (84)	12 (16)
	> 150	55	52 (94)	3 (6)

Table 12. Fates of seal structures in relation to distance from seismic lines and timing of seismic exploratory activity. Data are for first visits only.

Time found in relation to time line was vibrated[1]	Distance from seismic line (m)	Number of structures		
		Total	Open (Includes altered)	Abandoned (frozen)
Before line vibrated	≤ 150	16	14	2
	> 150	6	5	1
Within 1 week after vibration	≤ 150	13	13	0
	> 150	13	13	0
1-2 weeks after vibration	≤ 150	1	1	0
	> 150	5	4	1

[1] Refers to lines searched after being surveyed and cleared but prior to use of vibroseis equipment, and lines searched within indicated time periods after operations of vibroseis equipment.

foxes subsequent to our final visits. Considering lairs opened by foxes as well as all structures simply marked (feces and/or urine present), 33% of all structures had been visited by foxes.

C. Regional Survey of Abundance and Types of Seal Structures, 1983

An extensive survey of fast ice in the broad region between southern Norton Sound and Peard Bay was made from 22 February to 15 March 1983. This preliminary survey was undertaken to determine if there were regional differences in the types and relative abundance of subnivean structures and to locate an area suitable for more intensive investigation. This effort was begun in Norton Sound and progressed northward in order to take advantage of increasing daylight and seasonally moderating temperatures. Logistic bases of operation were Unalakleet, Nome, Kotzebue, Cape Lisburne, and Barrow.

A total of 119 structures were found along 23 different lines that, in aggregate, made up about 82 km (Table 13, Figure 6). The exact length of line 4 could not be determined due to failure of navigation equipment, and line 21 was found to be on ice that was mostly grounded. Those lines were excluded from our analysis, except for description of the types and settings of structures found. Along the remaining 22 search lines, totalling 77 km, the dogs found 115 structures, an average of 1.5 per linear kilometer (range = 0.7 to 2.8/km). The highest relative densities of structures occurred in eastern Norton Sound (predominantly breathing holes) and near Peard Bay (predominantly lairs).

Of the 119 structures, 4 (3%) were in ice ridges and could not be excavated and classified by type. Of the remaining 115, 40 (35%) were lairs and 75 (65%) were breathing holes. There were major regional differences in the types of structures found (Table 14). In Norton Sound, lairs composed only 22% of all identified structures, compared to 54% along the northwestern Seward Peninsula and in southern Kotzebue Sound, 15% in northern Kotzebue Sound, and 58% in the northeastern Chukchi Sea.

The 2 regions with small proportions of lairs were characterized by relatively flat (less than 10% deformed) ice that was largely blown bare of snow. In Norton Sound, this condition was the result of newly formed ice that had not been subjected to ridging or extensive snow accumulation by the time of our surveys. In northern Kotzebue Sound the ice had remained relatively flat with little snow accumulation, even though it had been in place since freeze-up, which occurred in late October.

Of the 115 identified structures, only 4 had been abandoned or altered. All abandoned structures were lairs. There were no indications, either from sign inside lairs, or by the presence of lanugo (white hair from newborn pups) in fox scats, that ringed seal pups were born prior to termination of this survey on 15 March. We did not find any indications of successful predation on ringed seals by either arctic foxes or polar bears in the areas of fast ice we surveyed. Based on the findings of this extensive coastal survey, a site suitable for intensive study was selected in southern Kotzebue Sound, in the vicinity of line number 19.

Table 13. Results of searches for ringed seal structures on landfast ice between southern Norton Sound and Peard Bay, 22 February to 15 March 1983.

Date	Line no.	Location	Length of search line (km)	Number of structures	Structures/ linear km	Percent lairs
Feb. 24	1	Isaacs Point	3.5	8	2.3	62
25	2	Egg Island	4.8	9	1.9	11
25	3	Stewart Island	2.6	7	2.7	0
26	4	Norton Bay		2	-	50
27	5	Sledge Island	3.5	8	2.3	25
28	6	Cape Nome	2.3	4	1.8	0
Mar. 1	7	Bluff	1.8	5	2.8	20
2	8	Port Clarence	5.0	4	0.8	0
3	9	Ikpek	4.0	5	1.2	0
3	10	Ikpek	1.3	1	0.8	100
4	11	Shishmaref	6.3	9	1.4	66
7	12	Kotzebue Sound	1.8	2	1.1	0
7	13	Kotzebue Sound	1.6	2	1.2	50
7	14	Kotzebue Sound	1.6	2	1.2	50
8	15	Chamisso Island	4.0	6	1.5	50
9	16	Cape Espenberg	1.8	2	1.1	0
9	17	E. Kotzebue Sound	8.2	6	0.7	17
9	18	E. Kotzebue Sound	6.8	6	0.9	0
10	19	Deering	5.0	10	2.0	70
10	20	Choris Peninsula	4.3	7	1.6	43
11	21	Kotzebue	5.6	2	*	0
13	22	Cape Lisburne	2.6	3	1.2	33
15	23	Peard Bay	3.7	9	2.4	66

* Search line was found to be on extensively grounded ice.

Table 14. Regional differences in kinds of ringed seal structures found on landfast ice from Norton Sound to Peard Bay, 22 February to 15 March 1983.

Region	Line ID numbers[1]	Number of structures	Proportion of lairs[2] N	Proportion of lairs[2] %	Length of lines (km)[3]	Structures/ km searched[3]
E. Norton Sound	1-4	26	7	27	10.9	2.2
N. Norton Sound	5-8	21	3	16	12.6	1.7
NW. Seward Peninsula	9-11	15	7	50	11.6	1.3
S. Kotzebue Sound	15, 19-20	23	13	57	13.3	1.7
N. Kotzebue Sound	12-14, 16-18, 21	22	3	15	21.8	0.9
Cape Lisburne	22	3	1	33	2.6	1.2
Peard Bay	23	9	6	67	3.7	2.4

[1] Line numbers correspond to those indicated in Table 13 and Figure 6.
[2] Does not include 4 unidentified structures.
[3] Does not include lines 4 and 21.

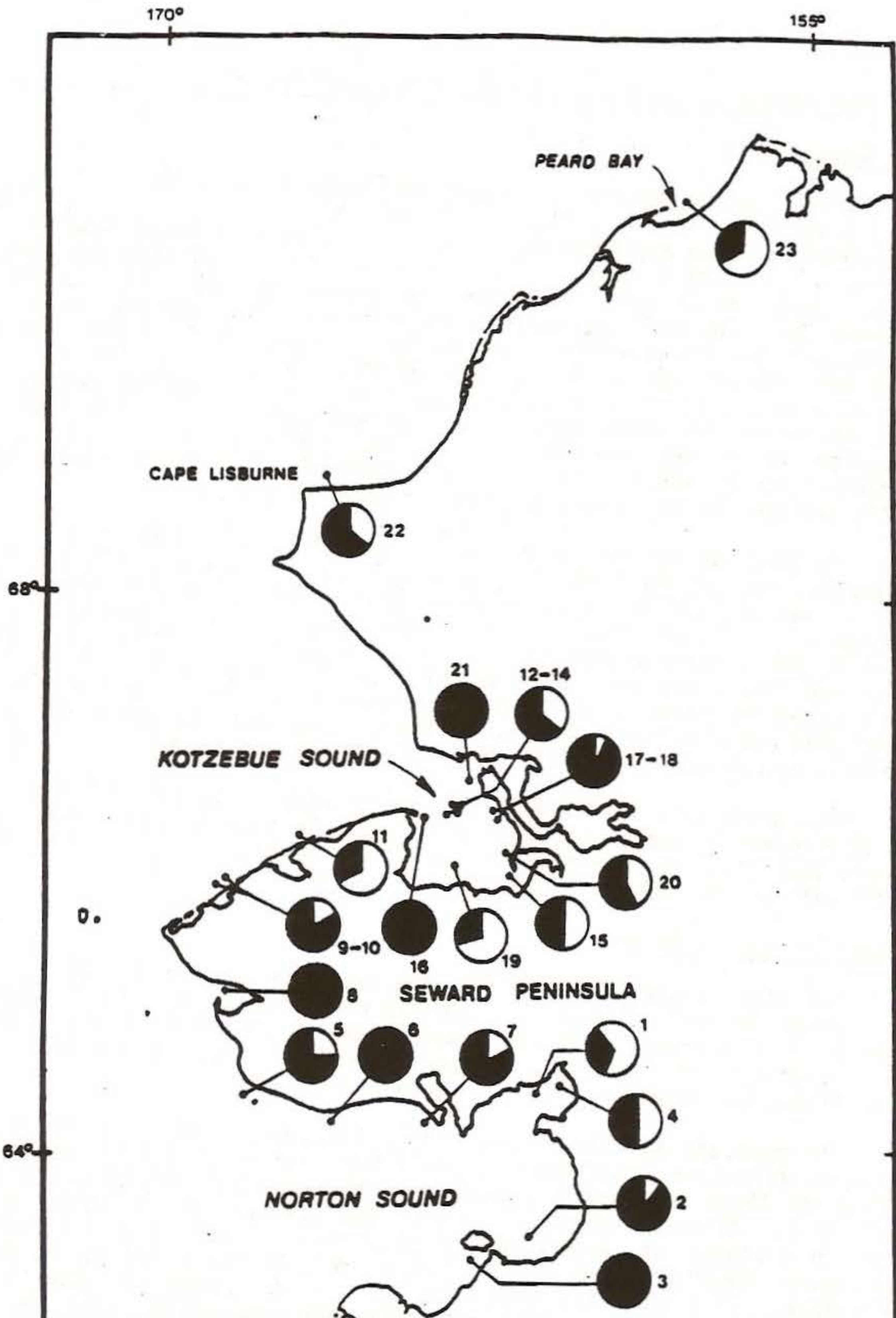


Figure 6. Locations of 22 search lines on landfast ice in western Alaska, 22 February - 15 March 1983. Small dots indicate starting positions of each line. Pie diagrams indicate proportions of lairs (unshaded) and breathing holes (shaded) found along each line. Numbers indicate the designation of lines represented by each circle and correspond to those in Table 13.

D. Seal Structure Studies - Kotzebue Sound Fast Ice, 1983

Grid Descriptions

In 1983, we established 2 rectangular-shaped study grids on the fast ice of southeastern Kotzebue Sound (Table 15). Grid 83-1 was located approximately 24 nm northwest of the village of Deering (near line 19, shown in Figure 6), along a long, linear, refrozen crack which extended almost to shore. Water depth was 14 m near the center of the grid, and the ice thickness in early April was approximately 102 cm. This was the larger of the 2 grids and the ice conditions were quite variable. Overall deformation was about 35% with an average relief of 60-90 cm. The grid was bisected east to west by a large (90-275 m wide) refrozen lead. Another smaller perpendicular lead ran north to south through the western end of the grid. With the exception of a few extensive flat areas (>400 m wide), the grid was characterized by small, flat pans interspersed among large fields of low rubble and some larger pressure ridges or areas of jumbled ice.

Grid 83-2 was located about 4 km offshore from Point Garnet on the Choris Peninsula, near survey line 15 (Figure 6). Water depth was from 11-13 m and the ice was 120-130 cm thick in late April. The ice within Grid 83-2 was considerably flatter than in Grid 83-1, with overall deformation about 10%-20%, and average relief of 30-60 cm. In general, the grid consisted of extensive flat areas surrounded by irregular pressure ridges of low relief. The southwestern edge of the grid was bordered by an extensive flat expanse of undeformed ice with very little snow cover. Snow cover on the grid itself was minimal, except near pressure ridges where drifts had formed.

Both grids were worked mainly in light winds. Between 5 and 29 April, winds exceeded 10 knots on only 3 or 4 days. In general, wind speed was less than 5 knots; our most persistent problem was the lack of wind, which made it difficult for the dogs to detect seal structures.

Search Effort and Biases

Two dogs, Clyde and Charlie, were used to conduct searches for seal structures in 1983. Since the possibility existed that the 2 dogs might search in a somewhat different manner, be more effective at detecting a particular type of structure, or work differently under certain environmental conditions, we tested for such potential biases.

The mean and maximum distances from the search line at which the 2 dogs detected structures were similar. Mean distances of detection were 134 m and 125 m for Clyde and Charlie respectively on Grid 83-1, and 154 m and 147 m on Grid 83-2. Although the mean distance was greater on the second grid, the maximum distance of detection was approximately 60% less for both dogs. Structures were detected at over 600 m on Grid 83-1, and up to 400 m on Grid 83-2. This may have been attributable to weather or snow conditions which affected odor strength; on Grid 83-2 the snow and ice were very wet and many lairs were collapsed and exposed.

The dogs were also similar in their success at finding seal structures under different wind conditions. Although Clyde found 16% more structures per mile searched on Grid 83-1 than did Charlie (probably because Charlie was less experienced), the difference was similar at all wind speeds and wind angles

Table 15. Grids searched for seal structures in Kotzebue Sound, Alaska, April 1983.

Grid #	Dates searched	Center point of grid	Area (km^2)	Distance from shore (km)	Comments
83-1	5-22 April	66°12.4'N 163°09.3'W	27.37	14.8	Two large, perpendicular, refrozen leads running through. Diverse ice conditions including some extensive flat areas, mostly intermediate 60-90-cm relief, some areas with relief to 200 cm and large deep snow drifts.
83-2	25-30 April	66°19.0'N 162°01.0'W	5.87	3.7	Generally low relief with rubble field at one end. Many flat areas divided by low pressure ridges. Grid adjacent to very extensive flat ice. Melt well advanced when this grid was worked.

(Table 16) with no indication that either dog was consistently more successful under particular conditions. The dogs similarly showed no bias ($G = 0.919$, $df = 4$, $p > 0.05$) in the types of structures they located, each dog finding about the same proportions of breathing holes and lairs (Clyde - 29% breathing holes and 70% lairs, n = 141; Charlie - 32% breathing holes and 67% lairs, n = 105). Overall, for both dogs combined, the number of structures per kilometer searched for all wind speeds and wind angles ranged from 1.0 to 1.9.

The percentage of structures in each wind speed and wind angle category corresponded closely to the percentage of total distance searched in that category (Table 17). For example, for both dogs and both grids combined, 48% of the kilometers searched and 49% of the structures found were in 0- to 9-km/hr winds; 36% of both kilometers and structures were in 10- to 18-km/hr winds; and 5% of both kilometers and structures were in 19- to 27-km/hr winds. Similarly, 66% of the kilometers searched and 65% of the structures were at wind angles $\leq 50°$. This suggests that despite the perception that some winds may be better than others for searches, the dogs were equally effective at all moderate wind speeds and all angles between wind and search lines.

In 1983, all major grid lines were searched at least once on each side of the line. In addition, some lines were searched more than once and perpendicular cross lines were searched to ensure that all structures within the grid were found. For the 2 grids, 56% of the structures found on 2 searches of the same line (n = 27) were found on the first search.

Numbers and Distribution of Structures

In 1983, 235 seal structures were located within the study grids: 185 of those were found on Grid 83-1 and 50 on Grid 83-2 (Table 18). Two of the structures on Grid 83-1 could not be identified as to type. The overall density of structures on Grid 83-2 (8.5/km²) was 25% higher than on Grid 83-1 (6.8/km²). Breathing holes and complex lairs occurred at greater densities on the second grid, whereas simple lairs were less abundant. Although densities were different, breathing holes made up a similar proportion of total structures on Grid 83-1 (34%) and Grid 83-2 (38%). The relative abundance of simple and complex lairs, however, differed considerably. Simple lairs made up 45% of all structures on Grid 83-1, but only 22% on Grid 83-2. Conversely, complex and pupping lairs made up 20% of the structures on Grid 83-1, but 40% on Grid 83-2. The proportions of different types of structures on the 2 grids were significantly different ($x^2 = 17.5763$, $df = 4$, $p < 0.005$). Within Grid 83-1 the ratio of simple lairs to complex lairs (including pupping lairs) was approximately constant throughout the study period. Simple lairs accounted for 69% of all lairs during the first 9 days and 71% during the last nine. A similar result was obtained when the period was divided into a first portion lasting 12 days and a second lasting 6.

Grids were also treated as groups of adjacent blocks (2.6 km²), to examine within-grid variability. In the 9 blocks within Grid 83-1, simple lairs made up 28%-59% of structures, compared to 20% and 23% in the 2 Grid 83-2 blocks. Complex lairs ranged from 6%-34% on Grid 83-1 and 37%-45% on Grid 83-2 (Table 19).

Table 16. Influence of wind on the number of seal structures found in Kotzebue Sound, April 1983. A. Wind speed. B. Wind angle to search line.

A. Wind speed

	Clyde			Charlie			Both dogs combined		
Km/hr	# km	# structures	structures/ km	# km	# structures	structures/ km	# km	# structures	structures/ km
0-9	36.7	52	1.4	23.8	31	1.3	60.3	83	1.4
10-18	27.0	37	1.4	24.9	30	1.2	52.0	67	1.3
19-27	3.7	5	1.4	3.2	5	1.6	6.9	10	1.4
28-36	3.7	7	1.9	8.0	6	0.8	11.7	13	1.1
37-45	0.0	0	0.0	3.2	6	1.9	3.2	6	1.9
Total	70.8	101	1.4	63.2	78	1.2	134.1	179	1.3

B. Wind angle to search line

	Clyde			Charlie			Both dogs combined		
Wind angle	# km	# structures	structures/ km	# km	# structures	structures/ km	# km	# structures	structures/ km
0-10	5.6	12	2.1	8.5	12	1.4	14.2	24	1.7
>10-20	2.4	3	1.3	3.2	4	1.3	5.6	7	1.3
>20-30	19.3	25	1.3	21.4	17	0.8	40.7	42	1.0
>30-40	2.4	4	1.7	4.8	8	1.7	7.2	12	1.7
>40-50	10.5	8	0.8	13.4	17	1.3	23.8	25	1.1
>50-60	14.5	22	1.5	6.4	11	1.7	20.9	33	1.6
>60-70	3.2	6	1.9	0.0	0	0.0	3.2	6	1.9
>70-80	9.3	14	1.5	0.0	0	0.0	9.3	14	1.5
>80-90	3.7	7	1.9	5.6	9	1.6	9.3	16	1.7
Total	70.8	101	1.4	63.3	78	1.2	134.1	179	1.3

Table 17. Relationship between search effort (% of all kilometers searched) and the percent of structures found for various wind categories. A. Wind speed. B. Wind angle.

A. Wind speed

Km/hr	Grid 83-1		Grid 83-2		Combined	
	% km	% structures	% km	% structures	% km	% structures
0-9	45	46	61	59	48	49
10-18	39	37	27	30	36	36
19-27	5	6	2	3	5	5
28-36	9	7	10	8	9	7
37-45	2	3	0	0	2	3

B. Wind angle to search line

Wind angle	Grid 83-1		Grid 83-2		Combined	
	% km	% structures	% km	% structures	% km	% structures
0-10	11	13	2	3	9	12
10-20	4	4	22	22	8	7
20-30	30	23	20	24	28	24
30-40	5	7	12	27	7	10
40-50	18	14	0	0	14	12
50-60	16	18	0	0	13	15
60-70	2	3	0	0	2	3
70-80	7	8	39	19	13	10
80-90	7	9	5	5	7	8

Table 18. Density (number/km²) of ringed seal structures for 2 grids in Kotzebue Sound, April 1983.

