Distribution and Abundance of Seals in the Eastern Beaufort Sea

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Beaufort Sea Project

THE DISTRIBUTION AND ABUNDANCE OF SEALS IN THE EASTERN BEAUFORT SEA

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1. SUMMARY

The two main seal species which occur in the Beaufort Sea are the ringed seal (*Phoca hispida*) and the bearded seal (*Erignathus barbatus*). Harvest of these seals provides an important part of the Inuit economy. In addition, the seals support the polar bear (*Ursus maritimus*) population of the western Arctic and, to a substantial degree, the arctic fox (*Alopex lagopus*), both of which are also important to the Inuit economy and culture.

In a randomly stratified aerial survey, conducted in 1974, we counted 41,982 ringed seals and 2,759 bearded seals. In an identical survey, conducted in 1975, we counted 21,661 ringed seals and 1,197 bearded seals, which indicated a substantial decline in the total population size. Tests for observer bias in the surveys were negative. Substantial reductions in pup productivity, pup survival, ovulation rate, and pregnancy rate were also recorded in 1974 and 1975, compared with available data from the same population in earlier years and from other studies. It appeared that these changes were caused by abnormally heavy sea ice conditions in 1974. However, the mechanisms by which these changes in environmental conditions stimulated the changes in seal numbers, distribution, and productivity were not clear.

Neither ringed nor bearded seals were distributed randomly over depth but their distributions were different. Bearded seals were more strongly associated with shallow water areas.

Ringed seal pupping habitat is widely distributed in the inshore fast ice areas of the western Arctic. Bearded seal pupping habitat is mainly restricted to the offshore moving lead areas north of the mainland coast and west of Banks Island. Both ringed and bearded seals concentrate in the moving lead areas during the winter.

2. INTRODUCTION

2.1 Nature, Scope and objectives of the Study

Current plans for offshore oil exploration in the eastern Beaufort Sea call for the initiation of drilling activity in the late summer of 1976. If the exploratory phase is successful, much more drilling activity will ensue, followed naturally by production for several years thereafter.

In any offshore drilling program, there is a possibility of a blowout and such accidents have been well documented from other parts of the world. In the eastern Beaufort Sea, which is ice covered for most of the year, and where drifting ice may be present at any time, the normal hazards to an off-shore drilling program appear to be aggravated.

The possibility of a large-scale oil spill or blow out resulting from drilling or production activities in the eastern Beaufort Sea represents a considerable threat to all the species of marine wildlife inhabiting the area, including the seals. The principle pinniped species in this area are the ringed seal (*Phoca hispida*) and the bearded seal (*Erignathus barbatus*). The walrus (*Odobenus rosmarus*) and harbour seal (*Phoca vitulina*) are regular visitors to the area (Harington, 1966; Stirling, 1974a) but their numbers are too insignificant to merit consideration in this report. Interesting but ephemeral records have also been made for the northern fur seal (*Callorhinus ursinus*) as far west as the Mackenzie Delta (Radvanyi, 1960) and a single hooded seal (*Cystophora cristata*) from the west coast of Banks Island (A. Elias, pers. comm.).

Clearly, with the prospect of large scale oil exploration and production activities in the future, baseline data are required on the present status of all the species that might be affected. With these data, we may be able to do a quantitative assessment of the effect on the wildlife species of events such as an oil spill, or the large-scale disturbance that is inevitable with such a project. Without baseline data, post-impact assessment is of considerably less value.

Rather than present a broad treatise on the general biology of the ringed and bearded seals, this report will concentrate on two specific objectives which we believe will realistically meet the needs of the Beaufort Sea Project. These two objectives are:

1. To provide baseline information on the biology, distribution, and abundance of ringed and bearded seals in the eastern Beaufort Sea; and

2. To identify critical areas or times in the annual cycles of ringed and bearded seals that might warrant protection from, or modification of, exploration and production activities.

The data required for a meaningful report of the nature required by the Beaufort Sea Project takes several years, not 18 months. In our seal research, we were fortunate to already have some baseline information collected in conjunction with CWS research on polar bears in the area between

1970 and 1973, and from research conducted both independently by, and in conjunction with, Dr. T.G. Smith of the Arctic Biological Station in Ste. Anne de Bellevue, Quebec. In particular, these data enabled us to appreciate the significance to the seals of the offshore area in which the first drilling is proposed and the fact that we are dealing with a highly mobile population which may range over the entire eastern Beaufort Sea and Amundsen Gulf. This information enabled us to plan our field work more effectively and gave us the background with which to interpret some of the rather anomalous results we obtained in 1974 and 1975. Our greatest difficulty was the lack of quantitative baseline data on numbers, distribution, and age structure of seals in the offshore ice prior to 1974 which would have facilitated a better understanding of the full effect of the unusually heavy ice conditions experienced in 1974.

2.2 Relationship of the Research to Offshore Drilling

The seals of the eastern Beaufort Sea and Amundsen Gulf provide an important portion of the annual income of the Inuit of that area. The main value in more recent years has been in the sale of raw hides and the products made from them such as coats, mukluks, and souvenirs. At one time, the seals were also an important source of food for both people and dog teams. Now that dogs have been largely replaced by oversnow machines, and the Inuit rely to a greater degree on other food sources, that form of utilization takes place on a lesser scale overall although it is still critical to the individuals who have retained their dog teams. It is quite likely that as the cost of oversnow machines, parts, and fuel continue to rise that more Inuit will again use dog teams, in which case the seals will become important again for dog food.

The other main economic value of seals to the Inuit economy is as food for polar bears which are hunted each winter for their hides. In this context it is worth noting that in 1973, Canada signed an international agreement on the conservation of polar bears (see Appendix 1 in Stirling *et al.*, Beaufort Sea Project Report on polar bears). That agreement also provided for conservation of the habitat on which polar bears depend which consequently entails the maintenance of a viable seal population.

As the reports on both seals and bears will detail, the moving lead areas offshore from the Tuktoyaktuk Peninsula and the west coast of Banks Island are of vital importance to the survival of these mammals. Thus, since offshore drilling is about to occur in these vital areas, we must ensure that environmental damage and detrimental disturbances are minimal.

It is equally important that we have some quantitative assessment of the fluctuation in numbers which are likely to be caused as a result of natural phenomena to ensure that unfair blame is not attached to industrial activities should a major decline in numbers or change in distribution take place. For example, as will also be discussed in both the seal and polar bear reports, major changes in both these parameters appear to have taken place in 1974 and 1975, independent of any external factors. The magnitude and speed with which some of these changes occurred have been a bit surprising to most biologists who have up until now assumed a greater stability in the arctic marine ecosystem of the western Canadian Arctic. Thus, it will be of critical importance to ensure that possible detrimental effects of exploration do not coincide with and thus aggravate the problems that the populations may already be experiencing through natural and uncontrollable causes.

3. RESUME OF CURRENT STATE OF KNOWLEDGE

3.1 Biology of the Seal Species

Ringed and bearded seals occupy a position near the top of the ecological food chain in the eastern Beaufort Sea. They are not gregarious animals (McLaren, 1958a and b; Burns, 1967; Stirling, 1974) but seasonal aggregations of both species may occur, most notably in early summer when they haul out to moult.

The preferred habitat of the adult ringed seal is the stable inshore fast ice (McLaren, 1958a; Smith, 1973a). Breathing holes are kept open by abrading the newly forming ice with the claws of their foreflippers. Seasonal mass movements or migrations, of several hundred miles have been suggested by Johnson *et al.* (1966) and Burns (1970) in the Cape Thompson area.

Preferred bearded seal habitat is characterized by shallow water zones in areas of moving ice (Burns, 1967; Ivashin *et al.*, 1972; Benjaminsen, 1973). Previous investigators (Johnson *et al.*, 1966; Burns, 1967; Fedoseev, 1970) have documented seasonal migrations of the bearded seal with the advancing and retreating ice edge. During prolonged ice-bound periods in Amundsen Gulf, bearded seals actively maintain their breathing holes in a manner identical to that of ringed seals (Stirling and Smith, 1975).

The peak of pupping activity for ringed seals occurs from late March to early April (McLaren 1958a; Smith, 1973a). The pups are born in a subnivean lair that is excavated above the enlarged breathing hole on fast ice (McLaren, 1958a; Smith and Stirling, 1975). The weaning period for ringed seals is long compared to other phocids, possibly extending for more than two months (McLaren, 1958a).

In Alaska, the peak of the bearded seal pupping period occurs around the end of April (Burns, 1967). The precocious pup is born on the ice and is able to enter the water shortly after birth (Chapskii, 1938; Burns, 1967). The nursing period is reportedly 12 to 18 days (Burns, 1965).

Breeding activity extends from mid-March through mid-May for both species (McLaren, 1958a and b; Burns, 1967; Smith, 1973a). The social system has not been described for either species since it occurs beneath the ice. Mating takes place in the water.

The ringed seal is an opportunistic feeder, preferring plankton, crustaceans and fish, most noticeably *Themisto* sp., *Mysis* sp. and *Boreogadus* sp. respectively (McLaren, 1959a). The bearded seal feeds almost exclusively on benthic organisms (Burns, 1967) and may be limited to an effective feeding depth of 90-100 metres (Ivashin *et al.*, 1972).

3.2 Knowledge of Seals in the Beaufort Sea

There is little published data on seals in the Beaufort Sea. The principal species considered here are the ringed seal (Fig. 1) and the bearded seal (Fig. 2). A limited amount of information on Inuit utilization is available in the Area Economic Surveys conducted by the Department of Indian Affairs and Northern Development (Abrahamson, 1962; Usher, 1965). Smith *et al.*, (1973) and Smith and Geraci (1974) give preliminary results of long term research being conducted by the Arctic Biological Station (Ste. Anne de Bellevue, Quebec) on the population dynamics of ringed seals in Amundsen Gulf. Smith and Stirling (1975) described ringed seal breeding habitat and discussed some of the aspects of seasonal variation in productivity. Stirling and Smith (1975) discussed the interrelationships of the mammals in the sea ice habitat. Smith (1973b) published preliminary results of aerial surveys conducted in Amundsen Gulf.

Burns and Harbo (1972) published the results of their aerial surveys of ringed seals further to the west and Burns (1970) gave a general description of the general biology of the pagophilic seals in Alaskan waters.

Burns, Smith, and we all have several years of unpublished data, much of which is presently being analyzed and written up for publication.

4. STUDY AREA

4.1 Outline of the Area

The study area was broadly defined as the Beaufort Sea, east of 140° W and south of 78° N, including Amundsen Gulf (Fig. 3). The reason for considering such a large area, relative to the small zone in which the first offshore drilling was proposed was twofold:

1. Besides the area north of the Tuktoyaktuk Peninsula, the offshore areas have already been leased all the way up the west coast of Banks Island; and,

2. Both published and unpublished data indicate ringed and bearded seals in the Beaufort Sea may undertake large scale movements throughout the study area in the course of a year (Johnson *et al.*, 1966; Burns, 1970; and T.G. Smith, unpublished).

