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THE RELATIONSHIPS OF MARINE MAMMAL DISTRIBUTIONS, DENSITIES AND ACTIVITIES TO SEA ICE CONDITIONS

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I. SUMMARY

The general objectives of this project are to determine the distribution and aerial extent of the different ice habitats utilized by marine mammals of the Bering, Chukchi and Beaufort seas, to investigate the relationships of the various marine mammals to these ice habitats, and to determine how the seasonal changes in sea ice cover regulate the distribution and activities of marine mammals.

Field work for this project has just begun which limits the data available upon which to base conclusions. An exception is provided by a comparison of the results of two previous studies (Burns, 1970; Shapiro and Burns, 1975a), which permit a correlation to be made between the distribution of breeding adults of the pagophilic pinnipeds and average ice conditions in the Bering and Chukchi seas in March and April. This suggests that those areas most heavily used by marine mammals at various times of year, and the associated ice conditions, can be identified and described. This in turn provides the basis for estimating the effect that various types of development may have on these populations.

II. INTRODUCTION

A. General Nature and Scope of Study

The relationships of ice inhabiting marine mammals to the variety of ice-dominated habitats which exist in the Bering, Chukchi and Beaufort seas are not well understood. It is generally known that the distribution and activities of mammals in these areas are related to, and broadly synchronous with, the seasonal dynamics of the sea ice; that each species occupies a different ecological niche within the ice-dominated system; that a variety of ice 'habitats' are present; and that the various species 'utilize' sea ice in different ways (Burns, 1970; Fay, 1974).

As pointed out by Fay (1974), ice of these and other sub-polar and polar seas is important to marine mammals in several ways. It serves as a substrate on which some pinniped species haul out to sleep and bear their young. It also forms a rigid barrier through which pinnipeds and cetaceaus alike must find or make holes in order to have access to the air that they breathe and the sea that holds their food. For some species of marine mammals, the nature of the ice may be as important in habitat selection as are terrain, soil type and vegetation to terrestrial mammals. For other species, the presence of ice may be disadvantageous, requiring them to carry on extensive migrations in order to avoid it.

Almost all investigations to date of the relationships of marine mammals to sea ice have focused on the species and its adaptations to the ice. This approach is understandable because more is known about the form, function and distribution of the animals than about the dynamic processes of ice formation, movement and deformation. The latter have been difficult to study in broad perspective from land, ships, or aircraft, but the recent introduction of repetative high-resolution satellite imagery has provided that greater perspective. Broad views of sea ice distribution are now available from which these processes can be observed, so that the chronological and spatial distribution of marine mammals may now be related to sea ice characteristics, conceivably to the degree that a predictive model can be developed.

Our general objectives are to determine the distribution and aerial extent of the different ice habitats utilized by marine mammals of the Bering, Chukchi and Beaufort seas, to investigate the relationships of the various marine mammals to these ice habitats, and to determine how the seasonal changes in sea ice cover regulate the distribution and activities of marine mammals. A continuing program for obtaining various kinds of 'ground truth' is an integral part of this project.

Of necessity, this project requires, and is designed around, the involvement of both physical and biological scientists.

B. Specific Objectives

The specific project objectives are:

(1) To determine the extent and distribution of regularly occurring ice-dominated marine mammal habitats in the Bering, Chukchi and Beaufort seas;

(2) to describe and delineate these habitats;

(3) to determine the physical environmental factors which produce these habitats;

(4) to determine the distribution and densities of the various marine mammal species in different ice habitats; and

(5) to determine how the dynamic changes in quality, quantity and distribution of sea ice relates to major biological events in the lives of marine mammals (e.g., birth, nurture of young, mating, molt and migrations).

C. Relevance to Problems of Petroleum Development

Petroleum development in the Bering, Chukchi and Beaufort seas will, without exception, take place in regions of seasonal sea ice cover in which ice-associated marine mammals occur abundantly and are involved in major annual biological events. As examples, proposed lease areas in Bristol Bay, St. George Basin and Havarin Basin are in areas seasonally covered by the ice front in which spotted and ribbon seals concentrate in winter to give birth and nurture their pups. The Hope Basin is within the migration route of all ice-associated marine mammals which winter in the Bering Sea. The Beaufort Sea lease area is occupied by ringed seals and polar bears almost all year.

The different regions are subjected to different ice conditions. In turn, the variety of ice conditions support different marine mammal species in varying numbers.

The relevance of this project to problems of petroleum development is that we are attempting to determine (1) what major recognizable marine mammal habitats exist, (2) how these habitats are spatially and temporally distributed, (3) to what extent the various mammal species depend on them and, (4) how important aspects of the biology of marine mammals are related to the physical changes in a major component of their environment - ice.

The answers to these questions are necessary in order to determine what species are likely to be affected by development, in what numbers and to some extent, how.

III. CURRENT STATE OF KNOWLEDGE

Ice-associated mammals of the Bering, Chukchi and Beaufort seas include polar bears (Ursus maritimus), walrus (Odobenus rosmarus), spotted seals (Phoca vitulina largha), ringed seals (Phoca hispida), ribbon seals (Phoca fasciata), bearded seals (Erignathus barbatus), belukha (Delphinapterus leucas) and bowhead whales (Balaena mysticetus).

The biology of some of these species has been intensively studied (i.e., Burns, 1965, 1967; Burns et al., 1972; Gol'tsev, 1968; Kleinenberg et al., 1964; McLaren, 1958; Tikhonirov, 1961). However, the ecology of some species such as the bowhead whale and ribbon seal is poorly understood.

Recent studies (Burns, 1970; Fay, 1974) have focused attention on the role of sea ice in providing a variety of habitats, each of which supports a different faunal association. However, the characteristics of these habitats (and others which have since been recognized) and the physical and biological processes which produce them are only beginning to be investigated.