Grid	Area (km²)	Total # structures	Density/km² breathing holes	simple lairs	complex/ pupping lairs	unknown	total
83-1	27.4	185	2.3	3.0	1.4	0.1	6.8
83-2	5.9	50	3.2	1.9	3.4	0.0	8.5

Table 19. Number of identified ringed seal structures in blocks (2.6 km²) within grids in Kotzebue Sound, April 1983.[1]

Grid	Block	Breathing hole	Simple lair	Complex and pupping lairs	Total
83-1	1	9	15	6	30
	2	8	7	4	19
	3	4	7	3	14
	4	11	8	10	29
	5	8	8	7	23
	6	5	8	1	14
	7	6	10	1	17
	8	7	8	1	16
	9	5	12	4	21
	$\bar{x}$	7.0	9.2	4.1	20.3
83-2	1	7	4	9	20
	2	12	7	11	30
	$\bar{x}$	9.5	5.5	10.0	25.0

[1] Although 185 structures were found within Grid 83-1, 2 of them could not be identified as to type.

The distances between structures were compared for both Kotzebue Sound grids (Table 20). Grid 83-2, with the highest density of structures, had the smallest mean distance between structures ($\bar{x}$ = 172 m for Grid 83-1 vs. $\bar{x}$ = 134 m for Grid 83-2). The mean distances between breathing holes, simple lairs, and complex lairs were proportionately smaller (6%-27%). In contrast, pupping lairs were over twice as far apart on Grid 83-1 ($\bar{x}$ = 113 m) as they were on Grid 83-2 ($\bar{x}$ = 51 m), where they occurred at significantly higher densities (1.4/km^2 vs. 3.4/km^2).

More structures occurred in "groups" in Grid 83-2 than in Grid 83-1. Nineteen percent of all structures of Grid 83-1 occurred within 75 m of another structure, compared to 40% on Grid 83-2 (Table 21). The most common group size was 2, but on each grid there were single incidences of groups of 3, 4, and 5 structures. Most paired structures (12 of 15 instances) consisted of 2 nearby lairs. Five of 6 groups that included more than 2 structures consisted of at least 1 breathing hole and multiple lairs, of which 2 and sometimes 3 were pupping lairs. Most groups of lairs were found in areas of somewhat higher relief, greater deformation, and many very large, long drifts of deep snow.

Characteristics of Snow, Ice, and Seal Structures

Percent deformation, average relief of the ice, and maximum snow depth were recorded for each structure we located. In most instances, mean values for each of these 3 parameters were least for breathing holes, somewhat greater for simple and complex lairs, and greatest for pupping lairs (Table 22). This trend was very consistent on Grid 83-1, which was worked early in the season. Mean ice deformation and relief for pupping lairs were approximately 30% greater than for breathing holes, and maximum snow depth was over 90% greater. There was more variability on Grid 83-2, which was worked late in the season after much of the snow cover had melted, making the general topography look quite different.

Ice deformation and relief were greatest on Grid 83-1, with mean values for the different structure types ranging from 22%-29% deformation and 70-95 cm relief. In contrast, Grid 83-2 had mean deformation values of 8%-19% and mean relief of 55-61 cm. Depending on structure type, maximum snow depth was 12-30 cm greater on Grid 83-1. It was difficult to estimate what proportion of the difference was due to melting and settling of the snow, caused by the warm weather and rain that occurred while Grid 83-2 was being studied.

Dimensions of breathing holes and lairs are given in Table 23. As would be expected, on both grids the diameter of access holes to lairs was larger than the diameter of breathing holes. Height was the least variable lair measurement. Minimum height of active lairs was 20 cm.

Simple lairs were smaller than complex ($F = 46.04$, df = 1, $p < 0.0001$) and pupping lairs ($F = 118.62$, df = 1, $p < 0.0001$). They consisted of a single oval or circular chamber with mean length for both grids combined of 162.8 cm and mean width of 112.2 cm (n = 94). Complex lairs with no evidence of pups were smaller than pupping lairs ($F = 9.54$, df = 1, $p < 0.005$) and had a mean length and width of 235.4 and 137.3 cm (n = 29). Comparable values for pupping lairs were 302.9 and 184.9 cm (n = 25). The largest lair we measured was a pupping lair found outside Grid 83-2 on 25 April. This lair was 641 cm long and consisted of at least 9 chambers.

Table 20. Distance between ringed seal structures (m) on 2 grids in Kotzebue Sound, April 1983.

	Breathing holes	Lairs simple	Lairs complex	Lairs pupping	All
Grid 83-1					
MEAN	202	163	159	113	172
RANGE	1-413	1-425	1-359	1-359	1-425
S.D.	101	107	100	127	108
N	63	83	23	14	185
Grid 83-2					
MEAN	190	128	145	51	134
RANGE	2-330	1-285	1-420	2-268	1-420
S.D.	97	97	157	74	113
N	19	11	7	13	50

Table 21. Occurrence of ringed seal structures in groups of different sizes on 2 grids in Kotzebue Sound, April 1983.

Group size	Grid 83-1 # groups	Grid 83-2 # groups
1	151	30
2	11	4
3	1	1
4	1	1
5	1	1

Table 22. Characteristics of snow and ice on 2 grids in southeastern Kotzebue Sound, 1983.

			Type of structure			
Grid	Parameter	Statistic	breathing holes	simple lairs	complex lairs	pupping lairs
83-1	Ice deformation (%)	Mean	22.1	25.8	26.1	28.9
		Range	0-70	10-60	10-80	10-80
		S.D.	15.4	13.8	12.9	18.8
		N	62	83	23	14
	Relief (cm)	Mean	70.1	79.2	79.2	94.5
		Range	0-183	30-183	61-152	61-152
		S.D.	33.5	27.4	18.3	27.4
		N	63	83	23	14
	Snow depth (cm)	Mean	46.4	73.4	77.9	89.2
		Range	2-85	35-120	58-110	75-132
		S.D.	19.8	18.6	15.6	16.7
		N	62	83	23	14
83-2	Ice deformation (%)	Mean	18.7	12.7	8.3	9.6
		Range	5-70	5-40	5-15	5-15
		S.D.	18.2	11.7	2.6	3.8
		N	19	11	6	13
	Relief (cm)	Mean	57.9	57.9	61.0	54.9
		Range	30-122	30-91	30-122	30-91
		S.D.	21.3	21.3	39.6	18.3
		N	19	11	6	13
	Snow depth (cm)	Mean	34.8	54.0	48.3	62.3
		Range	18-65	39-74	35-70	61-64
		S.D.	14.4	14.9	11.7	1.5
		N	13	7	6	3

Table 23. Dimensions of seal-made structures on 2 grids in southeastern Kotzebue Sound, 1983.

		Type of structure			
Parameter	Statistic	breathing holes	simple lairs	complex lairs	pupping lairs
Diameter of hole (cm)	Mean	30.6	47.4	61.9	57.6
	Range	10-67	21-105	25-120	20-106
	S.D.	13.5	20.9	30.4	26.4
	N	76	55	21	23
Length of lair (cm)	Mean	-	162.2	235.4	302.9
	Range	-	65-303	150-496	170-509
	S.D.	-	44.2	67.5	92.2
	N	-	94	29	25
Width of lair (cm)	Mean	-	112.2	137.4	184.9
	Range	-	40-224	73-348	94-348
	S.D.	-	30.3	39.6	58.4
	N	-	94	29	25
Height of lair (cm)	Mean	-	33.2	33.4	36.4
	Range	-	20-63	20-50	27-52
	S.D.	-	8.6	8.3	7.0
	N	-	52	21	21

The lengths of lairs remained similar throughout the study period. We tested the slopes of regression lines for date vs. length for the 3 lair types and found no significant trends ($p > 0.25$), although the average length of pupping lairs did increase as spring progressed. The wide variability in lair length on the last 4 days (170-509 cm) undoubtedly precluded a significant regression. If measurements of the 4 smallest lairs were deleted, the trend was significant ($F = 9.06$, $p < 0.01$). These small lairs were not primary pupping lairs but were part of "lair complexes" which contained at least 1 other very large pupping lair, or in one case contained a very young (less than 1 week old) pup born considerably after the mean birth date. The wide range in lair size suggests an extended pupping period.

In order to investigate the effect of ice topography on the distribution of structures, Grid 83-1 was subdivided into 144, approximately 400-m^2 blocks and each block was classified as flat (>50% of the surface with <0.3 m relief and <5% deformation) or rough ice. Seventy-four percent of all blocks were in rough ice. A comparison of the incidence of structures in rough and flat ice showed 56% more structures per block (1.39 vs. 0.89) in the rougher areas (Table 24). Breathing holes were equally abundant in both types of ice, whereas lairs, in aggregate, were over twice as abundant in the blocks characterized by rougher ice and greater snow depths. The difference was greatest for complex and pupping lairs, which together were 3 times more common in rough areas. In total, 70% of all structures in blocks of rough ice were lairs and 30% were breathing holes, in contrast to blocks of flat ice, where 50% were lairs and 50% breathing holes.

Fox and Bear Activity

Arctic and red foxes (*Vulpes vulpes*) were uncommon in and near our study grids during April 1983, as evidenced by very few fox tracks in the area. Only 6 structures (3%) on Grid 83-1 had any sign of foxes: 5 structures had been dug into and 1 other was marked with fox scat containing lanugo (white pup hair). Five of the 6 structures visited by foxes were simple lairs with no evidence of a pup, and none showed any evidence of a successful kill. Two of these were completely refrozen, 2 were altered (being used only as breathing holes), and 1 was unaltered. The sixth structure, found on 12 April, was a pupping lair where a kill had occurred. There was fox scat on the snow above the lair, blood inside the lair, and pieces of frozen placenta near the access hole. The access hole was neither refrozen nor altered. About 15 m away the dog found a dead seal pup with the snout bitten off. The umbilicus was still attached but shrunken and white, indicating that the pup was at least several days old.

Sign of foxes was not obvious on Grid 83-2, but the snow was so melted that it would have been difficult to see tracks. The forelimb of a dead seal pup was found on top of an ice ridge near this grid.

There were no signs indicating the presence of polar bears on either grid.

Table 24. Distribution of structures in relation to ice topography, based on 400-m^2 blocks within Grid 83-1, Kotzebue Sound, April 1983.

	Flat ice (n = 37 blocks)		Rough ice (n = 107 blocks)	
	#	#/block	#	#/block
Breathing holes	17	0.46	45	0.42
Simple lairs	12	0.32	71	0.66
Complex lairs	2	0.05	21	0.20
Pupping lairs	2	0.05	12	0.11
Total structures	33	0.89	149	1.39

Alteration of Structures

At the time seal structures were found and first examined, they were classified as open, altered, or refrozen. Open structures included all breathing holes, no matter how small, that were not completely frozen; and all lairs in which the hole was large enough for a seal to haul out, the roof was not caved in, and there were no icicles hanging from the roof that blocked access to the lair chambers. Lairs were considered altered if the access hole was frozen to a constricted diameter which precluded a seal from passing through, or if the roof was caved in or had built-up ice which did not permit a seal to enter the chamber. On both grids combined, the overall alteration rate (altered and refrozen) was 25% (Table 25). The lowest alteration rate was for pupping lairs, of which only 1 of 27 (4%) was altered and none were refrozen. In contrast, 41% of all simple lairs (N = 94) were altered or refrozen ($x^2 = 12.9493$, df = 1, $p < 0.001$).

Grid 83-1 was traversed by and laid out along a wide, refrozen lead which served as an ice road during our stay. This road was our primary travel route to and from all grid lines. It was also used as the airstrip for supply planes, the main route to shore, and the place where snow machines were tested. Consequently, vehicle traffic and the associated noise was considerable. We compared the incidence of altered and refrozen seal structures adjacent to the heavily used ice road with the remainder of the grid which had far less vehicle traffic (Table 26). Forty-one percent of all structures along the ice road (within 200 m of it, on either side) were altered or refrozen, compared to 23% on the remainder of the grid. The difference was greatest for simple lairs; 67% of those along the ice road, compared to 34% elsewhere, were altered or refrozen. The difference could not be attributed to a difference in proportion of structure types or their inherently different alteration rates since breathing holes and lairs occurred with approximately the same frequency along the ice road as elsewhere in the grid. A comparison between the most heavily used portion of the ice road, with the portion that received the least traffic, also indicated a higher alteration rate in the heavy-use area. Forty-six percent of structures in the high-use section (n = 24) compared to 20% (n = 5) in the lower-use area were altered or refrozen.

E. Seal Structure Studies - Cape Lisburne Fast Ice, 1984

Grid Descriptions

In spring 1984, 5 rectangular-shaped study grids were established on fast ice near Cape Lisburne (Figure 7). Grids 84-1 to 84-3 were 56-65 km east and Grid 84-4 was 43 km east of the Cape Lisburne NORAD facility. Each was in somewhat different ice conditions and at different distances from shore (Table 27). Grid 84-5 was 2-4 km east of the Cape Lisburne facility.

All grids were worked in light to moderate winds (almost always $\leq$10 knots). Between 3 April and 7 May the wind exceeded 15 knots on only 4 days. As in 1983 in Kotzebue Sound, light and variable winds less than 5 knots were our most persistent problem.

Table 25. Proportion of identified ringed seal structures that were altered or refrozen on 2 grids in Kotzebue Sound, April 1983.

Grid	Structure type	n	Altered #	Altered %	Refrozen #	Refrozen %
83-1	Breathing hole	63	n/a	-	8	13
	Simple lair	83	22	27	11	13
	Complex lair	23	4	17	2	9
	Pupping lair	14	1	7	0	0
	Total	183	27	15	21	11
83-2	Breathing hole	19	n/a	-	4	21
	Simple lair	11	2	18	4	36
	Complex lair	7	1	11	0	0
	Pupping lair	13	0	0	0	0
	Total	50	3	6	8	16

Table 26. Alteration of seal structures along an ice road and in the rest of Grid 83-1, Kotzebue Sound, April 1983.

	Altered or refrozen					
	Ice road			Remainder of grid		
	n	#	%	n	#	%
Breathing holes	10	2	20	53	6	11
Simple lairs	15	10	67	68	23	34
Complex and pupping lairs	4	0	0	33	7	21
Total	29	12	41	154	36	23

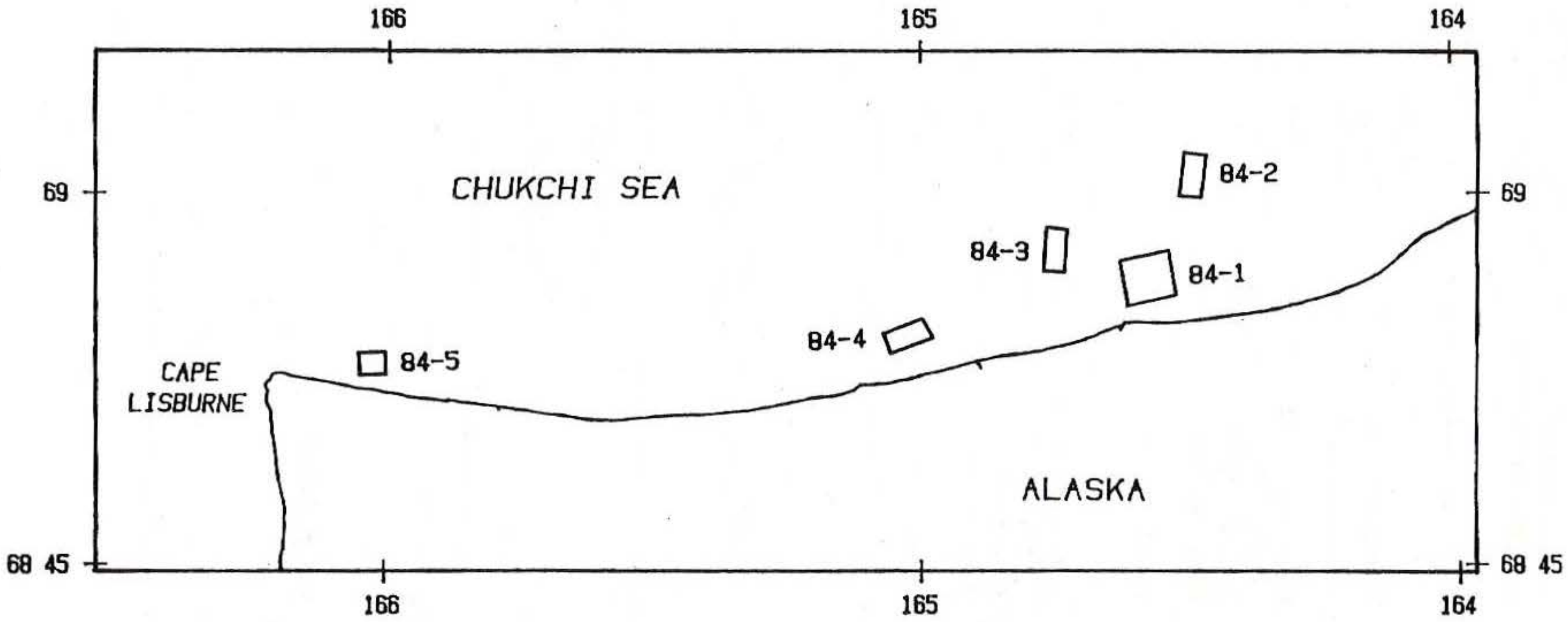


Figure 7. Location of 5 study grids near Cape Lisburne, April-May 1984.

Table 27. Description of grids searched for seal structures near Cape Lisburne, Alaska, April-May 1984.

Grid#	Dates searched	Center point of grid	Area (km^2)	Distance from shore (km)	Comments
84-1	6-19 Apr	68°56.6N 164°34.5W	10.92	3.0	Fairly uniform ice conditions with one moderate pressure ridge (to 4 m high). Otherwise relief to 1.5 m but mostly 0.6-0.9 m.
84-2	17-26 Apr	69°00.8N 164°29.1W	5.32	10.4	Seaward of large pressure ridge. Several small-medium height ridges (2.4-3.0 m) and much jumbled ice. Otherwise relief to 2.1 m, mostly 0.6-1.5 m.
84-3	24 Apr-3 May	68°58.1N 164°44.9W	5.43	7.4	Just west of large area of flat ice and inshore from large pressure/jumble ridge. Relief to 2.4 m but mostly 0.6-1.8 m.
84-4	30 Apr-7 May	68°54.5N 165°01.6W	5.56	3.1	Inshore of large jumble/pressure ridge up to 6 m high. Within grid relief variable, up to 3 m but mostly 0.9-1.2 m. Some fairly small flat areas.
84-5	8-12 May	68°53.3N 166°01.5W	3.40	1.9	Just offshore from flat shore ice and inshore from large pressure ridge. Relief to 2.1 m, mostly 0.6-1.5 m. Offshore from Cape Lisburne dump, 2-4 km east of NORAD facility.