4.2 Physical Parameters

Knowledge of the physical and biological characteristics of the Beaufort Sea, as known to date, is summarized in Reed and Sater (1974) and in the 1974 Interim Reports to the Beaufort Sea Project. Only a brief summary of the most relevant aspects will be included here. From break-up in the late spring to freeze-up in the fall, the area has an arctic maritime climate with coastal temperatures in the range of 5-15°C. Along the mainland coast, the sea may be ice free for up to 250 to 350 km offshore in late summer, or, in some years, as little as a few kilometres. Details of ice distribution and type through each year are given in the weekly summaries of the Ice Forecasting Central, Department of Environment. The sea is completely ice covered during the

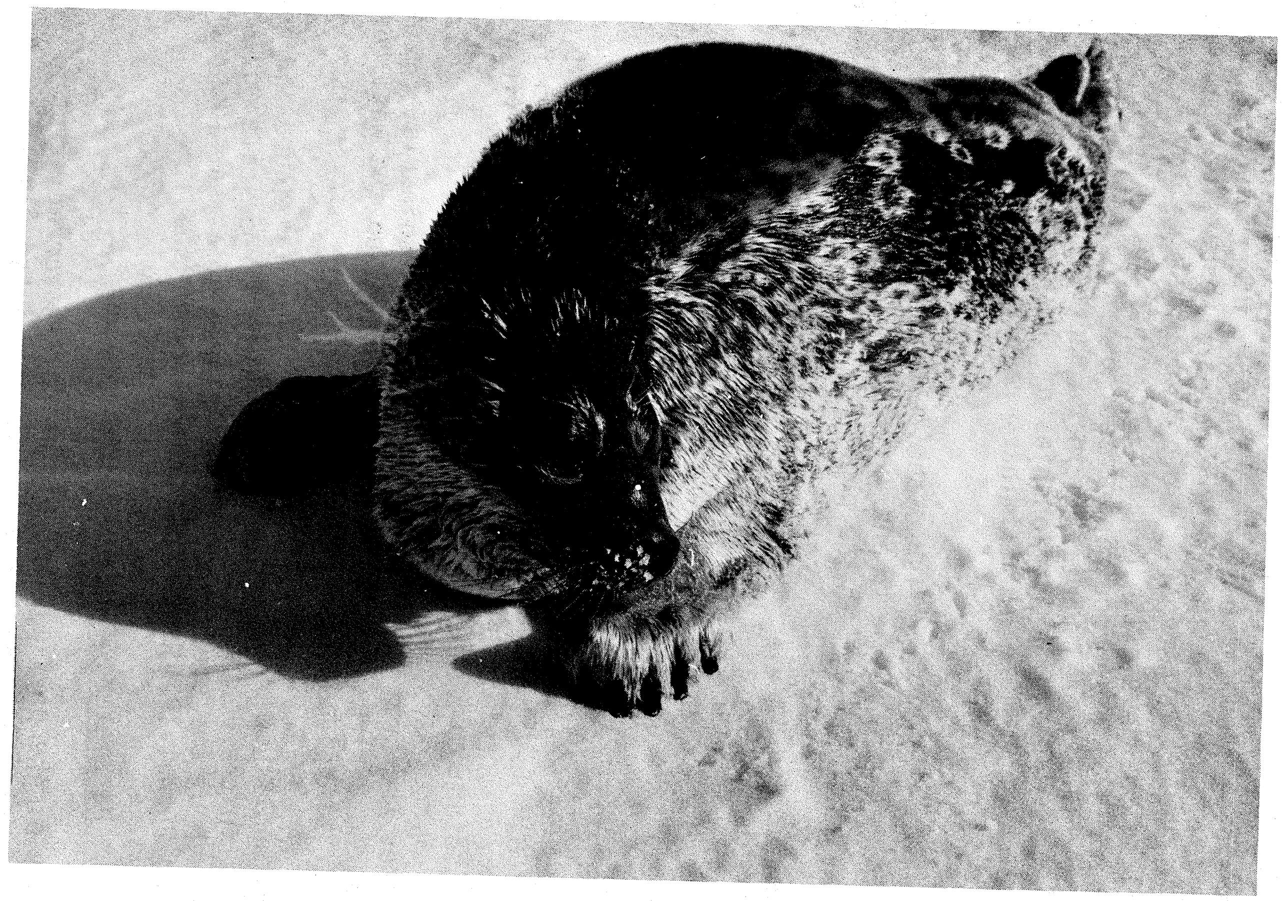

Figure 1. Adult ringed seal.

Figure 2. Young bearded seal.

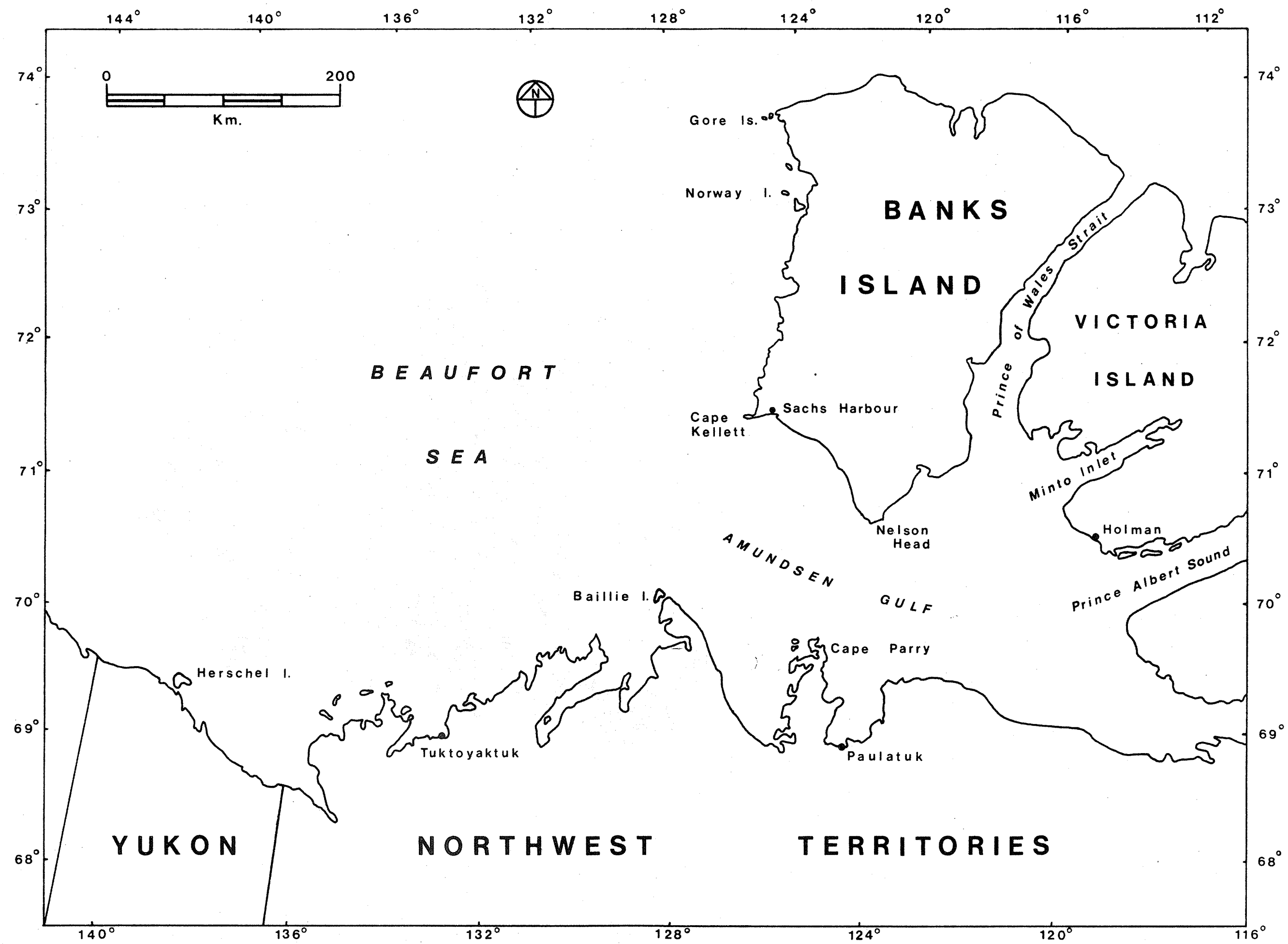

Figure 3. Map of study area.

winter months with the exception of a few leads which periodically open and refreeze, depending on the wind and temperature. Winter minimum temperatures may exceed -40 C. The wind causes snow to form compacted drifts around pressure ridges and on the various land masses. There is 24 hour daylight during the summer months and a corresponding absence of sun during the winter, although some light may still be provided by the moon and stars on clear nights.

5. MATERIALS AND METHODS

5.1 Field Techniques

5.1.1 Aerial Survey Design

Ringed and bearded seals are most easily seen and counted when basking on the sea ice. The greatest number of seals haul out on the ice to moult in late June, immediately prior to break-up (McLaren, 1958a; Smith, 1973a and b). There is also a diurnal fluctuation in the number hauled out on the ice with a maximum in early to mid-afternoon (Burns and Harbo, 1972; Smith, 1973a). However during this optimal period, there is no accurate way of correlating the number of seals hauled out with the total number present. Despite this failing, aerial surveying continues, for lack of a better quantitative replacement, with a variety of designs (Burns and Harbo, 1972; Smith, 1973b; Stirling and Archibald, 1974).

Because of the limitations encountered in aerial surveying and the heterogenous environment, we employed a stratified design to increase the precision of the estimates (Seber, 1973). The eastern Beaufort Sea was subdivided into a series of transects drawn north from the mainland coast and west from Banks Island, 5 miles (8 km) apart and offshore to a distance of 100 miles (160 km). There were a total of 101 such transects (Fig. 4). From our previous quantitative observations of seals in the study area, we suspected that their distribution and abundance in the sea ice habitat was not uniform. Although we lacked detailed information on the parameters that caused those differences, we subjectively subdivided the transects into four mutually exclusive strata. The criteria for subdividing the strata were as follows: Strata 1 was most affected by the inflow of fresh water from the Mackenzie River; Strata 2 was a fairly shallow area characterized each year by a series of east-west leads running parallel to the Tuktoyaktuk Peninsula, beginning at a depth of 20 m (Cooper, 1974); Strata 3 was an extensive area of relatively unstable ice, predominantly over deeper water; and Strata 4 was a relatively stable ice area over a moderate water depth, usually with only one main north-south lead running parallel to Banks Island, and was the only area that sometimes remained heavily ice covered throughout the summer months.

Not all transects could be surveyed because of budgetary limitations. Thus, approximately 60% of the lines in each strata were selected at random, using a random number table (Table 1).

The transects selected were flown at an altitude of 500 ft (152 m) in a Cessna 337 with an observer in the back seat on each side of the aircraft counting strips from 0-1/8 mi and 1/8-1/4 mi wide (Fig. 5) delineated by precalculated angles marked on the wing strut to ensure that the area

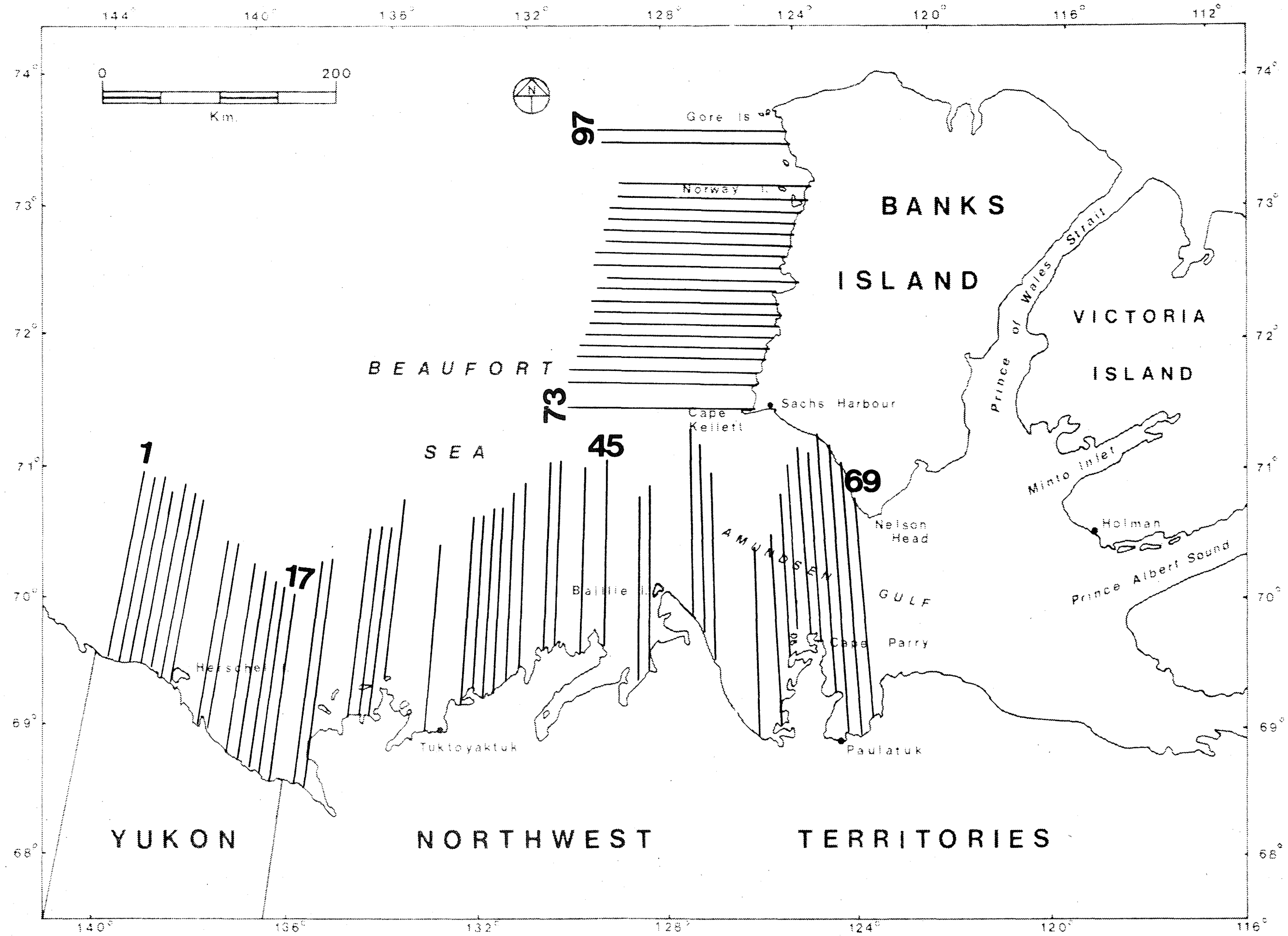

Figure 4. Map of study area with transect lines.

Table 1. Number of transect lines per stratum and the proportion of total number of lines that were samples in each stratum.

Stratum	Lines	Transects/stratum	Proportion of total	Number in sample
1	1 -16	16	.159	10
2	17-46	30	.297	18
3	47-72	26	.257	15
4	73-101	29	.287	17
TOTAL		101	1.00	60

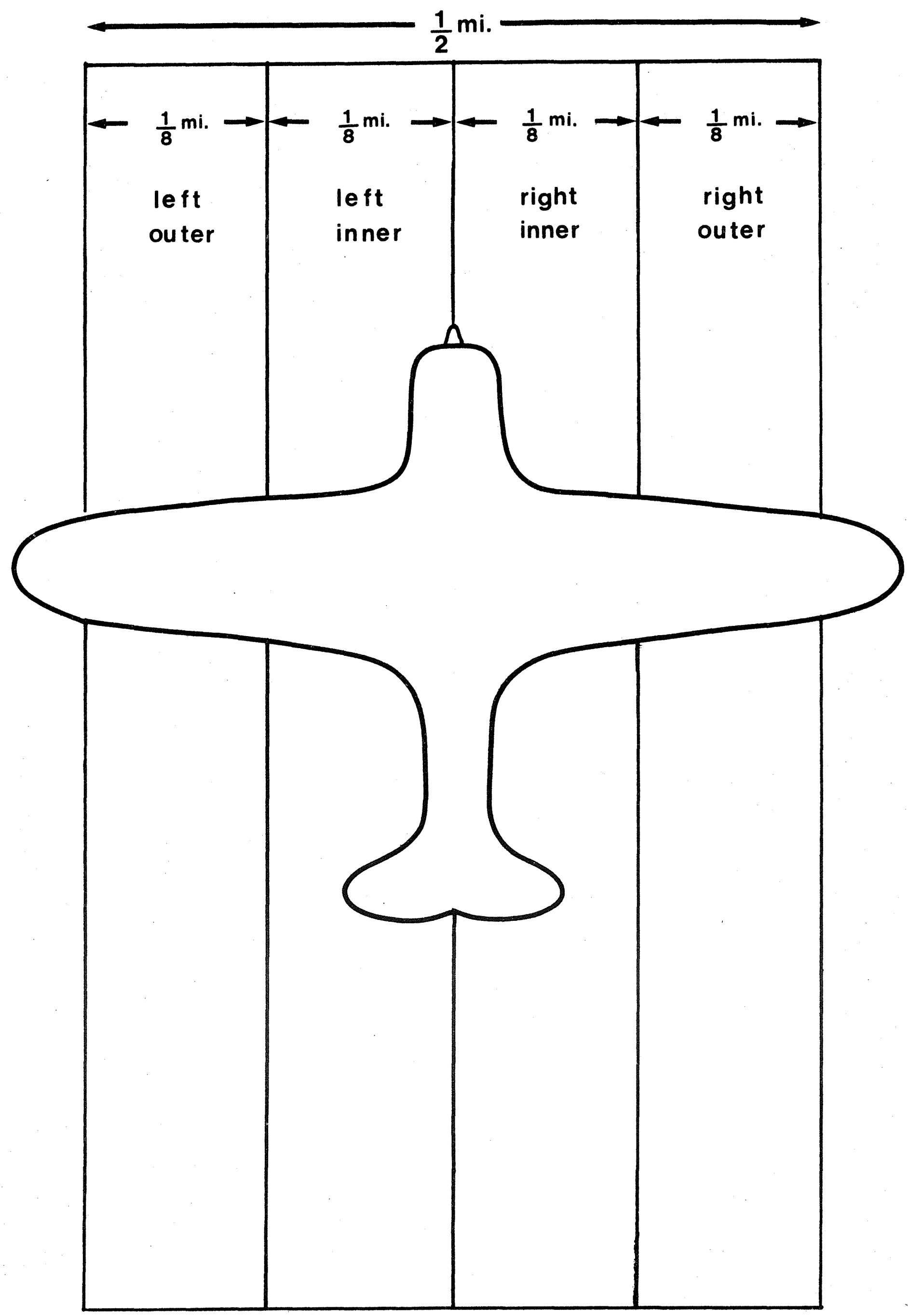

Figure 5. Diagramatic sketch of airplane with left and right surveying strips.

surveyed was constant. Data from each transect were partitioned into two minute intervals to facilitate later analysis of possible relationships between seal distribution and distance from shore or water depth. In the event that a portion of the transect was ice free, it was deleted from the sample. In this way, only areas of potential habitat for hauling out were surveyed. Therefore, all figures are in units of seals/square unit of ice.

Figure 6 is a sample of the data coding form. The side of the plane from which each set of observations was made was recorded on all transects to facilitate testing for observer bias. For ringed seal counts, this was further subdivided into the inner and outer 1/8 mile surveyed. Besides ringed and bearded seals counted, all sightings of whales, polar bears, and unidentified seals were recorded.

5.1.2 Collection of Specimens in the Field

Ringed and bearded seals were collected by ourselves from areas of offshore ice during the course of the study. The sex, standard length, axillary girth and blubber thicknesses on neck, chest and belly were recorded for each seal. Jaws, claws, and reproductive tracts were collected to determine the species composition, age structure and reproductive condition of the seals inhabiting the areas of offshore ice in the eastern Beaufort Sea. The same specimens were also collected from seals shot by Inuit hunters at Sachs Harbour, N.W.T. from June through August. Reproductive material was examined fresh whenever possible and then preserved in AFA.

5.1.3 Collection of Specimens from Seals killed by Polar Bears

During the continuing polar bear research in the western Arctic since October 1970 specimens were collected from all polar bear killed seals. Bears usually consume only the skin and blubber of seals the remainder being scavanged mostly by arctic fox (Stirling and Jonkel, 1972). Whenever possible complete collections were taken to determine what proportion of the available prey population was being utilized.

5.2 Data Analysis

5.2.1 Population Estimates

In studying the distribution of any animal population the number of individuals per unit of sampling area may be tallied and the resulting frequency distribution examined. If every unit in the series was equally exposed to the chance of containing individuals, the frequency distribution would follow the Poisson series. If the tails of the observed series are higher than would be expected, this implies a clumped distribution. An alternative model is the negative binomial. This model can be derived from a number of different assumptions (Bliss, 1953) but the biological meaning of a good fit may be difficult to assess. However, if a good fit is established, it should be informative to compare the Negative binomial paramaters from one year to the next and between species. It could also be used to estimate $V(\hat{N})$, the estimate of the variance for the total population.

A weighted linear regression was used to calculate the average

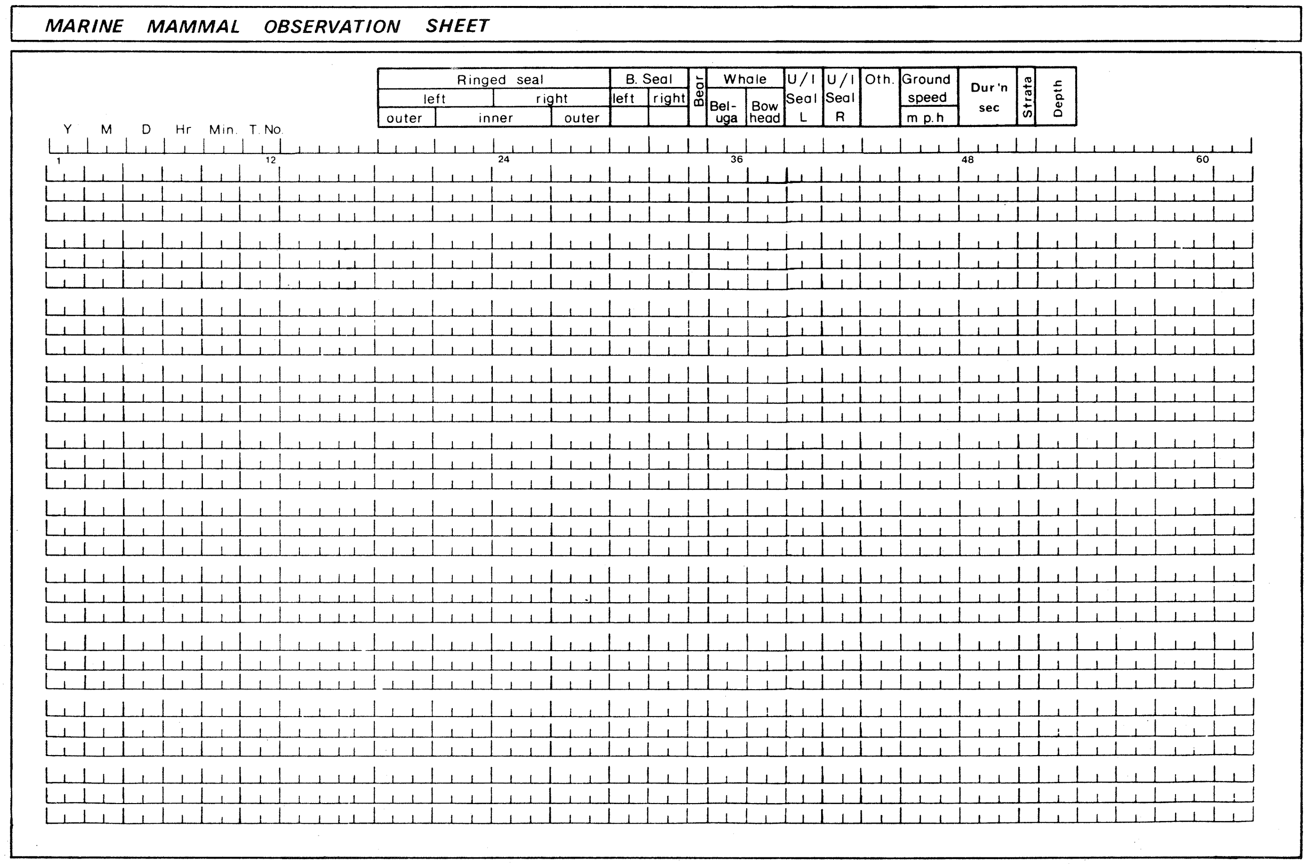

Figure 6. Sample of data coding sheet.

density (bi) and variance ($\Sigma ij = \sigma i^2 \sqrt{Xij}$) of ringed and bearded seals per stratum.

Model: $Yij = biXij + \Sigma ij$

where Yi = #seals seen on the j^{th} transect in the i^{th} strata

Xij = j^{th} transect length in miles in the i^{th} strata

Σij = error in the j^{th} transect of the i^{th} strata

bi = seals/sq mi of ice in the i^{th} strata

then bi is estimated by:

$$\hat{b}i = \frac{\sum_{J=1}^{Ji} Yij}{\sum_{j=1}^{Ji} Xij}$$

when Ji = no transects in the i^{th} strata

and, the standard error of $\hat{b}i$ is given by:

$$S(bi) = \sqrt{\frac{\sum_{j=1}^{Ji} \frac{Yi^2j}{Xij} - \frac{\sum_{J=1}^{Ji} Yij}{\sum_{j=1}^{Ji} Xij}}{Ji - 1 \quad \sum_{j=1}^{Ji} Xij}}$$

The data were also checked to see if the observed frequencies agreed with either the Poisson or Negative binomial models.