April-early May 1984 was unusually cold in the Cape Lisburne area. Snow conditions that were ideal for working the dogs and for maintaining seal lairs prevailed until the second week of May. Daytime temperatures ranged from -42°C in early April to -2.2°C in early May. This was in sharp contrast to temperature regimes in Kotzebue Sound during spring 1983, where extensive settling of melting snow and collapse of lairs occurred in late April.

Search Effort and Biases

The 2 Labrador retrievers (Clyde and Charlie) that were utilized in 1983 were again used during our studies near Cape Lisburne in 1984. As in 1983 (see Section D), the results of field work in 1984 indicated that the dogs performed in a comparable manner. There were no differences in the types of seal structures found by either dog within the 5 grids searched ($x^2 = 1.21$, df = 3, $p > 0.05$). Similarly, there were no significant differences in the number of structures found per kilometer of search line by either dog when lines were searched for the first time (Table 28).

Performance of the dogs in different wind conditions was not evaluated in 1984 since (1) conditions were relatively constant throughout the study period and (2) analysis of 1983 data indicated no difference in performance of the dogs under any conditions that were considered satisfactory for working.

In conducting grid searches, it is difficult to determine what proportion of the structures present are found by the dogs. For 4 of the 5 grids worked in 1984, we compared lines that were searched twice by the same or different dogs (Table 29). Of the total structures found on 32 pairs of replicate lines, 73% (65%-82% range) were found on the first search. A few lines were searched more than twice. On 9 of those which were run three times each, 67% of the structures (n = 39) were found on the first search, 23% on the second, and 10% on the third. Three lines were run 4 times each: 65% of the total structures (n = 17) were found on the first run, 6% on the second, 18% on the third, and 12% on the fourth.

The efficiency of first-time searches can be derived somewhat differently by comparing total structures found on grids to the number of structures found after each major grid line was searched once. If data from only 1 side of the major lines are tabulated, assuming that the dogs could effectively search the entire 400 m between lines, the proportion of total structures detected on the first search was 41% (range 39%-44%). If effective strip width was more conservatively estimated at 200 m, then it was necessary to search both sides of a line (under different wind conditions) in order to achieve "complete" coverage of an area (i.e., to completely cover the area between 2 adjacent grid lines, the dogs searched the left side of one and the right side of the other). Of the total structures found, 60% (55%-78% within individual grids) had been located after all lines were searched once on each side (Table 30). This is similar to the 65%-67% determined by comparing lines that were searched 3 to 4 times, suggesting that 60%-70% may be a reasonable estimate of the proportion of structures detected on a once-only search of a 200-m strip.

The procedure we used to attempt to find all seal structures within a grid was to repeat searches of primary lines or to search secondary lines until no undiscovered structures were located.

Table 28. Number of structures found per linear kilometer searched for the first time for 4 grids near Cape Lisburne, April-May 1984.

Grid	Clyde			Charlie		
	# km	# struct	struct/km	# km	# struct	struct/km
84-1	15.0	17	1.1	24.6	33	1.3
84-2	19.8	24	1.2	3.2	4	1.3
84-3	7.2	7	1.0	9.7	13	1.3
84-4	17.7	28	1.6	0	0	0

Table 29. Comparison of the proportion of structures found on multiple searches of the same line for study grids near Cape Lisburne, April 1984.

Grid	# of lines	Search 1		Search 2	
		# of structures	%	# of structures	%
84-1	13	26	68	12	32
84-2	6	18	82	4	18
84-3	7	17	81	4	19
84-4	6	15	65	8	35
Total	32	76	73	28	27

Table 30. Comparison of number of structures found on first searches of primary grid lines vs. total structures found on all searches combined for 4 grids near Cape Lisburne, April 1984.

Grid	Total all searches	First search		Both	
		1° side	2° side	number	percent
84-1	92	36	18	54	59
84-2	36	16	12	28	78
84-3	47	20	6	26	55
84-4	60	24	9	33	55

Numbers and Distribution of Structures

The five grids searched in 1984 had a total area of 30.6 km². Within those grids, 247 seal-made structures were found, of which all but 2 were identified to type (Figure 8). The average density of structures for all grids was 8.1/km². The area of Grids 84-1 through 84-4 was 27.2 km² and within that total area 235 seal-made structures were found for a density of 8.6/km². Grid 84-5 had a much lower density of 3.5 structure/km².

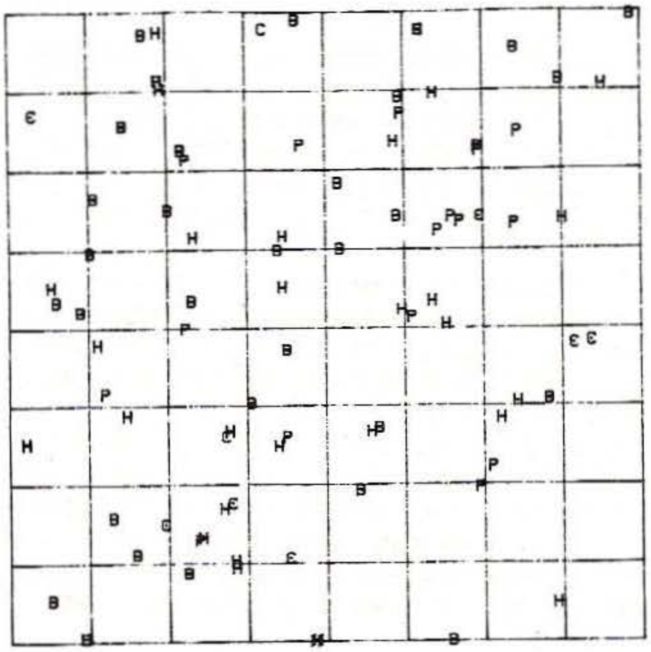
Grid 84-5 will not be included in further discussions of density, although it will be included in discussions of structure composition, fate of structures, and predation. That is because Grid 84-5 was located within 3 km of the Cape Lisburne dump. Refuse was continuously burned and debris and ash were blown over the search grid. Additionally, heavy equipment was used to haul trash to the dump and to move it within the dump. Noise, odor, and debris (that continuously became incorporated into the changing snow cover) may have caused or contributed to the low density of seal structures within this grid and/or hindered the dogs in locating structures. In May, when seals began to bask in high numbers, opportunistic observations made from the helicopter indicated that the number of seals hauled out near the Cape Lisburne site was low.

Composition of all structures (N = 247) was 25% breathing holes, 43% simple lairs, 13% complex lairs, 18% pupping lairs, and 1% unidentified structures (Table 31). By our classification system, a pupping lair is a complex lair with evidence of a birth or of occupancy by a pup (usually extensive pup tunnels). During the latter part of the 1984 field season, we found evidence of pups in simple lairs. Such simple lairs were not considered pupping lairs as apparently the young seals were moving about and hauling out in these and other lairs.

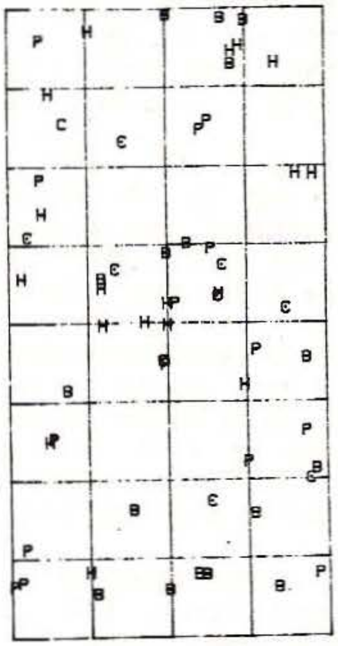
Simple lairs occurred in the highest densities, generally followed by breathing holes, complex lairs, and pupping lairs, in that order (Table 32). Overall density of the 3 types of lairs combined was 6.4/km².

Differences in proportions of the types of structures found, as the spring season progressed, were also examined. Grids 84-1 to 84-4 were sampled over a 30-day period from 6 April to 5 May. Composition of structures found during the early and late halves of this sampling period were compared in two ways; as a proportion of the sum of each structure type and as a proportion of all structures found in each sampling period (Table 33).

There was no difference in the proportion of pupping lairs found in the early or late sampling periods. The proportion of breathing holes declined markedly and the proportions of lairs, other than pupping lairs, increased over time. Although the changes observed are not statistically significant, the similarities and differences between sampling periods are consistent with the fact that the peak period of births is during the early sampling period (the number of new pupping lairs found after April 20 is insignificant). Explanation of the reasons for a decrease in proportion of breathing holes and increase in proportion of simple and complex lairs is more speculative. It is our hypothesis that as the main basking period approaches, more ringed seals in the fast ice habitat begin hauling out in lairs more frequently. They



Grid 84-1



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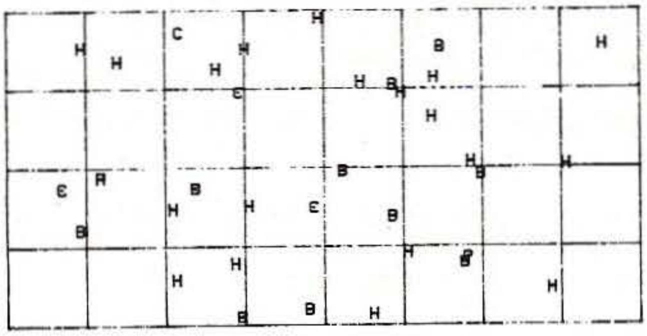

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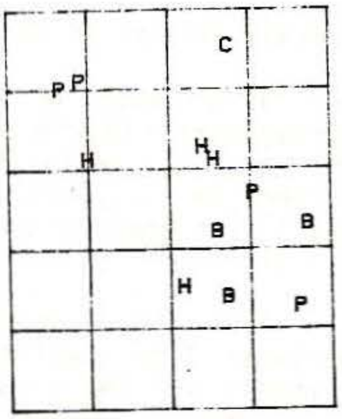

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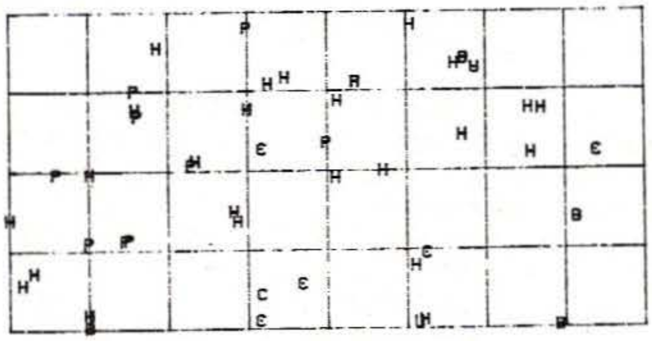

Grid 84-3

Figure 8. Diagrams of 5 study grids near Cape Lisburne showing locations of seal structures (B = breathing hole, H = simple lair, C = complex lair, P = pupping lair). Each block is approximately 400 m on a side.

Table 31. Numbers and proportions of seal-made structures found within 5 study grids on landfast ice near Cape Lisburne, Alaska, April-May 1984.

Grid No.	Structure type										Total
	breathing hole		simple lair		complex lair		pupping lair		unident.		
	N	%	N	%	N	%	N	%	N	%	
84-1	28	30	34	37	11	12	19	21	0	0	92
84-2	10	28	20	56	4	11	2	6	0	0	36
84-3	4	9	25	53	6	13	10	21	2	4	47
84-4	17	28	23	38	10	17	10	17	0	0	60
84-5	3	25	5	42	1	8	3	25	0	0	12
Totals	62	25	107	43	32	13	44	18	2	1	247

Table 32. Density of seal-made structures found within 4 study grids on landfast ice near Cape Lisburne, Alaska, April-May 1984.

Grid No.	Area (km^2)	Density of structures (number/km^2)				
		breathing holes	simple lairs	complex lairs	pupping lairs	all structures
84-1	10.92	2.6	3.1	1.0	1.7	8.4
84-2	5.32	1.9	3.8	0.8	0.4	6.8
84-3	5.43	0.7	4.6	1.1	1.8	8.7*
84-4	5.56	3.1	4.1	1.8	1.8	10.8
Totals	27.23	2.2	3.7	1.1	1.5	8.6

* Includes consideration of 2 structures of an undetermined type.

Table 33. Differences in proportions of breathing holes and lairs found in 4 study grids on landfast ice near Cape Lisburne, Alaska during 2 sampling periods in 1984: A - expressed as a proportion of the sum of each structure type; B - expressed as a proportion of the total number of structures found in a sample period.*

A.

Type of structure	Sample periods: 6-20 April N	%	21 Apr-5 May N	%	Total structures
Breathing holes	37	63	22	37	59
Simple lairs	49	48	53	52	102
Complex lairs	13	42	18	58	31
Pupping lairs	21	51	20	49	41

B.

Type of structure	6-20 April N	%	21 Apr-5 May N	%	Total structures
Breathing holes	37	31	22	19	59
Simple lairs	49	41	53	47	102
Complex lairs	13	11	18	16	31
Pupping lairs	21	17	20	18	41
Total structures	120	100	113	100	233

* Structures on Grid 84-5, all of which were found on or after 8 May, were not included in this analysis in order to keep the duration of sampling periods and sample sizes comparable.

eventually open the lairs and haul out on the snow surface as optimum weather prevails. In this process, breathing holes under deeper snow are enlarged, lairs are made and eventually the seals haul out on the surface.

A comparison of distances between structures of different types was made for each grid and for our combined sample of structures of each type (Table 34). Based on the pooled data from all grids, breathing holes were more distant from other structures of any type and pupping lairs were closest to other structures. The difference in distance for these 2 types was significant ($t = 4.3862$, $df = 104$, $p < 0.05$). For simple and complex lairs, the difference in mean distances to other structures of any type was not significant, although the mean distance for simple lairs was less than for complex lairs.

Characteristics of Snow and Ice at Structures

In 1984, all of the search grids were in a zone of generally homogenous fast ice along a simple coast of northerly exposure between Cape Lisburne and the Pitmegea River. Comparisons of ice deformation, surface relief, and snow depth among the different grids, which were relatively small and therefore reflected localized rather than average conditions, are less appropriate than consideration of the combined samples.

For all grids combined, ice deformation and relief were similar for all types of lairs, and slightly lower for breathing holes (Table 35, Figure 9). Snow depths were markedly different. Breathing holes were sited in relatively shallow snow, pupping lairs in deep snow, and simple and complex lairs were intermediate. Differences in snow depth were not significant for simple and complex lairs ($t = 0.3465$, $df = 135$, $p > 0.7$). They were significantly different in a 3-way comparison of breathing holes, simple and complex lairs (combined), and pupping lairs ($F [2, 1521] = 41.396$, $p < 0.005$). The minimum depth of snow for the different types of structures was 0 cm for breathing holes, 20 cm for simple lairs, 37 cm for complex lairs, and 47 cm for pupping lairs.

Characteristics of Seal-made Structures

Comparisons of the dimensions of all structures of similar type from all grids combined showed a progressive increase in size from breathing holes to simple lairs to complex lairs to pupping lairs (Table 36). The diameter of breathing holes was significantly smaller than the diameter of holes allowing access to lairs ($t = 8.1664$, $df = 173$, $p < 0.001$). In paired comparisons among the different kinds of lairs, the observed mean values for diameter of access holes were not significantly different.

Length and width of the 3 kinds of lairs were significantly different. (For length, $F [2, 65] = 48.747$, $p < 0.005$ and for width, $F [2, 59] = 26.096$, $p < 0.005$.). Complex lairs were larger than simple lairs, and pupping lairs were larger than both other types.

Lair height was the least variable of the parameters we measured, though there was a trend of increasing height in the order of simple lairs, complex lairs, and pupping lairs. Statistical comparisons of those data showed no significant difference between simple and complex lairs, nor between complex

Table 34. Distance (m) to the nearest structure of any type, from structures of the indicated type, within 5 study grids on fast ice near Cape Lisburne, Alaska, in 1984.

Grid No.	Statistic	Breathing holes	Simple lairs	Complex lairs	Pupping lairs	Complex & pupping lairs combined
84-1	Mean	210	98	134	82	101
	N	28	34	11	19	30
	S.D.	117	116	138	81	107
	Range	3-572	1-572	1-463	1-273	1-463
84-2	Mean	176	244	218	16	151
	N	10	20	4	2	6
	S.D.	97	151	44	21	110
	Range	31-330	1-639	165-267	1-31	1-267
84-3	Mean	256	128	186	104	134
	N	4	25	6	10	16
	S.D.	242	98	88	102	102
	Range	56-556	3-347	85-333	3-306	3-333
84-4	Mean	155	117	140	131	135
	N	17	23	10	10	20
	S.D.	101	77	103	91	94
	Range	41-389	14-255	14-317	21-271	14-317
84-5	Mean	214	142	-	196	251
	N	3	5	1	3	4
	S.D.	37	103	-	105	141
	Range	180-252	68-306	419	85-294	85-419
All 1984 grids	Mean	193	138	165	103	129
	N	62	107	32	44	76
	S.D.	118	121	117	92	107
	Range	3-572	1-639	1-463	1-306	1-463

Table 35. General characteristics of ice and snow at and near seal-made structures within all grids on fast ice near Cape Lisburne, Alaska, in spring 1984.