5.2.2 Observer Bias

To test for observer bias, caused by variations in either the ability to see or identify the species, the data were broken down within each strata to test the null hypothesis that the means for the strata derived from the left half of the transects were no different than the means of the right half of the transects.

The means of the numbers of ringed seals counted in the inner 1/8 miles were also compared with the means of the outer 1/8 mile portions of the transects. The sample sizes for bearded seals were too small to permit a similar analysis of data.

5.2.3 Distribution in Relation to Depths

As described earlier the survey data were tallied in two minute intervals on each transect so that the location of each datum could be plotted in relation to water depth. Bathymetric maps were used to determine the average depth of water for each two minute interval. If seals are randonly distributed over depth, the expected number of seals would be solely a function of average density and the amount of area within each depth category:

$$E\ (Yi) = (Xi)\left(\frac{\Sigma\ Yi}{\Sigma\ Xi}\right)$$

where Yi denotes the number of seals tallied in the i^{th} depth category and Xi is the amount of area sampled in the i^{th} depth category.

By comparing the expected and observed values we can test the null hypothesis that ringed and bearded seals are randomly distributed over depth.

To determine whether ringed and bearded seals were distributed in an identical fashion a contingency table was generated to compare the number of ringed seals observed in a specific category with the number of bearded seals.

5.2.4 Age Determination

Canine teeth collected from the lower jaws of ringed seals (McLaren, 1958a) and the upper jaws of bearded seals (Benjaminsen, 1973) were used for age determination. The teeth were placed in a buffered 30% formic acid solution for decalcification. Decalcification in buffered formic acid progresses gently, can be easily controlled and no damage is done in the event the tooth remains in the acid too long. Dried teeth were decalcified in 7-10 days while teeth previously preserved in 10% formaldehyde took 15-20 days. The decalcification point was determined by checking for calcium ions in the formic solution.

Decalcified teeth were washed for 12-15 hours in running tap water. If teeth needed to be stored prior to sectioning, they were placed in 70% ethanol. Teeth were soaked for at least 24 hours immediately prior to sectioning for hydration of tissue, then imbedded in Lab-tech compound and cut on a cryostat at -10 to -20°C into longitudinal sections 10 microns thick.

Cut sections were placed in water pH 8-9 for at least 20 minutes before being affixed to a glass slide with egg albumen. Drying occurred in 30-45 minutes at room temperature.

Sections were stained in a 0.032% aqueous solution of Toluylene Blue (Allied Chemical, Morristown, N.J.) - solution filtered before use. A more intense stain was obtained when the Toluylene blue crystals were dissolved in alkaline water (pH 8-9).

Staining was watched closely, (checked every 30-45 seconds, one slide at a time), taking from 1-5 minutes. Sections were covered with a glass cover slip before being photographed. Results were sometimes improved by overstaining and then destaining in water.

Stained sections were dried and stored with cover slips on. If necessary, sections in this form were restained, or, if less than 1 month old, simply wetted in water to restore brilliance, although they never obtained original brightness.

Ages for both ringed and bearded seals were determined by counting the cementum annuli. Previous investigations (McLaren, 1958a; Smith, 1973a) used dental annuli to determine the ages of ringed seals. McLaren (1958a) reported that this method was unreliable for some animals beyond 10 years and for most beyond 20 because the yearly dental lines were highly compacted. The increase in thickness of the cementum is relatively constant, averaging 0.043 mm annually (Smith, 1973a), and the corresponding cementum annuli were clear and easily read.

Figure 7 illustrates a tooth from a seal in its first year of life characterized by the lack of cementum. Figure 8 is a photograph of a canine tooth from a seal that had just turned 5 years of age.

Benjaminsen (1973) first reported that bearded seals could be aged by counting the annuli in the cementum of the upper canine tooth. Bearded seal teeth are poorly developed and wear rapidly so that most are worn down or missing by the 9th year (Burns, 1967). In instances where canine teeth were not available, the roots of any of the remaining teeth proved satisfactory for age determination.

Teeth collected from seals killed by polar bears were aged in the same way. In some instances only the claws of seals killed by polar bears could be located. These were cleaned in the laboratory, moistened on the surface, and the annual laminae counted (McLaren, 1958a). This technique was adequate for young seals but only gave a minimum age for older animals.

5.2.5 Analysis of Reproductive Material

Fresh ovaries were hand sectioned with a scalpel and the presence of a corpus luteum, which indicated ovulation, corpus albicans which indicated recent pregnancy, and follicular activity were recorded. The uterine horns were opened and checked for scars of recent pregnancy.

All tracts were then fixed and preserved in AFA for subsequent laboratory examination.

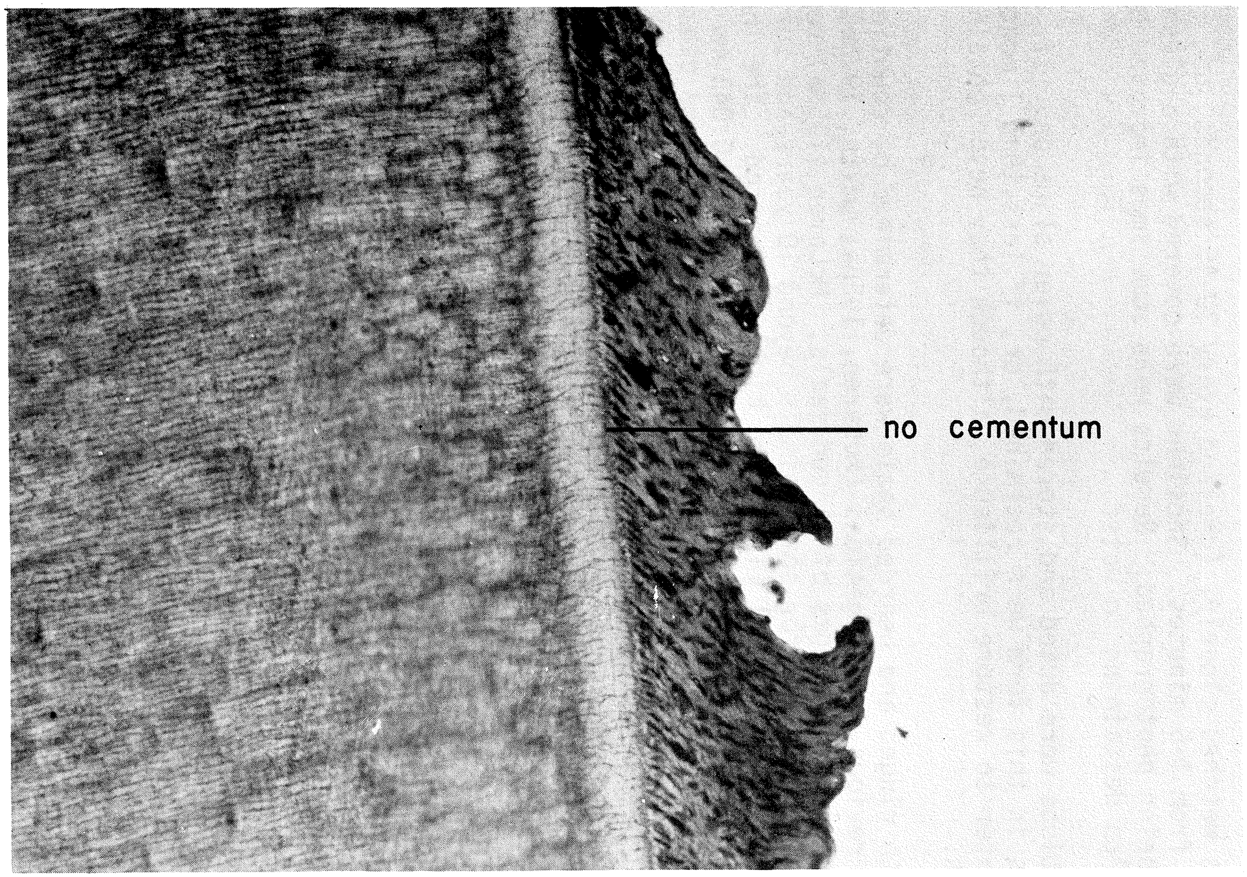

Figure 7. Thin section of the tooth of a newborn ringed seal showing the lack of cementum.

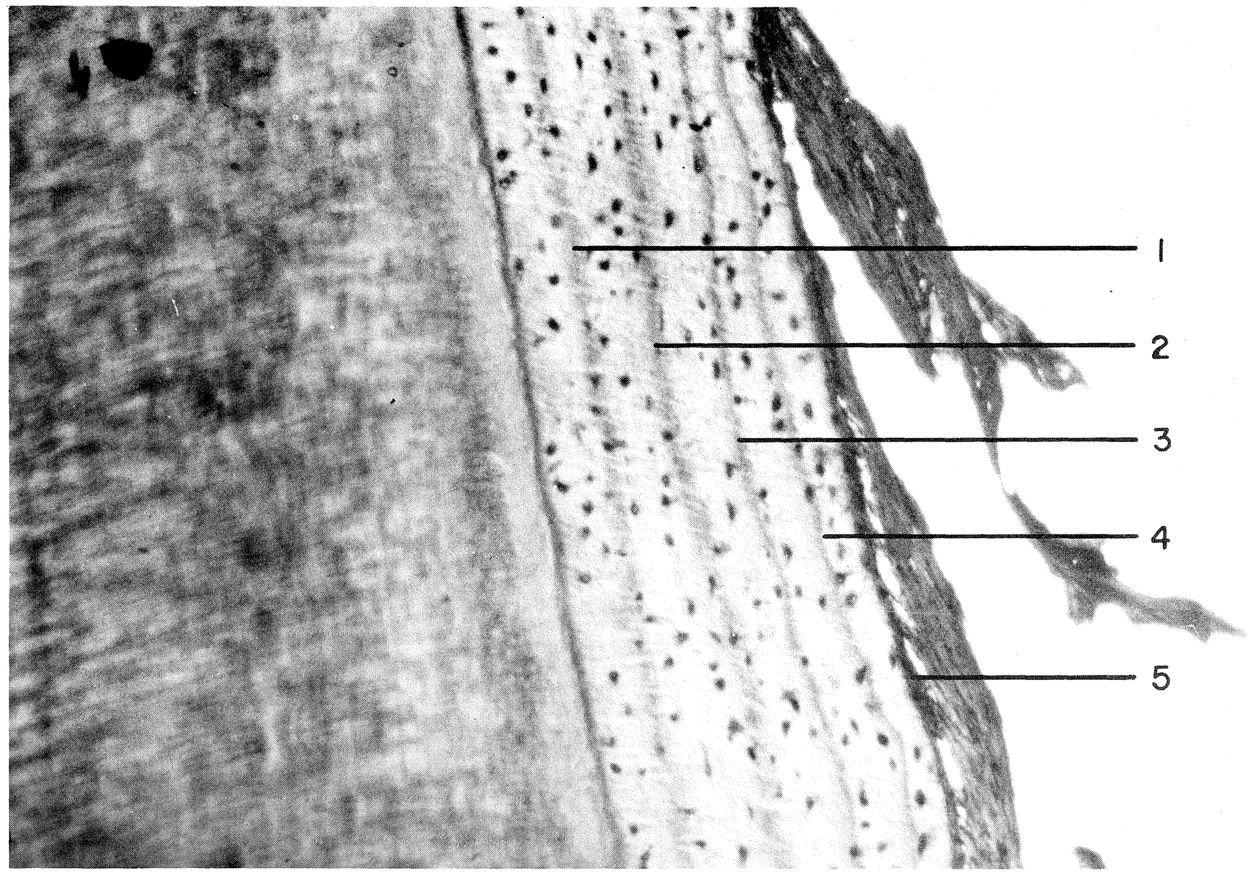

Figure 8. Thin section of the tooth of a 5-year-old ringed seal showing the annuli in the cementum.

6. RESULTS AND DISCUSSION

6.1 Population Estimates

The densities of ringed and bearded seals per stratum plus the population estimates for each species are given in Tables 2-5.

The numbers of both ringed and bearded seals declined between 1974 and 1975. T statistics for the 1974 and 1975 population levels were:

$$\text{ringed seals} \quad \frac{41{,}982 - 21{,}661}{\sqrt{4159^2 + 2509^2}} = 4.18$$

$$\text{bearded seals} \quad \frac{2{,}759 - 1{,}197}{\sqrt{371^2 + 120^2}} = 4.01$$

Both of these statistics were significant at the 95% confidence level.

An approximation of the relative abundance of ringed seals to bearded seals in the study area is:

$$\frac{\text{total ringed seals}}{\text{total bearded seals}} = \frac{41{,}982 + 21{,}661}{2{,}759 + 1{,}197} = 16.08:1$$

Tables 6-11 give the frequency counts and distribution analysis for both the 1974 and 1975 ringed and bearded seal data. For both the 1974 and 1975 data, the Poisson series did not agree with the observed distributionof either the ringed seal or the bearded seal.

($X^2_{74} = 2714$, df = 7 and $X^2_{75} = 1571$, df = 6 for ringed seals;

$X^2_{74} \simeq 113$, $X^2_{75} \simeq 51$, df = 2 for bearded seals)

For the bearded seal, the distribution of seals per area closely agreed with the Negative binomial model. ($X^2_{74} = 2.9$, df = 4 and $X^2_{75} = 4.7$, df = 3.) The K values for 1974 and 1975 are .8287 and .671 respectively (Tables 6 and 7). A T test between the two estimates suggests no significant differences. The ringed seal data was only found to fit in 1975. ($X^2_{75} = 15.4$, df = 12). The K (Bliss, 1953) statistic was estimated as .123 (Table 11). Comparing this K value with an averaged bearded seal K value (and $\hat{V}(K)$, a T test suggests a significant difference between species.

Table 12 presents a comparison of the 95% confidence limit, derived from observed populations that fit the Negative binomial to that derived from the linear regression model.

Table 2. Population estimate calculations for 1974 ringed seal observations.

Strata	Density	±	Confidence Interval	S.E.*	Area	Proportion of ice cover	Population of stratum	±	Confidence Interval	Width of CI (Z)	Z^2
1	1.358	±	.386	.197	7,625	1.00	10,355	±	2,943	5,886	34,650,882
2	1.044	±	.409	.209	17,163	.91	16,306	±	6,388	12,776	163,226,171
3	.744	±	.254	.130	15,441	.92	10,569	±	3,608	7,216	52,074,306
4	.396	±	.166	.085	14,999	.80	4,752	±	1,992	3,984	15,871,198

Population of stratum = (Density) (Area) (Proportion of area with ice cover)

Total population = Σ population stratum = 48,982

Interval = $\sqrt{\Sigma(Z^2)}$ = 16,304

Population = 41,982 ± 8,152

* S.E. = Standard Error

Table 3. Population estimate calculations for 1974 bearded seal observations

Strata	Density	±	Confidence Interval	S.E.*	Area	Proportion of ice cover	Population of stratum	±	Confidence Interval	Width of CI (Z)	Z^2
1	.012	±	.006	.003	7,625	1.00	92	±	46	92	8,464
2	.091	±	.031	.016	17,163	.91	1,421	±	484	968	937,350
3	.048	±	.022	.011	15,441	.92	682	±	313	625	390,657
4	.047	±	.037	.019	14,999	.80	564	±	444	888	788,491

Population of stratum = (Density) (Area) (Proportion of area with ice cover)

Total population = 2,759

Interval = $\sqrt{\Sigma(Z^2)}$ = 1,458

Population = 2,759 ± 729

* S.E. = Standard Error

Table 4. Population estimate calculations for 1975 ringed seal observations.

Strata	Density	±	Confidence Interval	S.E.*	Area	Proportion of ice cover	Population of stratum	±	Confidence Interval	Width of CI (Z)	Z^2
1	.546	±	.238	.122	7,625	.970	4,038	±	1,760	3,521	12,397,441
2	.333	±	.292	.149	17,163	.633	3,618	±	3,172	6,344	40,246,336
3	.933	±	.277	.141	15,441	.676	9,739	±	2,891	5,782	33,431,524
4	1.185	±	.454	.232	14,999	.240	4,266	±	1,634	3,269	10,684,995

Population of stratum = (Density) (Area) (Proportion of area with ice cover)

Total population = 21,661

Interval = $\sqrt{\Sigma(Z^2)}$ = 9,837

Population = 21,661 ± 4,918

* S.E. = Standard Error

Table 5. Population estimate calculations for 1975 bearded seal observations.

Strata	Density	±	Confidence Interval	S.E.*	Area	Proportion of ice cover	Population of stratum	±	Confidence Interval	Width of CI (Z)	Z^2
1	.033	±	.012	.012	7,625	.970	244	±	89	178	31,597
2	.040	±	.017	.017	17,163	.633	435	±	185	369	136,301
3	.031	±	.008	.008	15,441	.676	324	±	84	167	27,890
4	.054	±	.022	.022	14,999	.240	194	±	79	158	24,964

Population of stratum - (Density) (Area) (Proportion of area with ice cover)

Total population = 1,197

Interval = $\sqrt{\Sigma(Z^2)}$ = 470

Population = 1,197 ± 235

* S.E. = Standard Error

Table 6. 1974 bearded seal observations fitted to Poisson model and Negative Binomial model.

Class (seals/sample unit)	Poisson: Seals observed	Poisson: $E(f_x)_p$	Poisson: $\frac{(E-O)}{E}$	Negative Binomial: Seals observed	Negative Binomial: $E(f_x)_{nb}$	Negative Binomial: $\frac{(E-O)}{E}$
0	957	906	2.871	957	954	.009
1	59	135	42.785	59	64	.391
2	22	10	67.600	22	20	.200
3	6	0		6	8	.500
4	6 } 36	0 } 10		6	3	1.8
5	0	0		0 } 8	1 } 5	
6	2	0		2	1	
	1,052		X^2 = 113.256			X^2 = 2.9
			$X^2_{.05,2}$ = 5.99			$X^2_{.05,4}$ = 9.49
				$\overline{X}$ = .1490	$V(K_1)$ = .0072	
				K = .8287		

Table 7. 1975 bearded seal observations fitted to Poisson model and Negative Binomial model.

Class (seals/sample unit)	Poisson: Seals observed	Poisson: $E(f_x)_p$	Poisson: $\frac{(E-O)^2}{E}$	Negative Binomial: Seals observed	Negative Binomial: $E(f_x)_{nb}$	Negative Binomial: $\frac{(E-O)^2}{E}$
0	688	669	.540	688	695	.071
1	36	71	17.254	36	27	3.000
2	10 ⎫	3	33.330	10 ⎫	9	.111
3	2 ⎪			2 ⎪	3 ⎫	1.500
4	0 ⎪			0 ⎪	2 ⎬ 6	
5	0 ⎪			0 ⎪	1 ⎪	
6	0 ⎬ 13			0 ⎬ 3	0 ⎭	
7	0 ⎪			0 ⎪		
8	0 ⎪			0 ⎪		
9	1 ⎭			1 ⎭		
	737		$X^2 = 51.126$			$X^2 = 4.682$
			$X^2_{.05,2} = 5.99$			$X^2_{.05,3} = 7.81$
				$\overline{X} = .963$	$V(K_1) = .015$	
				$K = .6710$		

Table 8. 1974 ringed seal observations fitted to Poisson model.

Class (seals/sample unit)	Seals observed	$E(f_x)_p$	$\frac{(E-0)^2}{E}$
0	509	97	1749
1	169	232	17
2	105	276	105
3	79	219	89
4	38	130	65
5	32	62	14
6	23	25	.16
7 and over	97	11	672
			$X^2 = 2714$
			$X^2_{.05,7} = 14.0671$

Table 9. 1974 ringed seal observations fitted to Negative Binomial model.

Class (seals/sample unit)	Seals observed	$E(f_x)_{nb}$	$\frac{(E-O)^2}{E}$
0	509	591	11.377
1	169	130	11.700
2	105	73	14.027
3	79	50	16.820
4	38	37	.027
5	32	28	.500
6	23	22	.043
7	12	18	2.000
8	20	15	1.250
9	14	12	.333
10	4	10	.360
11	5	9	1.770
12	4	7	1.286
13	3	6	1.500
14	5	5	.000
15	1	5	3.200
16 and over	27	31	.138

$X^2 = 69.58$

$X^2_{.05,16} = 26.29$

$\overline{X} = 2.130$ $\hat{V}(K) = .000007$

$\hat{K} = 0.115$

Table 10. 1975 ringed seal observations fitted to Poisson model.

Class (seals/sample unit)	Seals observed	$E(f_x)_p$	$\frac{(E-0)^2}{E}$
0	439	120	848.000
1	80	218	87.358
2	58	198	90.990
3	33	119	62.151
4	33	54	8.167
5	25	20	1.250
6 and over	69	8	465.125
			$X^2 = 1{,}571$
			$X^2_{.05,6} = 12.59$

Table 11. 1975 ringed seal observations fitted to Negative Binomial model.

Class (seals/sample unit)	Seals observed	$E(f_x)_{nb}$	$\frac{(E-0)^2}{E}$
0	439	450	.269
1	80	89	.910
2	58	49	1.653
3	33	32	.031
4	33	23	4.348
5	25	17	3.765
6	15	13	.308
7	13	11	.364
8	5	9	1.778
9	5	7	.571
10	4	6	.667
11	5	5	0.0
12 and over	17	21	.762

$X^2 = 15.426$

$X^2_{.05,12} = 21.0261$

$\overline{X} = 1.821$ $\quad V(K_1) = .000014$

$\hat{K} = 0.123$

Table 12. Comparison of the 95% confidence interval derived from Negative Binomial and Linear Regression Models.

Year	Species	K Value	Negative Binomial	Linear Regression
1974	bearded seal	.82	864	729
1975	bearded seal	.67	1039	470
1975	ringed seal	.12	3945	4918

6.1.1 Evaluation of Population Estimates

From Tables 2 to 5, it was clear that a major decline in numbers of both ringed and bearded seals took place between 1974 and 1975. The decline appeared to take place in varying degrees in different strata. For ringed seals, the greatest reduction in numbers occurred in Strata 1 and 2. Numbers declined slightly in Strata 3 and 4 while the density actually increased (Tables 2 and 4). The reason for the increase in density in Strata 3 and 4 is probably that there was considerably less ice so that moulting seals were much more concentrated on the remaining ice available. Similar increases in densities of Weddell seals, (the ecological counterpart of the ringed seal in Antarctica) have been recorded in similar circumstances (Smith, 1965; Stirling, 1969).

The pattern of changes in numbers and density of bearded seals in the various strata was difficult to monitor because no data were available on diurnal fluctuation in numbers. However the magnitude of recorded population estimates in Strata 2 and 4, (Tables 3 and 5) which have the greatest amount of suitable bearded seal habitat probably reflects seal differences in absolute numbers.

Although it is difficult to assess the biological importance of the K statistic obtained from the Negative binomial model, the fact that a significant difference was observed between the derived values from ringed and bearded seals suggested that they were distributed differently. The difference was that ringed seals were more clumped in distribution than bearded seals.

It can be seen from Table 12 that the K value was useful in increasing the precision of the population estimate when the value was relatively low, in this case around 0.1; whereas the linear regression model was more precise in populations whose K values were estimated around 0.7 or higher. Future ringed seal estimates would probably benefit if the Negative binomial model were used to estimate $V(\hat{N})$. However, little or no such benefit would probabl- occur with bearded seals considering the pattern in which they are distributed. Considering cost implications it seems reasonable that a stratified design incorporating a weighted linear regression model is most efficient and effective for general estimating of ringed seal and bearded seal populations.

Other forms of data also appear to indicate a decline in the size of the seal populations.

Ringed seals give birth to their single young in subnivean lairs in late March to early April. From 1972 to 1975, Smith and Stirling (1975 and unpublished) quantitatively surveyed the same areas of sea ice habitat for ringed seal birth lairs in Amundsen Gulf. In 1972 and 1973, ringed seal birth lairs were abundant in the offshore ice of Amundsen Gulf and in Prince Albert Sound while in 1974 and 1975 the density dropped, possibly by as much as a factor of 10 (Stirling and Smith, 1975). The number of sub-ice vocalizations/ minute recorded with a hydrophone and tape recorder were also roughly ten times as abundant in 1972 and 1973 than they were in 1974 and 1975, although the relationship of vocalizations to numerical abundance is not clear. From

1972 to 1975, in comparable searches for polar bears in Amundsen Gulf, 270, 270, 35, and 56 sites were found where polar bears had dug out ringed seal lairs (Stirling and Smith, 1975).