Parameter	Statistic	Type of structure: Breathing hole	Simple lair	Complex lair	Pupping lair
Ice deformation (%)	Mean	24.7	30.1	34.2	28.2
	N	62	99	32	50
	S.D.	19.9	17.7	17.2	17.2
	Range	5-80	5-85	5-75	5-80
Relief (cm)	Mean	57.0	67.1	63.8	71.3
	N	62	99	32	50
	S.D.	40.8	32.3	30.3	38.3
	Range	30-183	30-183	30-122	30-183
Snow depth (cm)	Mean	35.2	61.9	62.1	77.3
	N	61	98	32	49
	S.D.	24.7	20.9	20.6	20.9
	Range	5-150	20-183	37-130	47-130

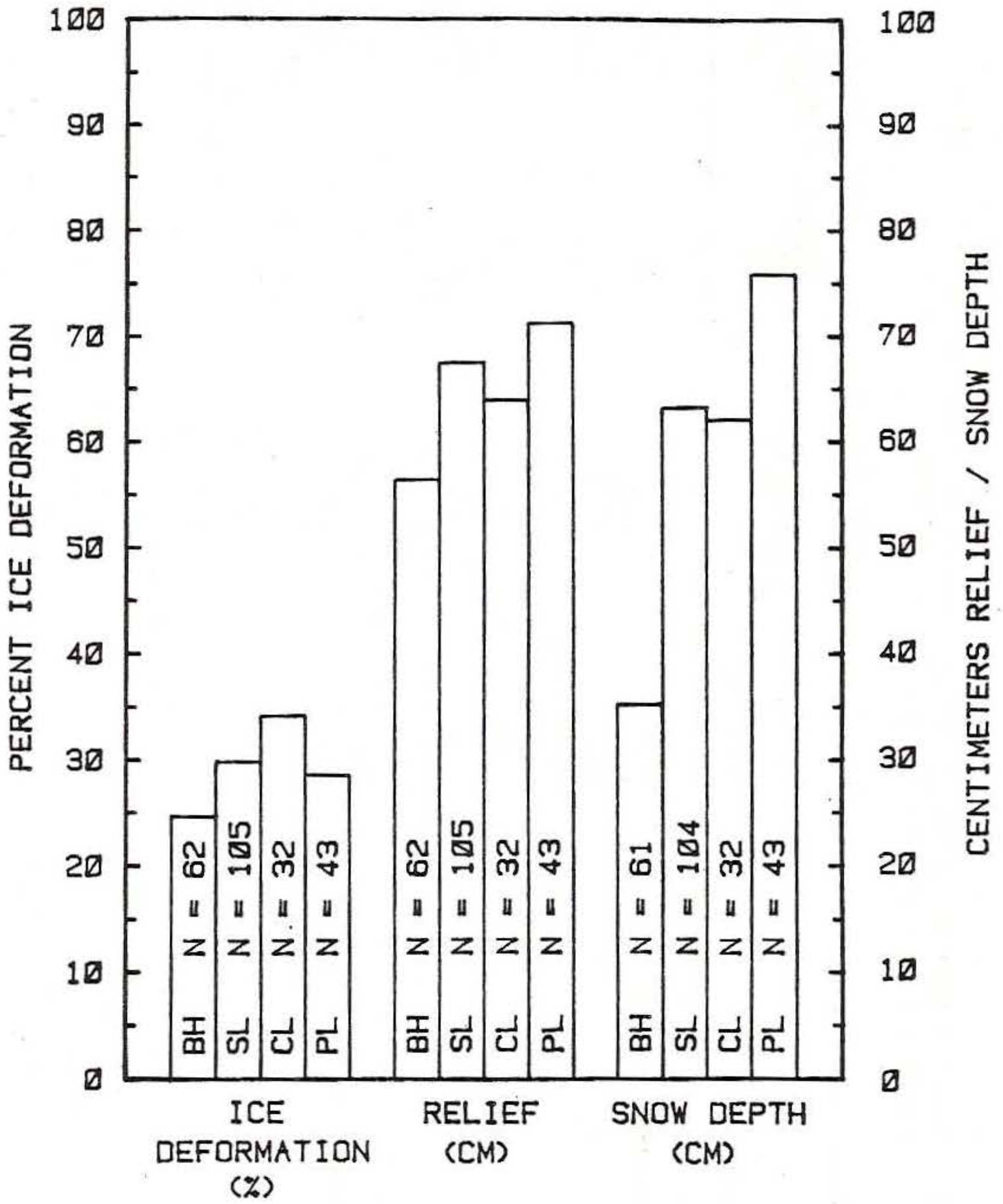

Figure 9. Snow and ice characteristics of ringed seal structures on fast ice near Cape Lisburne in 1984.

Table 36. Dimensions of seal-made structures on 5 grids near Cape Lisburne, 1984.

Parameter	Statistic	Type of Structure breathing hole	simple lair	complex lair	pupping lair
Diameter of hole (cm)	Mean	27.1	40.7	37.6	44.1
	N	60	70	22	23
	S.D.	10.0	11.1	9.0	13.8
	Range	3-46	20-76	20-51	25-81
Length of lair (cm)	Mean	-	156.2	229.3	268.6
	N	-	104	31	43
	S.D.	-	52.6	53.7	80.6
	Range	-	58-427	140-333	147-549
Width of lair (cm)	Mean	-	100.8	126.1	154.0
	N	-	104	31	43
	S.D.	-	24.8	31.7	51.7
	Range	-	33-183	81-224	56-343
Height of lair (cm)	Mean	-	29.7	30.9	31.9
	N	-	93	26	38
	S.D.	-	5.8	4.5	5.6
	Range	-	19-45	25-42	22-46

and pupping lairs. However, a comparison of the smallest with the largest types of lairs (simple vs. pupping lairs) indicated a significant difference ($t = 2.0127$, $df = 129$, $p < 0.05$).

Predation

The frequency and kind of predator activity around seal structures in each of our 5 study grids was quite variable (Table 37). For all structures ($N = 247$) in the 5 grids, polar bears marked 22 (9%), exposed or entered 19 (8%), and made kills at 3 (1%). Arctic foxes marked 104 (42%), entered 50 (20%), and made a kill at 10 (4%). Twelve kills were made by foxes and bears in the total sample of 44 pupping lairs; thus, kills occurred at 27% of such lairs in spring 1984.

It appeared that the digging and exposing of breathing holes was done initially by bears and that exposed holes were subsequently visited by foxes. Breathing holes exposed by the digging of bears were only found within Grid 84-1.

Grid 84-1 had the most activity by predators. This grid was directly seaward of a polar bear den from which a sow and 2 cubs of the year emerged in mid-April. The sow actively hunted within the grid. Of the 92 seal-made structures in Grid 84-1, polar bears marked 19 (21%), opened or entered 16 (17%), and killed a seal pup at 2 (2%). Arctic foxes marked 45 (49%), entered 21 (23%), and killed a seal pup at 3 (3%). The kill sites were only at lairs, mainly pupping lairs. In Grid 84-1, kills (by both foxes and bears) were made at 8% of all lairs or 26% of the 19 pupping lairs. Although total predator activity as measured by the proportion of structures marked or entered was greater in Grid 84-1 than in the other 4 grids, the rate of predation at lairs was similar.

The predation rate in Grid 84-1 (foxes and bears combined) was 1 seal pup per 2.2 km^2. For all grids combined, the kill rate was 1 pup per 2.4 km^2 (or 0.4 kills/km^2, range 0 to 0.7 kills/km^2).

We also observed wolverines (Gulo gulo) and red foxes on the fast ice east of Cape Lisburne during 1984, though they were not observed on our study grids.

Alteration of Seal Structures

On the 5 grids searched in 1984, the status of structures on grids was noted the first time they were found as open, altered, or frozen. The only human presence on or near the grids, except for Grid 84-5 near the Cape Lisburne site, was ours, and the duration of our activities was relatively brief. Thus, these data are indicative of part of the naturally occurring flux in use of structures by seals. However, the data reflect only part of the dynamic changes in structure use because we could only identify changes tending toward alteration or freezing of active or once-active holes and lairs. We could not detect change of the opposite type; i.e., the opening of new or refrozen holes or the construction and/or reconstruction of new or previously abandoned lairs. That can only be accomplished by continuous searching for and monitoring of structures over a period of time. We also do

Table 37. Kind and frequency of predator activity at subnivean seal structures on study grids in the eastcentral Chukchi Sea, 1984. Marked structures include those which were opened. Opened structures include those at which a kill occurred.

			Kind of structures				
Grid No.	Predator	Activity at structure	breathing hole	simple lair	complex lair	pupping lair	Totals
84-1		N	28	34	11	19	92
	Polar bear	Marked	5	7	1	6	19
		Opened/entered	3	7	1	5	16
		Kill site	0	0	0	2	2
	Arctic fox	Marked	9	14	7	15	45
		Opened/entered	3	5	4	9	21
		Kill site	0	0	0	3	3
84-2		N	10	20	4	2	36
	Polar bear	Marked	0	0	0	0	0
		Opened/entered	0	0	0	0	0
		Kill site	0	0	0	0	0
	Arctic fox	Marked	0	7	0	1	8
		Opened/entered	0	6	0	0	6
		Kill site	0	0	0	0	0
84-3		N	4	25	6	10	45 *
	Polar bear	Marked	0	1	0	0	1
		Opened/entered	0	1	0	0	1
		Kill site	0	0	0	0	0
	Arctic fox	Marked	1	12	4	8	25
		Opened/entered	0	4	2	5	11
		Kill site	0	0	0	4	4

-Continued-

Table 37. Continued.

Grid No.	Predator	Activity at structure	Kind of structures: breathing hole	simple lair	complex lair	pupping lair	Totals
84-4		N	17	23	10	10	60
	Polar bear	Marked	0	1	0	1	2
		Opened/entered	0	1	0	1	2
		Kill site	0	0	0	1	1
	Arctic fox	Marked	2	10	5	7	24
		Opened/entered	0	3	3	5	11
		Kill site	0	0	0	2	2
84-5		N	3	5	1	3	12
	Polar bear	Marked	0	0	0	0	0
		Opened/entered	0	0	0	0	0
		Kill site	0	0	0	0	0
	Arctic fox	Marked	0	1	0	1	2
		Opened/entered	0	1	0	0	1
		Kill site	0	1	0	0	1

* A total of 47 structures were found on this grid; two were unidentified, one of which was marked by a fox.

not know how long that scent which is detectable by the dogs persists in an abandoned structure. The abandonment rate we measured reflected only structures that had frozen recently enough that the dogs could find them.

The rates of abandonment and alteration of the different types of structures varied considerably among grids (Table 38). In several instances, the sample size of a specific type of structure within a particular grid was too small to make statistically valid tests of similarity or difference among grids. In general, Grid 84-1, which had the highest incidence of disturbance by foxes and polar bears, also had the highest frequency of displacement, as indicated by the complete freezing/abandonment of access holes leading into lairs: 18% for simple lairs, 18% for complex lairs, and 53% for pupping lairs.

For all structure types and all grids, 36% of the total structures were altered or abandoned (Table 39). Excluding Grid 84-5, for which the sample size was only 12, the proportion of altered structures varied from 17% to 36% ($\bar{x}$ = 23%, N = 233). The proportion of abandoned (frozen) structures in Grids 84-1 through 84-4 ranged from 7% to 21% ($\bar{x}$ = 14%, N = 233).

Table 40 shows alteration and freezing on the basis of type of structure for all grids combined. The proportion of altered structures ranged from 0% for breathing holes to 38% for complex lairs. Abandonment (freezing) of structures ranged from 5% for breathing holes to 30% for pupping lairs. For simple and complex lairs combined (N = 139), 35% were altered and 13% abandoned. For pupping lairs (N = 44), 11% were altered and 30% were abandoned. Thus, in comparing simple and complex lairs with pupping lairs, the latter tended to be altered less frequently (x^2 = 8.72, df = 1, $p < 0.005$) and abandoned (frozen) more frequently (x^2 = 6.54, df = 1, $p < 0.05$) than simple and complex lairs. These data suggest that ringed seals tend to continue to frequent breathing holes in former simple and complex lairs rather than abandoning them completely. Conversely, the seals tend to abandon disturbed pupping lairs.

We presume that a predator entering and killing a pup in a lair is an extreme case of disturbance, often resulting in abandonment of the lair by the mother. When 3 sites where kills had occurred were probed approximately 1 week later, all were found to be abandoned.

Although we did not systematically re-examine all structures to determine how they may have changed after they were initially found, we did probe approximately 80% of the total structures on Grids 84-2 through 84-4, 3-12 days after they were first examined to determine whether the hole was open or frozen. Grid 84-1 was not probed upon completion because a major storm obliterated the stakes and trails that marked the structures. By probing, it was not possible to determine whether open structures had become altered or whether altered structures had been reopened, but we could determine the proportion of originally open or altered structures which froze after our initial visit. Of 11 structures which were frozen the first time we examined them, all remained frozen when they were later checked by probing. Twenty-two additional structures were frozen.

Table 38. The condition of seal-made structures in 5 grids on landfast ice near Cape Lisburne, Alaska, April-May 1984.

Grid no.	Type of structure	N	Condition of structures: open no.	open %	altered no.	altered %	frozen no.	frozen %
84-1	Breathing holes	28	27	96	0	0	1	4
	Simple lairs	34	19	56	9	26	6	18
	Complex lairs	11	6	55	3	27	2	18
	Pupping lairs	19	6	31	3	16	10	53
84-2	Breathing holes	10	9	90	0	0	1	10
	Simple lairs	20	9	45	9	45	2	10
	Complex lairs	4	2	50	1	25	1	25
	Pupping lairs	2	2	100	0	0	0	0
84-3	Breathing holes	4	3	75	0	0	1	25
	Simple lairs	25	13	52	10	40	2	8
	Complex lairs	6	2	33	4	67	0	0
	Pupping lairs	10	6	60	2	20	2	20
84-4	Breathing holes	17	17	100	0	0	0	0
	Simple lairs	23	14	61	7	30	2	9
	Complex lairs	10	5	50	4	40	1	10
	Pupping lairs	10	9	90	0	0	1	10
84-5	Breathing holes	3	3	100	0	0	0	0
	Simple lairs	5	3	60	0	0	2	40
	Complex lairs	1	1	100	0	0	0	0
	Pupping lairs	3	3	100	0	0	0	0

Table 39. The condition of all seal-made structures within each of 5 grids on landfast ice near Cape Lisburne, Alaska, April-May 1984.

Grid no.	Sample size	Condition of structures: open no.	open %	altered no.	altered %	frozen no.	frozen %	Percent altered or frozen
1	92	57	62	16	17	19	21	38
2	36	22	61	10	28	4	11	39
3	45	24	53	16	36	5	11	47
4	60	45	75	11	18	4	7	25
5	12	10	83	0	0	2	17	17
Totals	245	158	64	53	22	34	14	36

Table 40. Condition of 4 different types of seal-made structures found in 5 grids on landfast ice near Cape Lisburne, Alaska, April-May 1984.

Type of structures	Sample size	Condition of structures: open no.	open %	altered no.	altered %	frozen no.	frozen %	Percent altered or frozen
Breathing holes	62	59	95	0	0	3	5	5
Simple lairs	107	57	53	36	34	14	13	47
Complex lairs	32	16	50	12	38	4	12	50
Pupping lairs	44	26	59	5	11	13	30	41
Totals	245	158	64	53	22	34	14	36

There was no change in the status of any of the breathing holes between visits; 2 of 22 (9%) were frozen on both occasions. The greatest change between visits was in simple lairs. Of the subsample which was checked by probing (n = 55), 4 (7%) were frozen on the initial visit and 22 (40%, range 31%-48% among grids) on the later visit. Thirty-six complex or pupping lairs were rechecked. Five (14%) were frozen on the initial visit and 9 (25%) on the later visit; all of these newly abandoned lairs were on Grid 84-3, which also had the highest incidence of refrozen simple lairs (48%). For all of the rechecked structures combined (n = 113), the abandonment rate increased from 11% on the initial visit to 29% after the structures had been opened and reconstructed and the entire grid worked repeatedly by snow machines and dogs. This compares to 14% initial abandonment rate for all 5 grids combined.

F. Seal Structure Studies - Pack Ice, 1984

A total of 12 search lines in the western part of the flaw zone and the heavier pack ice seaward of the flaw zone were searched between 15 April and 13 May. Search lines were at distances of 27-97 km off shore (Figure 10).

Ice conditions in both regions of the drift ice were highly variable, ranging from extensive, large, relatively flat, old floes to very rough, highly deformed floes of mostly annual sea ice. Because of the great variability in habitat that was searched on different days by 2 different dogs (Charlie and Lil), comparisons of their relative performance are not appropriate. Hunting range of the dogs was sometimes restricted by size of floes (which were usually surrounded by slush ice or water) and their success was greatly influenced by extent and proximity of ice ridges close to and paralleling the search lines.

In total, 35 km of line were searched and 59 structures (1.7/linear km) were located (Table 41). We attempted to open and examine all structures, although it was not possible to do so when they were within large piles of ice. Of the 59 structures, 33 were breathing holes, 19 were single-chambered (simple) lairs, 2 were pupping lairs, and 5 were unidentified. The composition of identified structures (N = 54) was 61% breathing holes, 35% simple lairs, and 4% pupping lairs. Of the 54 identified structures, 45 (83%) were active and unaltered, 4 (7.5%) were altered (access holes into lairs were partially refrozen to the size of breathing holes), 4 (7.5%) were abandoned (frozen), and 2 (4%) could not be classified as open or frozen.

As a crude estimate of structure density in the drift ice, all structures within 200 m of the search lines were considered. Combining the results of all 12 lines, 47 structures were within 200 m of lines totaling 35 km, resulting in a density estimate of 6.7 subnivean structures per km^2. Characteristics of the snow and ice conditions near seal-made structures that we examined are indicated in Table 42. Dimensions of the structures are indicated in Table 43.

In the pack ice, there was a higher probability that some of the structures were made or used by bearded seals, Erignathus barbatus, though there were no specific indications that that was the case.

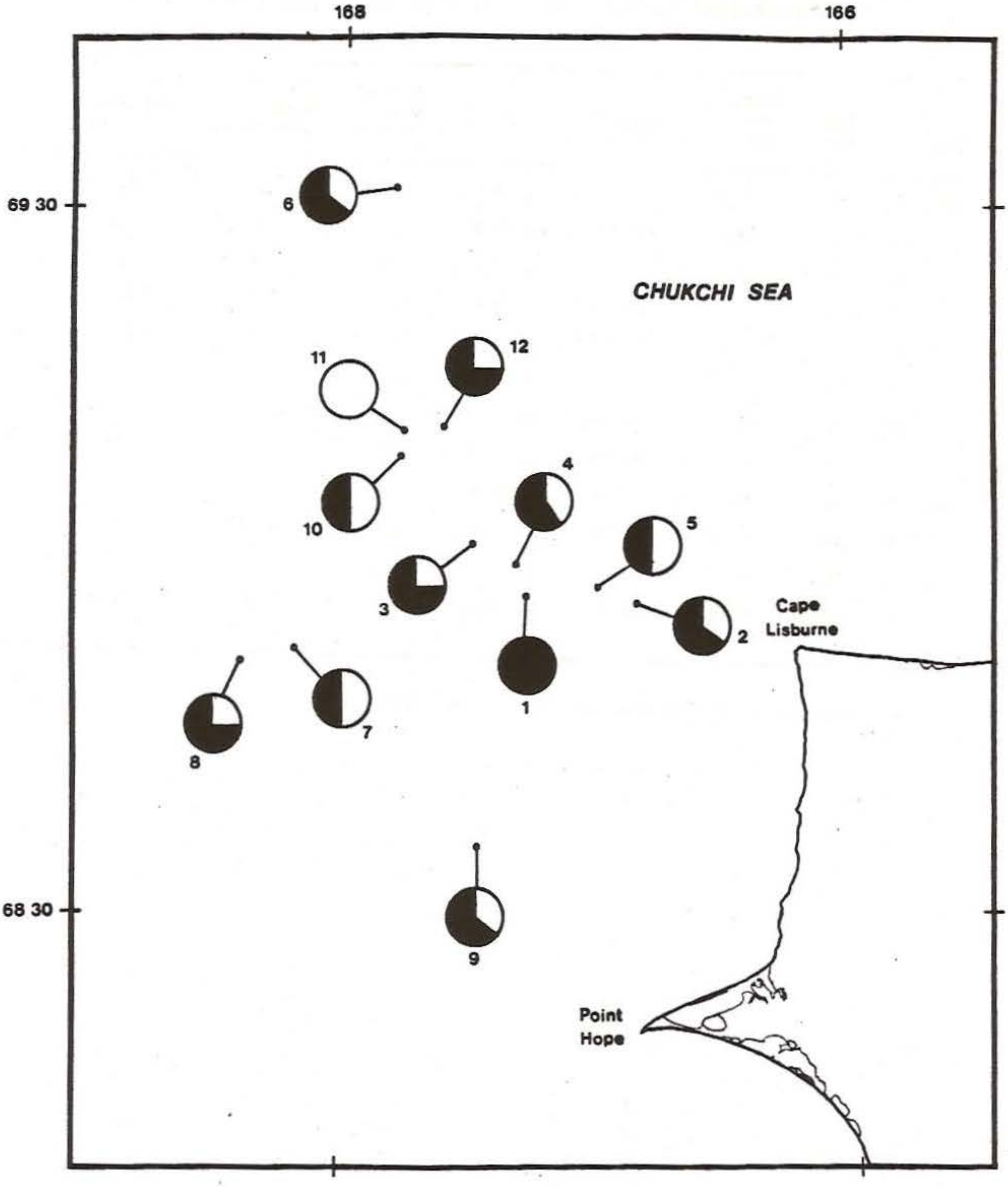

Figure 10. Locations of 12 search lines on pack ice near Cape Lisburne, Alaska, spring 1984. Small dots indicate starting positions of each line. Pie diagrams indicate proportions of lairs (unshaded) and breathing holes (shaded) found along each line. Numbers indicate the designation of lines represented by each circle, and correspond to those in Table 41.