From these data, it is clear that a marked reduction in both numbers and productivity of ringed seals has taken place in the eastern Beaufort Sea and Amundsen Gulf. On the basis of the aerial surveys, but fewer corroborative data, it appears that a similar decline in bearded seal numbers took place.

It is not clear which factors caused these changes but some points should be considered. In 1974 and 1975, there was much less snow cover than in 1972 or 1973 in which the seals could construct their subnivean birth lairs during the late winter and early spring. Also, in 1974, the winter winds blew predominantly from the NW instead of alternating between the SE and the NW. Consequently, instead of the usual series of leads which open and refreeze parallel to the mainland coast and the west coast of Banks Island, the ice was heavily compacted and frozen solid against the land and for many miles offshore. Thus, it was probably much more difficult for the large numbers of subadult seals that normally concentrate along those lead systems to maintain their breathing holes through the winter. We do not know for certain if seals can still maintain their breathing holes adequately under these conditions, if a large proportion cannot and thus die, or if there are large scale movements of a substantial proportion of the population. Nor do we know if such ice conditions have any adverse effect on the prey species of the seals. We do know that the numbers of seals present in the eastern Beaufort Sea and Amundsen Gulf dropped markedly. Smith and Geraci (1974) also demonstrated that the ringed seals were in a much poorer nutritional condition in 1974. Because of the extent of the change in numbers, it is particularly unfortunate that we do not have comparable survey data from this area for 1972 or 1973 when conditions appeared to be more suitable.

6.2 Observer Bias

The results of a two-sided T test to check for observer bias are presented in Tables 13 and 14. Only one significant difference appeared from the 1974 and 1975 surveys, the bearded seal observations in Stratum 1 in 1974 (Table 13).

The signs of all the T statistics were negative. If it were assumed that for each of the eight comparisons that the inner mean equalled the outer mean, then the probability of observing X negative differences between the inner and outer means would have a binomial distribution with $p = 0.5$ and $n = 8$. Thus, the probability of observing 8 negative differences ($X=8$) is approximately .004, which suggests that the mean of the outer 1/8 mile of the transect is significantly different from the inner mean.

6.2.1 Evaluation of Bias

In only one test for observer bias in the means of the left and right sides of the transects was there a significant difference. That difference was in bearded seals in Stratum 1 in 1974 but, since only six seals were seen altogether, the difference probably reflects an inadequate sample size. Thus,

Table 13. Bias calculations for 1974 ringed and bearded seal observations.

Strata	Left Mean	Right Mean	T Statistic	95% Significance	Inner Mean	Outer Mean	T Statistic	95% Significance
Ringed Seal								
1	1.695	1.022	1.770	-	.994	1.723	-2.08	-
2	1.170	.918	.754	-	.617	1.471	-2.58	+
3	.766	.722	.224	-	.537	.951	-1.96	-
4	.377	.415	.234	-	.238	.553	-1.86	-
Bearded Seal								
1	0.0	.024	-4.000	+				
2	.061	.120	-1.680	-				
3	.039	.058	- .833	-				
4	.047	.047	0.0	-				

Table 14. Bias calculations for 1975 ringed and bearded seal observations.

Strata	Left Mean	Right Mean	T Statistic	95% Significance	Inner Mean	Outer Mean	T Statistic	95% Significance
Ringed Seal								
1	.511	.581	- .39	-	.40	.693	-1.40	-
2	.256	.410	- .63	-	.287	.379	- .41	-
3	1.050	.816	1.07	-	.906	.959	- .24	-
4	1.175	1.195	- .05	-	.960	1.410	-1.23	-
Bearded Seal								
1	.033	.033	0.0	-				
2	.060	.021	1.22	-				
3	.023	.038	- .84	-				
4	.069	.039	.86	-				

we concluded that there was no significant observer bias, in either the ability to see or identify seals, between the left and right sides of the transects.

The test of the means of ringed seals counted in the outer half of each transect versus the inner half showed that the outer half was consistently higher. However, the reason for this is not clear. One possibility is that when flying at 500 ft (152 m) at a ground speed of 150-200 mph (240-320 kmph), it may subconsciously be less of a strain on the eyes to look out further. A slower survey speed would not resolve the problem because the seals would go into the water before the plane was over them so that they would not be counted. The difficulty most likely occurs in looking straight down to observe the innermost portion of the inner half of each side of the transect. One possible solution might be to precalculate the observer's viewing angles so that the 1/4 transect was transposed slightly further out, thus making it more comfortable to scan the whole area continuously.

6.3 Distribution in Relation to Depth

The numbers of ringed seals and bearded observed within each depth interval for 1974 and 1975 were recorded in Tables 15 to 18.

A comparison of the expected and observed values yielded X^2 values of 220.5 for ringed seals and 100.0 for bearded seals in 1974 and values of 130.3 for ringed seals and 12.5 for bearded seals in 1975, all of which were significant at the 95% confidence level. This demonstrated that neither species was distributed randomly with respect to depth.

Results of comparisons between ringed and bearded seals in each specific category for 1974 and 1975 were outlined in Tables 19 and 20. The X^2 values generated were both significant at the 95% level of confidence. This suggests that ringed and bearded seals were not distributed over depth in the same manner.

Further evidence of this difference is gained if the densities of each species are compared over depth (Figs. 9 to 12).

6.3.1 Evaluation of Distribution over Depth

Although neither ringed nor bearded seals were distributed randomly over depth (Tables 15 to 18), they were not distributed in the same way over depth (Figs. 9 to 12). The bearded seal is mainly a shallow water benthic feeder. It also favours areas with open leads and moving pack to the solid fast ice areas that characterize ringed seal habitat. It is probably this combination of preferences that gives rise to their greatest density in Stratum 2 and to a lesser degree in Stratum 4. Even so bearded seal habitat requirements are not that stereotyped since Stirling and Smith (1975) reported bearded seals maintaining their own breathing holes in the fast ice and recorded their underwater vocalizations up to 400 km from the nearest open water.

Ringed seals are pelagic feeders and thus much less tied to water depth. They are capable of maintaining their own breathing holes with the heavy claws of their foreflippers and do so whenever they have to. However,

Table 15. Distribution versus depth calculations for 1974 ringed seal observations.

Depth (metres)	Number of seals observed at i^{th} depth Y_i	Number of sq. miles of i^{th} depth X_i	$\left(\frac{\Sigma Y_i}{\Sigma X_i}\right)X_i = E(Y_i)$	$\frac{(O-E)^2}{E}$	Signs
0-25	472	680	585	21.83	-
26-50	619	586	504	26.24	+
51-75	235	262	225	.44	+
76-100	63	120	103	15.53	-
101-150	212	244	210	.02	+
151-200	105	178	153	15.06	-
201-300	239	248	213	3.17	+
301-400	88	174	150	25.63	-
401-500	59	25	22	62.23	+
501-1000	63	76	65	.06	-
over 1000	142	92	79	50.24	+

$X^2 = 220.45$

$X^2_{.05,10} = 18.3$

Table 16. Distribution versus depth calculations for 1974 bearded seal observations.

Depth (metres)	Number of seals observed at i^{th} depth Yi		Number of sq. miles of i^{th} depth Xi	$\left(\frac{\Sigma Yi}{\Sigma Xi}\right) Xi$ = E (Yi)		$\frac{(O-E)^2}{E}$	Sign
0-25	19		680	39		10.26	-
26-50	79		586	33		64.12	+
51-75	21		262	15		2.4	+
76-100	6		120	7		.14	-
101-150	8		244	14		2.57	-
151-200	12		178	10		.4	+
201-300	4		248	14		7.14	-
301-400	3		174	10		4.9	-
401-500	1		25	1			0
501-1000	0	1	76	4	10	8.1	-
over 1000	0		92	5			-

$X^2 = 100.04$

$X^2_{.05,10} = 18.3$

Table 17. Distribution versus depth calculations for 1975 ringed seal observations.

Depth (metres)	Number of seals observed at i^{th} depth Yi	Number of sq. miles of i^{th} depth Xi	$\left(\frac{\Sigma Yi}{\Sigma Xi}\right)Xi$ = $E(Yi)$	$\frac{(O-E)^2}{E}$	Sign
0-25	455	597.1	434	1.016	+
26-50	210	324.6	240	3.750	-
51-75	50	138.9	101	25.742	-
76-100	28	72.0	52	11.236	-
101-150	176	146.0	106	46.133	+
151-200	84	90.2	66	5.025	+
201-300	103	111.0	81	5.975	+
301-400	27	70.1	51	11.277	-
401-500	8	23.8	17	4.925	-
501-1000	35	66.2	48	3.555	-
over 1000	55	47.7	35	11.613	+

$X^2 = 130.247$

$X^2_{.05,10} = 18.3$

Table 18. Distribution versus depth calculations for 1975 bearded seal observations.

Depth (metres)	Number of seals observed at i^{th} depth Y_i	Number of sq. miles of i^{th} depth X_i	$\frac{\Sigma Y_i}{\Sigma X_i} X_i = E(Y_i)$	$\frac{(O-E)^2}{E}$	Sign
0-25	19	597.1	22	.409	-
26-50	20	329.6	12	5.333	+
51-75	9	138.9	5	3.200	+
76-100	1	72.0	3	3.522	-
101-150	4	146.0	5		
151-200	0	90.2	3		
201-300	6	111.0	4		
301-400	0	70.1	3		
401-500	1	23.8	1		
501-1000	2	66.2	2		
over 1000	0	47.7	2		
(76-100 to over 1000, bracketed)	14		23		

$X^2 = 12.464$

$X^2_{.05,3} = 7.8$

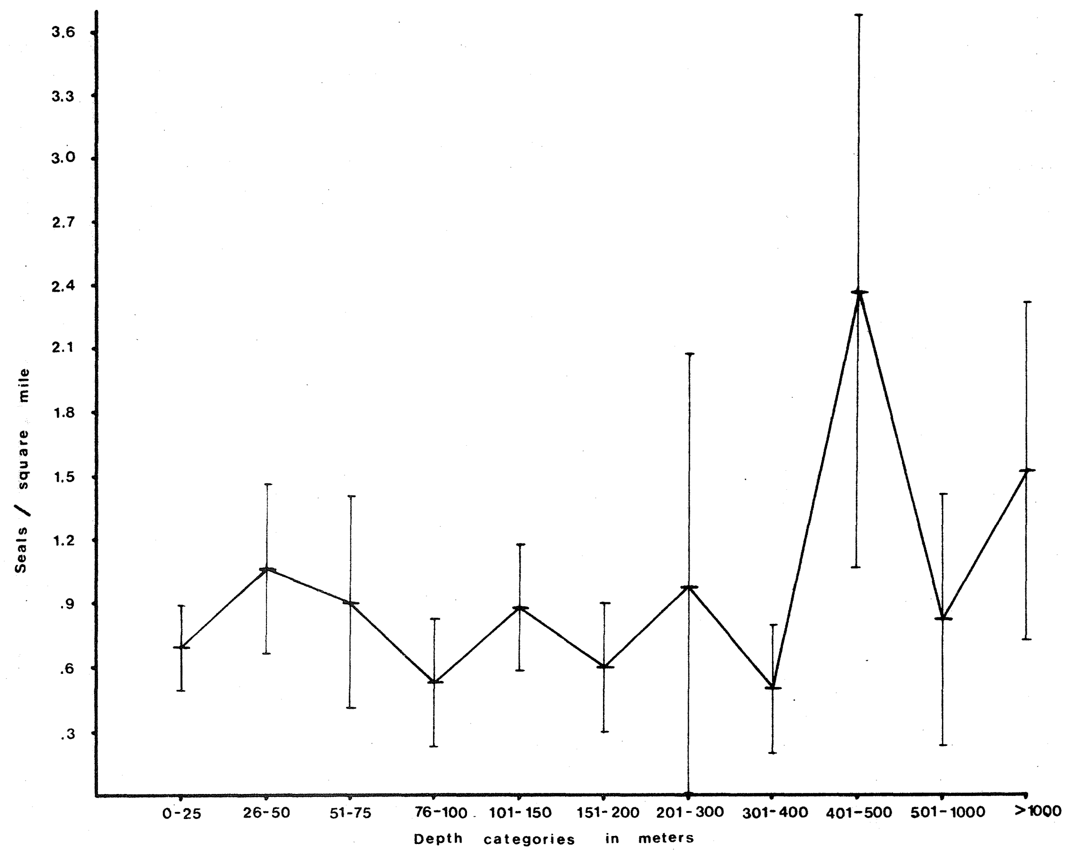

Figure 9. Ringed seal density versus depth for 1974.