Table 41. Results of searches for ringed seal structures on the pack ice of eastcentral Chukchi Sea, 15 April to 13 May 1984.

Date	Line no.	Distance from shore (km)	Beginning location	Length of search line (km)	Number of structures	Structures/ linear km	Percent lairs[1]
Apr. 15	1	43.3	68 57.3, 167 16.3	0.8	2	2.5	0
16	2	26.7	68 56.7, 166 50.6	2.6	5	1.9	33
16	3	53.3	69 01.7, 167 29.4	1.0	4	4.0	25
19	4	46.5	69 00.0, 167 19.2	3.9	9	2.3	37
20	5	32.8	68 58.1, 166 59.8	2.4	4	1.7	50
29	6	97.0	69 32.1, 167 48.1	2.9	3	1.0	33
30	7	79.3	68 52.7, 168 11.1	3.2	8	2.5	50
30	8	87.6	68 51.6, 168 23.7	3.2	4	1.3	25
May 1	9	38.7	68 36.0, 167 28.1	4.8	6	1.3	33
2	10	79.5	69 09.1, 167 46.5	3.2	6	1.9	50
13	11	71.1	69 11.3, 167 45.8	3.4	3	0.9	100
13	12	65.6	69 11.7, 167 36.4	3.5	4	1.1	25

[1] The percent of identified structures that were lairs.

Table 42. Snow and ice characteristics near seal structures in drifting ice near Cape Lisburne, Alaska, spring 1984.

Parameter	Statistic	Type of structure: breathing holes	simple lairs	pupping lairs
Ice deformation (%)	Mean (range)	30.6 (0-65)	35.8 (15-60)	20.0 (-)
	N	33	19	2
	S.D.	19.1	12.4	0.0
Relief (cm)	Mean (range)	100.6 (15-244)	100.6 (61-183)	91.4 (-)
	N	18	12	2
	S.D.	59.4	35.1	0.0
Snow depth (cm)	Mean (range)	22.1 (0-70)	67.2 (41-100)	82.5 (68-97)
	N	33	17	2
	S.D.	20.6	16.3	20.5

Table 43. Dimensions of seal-made structures along search lines in drifting ice near Cape Lisburne, Alaska, spring 1984.

Parameter	Statistic	Type of structure: breathing holes	simple lairs	pupping lairs
Diameter of hole (cm)	Mean (range)	20.4 (2-41)	36.7 (21-58)	39.5 (38-41)
	N	29	15	2
	S.D.	12.8	9.6	2.1
Length of lair (cm)	Mean (range)	-	138.9 (79-225)	222.0 (213-231)
	N	-	17	2
	S.D.	-	44.6	12.7
Width of lair (cm)	Mean (range)	-	93.4 (53-163)	95.5 (89-102)
	N	-	17	2
	S.D.	-	29.1	9.2
Height of lair (cm)	Mean (range)	-	34.7 (18-52)	23.0 (23-23)
	N	-	17	2
	S.D.	-	9.1	0.0

In aggregate, 14 (26%) of the 53 structures were marked or opened by predators, mainly polar bears, which were quite selective: 3 of 32 (9%) breathing holes were marked (2 by arctic foxes and 1 by a bear), 9 of 19 (47%) simple lairs were excavated by bears, as were both of the pupping lairs (100%). None of the lairs appeared to have been excavated by foxes.

G. Comparison of Coastal and Offshore Seals, 1984

Sixty-six ringed seals were collected in late winter-spring 1984. Of those, 20 were obtained in Norton Sound between 6 and 15 March and 46 were taken in the eastcentral Chukchi Sea near Cape Lisburne between 1 April and 13 May (Figure 11). In both regions, seals were collected in 2 different ice habitats: the nearshore lead systems and the offshore pack ice. Only 1 seal was from the fast ice near Cape Lisburne, and this habitat remains to be adequately sampled.

The Norton Sound collection was made prior to the birth period and included 4 females that had a near-term fetus. Adult females in the Cape Lisburne sample were taken after completion of birth and lactation. Difference in time of collection and reproductive status of mature females no doubt magnified the weight differences between these samples. In the Norton Sound sample, mean weight of sexually mature, non-pregnant females (N = 3) was 59.6 kg and mean weight of 4 pregnant animals was 64.2 kg. In the Cape Lisburne sample, 4 females that had completed lactation and were beginning to molt weighed an average of 48.8 kg. No adult females that had been barren during the preceding reproductive cycle were collected near Cape Lisburne.

Based on our relatively small samples, ringed seals from Norton Sound included a higher proportion of sexually mature animals of both sexes than did the Cape Lisburne sample (Table 44). Sexually mature females made up 35% of the Norton Sound sample compared to only 9% of the Cape Lisburne sample.

Samples of seals from Norton Sound and Cape Lisburne pack ice and nearshore leads were grouped to compare differences in age, length, and weight between: (A) seals from the lead system and pack ice within Norton Sound and within the region near Cape Lisburne; (B) all seals from the lead systems compared with all seals from the pack ice; and (C) all seals from Norton Sound compared with all seals from the Cape Lisburne area (Table 45). There were no statistically significant differences between samples of seals from the nearshore lead systems and the pack ice either in Norton Sound or near Cape Lisburne with respect to age, length, or weight (Table 45A). In combined samples of all seals from the lead systems and all seals from the pack ice, there were no statistically significant differences in age composition or length. The heavier weight of seals from the shore lead sample was significant (Table 45B). The difference in weight is partially a reflection of the higher proportion of adult (sexually mature) seals taken in the lead systems of Norton Sound during the period of maximum seasonal fatness and term pregnancy. However, it is probably more a function of sample distribution, since most pack ice seals were collected near Cape Lisburne (38 of 46), and the mean weight of all seals collected near Cape Lisburne was significantly less than for Norton Sound samples. Seals from Norton Sound were significantly older and larger than those from the Cape Lisburne area, at least in 1984 (Table 45C).

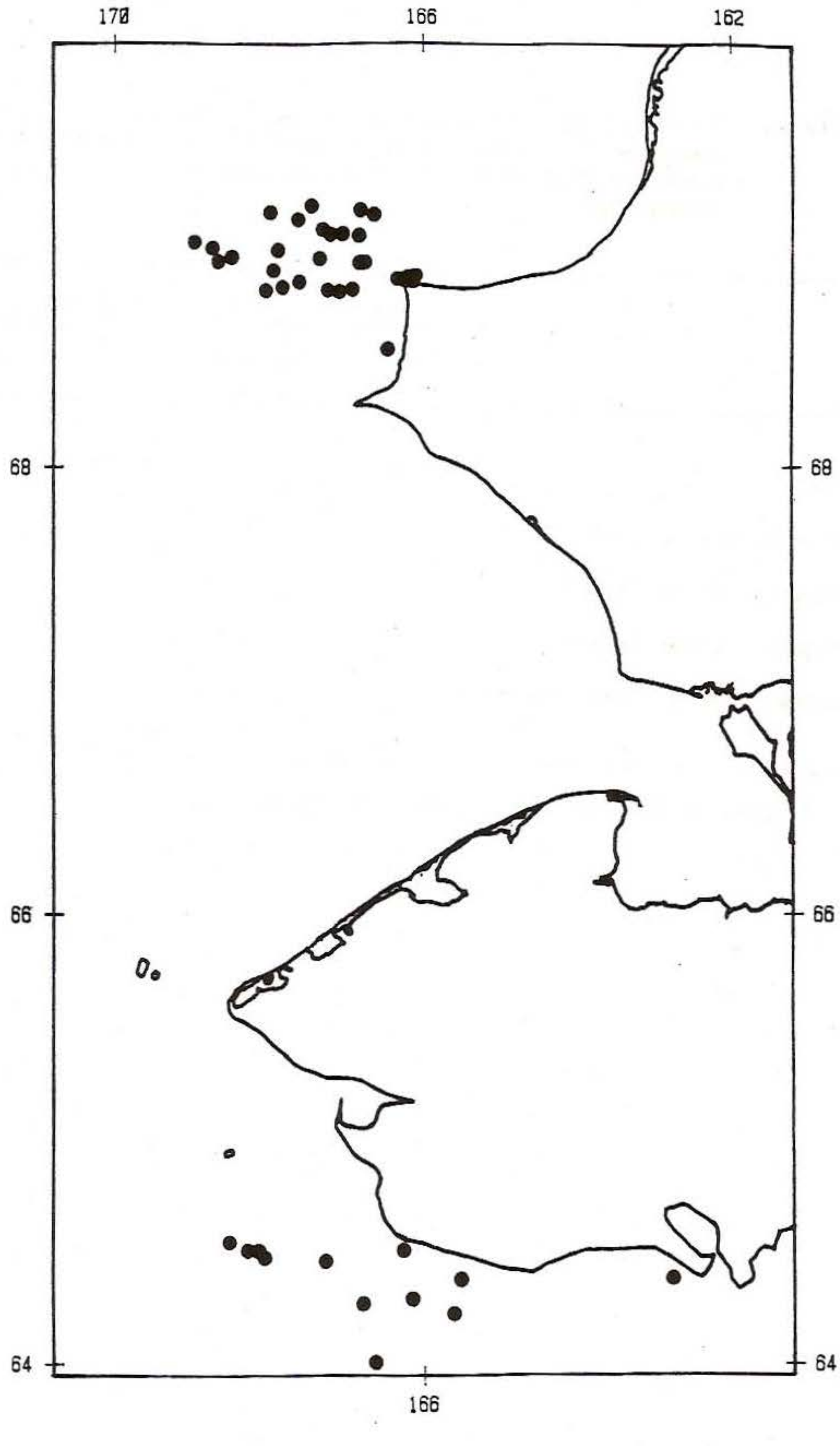

Figure 11. Collection locations of 66 ringed seals collected from nearshore leads and pack ice near Norton Sound and Cape Lisburne in March-May 1984.

Table 44. Reproductive status of ringed seals collected in Norton Sound and near Cape Lisburne in March-May 1984. Females from Cape Lisburne that were classified as pregnant (n = 4) were postpartum.

	Norton Sound n = 20		Cape Lisburne n = 46	
	No.	percent	No.	percent
Males	10	50	31	67
Sexually mature (both sexes)	12	60	13	28
Sexually mature females	7	35	4	9
Pregnant mature females*	4	57	4	100*
Mature females from lead system*	5	71	1	25

* Percent is the percent of total mature females.

Table 45. Statistical comparisons of ringed seals from Norton Sound and east-central Chukchi Sea, near Cape Lisburne, collected in March to May 1984.

A.

Parameter	Norton Sound			Cape Lisburne		
	lead system n = 12	pack ice n = 8	ANOVA test	lead system n = 7	pack ice n = 38	ANOVA test
Age (yrs)						
$\bar{x}$	7.5	7.9	F(1.18)=0.0072	6.3	5.8	F(1.43)=0.1066
SD	2.8	3.5	NS	4.2	3.7	NS
Length (cm)						
$\bar{x}$	114.3	112.6	F(1.18)=0.1565	105.6	106.4	F(1.43)=0.0415
SD	8.7	10.9	NS	9.6	10.1	NS
Weight (kg)						
$\bar{x}$	55.8	50.9	F(1.18)=0.6125	39.7	37.8	F(1.43)=0.1648
SD	13.6	13.7	NS	11.4	11.1	NS

B.

	All shore lead (n = 19)	All pack ice (n = 46)	ANOVA test
Age (yrs)			
$\bar{x}$	7.2	6.2	NS
SD	3.3	3.7	
Length (cm)			
$\bar{x}$	111.1	107.5	F(1.63)=1.6788
SD	9.8	10.4	NS
Weight (kg)			
$\bar{x}$	49.8	40.1	F(1.63)=7.3480
SD	14.8	12.5	$0.005<p<0.01$

C.

	All Norton Sound (n = 20)	All Cape Lisburne area (n = 46)	ANOVA test
Age (yrs)			
$\bar{x}$	7.8	6.0	F(1.64)=3.838
SD	3.0	3.7	$0.05<p<0.1$
Length (cm)			
$\bar{x}$	113.6	106.6	F(1.64)=7.212
SD	9.4	10.0	$0.005<p<0.01$
Weight (kg)			
$\bar{x}$	53.8	38.5	F(1.64)=22.643
SD	13.5	11.3	$p<0.005$

The stomach contents of seals collected in the coastal lead system and offshore pack ice near Nome and Cape Lisburne were compared to determine whether there were any detectable differences. Nine seals collected in coastal leads near Nome had eaten primarily shrimp and arctic cod (Boreogadus saida) (Table 46). The 10 offshore pack ice seals had also eaten primarily shrimp and arctic cod and somewhat more sculpins (Cottidae) than the coastal seals. In coastal samples, the major shrimp species was Pandalus hypsinotus whereas in offshore samples it was Pandalus goniurus.

Near Cape Lisburne, coastal seals also had eaten mostly shrimp and lesser amounts of gammarid amphipods and fish, mostly sculpins (Table 47). Offshore seals had eaten primarily shrimps and some mysids. Arctic cod and pricklebacks (Lumpenus spp.) were the most common fishes. While the proportions of fish and invertebrates were similar in coastal and offshore samples, there were differences in species composition. The shrimp Pandalus goniurus was important in both areas, but Eualus gaimardii was present in significant amounts only in the offshore sample. Similarly, sculpins were more numerous near shore and pricklebacks occurred only off shore.

Area-to-area differences were most notable when comparing the proportions of invertebrates and fishes. Near Nome for both samples combined (n = 19) invertebrates (mostly shrimps) made up 41% of the total volume of contents. In the combined Cape Lisburne samples (n = 42) invertebrates (also mostly shrimps) made up 94% of the total volume of contents. The fishes eaten by both coastal and offshore Norton Sound seals were primarily arctic cod (80% of identified individuals) and some sculpins, whereas the samples near Cape Lisburne contained similar numbers of arctic cod, sculpins, and pricklebacks.

The volume of stomach contents was similar for coastal and offshore seals near Cape Lisburne and coastal seals in Norton Sound. In the offshore Norton Sound sample where fish made up 66% of the volume of contents the mean volume was approximately twice that of the other samples.

Thus, although there were no significant differences between seals from the lead systems and pack ice either within both regions or between the 2 regions, the combined regional samples were substantially different from each other.

VII. Discussion and Conclusions

A. Ringed Seals and Seismic Activity

Aerial Surveys, 1981 and 1982

Aerial surveys in 1981 and 1982 were undertaken primarily in an attempt to determine whether on-ice seismic exploration affected the distribution of ringed seals. Comparisons of results of surveys in both 1981 and 1982 indicated no overall difference in density of ringed seals near seismic lines and near adjacent control lines. In 1981, there was a statistically significant difference in density on 1 of 3 survey days, when more seals were found along control transects. There were no significant differences on the other 2 days. In 1982, there was a statistically significant difference on 1 of 7 days, but the difference was the opposite of that found in 1981: more seals were along the seismic lines. Comparisons of blocks of area, with and

Table 46. Stomach contents of ringed seals collected near Nome, 6-15 March 1984.

Prey item	Coastal N = 9			Offshore N = 10		
	% volume	% number	% freq.	% volume	% number	% freq.
Mysid	*	-	33	*	-	20
Gammarid amphipod	*	-	22	*	-	30
Shrimp	55	-	89	34	-	90
Other invertebrate	*	-	11	-	-	-
Total invertebrate	55	-	89	34	-	90
Total fish	44	-	89	66	-	90
Saffron cod	-	2	22	-	2	30
Arctic cod	-	89	89	-	74	90
Sculpins	-	9	44	-	23	60
Pricklebacks				-	1	10
Mean volume of contents -	86.7 ml				154.5 ml	
Total # identified fishes -	79				145	

* = less than 1%

Table 47. Stomach contents of ringed seals collected near Cape Lisburne, 1 April-15 May 1984.

Prey item	Coastal n = 7			Offshore n = 35		
	% volume	% number	% freq.	% volume	% number	% freq.
Mysid	1	-	71	13	-	77
Gammarid amphipod	16	-	14	*	-	26
Shrimp	62	-	100	80	-	100
Other invertebrate	12	-	29	1	-	7
Total invertebrate	92	-	100	95	-	100
Total fish	8	-	100	5	-	94
Saffron cod	-	7	43	-	8	34
Arctic cod	-	7	43	-	31	69
Sculpins	-	83	71	-	13	51
Pricklebacks	-	-	-	-	40	9
Eelpout	-	-	-	-	5	6
Smelt	-	3	29	-	1	3
Other fish	-	-	-	-	2	9
Mean volume of contents -	74.1 ml				70.4 ml	
Total # identified fishes -	59				279	

* = less than 1%.

without seismic exploratory activity, also indicated no differences in density. Based on 1981 data, mean density of seals in 2 control blocks was $1.63/nm^2$, and in blocks where intensive seismic exploration had occurred, density was $1.62/nm^2$. Thus, results of both line-by-line and block comparisons suggest that winter seismic exploration conducted in 1981 and 1982 had no broad-scale impact, as measured by aerial surveys, on the density of ringed seals. Aerial surveys are not, however, well-suited to detecting small-scale differences in geographically restricted areas, and consequently are not, by themselves, adequate for determining the effects of industrial activity. To do so would require a combination of aerial surveys with on-ice studies that monitor the use of breathing holes and lairs on a finer scale. For a further discussion of the effects of industrial activity on the distribution and abundance of ringed seals as measured by aerial surveys, see Frost et al. (1985, 1987, 1988) and Kelly et al. (1988).

Seal Structure Studies - Beaufort Sea 1982

Our first intensive field season involving study of subnivean structures made by ringed seals was undertaken from 5 March to 26 May on fast ice of southcentral Beaufort Sea off Prudhoe Bay. That effort focused on the effects of on-ice seismic exploration on ringed seals as indicated by the fates of seal-made structures. Searches were "linear" and were conducted along lines laid out for purposes of seismic exploration and along nearby control lines. Structures were checked 1 to as many as 7 times after they were first found to determine changes in use by seals.

The question of disturbance to ringed seals resulting from seismic exploration and other activities by humans within ringed seal habitat is very difficult to address. Some degree of disturbance results from all on-ice activities, including those of the investigators. Thus, analyses of the effects of disturbance become examinations of degrees of difference, in a natural setting which is also changing.

Slight movements of the fast ice cover along the Beaufort Sea coast can open cracks at any time during the winter. Such movements result from strong impingement of the drifting ice, tidal surges associated with storms (often at some distance from the study area), and perhaps even because of major changes in barometric pressure. New openings such as cracks are used by seals. We have no measure of the rate of initiation of new subnivean structures throughout the freezing seasons, but this dynamic process was ongoing during our study and structures were found along newly formed cracks.

In the study of the fate of subnivean structures as conducted in 1982, there were, in actuality, no "control" lines, only lines along which seismic activity did not occur. The so-called control lines were frequently traversed by our light snow machines and were within several miles of a shore-based construction site at which an artificial gravel island (Seal Island) was being built. Kelly et al. (1988) found that radio-tagged seals departed their lairs 73% of the times in which snow machines or other vehicles passed within 3 km, and were also disturbed by helicopter traffic within 3-5 km, and by foot traffic over 500 m away. Assuming that all human activities on the fast ice disturbed seals to some degree, our major test of potential impact became an analysis of the abandonment rate of structures. In that analysis, it was necessary to consider potential biases resulting from the way structures were examined. Structures were either probed or opened by us. We thought that probing would be less disruptive than excavation. However, analysis of the data indicated that structures which were opened sustained no higher incidence of abandonment than did those that were simply probed. In both samples, 13% of the structures, whether opened or probed on the first visit, were frozen by the second visit.

Completely refrozen holes were considered to indicate irreversible abandonment. Once completely frozen, none of the abandoned structures we examined were reopened by seals during the course of our field work. Altered structures (partially blocked lairs and/or partially frozen access holes) apparently represented either a lesser response of seals to disturbance or a natural change in the use of structures. Unless they became completely frozen, such altered structures continued to be used as breathing holes, and in several instances were reopened and normal use for hauling out was resumed.

The sphere of high noise and vibration levels from seismic exploration per se appears to be limited to rather close proximity of the activity (A. Blix and J. Lentfer, pers. commun.). It is also of short duration. However, associated activities of laying out and clearing lines also create substantial noise and occur over a longer duration. Our results suggest that seismic exploration did not result in significantly greater abandonment immediately adjacent to seismic lines. Abandonment occurred in 16% of seal structures within 150 m of seismic lines and 5% beyond 150 m, compared to 14% within 150 m of control lines and 9% beyond 150 m. These differences were not substantially significant.

Our comparison of the fates of structures in relation to times when seismic lines were vibrated and distance from seismic lines was an attempt to determine whether the vibroseis equipment itself caused a disturbance that was different than that caused by other activities. There were no apparent differences in fates of structures found and revisited after lines were laid out but before they were shot and those found and revisited after seismic lines were shot. These results suggest that vibroseis equipment is not a long lasting source of disturbance.

Activity associated with the construction of an artificial island (Seal Island) apparently did cause significantly greater abandonment near the island than occurred farther away. Within 2 km of Seal Island, 60% of the structures located by the dogs were frozen, compared to 14% of the structures 2-10 km away (x^2 - 6.173, p > 0.025). Unlike seismic exploratory activity which was short lived but sometimes intense, island construction entailed relatively continuous activity over a 6-8 week period. Apparently this sustained activity caused a higher proportion of structures to be abandoned near the island.

Overall, data from this study do not demonstrate a clear relationship between seismic exploration and the fate of ringed seal structures. Specific analyses of abandonment relative to seismic and control lines, distance from seismic lines, and time of vibration did not clearly indicate that seismic exploration caused increased abandonment of seal structures. However, for the entire Beaufort Sea study area in 1982, which included the cumulative noise from island construction, heavy equipment, and seismic activity, 11% of all structures were abandoned. This is approximately triple the abandonment rate of 4% reported by Kelly et al. (1988 and pers. commun.) for non-industrialized areas of the Beaufort Sea, and double the abandonment rate for our study areas in the Bering and Chukchi seas, where no such noise sources were present (see section VII D for further discussion). Based on these results, we conclude that the aggregate industrial activity in the central Beaufort Sea in 1982 did not result in an area-wide increase in abandonment of subnivean ringed seal structures. The significance of this increased abandonment is unknown.

B. Characteristics of Structures

Composition of Seal Structures, Composite Data - 1982-1984

The composition of all identified structures found in this study during 1982 to 1984 (N = 794) was 321 breathing holes (40.4%), 310 simple lairs (39.1%), 81 complex lairs (10.2%), and 82 pupping lairs (10.3%).

We found considerable variation in the composition of seal-made structures in different areas during different years (Table 48). Lairs of all 3 types composed 53% of the identified structures found on fast ice of the Beaufort Sea in 1982, 64% of structures in Kotzebue Sound in 1983, and 75% of structures near Cape Lisburne in 1984.

The lowest proportion of lairs (35%) was found during the extensive surveys of February-March 1983, though the combined results from all 23 surveys made during that time are misleading. Those surveys can be separated into 2 broad areas, Norton Sound and eastern Chukchi Sea. Forty-seven identified structures were found in Norton Sound, of which only 10 (21%) were lairs. This compares with 72 identified structures in eastern Chukchi Sea, of which 30 (42%) were lairs. The low proportion of lairs found in Norton Sound was attributed to 3 factors: (1) the extent of recently formed, relatively thin fast ice; (2) lack of snow cover, particularly in eastern Norton Sound; and (3) the early timing of surveys in that region. The Norton Sound surveys were conducted between 24 February and 2 March. Extensive surveys of fast ice in the eastern Chukchi Sea were undertaken between 3 and 15 March, closer to the onset of pupping. Snow and fast ice conditions were far more favorable in the eastern Chukchi Sea.

In the eastern Chukchi Sea, surveys of grids on the fast ice and of lines in the pack ice were undertaken during the same time period in April and May 1984. Lairs composed 75% of the 245 identified structures on the fast ice and 39% of 54 structures on the pack ice. This difference was significant ($x^2 = 26.167$, df = 1, $p < 0.001$). The difference in proportions of lair types in these 2 habitats was even more striking; 31% of all structures on the fast ice were complex or pupping lairs, compared to 4% on the pack ice ($x^2 = 17.123$, df = 1, $p < 0.001$). These data suggest that ringed seals from the pack ice in the eastern Chukchi Sea either included a higher proportion of juveniles, a higher proportion of non-breeding adults, or both. Conversely, the significance of fast ice as important habitat for pupping was confirmed.

Comparison of the composition of ringed seal structures in Alaska with results of studies in other areas indicates considerable geographic variation (Table 49). Pupping lairs made up the greatest proportion of total structures (20%-25%) in Amundsen Gulf and the Canadian High Arctic (Smith and Stirling 1978; Smith et al. 1978) and on the fast ice of the central Chukchi Sea (18%).

Table 48. Composition of ringed seal structures, 1982-1984.

Year	Months	General location	N	Structures: breathing holes No.	breathing holes %	simple lairs No.	simple lairs %	complex lairs No.	complex lairs %	pupping lairs No.	pupping lairs %	unidentified structures No.	unidentified structures %
1982	5 Mar-26 May*	Fast ice southcentral Beaufort Sea	157	70	45	62	39	5	3	11	7	9	6
1983	27 Mar-1 May	Fast ice southeast Kotzebue Sound	235	82	35	94	40	30	13	27	11	2	1
1984	3 Apr-15 May	Fast ice eastcentral Chukchi Sea	247	62	25	107	43	32	13	44	18	2	1
1983	24 Feb-15 Mar	Fast ice - extensive survey, Norton Sound-Peard Bay	119	74	62	28	24	12	10	0	0	5	4
1984	15 Apr-13 May	Pack ice eastcentral Chukchi Sea	59	33	56	19	32	0	-	2	3	5	9

* Type of structures mainly determined during latter part of field effort, when they were opened and measured.

Table 49. Composition of structures made by ringed seals in different parts of their range.

Area (source)	N	Percent breathing holes	Percent non-pupping lairs	Percent pupping lairs
Norton Sound 1983 (this study, coastal survey)	47	79	21	0[1]
Kotzebue Sound 1983 - southern (this study, coastal survey)	23	43	57	0[1]
Kotzebue Sound 1983 - southern (this study, grids)	233	35	53	11
Kotzebue Sound 1984 (Kelly et al. 1986)	157	69	28	3
Kotzebue Sound 1983 - northern (this study, coastal survey)	22	85	15	0[1]
Cape Lisburne fast ice 1984 (this study, grids)	245	25	57	18
Cape Lisburne pack ice 1984 (this study)	54	61	35	4
Beaufort Sea 1982 (this study)	148	47	45	7
Beaufort Sea 1983 (Kelly et al. 1986)	57	35	61	4
Amundsen Gulf 1974-75 - Inshore	42	17	59	24
- Offshore (Smith & Stirling 1978)	35	11	69	20
Canadian High Arctic 1975-76 (Smith et al. 1978)	353	23	52	25
White Sea 1972-74 (Lukin & Potelov 1978)	647	77	14	9[2]

1 Searches conducted before pupping season.
2 The overall incidence of pupping lairs for all parts of the study area, including flat ice with little snow cover was 9%. Within areas of adequate snow cover and deformation, up to 33% of all structures were pupping lairs.

They made up a relatively small proportion of the total structures in the White Sea (9%), the Beaufort Sea off Alaska (4%-7%), and the pack ice in the central Chukchi Sea (4%) (Lukin and Potelov 1978; Kelly et al. 1986; this study). In southern Kotzebue Sound, there was a substantial difference between the 2 years in which studies were conducted, with pupping lairs making up 11% of all structures in 1983, but only 3% in 1984 (Kelly et al. 1986; this study).

Dimensions of Seal Structures, Composite Data - 1982-1984

During this study, measurements were obtained from 577 structures located in fast ice of the Chukchi and Beaufort seas (Table 50). It is clear from these data that holes used by seals only for breathing were considerably smaller than those through which seals hauled out onto the ice ($t = 10.17$, $df = 437$, $p < 0.001$). As lairs progressed from simple haul-out lairs to complex and pupping lairs, the size of the access hole increased, probably due to more frequent hauling out by the resident seal(s). Complex lairs were both longer and wider than simple lairs (t-test, $p < 0.001$). Pupping lairs were significantly larger than all other lairs ($p < 0.001$) with mean lengths and widths over 1.5 times greater than those of simple lairs.

Within Alaska, there was no apparent geographic trend in the size of lairs from one area to the next. Lairs of the same type were of similar length in each of our 3 study areas located on fast ice. By comparison, lairs in Amundsen Gulf in the eastern Beaufort Sea were significantly larger (Smith and Stirling 1975). Simple lairs were more than 20% longer ($t = 4.40$, $df = 389$, $p < 0.001$) and 30% wider ($t = 5.48$, $df = 378$, $p < 0.001$) than simple lairs on fast ice in Alaska. Pupping lairs were almost 30% longer ($t = 4.59$, $df = 192$, $p < 0.001$) and 40% wider ($t = 5.48$, $df = 191$, $p < 0.001$).

The reason for this difference is unclear. Lairs in all areas were measured during approximately the same time period (March through May in Alaska and March to mid-June in Amundsen Gulf). It is unlikely that the distribution of search effort by date affected the mean values, since in Kotzebue Sound in 1984 we found no significant trend in lair length by date, except for pupping lairs.

Little is known about the relationship or interchange of ringed seals between Amundsen Gulf and Alaska, and whether they come from the same or different stocks. However, the mean length of seals that were 10 years or older from Amundsen Gulf ($n = 498$) was 124.7 cm (Smith 1987) compared to 114.6 cm for seals of similar age in Alaska (Frost and Lowry 1981). The larger reported lair size in the eastern Beaufort may have been because the seals that constructed and used them were larger.

One of the objectives of this study in 1984 was to examine any differences between seals and seal structures in pack ice and fast ice habitats. The sample of lairs on pack ice from the Cape Lisburne area in 1984 was quite small ($n = 19$), and all but 2 were simple lairs. The mean diameters were smaller in the pack ice sample than in fast ice for breathing holes ($t = 3.99$, $df = 210$, $p < 0.001$) and access holes to simple lairs ($t = 2.42$, $df = 170$, $p < 0.02$). Although simple lairs on pack ice were smaller than those on fast ice, the difference was not significant ($t = 1.89$, $df = 266$, $p > 0.1$).

Table 50. Mean values for dimensions of ringed seal structures from fast ice habitats in Alaska.

Parameter	Type of structure			
	breathing holes	simple lairs	complex lairs	pupping lairs
Diameter of hole (cm)	30.6	43.4	48.5	52.0
Length of lair (cm)	-	160.3	235.0	276.6
Width of lair (cm)	-	104.5	128.7	164.0
Height of lair (cm)	-	32.1	32.5	33.4

The smaller mean diameter of breathing holes found in the pack ice is probably mainly due to the higher proportion of such structures in thin ice of recently refrozen leads. Such breathing holes tend to be smaller than those made in the much thicker landfast ice. Smaller diameter of access holes into simple lairs on pack ice may be partly a function of seal density, with fewer seals using any given lair in less crowded areas. Data from aerial surveys flown near Cape Lisburne in 1987 indicated that the density of seals on pack ice ($0.5/km^2$) was less than half the density on fast ice ($1.1/km^2$) in that area (Frost et al. 1988).

Small breathing holes and access holes may also indicate that seals in pack ice are smaller than those in fast ice. This could occur if the age structure of seals in the 2 habitats is different. In fact, 72% of the seals we collected in the nearshore lead system and pack ice near Cape Lisburne were immature (young) and therefore smaller. Although we have no comparable sample of seals collected from fast ice, the scarcity of pupping lairs on pack ice (0.3 pupping lairs/km^2, making up only 4% of all structures) compared to fast ice ($1.6/km^2$, making up 18% of all structures) also suggests that the age structure was different.

Regional Abundance of Seal Structures

Data obtained in this study provide the most accurate information available to date on the density of ringed seal structures. Earlier studies have generally compared relative abundance in different areas based on the number of structures found by the dogs in a specified amount of time, or by the unit of time required to locate structures (e.g., Smith and Stirling 1975; Smith et al. 1978). In some instances, investigators also estimated the approximate area searched in order to estimate the actual density of structures. In our studies in 1983 and 1984, searches were laid out in surveyed grids of known area in 2 regions, southern Kotzebue Sound and east of Cape Lisburne. The dogs were worked extensively within each area to obtain an accurate measure of the number of structures. The resultant densities of the different structure types can be used not only as an indication of the comparative abundance of ringed seals in different geographic areas or habitats, but also to identify areas of particular importance as pupping habitat.

The highest density of structures within our gridded searches was on the fast ice east of Cape Lisburne where, in 1984, the dogs located an average of 8.6 structures/km^2 (range 6.8-10.8/km^2) in 4 study grids totalling about 27 km^2. The density in southern Kotzebue Sound was somewhat lower, 7.1/km^2 (range 6.8-8.5/km^2).

For linear searches, in which the dogs worked a line only once, density estimates were also made by either estimating the strip width that the dogs searched as 200 m and multiplying that by length of the line to calculate the area searched (used for coastal searches in 1983), or by totalling all structures within a certain distance (either 50 m or 200 m) from the line (used for the Beaufort Sea in 1982 and Cape Lisburne pack ice searches in 1984). Density estimates derived in this manner are not strictly comparable to those from grids, since lines were searched only once. Comparisons within grids of the proportion of structures found on first and multiple searches indicated that the dogs found approximately 60%-70% of the total structures within 200 m of the line on the first search (see sections D and E, Search Effort and Biases). Thus, a correction factor should be applied to densities from line searches before they are compared to those from grids. We used a multiplier of 1.5, corresponding to a 65% detection rate on first searches.

After correction factors were applied, comparison of all of our study areas indicated that the highest densities of total structures were in the northern Bering Sea (12.8/km²), the pack ice off Cape Lisburne (10.0/km²), and, based on a single 3.7 km line with only 9 structures, outer Peard Bay (18.2/km²) (Table 51). Densities on the fast ice east of Cape Lisburne were also quite high. The lowest density found by us along the Alaska coast was in the Beaufort Sea (3.6/km²). Kelly et al. (1986) reported even lower densities for the Beaufort Sea in 1983 (0.8/km²) and southern Kotzebue Sound in 1984 (2.5/km²).

Densities reported by Smith and Stirling (1975) for inshore and offshore areas of Amundsen Gulf were similarly low. However, their technique for estimating density was quite different. Dogs were allowed to search an area for 30 minutes, during which time investigators estimated that they covered a roughly circular area with a radius of about 1,000 m or about 3.1 km². Lukin and Potelov (1978) reported the highest density of ringed seal structures found anywhere. In Kandalaksha Bay in the White Sea, the density of structures in ice of 30%-40% deformation was 27/km² in water deeper than 10 m and about half that in water 3-10 m deep. Elsewhere in the White Sea, the density of total structures varied from 8.3/km² to 12.3/km² (Table 51).

Data were available for 2 years in several areas in Alaska. Near Cape Lisburne, the corrected density for 1983 and the average density for grids in 1984 were similar. In contrast, there was a 4-fold difference in densities between years in the Beaufort Sea and a 3-fold difference in Kotzebue Sound. It is likely that some of this can be attributed to differences in technique and to differences in exact location of study areas since densities were from our work for one year and from Kelly et al. (1986) for the other. Annual variation was probably also a factor, as has been reported by other investigators. Lukin and Potelov (1978) noted a 30% reduction in structure density between 1972 and 1973. Smith and Stirling (1975) found 1 pupping lair per 6 minutes of searching near Iluvilik in 1973 compared to 1 per 64 minutes in 1974. In other areas and other years, densities remained similar from one year to the next, although comparisons were complicated by changes in search technique (Smith et al. 1978; Smith and Hammill 1981).

Regional differences in the density of lairs were also substantial, ranging from a low of 0.6/km² in the Beaufort Sea in 1983 to a high of 6.4/km² east of Cape Lisburne and 12.2/km² in the small Peard Bay sample. The areas with the highest densities of total structures, the northern Bering Sea and the Cape Lisburne pack ice, did not have particularly high densities of lairs.

Data were available on densities of pupping lairs for only a few areas of Alaska, since the coast-wide survey in 1983 was conducted prior to the pupping season. As was the case for total lairs, the density of pupping lairs was highest near Cape Lisburne (1.6/km²). Pupping lairs were also numerous on Grid 83-2 in Kotzebue Sound (2.2/km²). However, based on 2 years of study,

Table 51. Regional abundance of ringed seal structures in Alaska and elsewhere.