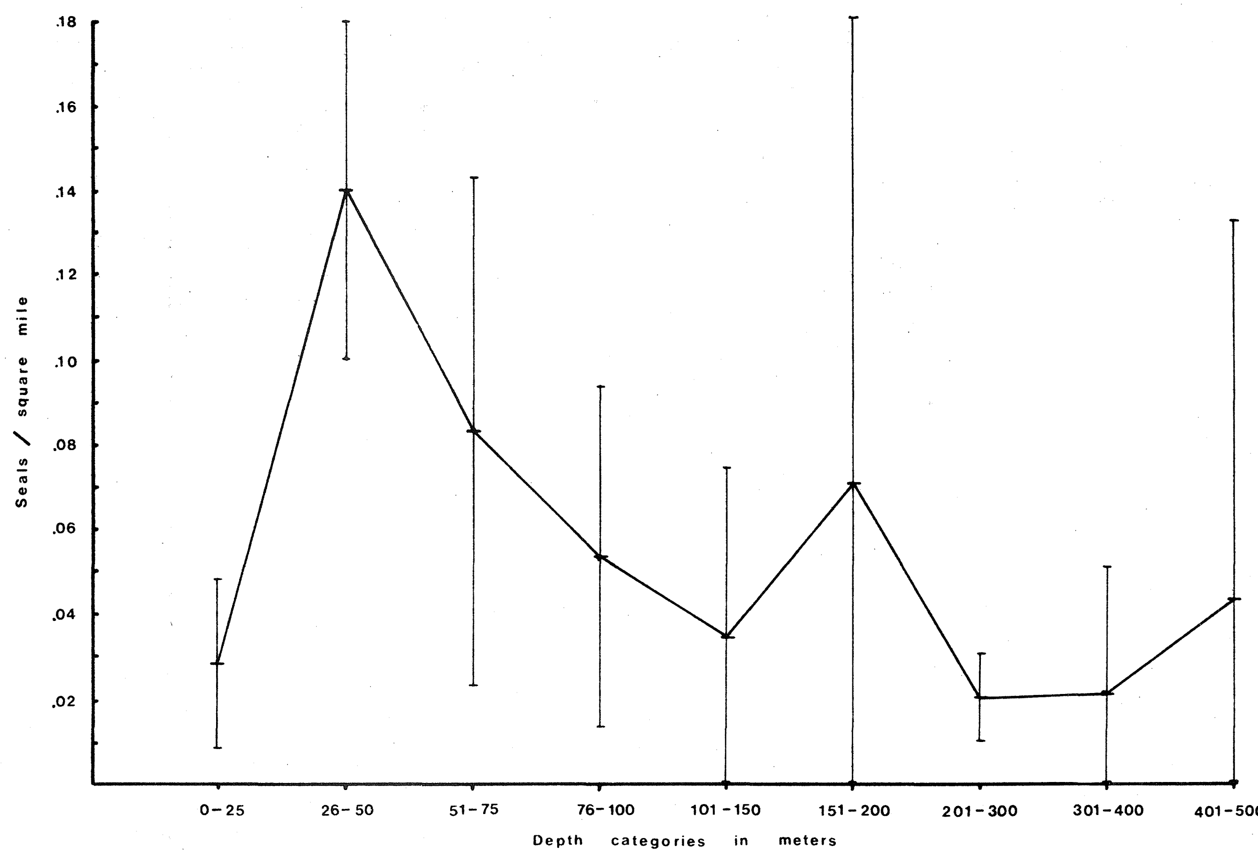

Figure 10. Bearded seal density versus depth for 1974.

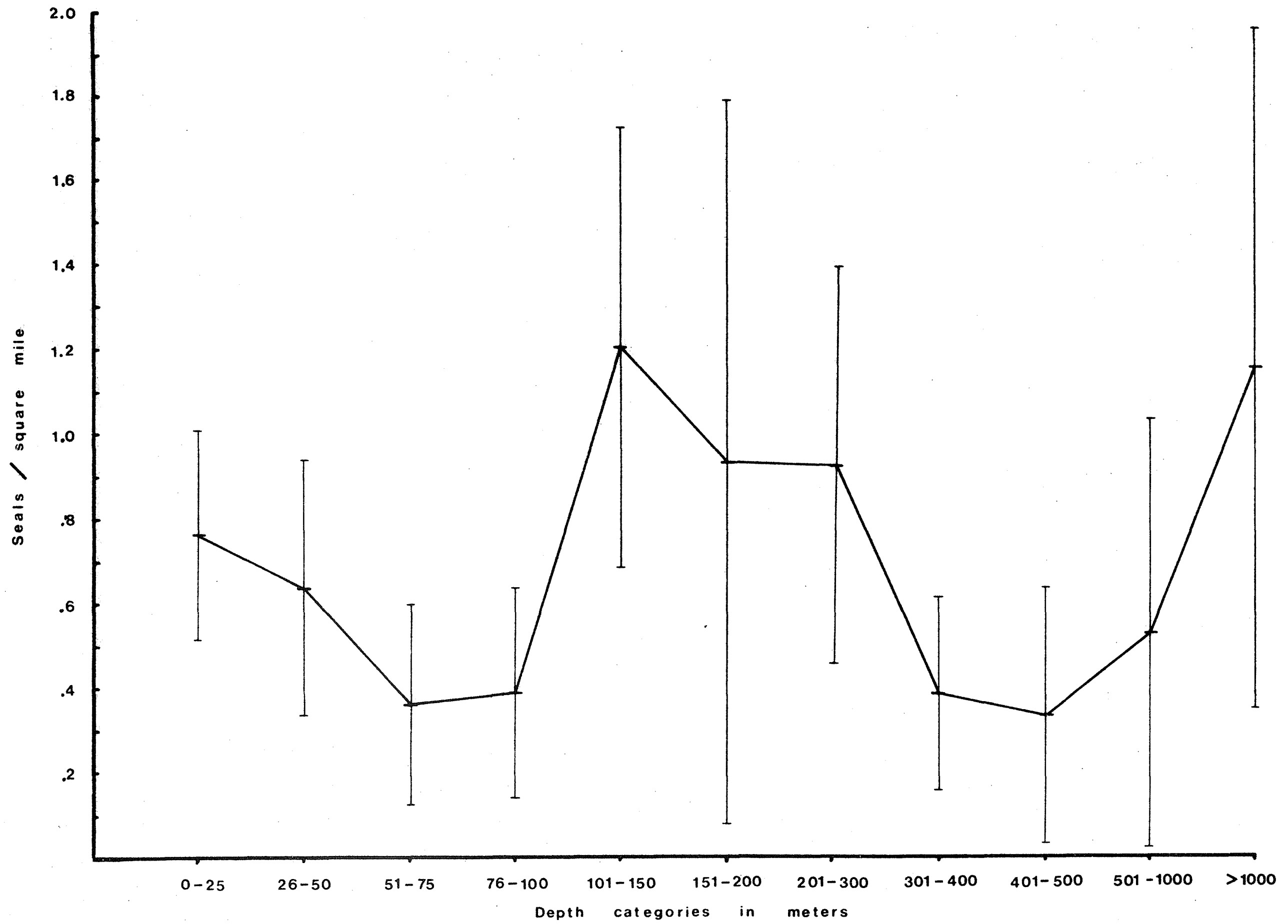

Figure 11. Ringed seal sensity versus depth for 1975.

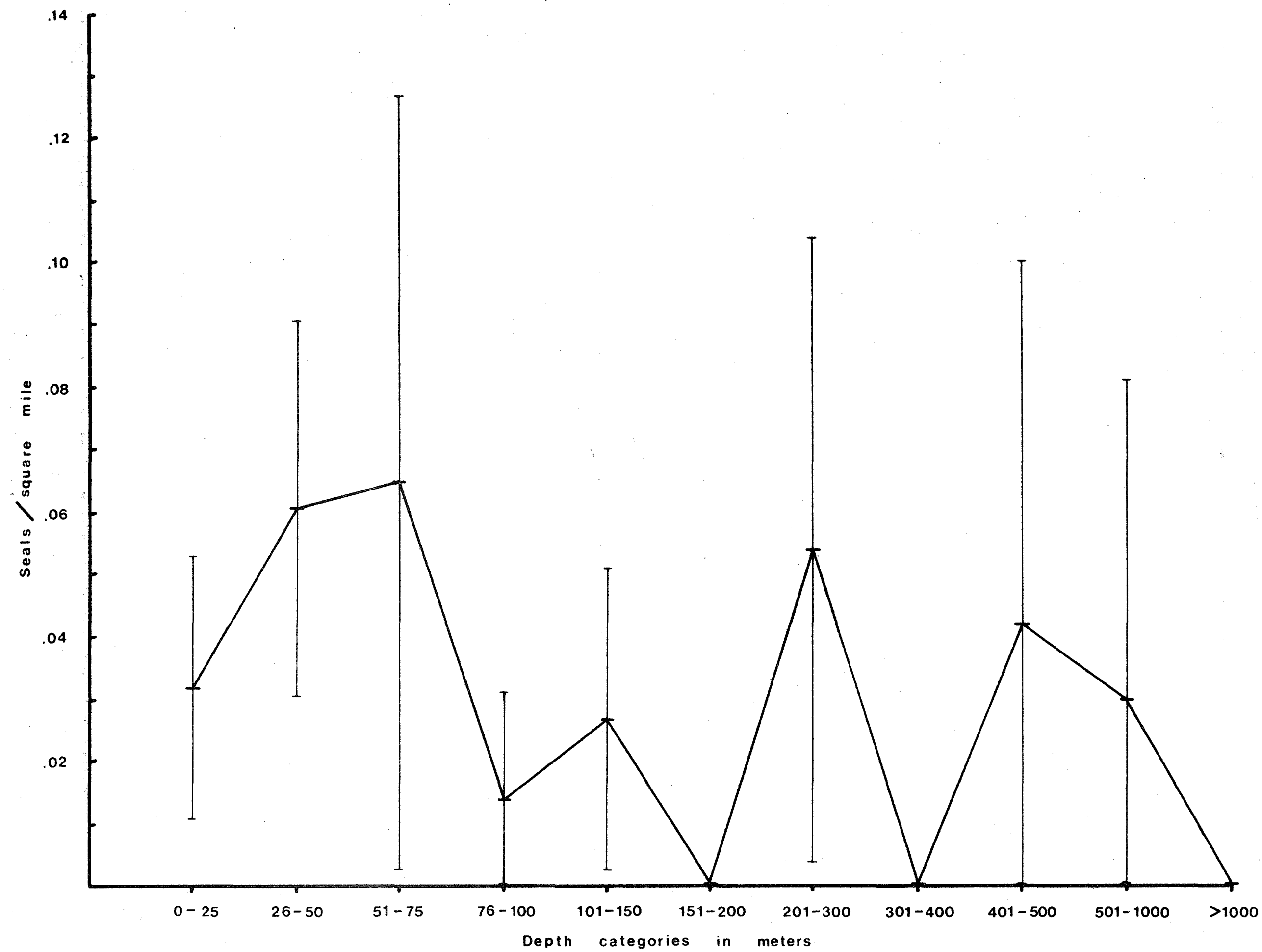

Figure 12. Bearded seal density versus depth for 1975.

Table 19. Comparison of specific depth categories between ringed seals and bearded seals in 1974.