Area	Mean density/km² (range) all lairs	pupping lairs	all structures	Source
Northern Bering Sea - 1983	3.6	0	12.8	This study - Tables 13 and 14
Southern Kotzebue Sound - 1983	4.5 (4.4-5.3)	0.8 (0.5-2.2)	7.1 (6.8-8.5)	This study - Table 18,
1984	0.7		2.5	Kelly et al. 1986
Northern Kotzebue Sound - 1983[1]	1.1	0	6.8	This study - Tables 13 and 14
Cape Lisburne fast ice - 1983[1]	3.0	0	9.0	This study - Tbls 13, 14
1984	6.4 (5.0-7.7)	1.6 (0.4-1.8)	8.6 (6.8-10.8)	This study - Tbls 31, 32
pack ice - 1984[1]	3.5	0.5	10.0	This study - Table 41 and text
Peard Bay - 1983	12.2	0	18.2	This study - Tbls 13, 14
Beaufort Sea - 1982[1]	1.9	0.3	3.6 (3.0-9.6)	This study
1983	0.6	-	0.8	Kelly et al. 1986
Amundsen Gulf - inshore	-	-	1.3	Smith & Stirling 1975
offshore	-	-	0.5	Smith & Stirling 1975
Eastern Arctic	1.5	0.7 (0.4-3.1)	2.8 (0.8-16.5)	Smith et al. 1978
Central Arctic	-	-	5.2-7.9	Hammill 1987
White Sea 3m-10m	-	1.5	13.1	Lukin and Potelov 1978
>10m	-	9.0	27.0	
Kandalaksha Bay Solovetski Isls	-	3.2-4.6	8.3-12.3	Lukin and Potelov 1978

[1] Values have been adjusted upward by a factor of 1.5 based on the assumption that dogs find 65% of structures present on a single search of a line.

ours and that of Kelly et al. (1986), it appears that annual variability in ice and snow conditions and therefore density of structures and suitability for pupping is far greater in Kotzebue Sound than near Cape Lisburne.

Data from aerial surveys in 1976, 1985, and 1986 also suggest greater stability in densities near Cape Lisburne than in Kotzebue Sound (Frost et al. 1985, 1987). Density ranged from 1.0 to 1.9 seals/km² between Cape Lisburne and Point Lay, and from 0.3 to 1.7 in Kotzebue Sound. In each of the 3 years, ringed seal densities in the Cape Lisburne sector were among the highest in Alaska. In contrast, Kotzebue Sound had the lowest observed density in 1976 and the highest in 1986.

An extrapolation of the density of pupping lairs to the estimated number of pups born reinforces the relative importance of the eastcentral Chukchi Sea as pupping habitat. Based on 3 years (1985-1987) of aerial surveys (Frost et al. 1985, 1987, 1988), the average area of fast ice between Cape Lisburne and Point Lay (sector C4) was 2,900 km². At 1.6 pupping lairs/km², this area would have produced approximately 4,600 ringed seal pups in 1984. By comparison, 8,900 km² in the central Beaufort Sea (sector B3) at 0.3 pupping lairs/km² would have produced only 2,670 pups in 1982. These are probably overestimates of actual pup production, especially near Cape Lisburne, since grids were located in areas that appeared to be good pupping habitat. Our data indicated that most lairs were located in ice of 10%-40% deformation. During aerial surveys in 1985-1987, about 40%-60% of the fast ice in the central Chukchi Sea and 50%-60% of that in the central Beaufort Sea was classified in the 10%-40% deformation categories.

C. Predation

Arctic foxes and polar bears are natural predators of ringed seals (Smith 1980; Stirling and McEwan 1975). Polar bears hunt and kill juvenile and adult seals year-round as the mainstay of their diet. Both bears and arctic foxes hunt newborn ringed seal pups in the spring (April and May) by excavating or entering lairs and killing the pups before they can escape to the water.

Lair studies in 1982-1984 were conducted from March to May, both before and during the pupping period. Our data provide a general indication of predator activity and the extent of predation on pups during spring.

Polar bears were present in abundance only on the lines and grids studied in the eastern Chukchi Sea in 1984. Although polar bears passed through our 1982 Beaufort Sea study area on 2 occasions, they did not mark or excavate any of the structures we found. The highest incidence of fresh polar bears tracks was encountered during the pack ice searches in 1984 on line 11, where 28 sets of fresh tracks were crossed in 3.3 km. On the fast ice, the greatest polar bear activity occurred in Grid 84-1, where a sow with new cubs hunted for several days.

During our 1984 field season and during the entire winter of 1983-84, polar bears were very abundant along the Chukchi Sea coast. Harvest records obtained by the U.S. Fish and Wildlife Service reflect that abundance. Reported bear harvests in the region between Bering Strait and Barrow during the time periods of July 1 to June 30 (the recording year) since 1980 were: 1980-81 = 46; 1981-82 = 62; 1982-83 = 49; 1983-84 = 182 (Dale Taylor, pers. commun.).

The relative abundance of arctic foxes, as indicated by tracks, was quite variable in the different study areas. They were of low-to-moderate abundance on fast ice in the southcentral Beaufort Sea during spring 1982, almost absent in southeast Kotzebue Sound in spring 1983, moderately abundant on fast ice near Cape Lisburne in spring 1984, and occurred in low abundance during the time we worked on the pack ice in 1984. It is common knowledge that arctic fox abundance varies in response to regular changes in abundance of voles (Microtus spp.) and lemmings (Lemmus sibiricus). Trappers that we talked to from Point Hope, Point Lay, and Wainwright indicated that foxes were not abundant during the winter of 1983-84.

Polar bears hunted seals differently than did arctic foxes. Bears collapsed or pushed in lairs or dug very large holes which completely obliterated the lair, whereas foxes entered lairs by digging small tunnels. Bears sometimes uncovered breathing holes as well as lairs. The only breathing holes entered by foxes had small chambers around them and were probably in the process of being enlarged to lairs.

There were substantial differences among study areas in the incidence of predator activity (Table 52). On the fast ice, the lowest incidence of predator activity was in southeastern Kotzebue Sound in 1983 where foxes marked only 3% of all structures and entered 5% of all lairs. The highest incidence was in the Cape Lisburne area in 1984, where both arctic foxes and polar bears were present. In combination, those 2 predators marked 47% of the structures found in the 5 study grids and entered 37% of all lairs. Foxes marked more structures, opened more lairs, and killed more pups than did polar bears. In the Beaufort Sea study area in 1982, foxes were quite active, but marked and entered a smaller proportion of total structures and lairs than they did near Cape Lisburne. Foxes were present in relatively low numbers until early April, at which time there was a noticeable increase in fox tracks and other sign. First indications that seal pups were being born occurred on 4 April when pup remains were found in fresh fox feces.

Polar bears were the predominant predator on the pack ice. They marked and/or entered more structures than arctic foxes, and the single pup kill found in our pack ice searches was made by a polar bear. In Amundsen Gulf, Smith (1976, 1980) also found that most polar bear predation occurred farther off shore, whereas fox activity was greatest near shore.

The total amount of successful predation on ringed seal pups, expressed as the number of kills per number of pupping lairs, was low in southeast Kotzebue Sound (7%) and high on the fast ice of southcentral Beaufort (30%) and eastcentral Chukchi (30%) seas. A pup was killed at 1 of 2 pupping lairs found on the pack ice. Nine other non-pupping lairs on the pack ice were opened without a successful kill. In the Amundsen Gulf area (Smith 1976), the fox predation rate from 1972-1974 averaged about 26% of all pupping lairs, with a range similar to that found in our study (about 9% in 1972, and 34%-40% in 1973-1974).

We compared the number of structures opened or entered to the number of kills, to estimate the success rates of polar bears and arctic foxes (Table 53). Off Cape Lisburne in 1984, polar bears successfully killed pups at 9% of the structures they opened on pack ice, and 16% of those on fast ice. Smith (1980) reported similar success by bears on fast ice of Amundsen Gulf

Table 52. Predator presence and predation at ringed seal structures, 1982-1984.

Year	Location	Predator	All structures		Lairs		Pupping lairs		Kills/ km²
			N	% marked	N	% entered	N	% kills	
1982	Beaufort Sea-fast ice	arctic fox	157	32.9	78	18.0	10	30.0	-
1983	SE Kotzebue Sound - fast ice[1]	arctic fox	185[1]	3.0	120	5.0	14	7.1	0.04
1984	Cape Lisburne - fast ice	arctic fox	247	42.1	183	25.7	44	22.7	0.33
		polar bear	247	8.9	183	8.2	44	6.8	0.10
1984	Cape Lisburne - pack ice	arctic fox	59	3.4	21	0.0	1	0.0	0.0
		polar bear	59	17.0	21	52.4	2	50.0	0.14

[1] Includes only those structures on grid 83-1.

Table 53. Proportion of total and successful predation attempts at seal-made structures that occurred at pupping lairs.

			Pupping lairs			Attempts resulting in kills (%)		
Year	Location	Predator	% of total structures	% of all attempts	% of kills	non-pupping	pupping	all
1983 (n=185)	SE Kotzebue Sound - fast ice	arctic fox	8	20	100	0	100	20
1984 (n=247)	Cape Lisburne - fast ice	arctic fox	18	38	90	3	47	20
		polar bear	18	32	100	0	50	16
(n=59)	pack ice	polar bear	3	9	100	0	50	9
1982 (n=157)	Alaskan Beaufort Sea - fast ice	arctic fox	7	43	100	0	50	21
1971-74 (n=370)	Amundsen Gulf (Smith 1976)	arctic fox	32	53	100	0	50	27
		polar bear	-	-	-	-	-	20
1971-75 (n=676)	Canadian Arctic (Stirling & Archibald 1977)	polar bear	-	-	-	-	-	8
1972-75	E. High Arctic	polar bear	-	-	-	-	-	6
1976 (n=207)	E. High Arctic (Smith 1980)	polar bear	-[1]	36	"majority"	8	29	20
1979 (n=222)	Southeastern Baffin (Smith 1980)	polar bear	-[1]	71	93	8	47	33
1984 (n=90)	Svalbard (Lydersen and Gjertz 1984)	arctic fox	-[1]	68	83	17	38	32
		polar bear	-[1]	31	100	0	25	8

[1] Number of total structures unknown.

and the High Arctic (20%) and somewhat higher success off southeastern Baffin Island (33%). Stirling and Archibald (1977) found that bears were successful on 6% of attempts in the eastern High Arctic, and 8% of attempts in the western Arctic. Kelly et al. (1987) estimated a 75% success rate of polar bears at pupping lairs by following bear tracks and recording kills.

Arctic foxes were successful on about 20% of the attempts documented in all of our studies and 27% in those conducted by Smith (1976) in Amundsen Gulf. Lydersen and Gjertz (1984) reported a somewhat higher success rate of 32% for foxes near Svalbard. In all areas, almost all kills (83%-100%) were made at pupping lairs.

The frequency with which pupping lairs were entered was 2-3 times the frequency at which they occurred relative to other structures. It appeared that bears and foxes could either distinguish between structure types before digging, or that their search patterns increased the probability that they would encounter pupping lairs. Although over half of all predation attempts occurred at structures other than pupping lairs, only an occasional kill was made. Approximately half of all attempts at pupping lairs (29%-100%) were successful, compared to 0% to 17% at other structures. Bears and foxes were apparently similarly successful in predation attempts on pupping lairs.

The actual rate of predation varied by area and by year, probably due to a combination of predator and prey abundance. In our studies, the number of pups killed by foxes and/or bears ranged from a low of 0.04 kills/km^2 in southern Kotzebue Sound (foxes only) to a high of 0.43 kills/km^2 on the fast ice near Cape Lisburne (both foxes and bears).

D. Alteration and Abandonment of Structures

How various factors influence the use of subnivean structures by ringed seals is an important question. The highly variable and dynamic nature of sea ice and the overlying cover of snow limit the location, number, and kinds of structures that seals can make and maintain. The movement of ice can destroy or alter existing structures or it can result in conditions favorable for their construction. As an example, landfast ice can break loose and become incorporated into the pack. At lower latitudes pack ice, which is less stable, is not a preferred habitat for construction of complex and pupping lairs. Leads in the pack ice and along the seaward margin of fast ice irregularly open and close, alternately destroying existing subnivean structures, or creating conditions favorable for the construction of new ones. This is especially true when leads open and subsequently freeze over, providing the opportunity for seals to establish new breathing holes. Pressure on both pack and fast ice results in ridging. This, in turn, promotes greater accumulation of snow and allows construction of lairs. That process was well illustrated by Smith and Stirling (1978) and Smith (1987).

Ringed seals have adapted in several general ways to the variability of ice cover. They select certain conditions in which to construct different kinds of structures. They may modify structures as ice and snow conditions permit (i.e., the progressive change of a breathing hole to a simple lair and then, in some cases, to a complex or pupping lair), or they may abandon structures.

Factors additional to ice dynamics may also result in change of the use of structures by seals. Social interaction among seals may influence the construction and maintenance of different structures. Activities of predators can result in modified patterns of use by seals. As examples, the high frequency of predation at pupping lairs in the Cape Lisburne area in 1984 was no doubt the major contributing factor to the abandonment of 13 of 44 (30%) such structures. Conversely, the incidence of predation at pupping lairs in southeastern Kotzebue Sound in 1983 was very low and none of 27 such structures were abandoned.

Human activities may also alter the use of subnivean structures by seals. Sources of human-caused disturbance during this study included the noise and vibrations resulting from seismic exploration and construction of a gravel island in southcentral Beaufort Sea during 1982; the noise associated with the Cape Lisburne radar facility, airstrip and dump; noise resulting from our repeated travel (on snow machines) in the study areas; and our opening of structures to inspect and measure them.

Data from the 3 years of our study were grouped in relation to the degree and kind of disturbance to which seals were exposed as follows: essentially free of anthropogenic disturbance (Group A); disturbance by industrial activities (Group B); disturbance by investigators (Group C); disturbance by predators (Group D).

Group A comprises structures not subjected to anthropogenic disturbance prior to being located. The samples include those structures found in the pack ice and during initial searches of grids on fast ice near Cape Lisburne in 1984, excluding Grid 84-5; the undisturbed, non-ice road portion of the Kotzebue Sound grid searches; and the extensive coastal survey of fast ice, undertaken in 1983 from Norton Sound to Peard Bay. Structures that were entered by predators are not included in these data sets. Data from Kelly et al. (1988) have also been included, since they are from the same geographic areas. Repeated human-caused noise was not significant at the time these structures were located and examined.

Group B includes first visits to structures in the Beaufort Sea in 1982. All search lines were located in areas where they were subjected to some form of industrial activity. The majority of the lines that were searched were seismic trails that had been bulldozed and prepared as ice roads on which seismic exploration crews worked, either before or during our study. Although "control" lines were not traversed by seismic crews, they were near Seal Island, an artificial gravel island that was under construction. Structures found from the 1982 control lines were previously considered to have been relatively free of anthropogenic disturbance. After reevaluation we, and others (cf. Kelly, et al. 1988) conclude that they were subjected to significant disturbance over a prolonged time. Trucking, gravel dumping, bulldozing, compacting, ice removal, and generator noises occurred near and on the island. This activity started in late February/early March, after ringed seals would have established territories in an area that was initially essentially free of human-caused disturbance. This situation was unlike that on Grid 84-5, which is also included in Group B, where moderate activity occurred all year. The grid was close to the Cape Lisburne Air Force site and was exposed to noise and vibrations from trucks, airplanes, and bulldozers (these were on land), as well as to smoke, ash, and other wind-blown debris from the dump. Seals probably had to be tolerant of noise and odors in order to initially establish territories.

Group C is made up of structures subjected to disturbance by the investigators, including revisited structures found in the 1982 searches in the Beaufort Sea and the 1984 searches in grids near Cape Lisburne. Those structures were opened and reconstructed, one or more times, by the investigators. Abandonment occurring between the first and last visits by investigators may have been attributable to disturbance by our activities. Structures within 200 m of an intensively travelled refrozen lead in Kotzebue Sound that was used as our transportation corridor for 18 days, and which was adjacent to our camp, are also in this group.

Group D includes structures that were entered by predators (foxes and bears). At some structures a kill had been made. The Chukchi Sea sample includes predator-entered structures from Kotzebue and Cape Lisburne grids. On one grid, 84-1, a sow and two cubs had hunted for several days, opening and destroying many lairs. Forty percent of all structures on that grid were opened by either foxes or bears.

In aggregate, Group A (n=877) had the lowest abandonment rate of 6% (Table 54). Samples in this group were not exposed to anthropogenic disturbance, nor to predation. Within Group A, abandonment ranged from 4% to 11%. The highest percent of abandoned structures occurred on the Kotzebue Sound grids, especially grid 83-2 where 16% of the 50 structures were frozen. That grid was searched in early May in very warm weather. Lairs had begun to collapse and melt and cracks had opened up in the flat ice nearby, where many seals hauled out.

Group B, which included structures exposed to seismic exploration, gravel island construction and the Cape Lisburne Air Force site and dump, had a significantly higher rate of abandonment than did the undisturbed structures in Group A (x^2=20.873, $p < 0.005$). Of 147 structures, 11% were abandoned. This is almost double the 6% abandonment for Group A.

The highest abandonment documented in our study occurred in structures that were opened by predators (Group D). Of 88 structures opened by bears or foxes, 32% were frozen. Predation attempts by bears resulted in a much higher rate of abandonment (58%) than entry into lairs by foxes (22%). This is not too surprising since the holes dug by bears generally demolished the entire lair whereas most fox holes were only 6-8 inches in diameter.

The real significance of the abandonment shown for samples in Group C, those disturbed by investigators, is unclear. In earlier draft reports for this project, the rates of abandonment found on revisits to structures were interpreted as unusually high and were attributed to disturbance caused by investigators. However, the proportion of abandoned structures for first-time searches of areas measures abandonment that has occurred over some unknown period of time during which the scent from an abandoned structure persists. Presumably, after an unknown number of days or weeks of disuse, the scent in the structure dissipates and eventually disappears. The time required for this to occur is probably somewhat variable, depending on temperature,

Table 54. Number of structures examined (N) in relation to the number that were abandoned (n), grouped according to the type of disturbances in the area. Unless otherwise noted data are from this study.

Sample	Disturbance		All structures N	n	(%)
A. No anthropogenic disturbance					
Chukchi Sea pack ice, 1984	none		43	3	(7)
Cape Lisburne grids, 1984	none		164	10	(6)
Kotzebue Sound grids, 1983	none		199	21	(11)
Kotzebue Sound, 1984 (Kelly et al., 1988 & pers. comm.)	none		156	8	(5)
Bering/Chukchi Coastal Survey, 1983	none		114	4	(4)
Beaufort Sea, 1983-87 (Kelly et al., 1988 & pers. comm.)	none		201	7	(4)
		TOTAL	877	53	(6)
B. Subjected to industrial activity					
Beaufort Sea, 1982	seismic surveys, island building		134	15	(11)
Cape Lisburne Grid 84-5, 1984	airforce site, dump, machine noise		11	1	(9)
		TOTAL	145	16	(11)
C. Disturbed by investigators					
Kotzebue ice road, 1983	snowmachine traffic		29	6	(21)
Cape Lisburne revisits, 1984	investigator examinations		99	22	(22)
Beaufort Sea revisits, 1982	investigator examinations		102	13	(13)
		TOTAL	230	41	(18)
D. Disturbed by predators					
Beaufort Sea, 1982	structures opened by foxes or bears		14	4	(29)
Chukchi Sea, 1983-84	structures opened by foxes or bears		85	25	(29)
		TOTAL	99	29	(29)

humidity and snow conditions. It is likely, over a period of several weeks, that such differences average out, and consequently, it is probably reasonable to compare rates of abandonment for samples made up only of first-time visits.

It is more complicated to interpret data on abandonment occurring between first and subsequent visits. Would those holes have frozen regardless of disturbance by investigators? Did they freeze only because of the investigators? or was it some combination of both? Previously, abandonment noted on successive visits has been treated as additive (Frost & Lowry 1988, Kelly et al. 1988). In the Beaufort Sea in 1982, the abandonment rate attributed to investigator disturbance was based on cumulative freezing for all visits combined. This was determined by counting the number of frozen structures at the time of the last revisit as follows: 19 of 149 structures were frozen on the first visit; 89 of those that were open were revisited and 13 more found frozen; 72 of those that were open were revisited a third time and 5 found frozen; the total abandonment was then calculated as 19F (1st visit) + 13F (2nd visit) + 5F of 72 (3rd visit) = 37F of 104 = 36%. Structures were relocated by marking them with stakes and mapping them relative to search lines, rather than searching for them a second or third time with dogs. This meant that the revisit data did not necessarily measure what the dog would have located using scent cues, and therefore may not have been comparable to data obtained from searches by dogs. In retrospect, it is possible that on later searches the dogs would not have located structures that had been found frozen 2-4 weeks earlier.

In the 1982 Beaufort Sea sample, 11% of structures found for the first time were abandoned. Between the first and second visits (most revisits were 2 or more weeks later) 13% of the originally open structures froze, and between the second and third visits, 7% froze. In both revisit samples, the new freezing was similar to the rate found on original visits. There was no difference between structures that were probed, and therefore disturbed very little, and those that were opened. It is possible that this new freezing represented natural changes rather than investigator-induced disturbance. On the Cape Lisburne grids all structures were opened and, since the snow was quite deep, some of the excavations were major. Furthermore, since these were grid searches, there was frequent and repeated snow machine traffic throughout the grids. The abandonment rate on second visits to structures on the Cape Lisburne grids was substantially higher than in the Beaufort Sea. Of 99 structures that were revisited, 22% had frozen since the initial visit (three times the rate of freezing found on first visits).

It should be possible to differentiate natural abandonment and disturbance-induced abandonment by examining the rate of freezing. If abandonment was occurring at a relatively constant natural rate, we would expect a linear increase in the number of frozen structures with time. If however, freezing was disturbance-induced, we would expect a marked initial increase in freezing, than a tapering off. Our revisit sampling effort was not equally distributed over different time intervals. In the Beaufort Sea in 1982, only 14% of second visits were made within two weeks of the initial discovery compared to 64% made two to three weeks later and 22% made three to five weeks later. On the 1984 Cape Lisburne grids, all revisits were made within 12 days and most (over 70%) were within the first 2-7 days. In the Beaufort Sea sample, only 2 of 23 (9%) structures revisited within two weeks had frozen. In contrast, near Cape Lisburne, 3 of 22 (14%) had frozen by the third day, and 16 of 76 (21%) by revisits made on or before the seventh day. We think this suggests that a substantial part of the abandonment that occurred between revisits on the Cape Lisburne grids was due to disturbance caused by our examinations, whereas the new freezing in the Beaufort Sea study area may have been unrelated to investigators. This is presumed to be attributable to the great care taken not to unnecessarily disturb structures and to the careful reconstruction of structures in the Beaufort Sea. In addition, since the Beaufort Sea searches were not grid searches, there was less frequent investigator activity near structures.

In aggregate, the data in Table 54 demonstrate that disturbance, whatever the cause, resulted in increased abandonment of subnivean ringed seal structures. In areas with industrial activity, almost twice as many structures were abandoned as in areas without industrial activity. The most extreme disturbance, excavation by predators, resulted in a five-fold increase in abandonment. Depending on study methods, investigator disturbance may or may not significantly affect the abandonment of structures by seals.

E. Evaluation of Methodology

The use of trained dogs to locate subnivean ringed seal structures allows the investigation of several aspects of the winter ecology of ringed seals that are otherwise difficult, if not impossible, to study. Because seal structures are covered with snow and invisible from the surface, they cannot be easily or efficiently located during winter without the use of dogs. In late spring, lairs collapse as the snow melts, and some are opened by seals in order to gain access to the snow surface on which they bask in the open. It is then possible to see holes from the air and detect them in aerial photographs because of the extensive meltwater drainage patterns radiating from them. However, such observations, at best, allow enumeration and mapping of holes, but provide no information about structure characteristics, pupping, or predation.

By using dogs to search areas in a systematic fashion, it is possible to determine and make geographic comparisons of the density of structures, the types and proportions of structures, the presence and relative abundance of pupping lairs, and the incidence of predation by arctic foxes and polar bears.

Working with and training dogs to search for seal structures requires familiarity with dogs and attention to detail. Successful searches for structures are totally dependent on the performance of the dogs, and while the presence of structures can be verified by the handler, their absence cannot. It is essential that the dogs are well cared for to ensure that sore feet or muscles, fatigue, or cold temperatures do not restrict their search activities. The trainer must be sure that the dogs are not distracted by fox or bear scent. Dogs must be taught to continue to search an area, even though a structure has been found, in order to detect multiple lairs in the same area. The dogs must be discouraged from merely running to previously discovered and marked structures for an "easy find".

An experienced dog will indicate presence of a structure by digging right over the breathing hole, whereas a novice dog may be off by 1-10 meters. This must be considered if structures are to be probed but not dug into in order to determine their status. The handler must be able to interpret the dog's behavior in order to determine when it may be having difficulty in detecting scent, when or if it is running by a structure because it has scented another, or when it is not locating structures because it is bored, tired, or otherwise reluctant to work.

If the results of different studies utilizing dogs are to be compared, it is necessary to be familiar with the methodology employed in each study. While dogs trained and reinforced in a similar manner perform similarly, those trained for a different study objective may search somewhat differently. For example, dogs conducting grid searches work closer to the search line than do dogs working one-time-only search lines. Dogs may be taught to search along predator tracks, to concentrate on ice features (such as pressure ridges) that are likely to contain structures, or to seek or avoid previously located structures.

If intensive searches, such as grid searches, are to be conducted, it is useful to have more than one trained dog. This provides a backup if one dog is injured or otherwise unable to work. It allows investigators to more efficiently utilize their time, since a single dog will not work well for more than 12-18 km of line, or 6-8 hours per day on a sustained basis. Within these limits, a dog can be worked daily for an extended period of time. Depending on the dog, these limits may be exceeded for a few days, but the dog must then be rested for one or more days in order not to compromise the results.

The use of two dogs also allows periodic checks to ensure that both dogs are working efficiently and are finding similar types and numbers of structures. If one dog's performance is questionable, areas can be searched again by the other dog, to verify results. In this study, we found that our two dogs performed in a comparable manner. Mean and maximum distances from the search line at which the dogs detected structures and the number of structures found per kilometer of search line were similar. The dogs' success was similar under different wind speeds and angles to the search line, and both dogs found similar proportions of breathing holes and lairs. We also found that the two dogs were equally effective in all moderate wind speeds and all angles between wind and search lines. Despite the perception that some winds were better than others for searches, this did not appear to be the case. (See section D2 and E2 for detailed discussion of search biases.)

In comparing the results of searches conducted by different methods, such as grid searches and one-time-only searches, it is necessary to know what proportion of the total structures present are located the first time a dog works a line. In 1983 in Kotzebue Sound, we found that 56% of the structures were detected on the first of two searches. In 1984 near Cape Lisburne, based on grid lines that were searched twice, we found that 73% of the structures were found on the initial search. However, additional searches detected more structures, and overall, for lines searched 3 or 4 times, 65-67% of the structures were found on the first search. We also calculated the effectiveness of first-time searches in 1984 in a somewhat different manner, by comparing the total number of structures found on the first search of all lines to the total number of structures found on the grid after all searches. Using this method, we determined that 41% of the total structures were found on the first search if we assumed the dogs were effective over a 400 m strip, or 60% if we more conservatively estimated a 200 m strip. In 1983, the mean distance of detection was 125-150 m. Based on data from both years of studies it is probably reasonable to assume that one-time-only searches detect 60%-70% of the total structures present within 200 m of the search line.

Limitations

While searching with dogs is a good way to find subnivean ringed seal structures, there may be problems when results of such studies are used to assess the effects of anthropogenic disturbance on the use of structures by seals. Comparisons based on first-time searches, such as those comparing abandonment rates in disturbed and undisturbed areas, or abandonment relative to distance from a noise source, are relatively straight-forward and we consider them valid. However, comparisons of abandonment that utilize revisits to structures to measure change relative to a particular event are probably not valid. Investigators can, depending on methodolgy, cause "unnatural" abandonment of structures between the first and subsequent visits. Furthermore, abandonment rates determined from revisits to mapped, marked structures, without the use of a dog, are independent of the scent characteristics of the structures. This makes it possible to return to all structures, both open and frozen, whether they retain any odor or not. While the dogs clearly can and do find frozen structures, odor at a frozen structure may dissipate quite rapidly, such that dogs do not locate structures that have been frozen for some, as yet unknown, period of time.

If revisits are made that do not rely on dogs, they must occur at similar intervals in both experimental and control areas. It is not sufficient to revisit only the structures in the experimental area and compare abandonment in this sample to the initial abandonment. The control area must also be revisited. If dogs are used to relocate structures, care must be taken to ensure that they do not follow their old tracks or visually relocate structures by running to marker stakes.

We recommend that future studies intended to measure the effects of anthropogenic disturbance on the use of subnivean structures by ringed seals should be based primarily on first visits to structures. Studies should be designed to minimize ambiguity introduced by investigator disturbance, unequal effort in experimental and control areas, small sample sizes, or multiple visits to structures. Ideally, carefully planned searches by dogs should be combined with radio-tagging of seals and instrumentation of lairs to provide direct data on use of lairs and response of seals to disturbance.

VIII. Literature Cited

Adams, A. M. 1986. Distribution of helminths of ringed seals, Phoca hispida Schreber, in northern Alaska. Abstract for ICOPA, August 1986, Sixth International Congress of Parasitologists, Brisbane, Australia.

Adams, A. M. 1987. Frequency distribution of helminths of ringed seals, with particular reference to Corynosoma semerme. Paper presented at the American Society of Parasitologists National Meeting, Lincoln, Nebraska, August 1987.

Burns, J. J. 1970. Remarks on the distribution and natural history of pagophilic pinnipeds in the Bering and Chukchi seas. J. Mammal. 51:445-454.

Burns, J. J. and T. J. Eley. 1978. The natural history and ecology of the bearded seal (Erignathus barbatus) and the ringed seal (Phoca hispida). Pages 99-162 in Environmental Assessment of the Alaskan Continental Shelf, Annual Reports, Vol. 1. Outer Continental Shelf Environmental Assessment Program, Boulder, CO.

Burns, J. J. and S. J. Harbo, Jr. 1972. An aerial census of ringed seals, northern coast of Alaska. Arctic 25:279-290.

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. Annu. Rep. RU #232 to Outer Continental Shelf Environmental Assessment Program, Juneau, AK. 81 pp.

Burns, J. J. and B. P. Kelly. 1982. Studies of ringed seals in the Alaskan Beaufort Sea during winter: impacts of seismic exploration. Annu. Rep. RU #232 to Outer Continental Shelf Environmental Assessment Program, Juneau, AK. 57 pp.

Fedoseev, G. A. 1975. Ecotypes of the ringed seal (Pusa hispida Schreber, 1777) and their reproductive capabilities. Rapp. P.-V. Reun. Cons. Int. Explor. Mer. 169:156-160.

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

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

Frost, K. J. and L. F. Lowry. 1981. Ringed, Baikal, and Caspian seals. Pages 29-53 in S. H. Ridgway and R. J. Harrison, eds. Handbook of Marine Mammals. Vol. 2. Seals. Academic Press, London.

Frost, K. J. and L. F. Lowry. 1988. Effects of industrial activities on ringed seals in Alaska, as indicated by aerial surveys. Pages 15-25 in W.M. Sackinger and M.O. Jeffries, eds. Port and Ocean Engineering Under Arctic Conditions. Vol. II. Symposium on Noise and Marine Mammals. Fairbanks, AK.

Frost, K. J., L. F. Lowry, and J. J. Burns. 1985. Ringed seal monitoring: relationships of distribution, abundance, and reproductive success to habitat attributes and industrial activities. Interim Report to Outer Continental Shelf Environmental Assessment Program, Anchorage, AK. RU #667. 85 pp.

Frost K. J., L. F. Lowry, and J. R. Gilbert. 1987. Ringed seal monitoring: relationships of distribution and abundance to habitat attributes and industrial activities. Interim Report to Outer Continental Shelf Environmental Assessment Program, Anchorage, AK. RU #667. 53 pp.

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. Final Report to Outer Continental Shelf Environmental Assessment Program, Anchorage, AK. RU #667. 101 pp.

Hammill, M.O. 1987. Ecology of the ringed seal (Phoca hispida Schreber) in the fast-ice of Barrow Strait, Northwest Territories. PhD. Thesis. Macdonald College of McGill University, Montreal, Quebec. 108 pp.

Johnson, M. L., C. H. Fiscus, B. T. Ostenson, and M. L. Barbour. 1966. Marine mammals. Pages 897-924 in N. J. Wilimovsky and J. N. Wolfe, eds. Environment of the Cape Thompson region, Alaska. U.S. Atomic Energy Commission, Oak Ridge, TN.

Kelly, B. P., L. T. Quakenbush, and J. R. Rose. 1986. Ringed seal winter ecology and effects of noise disturbance. Final Report to Outer Continental Shelf Environmental Assessment Program, Anchorage, AK. RU #667. Contract No. NA-81-RAC-00045. 83 pp.

Kelly, B. P., S. C. Amstrup, C. Gardner, and L. T. Quakenbush. 1987. Predation on ringed seals in the western Beaufort Sea. Abstract, Seventh Biennial Conf. on the Biology of Marine Mammals, 5-9 December 1987. Miami, FL. 37 pp.

Kelly, B. P., J. J. Burns, and L. T. Quakenbush. In press. The significance of noise disturbance to ringed seals. Pages 27-38 in W.M. Sackinger and M.O. Jeffries, eds. Port and Ocean Engineering Under Arctic Conditions. Vol. II. Symposium on Noise and Marine Mammals. Fairbanks, AK.

Lowry, L. F., K. J. Frost, and J. J. Burns. 1980. Variability in the diet of ringed seals, Phoca hispida, in Alaska. Can. J. Fish. Aquat. Sci. 37:2254-2261.

Lukin, L. R. 1980. Habitat of White Sea ringed seal in the initial period of postnatal development. Biol. Morya 5:33-37. (Transl. by Plenum Publ. Corp., 1981. UDC 599. 745.3:574.9 Ecology.)

Lukin, L. R. and V. A. Potelov. 1978. Living conditions and distribution of ringed seal in the White Sea in the winter. Biol. Morya 4:62-69. (Transl. Consultants Bureau, NY, pp. 684-690. 1978.)

Lydersen, C. and I. Gjertz. 1984. Studies of the ringed seal (Phoca hispida Schreber 1775) in its breeding habitat in Kongs fjorden, Svalbard. Rapportserie Norsk Polarinstitutt No. 19, Oslo, Norway. 46 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. 97 pp.

Minerals Management Service. 1988. Figure III-4 in Draft Environmental Impact Statements Proposed Beaufort Sea Lease Sale 97. Minerals Management Service, Anchorage, AK.

Reimnitz, E. and P. W. Barnes. 1974. Sea ice as a geologic agent on the Beaufort Sea shelf of Alaska. Pages 301-351 in J. C. Reed and J. E. Sater, eds. The Coast and Shelf of the Beaufort Sea. Arctic Inst. of North America, Arlington, VA.

Shapiro, L. H. and J. J. Burns. 1975. Major late winter features of ice in northern Bering and Chukchi seas as determined from satellite imagery. Univ. of Alaska Geophysical Inst. Rep. UAG R-236 and Sea Grant Rep. 75-8. 7 p. plus figures. Fairbanks, AK.

Smith, T. G. 1973. Population dynamics of the ringed seal in the Canadian Arctic. Bull. Fish. Res. Board Can. No. 181. 55 pp.

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

Smith, T. G. 1976. Predation of ringed seal pups (Phoca hispida) by the arctic fox (Alopex lagopus). Can. J. Zool. 54:1610-1616.

Smith, T. G. 1980. Polar bear predation of ringed and bearded seals in the land-fast sea ice habitat. Can. J. Zool. 58:2201-2209.

Smith, T. G. 1987. The ringed seal, Phoca hispida, of the Canadian Western Arctic. Can. Bull. Fish. Aquat. Sci. 216:81 pp.

Smith, T. G. and M. O. Hammill. 1981. Ecology of the ringed seal, Phoca hispida, in its fast ice breeding habitat. Can. J. Zool. 59:966-981.

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. 53:1297-1305.

Smith, T. G. and I. Stirling. 1978. Variation in density of ringed seal (Phoca hispida) birth lairs in the Amundsen Gulf, Northwest Territories. Can. J. Zool. 56:1066-1070.

Smith, T. G., K. Hay, D. Taylor, and R. Greendale. 1978. Ringed seal breeding habitat in Viscount Melville Sound, Barrow Strait and Peel Sound. Report to Arctic Islands Pipeline Program by Arctic Biological Station Fisheries and Marine Service, Fisheries and Environment Canada. INA Publ No. QS-8160-022-EE-AI ESCOM Report No. AI-22.

Sokal, R. R. and F. J. Rohlf. 1969. Biometry. W. H. Freeman and Co., San Francisco, CA.

Stirling, I. and W. R. Archibald. 1977. Aspects of predation of seals by polar bears. J. Fish. Res. Bd. Can. 34:1126-1129.

Stirling, I., W. R. Archibald, and D. DeMaster. 1977. Distribution and abundance of seals in the eastern Beaufort Sea. J. Fish. Res. Board Can. 34:976-988.

Stirling, I. and E. H. McEwan. 1975. The calorific value of whole ringed seals (Phoca hispida) in relation to polar bear (Ursus maritimus) ecology and hunting behavior. Can. J. Zool. 53:1021-1026.

Stringer, W. J. 1974. Morphology of the Beaufort Sea shorefast ice. Pages 165-172 in J. C. Reed and J. E. Sater, eds. The coast and shelf of the Beaufort Sea. Arctic Inst. N. America, Arlington, VA.

Stringer, W., S. Barrett, and L. Schreurs. 1980. Nearshore ice conditions and hazards in the Beaufort, Chukchi, and Bering Seas. UAGR #274. Geophysical Institute, University of Alaska, Fairbanks, AK. 96 pp. + 65 figures.

Tikhomirov, E. A. 1968. Body growth and development of reproductive organs of the North Pacific phocids. Pages 213-241 in V. A. Arseniev and K. I. Panin, eds. Pinnipeds of the North Pacific. (Transl. Israel Program for Scientific Translations, 1971.)