Depth	1974 ringed seal observed	1974 ringed seal expected	1974 bearded seal observed	1974 bearded seal expected	Total
0-25	472	460	19	31	491
26-50	619	654	79	44	698
51-75	235	240	21	16	256
76-100	63	65	6	4	69
101-150	212	206	8	14	220
151-200	105	110	12	7	117
201-300	239	228	4	15	243
301-400	88	85	3	6	91
401-500	59	56	1	4	60
501-1000	63	59	0	4	63
over 1000	142	133	0	9	142
Total	2297		153		2450

$X^2 = 70.44$

$X^2_{.05,10} = 18.3$

Table 20. Comparison of specific depth categories between ringed seals and bearded seals in 1975

Depth	1975 ringed seal observed		1975 ringed seal expected		1975 bearded seal observed		1975 bearded seal expected		Total
0-25	455		451		19		23		474
26-50	210	743	219	734	20	49	11	38	230
51-75	50		56		9		3		59
76-100	28		28		1		1		29
101-150	176	260	171	251	4	4	9	13	180
151-200	84		80		0		4		84
201-300	103	130	104	130	6	6	5	6	109
301-400	27		26		0		1		27
401-500	8		9		1		0		9
501-1000	35	98	35	96	2	3	2	5	37
over 1000	55		52		0		3		55
Total	1231				62				1293

$X^2 = 10.7$

$X^2_{.05,3} = 7.8$

whenever naturally occurring open water is present, it is used until it freezes over at which time new breathing holes are maintained. We suspect this use of open leads whenever possible has a more significant effect on the distribution of both ringed and bearded seals, especially in the offshore ice areas, than does the depth of the water.

6.4 Age Structure

Tables 21 and 22 give the proportions of pups, adolescents (as defined by McLaren, 1958a and Burns, 1967) and adult ringed and bearded seals collected in the offshore areas of the eastern Beaufort Sea and from three other studies. The sample sizes are too small and the number of age classes too numerous to warrant presentation in an age/frequency table or graph. Table 23 gives the proportions of the same three age classes of seals that were killed by polar bears.

Smith and Stirling (1975 and unpublished) documented a marked reduction in ringed seal productivity in 1974 and 1975 in comparison to 1972 and 1973. Note from Tables 21 and 23 the almost total absence of pups in either our collections or in the age structure of the seals killed by polar bears. The sample sizes of bearded seals in Table 22 are too small to be conclusive but give a result similar to that from the ringed seals.

Stirling and Smith (1975) further described several other data that also indicated a marked reduction in the numbers of seals in the western Arctic in 1974 and 1975. They were uncertain which factors caused these changes but several points were noted. Compared to 1972 and 1973, there was considerably less snow cover in which the seals could construct their subnivean lairs on the ice during the late winter and early spring of 1974 and 1975. In 1974, conditions were also such that the series of leads which open and re-freeze along the west coast of Banks Island, the mainland coast, and western Amundsen Gulf, were not present. Thus in 1974, the population of predominantly sub-adult seals that normally concentrated along those lead systems throughout the period of ice cover was either absent or at least was largely unavailable to the polar bears because of the heavy protective cover of pressure ice. In 1974 hardly any seals killed by polar bears were found, probably because fewer were killed and more was consumed, making it easier for the remains to be hidden by drifting snow. In 1975, although the offshore leads were again open periodically through the winter, young seals born the previous spring were virtually absent from the samples and the proportions of subadults were lower than in 1974 (Tables 21 and 23).

We are uncertain whether seals respond to unusually severe ice cover by moving out of an area and, if so, whether the proximate stimuli for these movements are lack of food or some other adverse conditions. However, heavy and late ice years, such as occurred in 1974, do appear to adversely affect the nutritional state of ringed seals (Smith and Geraci, 1974). In that context, it is of particular interest to note that in 1966, following on the exceptionally heavy ice years of 1964 and 1965, that young of the year were almost totally absent from the sample of seals taken that summer at Sachs Harbour.

Although the exact mechanisms are not understood, it is clear that

Table 21. Proportions (and frequencies) or pups, adolescents, and adult ringed seals collected from mid-April to Oct. 31 in the eastern Beaufort Sea, and two studies in the eastern Arctic.

Eastern Beaufort - Offshore

Age Class	1966		1972		1974		1975	
	P	(N)	P	(N)	P	(N)	P	(N)
Pups	.08	(15)	.50	(122)	.00	(0)	.02	(4)
Adolescents (1-6 yr.)	.30	(39)	.34	(78)	.33	(18)	.25	(42)
Adults	.62	(136)	.16	(46)	.67	(43)	.73	(140)

Eastern Arctic Collections

Age Class	McLaren 1958(a) Offshore		McLaren 1958(a) Inshore		Smith 1973(a) Inshore[1]		Smith 1973(a) Inshore[2]	
	P	(N)	P	(N)	P	(N)	P	(N)
Pups	.16	(17)	.13	(57)	.31	(896)	.32	(857)
Adolescents (1-6 yr.)	.63	(67)	.58	(262)	.36	(1046)	.55	(1447)
Adults	.21	(23)	.29	(135)	.33	(954)	.13	(338)

[1] Collected at Home Bay.
[2] Collect ed at Cumberland Sound.

Table 22. Proportions (and frequencies of pup, adolescent and adult bearded seals collected from mid-April to August 31 in the eastern Beaufort Sea as well as one study from Bering Strait, Alaska during the spring hunting season from 1964 through 1966.

	Eastern Beaufort Sea				Bering Strait, Alaska	
Age Class	1974		1975		Burns (1967)	
	P	(N)	P	(N)	P	(N)
Pups	.03	(1)	.02	(1)	.27	(107)
Adolescents (1-5 yrs.)	.26	(8)	.16	(8)	.26	(102)
Adults	.71	(22)	.82	(42)	.47	(182)

Table 23. Proportions (and frequencies) of pup, adolescent and adult seals found killed by polar bears from 1971 - 1975 in the eastern Beaufort Sea and Amundsen Gulf.

Ringed Seals

Age Class	1971-1973 P	(N)	1974 P	(N)	1975 P	(N)
Pups	.46	(17)	0	(o)	0	(0)
Adolescents	.43	(16)	.60	(3)	.09	(2)
Adults	.11	(4)	.40	(2)	.91	(20)

Bearded Seals

Age Class	1971-1973 P	(N)	1974 P	(N)	1975 P	(N)
Pups	.25	(1)	0	(0)	.25	(1)
Adolescents	.75	(3)	.5	(1)	0	0
Adults	0	0	.5	(1)	.75	(3)

large fluctuations in productivity and population size of ringed seals take place in the western Arctic in response to changes in environmental conditions. As discussed by Stirling *et al.* (1975), these changes have marked effects on the distribution and survival of their major predators, the polar bears.

6.5 Reproductive Data

Table 24 gives the number of adult female ringed seals (7+ years, McLaren, 1958a) and bearded seals (6+ years, Burns, 1967) in our samples from the offshore ice in the western Arctic that had a corpus albicans of recent pregnancy (based on size, Smith 1973a). Tables 25 and 26 gives the ovulation rates of adult female ringed and bearded seals collected from the offshore areas of the western Arctic and compares them to the results of other studies. Note that the frequencies of occurrence of both corpora albicantia and ovulation were markedly lower in 1974 and 1975 than in 1972 in the western Arctic or in the comparative studies. Presumably, the fact that as a group, the ringed seals were in poorer physical condition was responsible for almost half the adult females not ovulating. The more difficult question, which we cannot answer is, whether, because of more difficult environmental conditions, the adult females that did ovulate, did not copulate or conceive or if they experienced intrauterine mortality. However, the ovulation rate of ringed seals in the offshore ice in 1974 and 1975 was roughly half of what might have been expected from a normal population. Furthermore, three of the female reproductive tracts we examined showed evidence of having resorbed the foetus, and one that appeared to have aborted the foetus at some time prior to the normal period of parturition. Thus, the results clearly support other data discussed in this report which suggested the marked decline in productivity.

Although the sample sizes from adult female bearded seals in 1974 and 1975 were again low, they also indicated lower than expected rates of reproductive activity.

7. RECOMMENDATIONS

7.1 The Concept of Critical Areas

The concept of critical areas and its applicability to polar bears was discussed by Stirling, *et al.* (1975). However, the major points will be reiterated here. In the simplest of terms, the survival of any species is dependent on its ability to feed and reproduce successfully. For the ringed and bearded seals, there is the additional parameter of being able to obtain access to the air to breathe, through either naturally occurring or self-maintained openings in the sea ice. Thus, the most important aspect of the conservation and management of the ringed and bearded seals of the western Arctic is the protection of the most important areas of feeding and breeding habitat. If that condition is met, a population can recover, in time, from a large scale reduction in numbers, be it caused by accident or design. Attempt to preserve, in this instance, the maximum number of individual seals, would be of little value if irreparable damage were done to the key feeding and breeding areas. Therefore, we have restricted our comments to these two key aspects.

Table 24. Proportions of sexually mature ringed and bearded seals with a Corpus Albicans of recent pregnancy.

Year	Ringed Seal No.	Ringed Seal % with recent corpus albicans	Bearded seal No.	Bearded seal % with recent corpus albicans
1972	17	.59	-	-
1974	23	.00	9	.67
1975	82	.11	23	.30

Table 25. Ovulation rate of sexually mature ringed seals collected in the eastern Beaufort Sea and from three comparative studies. The samples from 1974 and 1975 include seals with mature follicles collected immediately prior to ovulation.

Year Collected	Ovulation Rate	Sample Size
1972	.94	17
1974	.50	18
1975	.53	70
Smith 1973(a)	.92	538
McLaren 1958(a)	.78	-
Johnson, *et al.* 1966 (as reanalyzed in Stirling, 1971)	.94	280

Table 26. Ovulation rates for sexually mature bearded seals collected in the eastern Beaufort Sea as well as Bering Strait, Alaska. The 1974 and 1975 samples include seals with mature follicles collected prior to ovulation.

Year Collected	Ovulation Rate	Sample Size
1974	1.0	9
1975	.52	23
Burns (1967)	.83	133

The pupping areas of ringed seals in the western Arctic are widely scattered through the fast ice areas, mainly in the large bays and to a lesser degree in the inshore fast ice areas off the Tuktoyaktuk Peninsula and the west coast of Banks Island. In some years there may also be a high degree of productivity in the NE portion of Amundsen Gulf. Bearded seal pupping appears to be much more limited in distribution and appears to be concentrated in the offshore moving lead systems north of the Tuktoyaktuk Peninsula and west of Banks Island, although a limited amount of pupping occurs in the fast ice as well (Stirling and Smith, 1975). These same off-shore lead systems are also critical to the survival of large numbers of adolescent and adult ringed seals, and consequently that is the most important area for polar bear feeding and white fox scavenging (Stirling, *et al.*, 1975).

7.2 Specific Recommendations

a) Ringed seal pupping habitat is extensive in the fast ice areas. Thus, it is probable that industrial activity would not have a significant impact provided that it were localized and that substances such as spilled oil or toxic chemicals were contained so they could not foul birth lairs and breathing holes over a large area or detrimentally affect the food chain. As discussed above however, bearded seal pupping habitat is far more localized in distribution in the offshore moving lead areas, which are also critical for overwintering seals, feeding polar bears, and scavenging arctic foxes. Therefore, ideally, as recommended in the polar bear report, no industrial activities should be permitted in the moving offshore areas (Stirling, *et al.*, 1975; Fig. 16) between mid-October and mid-May, or at least that industrial activity during that period be kept at a minimum level at highly specific sites.

b) During the open water period, industrial activities would probably not detrimentally affect seal numbers provided there were no large scale effects on the food chain. The possible exception is marine seismic activity and in this context it may be relevant to note that in Alaska only compressed air charges are permitted because of the possible detrimental effects on marine mammals of the regularly used explosives.

7.3 Recommendations for Future Research

a) It will be very important to continue to monitor the basic biological parameters of the ringed and bearded seal populations in the western Arctic to know the total effects of natural population trends that are taking place at present. There are two reasons why this is important; firstly, any management requirements for ringed and bearded seals should be responsible to major changes in the status of the populations and, secondly, to ensure that industrial activities are not unfairly blamed for changes in numbers, distribution, and productivity that may be occurring because of natural factors.

It would be extremely valuable to repeat the exact aerial survey design and analysis presented in this report to monitor possible changes in numbers and distribution, and to repeat the birth lair surveys of Amundsen Gulf as described by Smith and Stirling (1975) to monitor changes in productivity. It would probably be adequate to conduct these surveys in alternate years during the active period of exploration and possible production until a clear indication of the affect, or lack of it, was determined.

b) An in-depth study of the physical and physiological effects of different types of marine seismic devices on seals should be done. The results of such a study could apply to all areas where marine seismic studies were to be done and whatever regulations were required could be drawn up on a sound scientific basis.

c) Recommendations on research into heavy metal and toxic chemical contamination, and the importance of the relationship between the arctic foxes, seals, and polar bears were included in Stirling, *et al.*, (1975) and need not be repeated here although they are equally applicable to this report.

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