Recent studies of ice distribution and dynamics in the study area, using both LANDSAT and NOAA 2/3 satellite data, have been reported by Shapiro and Burns (1975a,b), Muench and Ahlnas (1976), Crowder et al. (1974), and Hibler et al. (1974). These illustrate the utility of satellite imagery for investigations of this type. However, the problem of using satellite data to define and identify those characteristics of the ice which determine its quality as habitat for particular species has not as yet been addressed. This constitutes an important part of this project.

IV. STUDY AREA

The study area includes all of the eastern Bering and Chukchi seas and the shelf of the Beaufort Sea.

V. SOURCES, METHODS AND RATIONALE OF DATA COLLECTION

Data about mammals are derived from several sources including the published literature, shipboard and aerial surveys, aircraft flights to coastal villages including those on St. Lawrence Island during which marine mammals are sighted, observation of marine mammal migrations past coastal hunting sites, analysis of records concerning characteristics of marine mammals harvested at different Eskimo villages, studies of the ecology of various species of marine mammals and occasional reports from interested individuals such as pilots and village residents.

Local ice conditions are monitored during the appropriate activities listed above. Additional data are available from aerial photographs and the results of other remote sensing flights in the study area. Finally, imagery from both LANDSAT and NOAA weather satellites is received at the remote sensing data library of the Geophysical Institute, University of Alaska. NOAA satellite data are available within one week of acquisition. Unfortunately, there is about a six-month delay in receipt of the LANDSAT data, plus time required for printing and preparation of special products.

The satellite data is useful for two related reasons. First, imagery which coincides with any type of ground truth data provides the opportunity to learn how to recognize, on that imagery, those ice conditions which various species utilize or, equally important, do not utilize. Second, all of the imagery can be studied for the purpose of defining the 'average' ice conditions in any area during some particular time of year. An example of this is given below, in which recurring features of the March-April ice cover of the Bering and Chukchi seas are described. This type of work will be more important, however, when the problem of identification of habitat from satellite imagery has been solved.

VI. RESULTS

A. Comparison of Winter Distribution of Pinnipeds with General Sea Ice Conditions

The generalized late winter distribution of reproductive adults of the pagophilic pinnipeds in the northern Bering and Chukchi seas, as reported in Burns (1970), is shown in Figure 1. This figure represents a compilation of sightings of animals made over a period of several years, and it is not meant to imply that these have been treated statistically.

Figure 2 is a summary of ice conditions in part of the same area for March and April of 1973 and 1974, modified from Shapiro and Burns (1975a). The data sources upon which the map is based included daily coverage of the area by the DAPP satellite for 1973, the NOAA 2/3 satellites for 1974, and all available LANDSAT (then ERTS-1) imagery for both years. The map is intended to represent 'average' conditions, in the sense that for about 50-75% of the time covered by the study, the configuration of the ice was similar to that shown.

Comparison of Figures 1 and 2 indicates the correlation between mammal distributions and ice conditions. As an example, breeding ringed seals are restricted to the landfast ice. In contrast, bearded seals occur throughout the Bering Sea, but north of Bering Strait their range is more restricted, apparently by the margin of the heavy pack ice. Thus, they tend to occur in the narrow shear zone along the west coast of Alaska (Figure 3), and to be more dispersed in the area just north of Bering Strait where the prevailing northerly winds tend to break the pack ice and drive it south through Bering Strait (Figure 4).

North of the pack ice edge in Bering Sea, walrus tend to congregate east, west and south of St. Lawrence and Nunivak islands, while apparently avoiding the north sides. The reason for this is apparent from Figure 2. The north sides of both islands are strong convergence zones in the ice drift pattern (Figure 5). In contrast, persistent polynya occur south of both islands, while their east and west margins are the sites of continuous breaking of the pack ice as it deforms in order to drift past the obstacles which the land masses represent. Note that the concentrations of walrus on the south side of the Diomede Islands are probably related to the small polynya at that location.

Finally, ribbon and spotted seals are associated with the marginal zone of the ice in the Bering Sea (Figure 6), which is characterized by small floes formed by disintegration of the heavier pack ice.

The discussion above shows a generalized correlation between the distribution of certain species and what has been defined as 'average' ice conditions. This result is particularly encouraging because the data sets upon which Figure 1 and 2 were based do not overlap in time. This implies a degree of repeatability, and hence, predictability in patterns of mammal distribution and ice characteristics. However, both the animals and the ice represent discrete dynamic systems. Ice conditions in any area can change rapidly, as can the density and types of mammals within that same area. It is thus important to accurately define those characteristics of the ice which each species utilizes in order to determine the extent of area which might be occupied by that species at any time.

Finally, it should be emphasized that the discussion above is concerned only with reproductive adults during the time the young are born. The question of how well ice conditions and mammal distribution will correlate at other times of year must still be considered.

B. Ice Classification

The objective of this part of the project is to develop a quantitative classification of sea ice conditions which defines the state of the ice as habitat for various species. That is, to determine the range of numerical values of various parameters which describe the ice conditions in any area within which each species will utilize that ice. Further, to be useful, the classification must be based upon measurements from satellite images in order to take advantage of the repetitive and synoptic aspects of this data. At present, only LANDSAT imagery is being used for this study.

There are two basic elements required for the development of such a classification. The first is to determine the parameters which define the character of the ice as habitat for various species and the second, to learn how to identify and measure these from satellite data. Data for the first requirement will be developed through ecological studies and survey flights, particularly those which coincide with satellite passes, while the second requires experimentation with procedures for extracting information from the satellite data. Surveys and ecological studies are in progress at present and more are planned in future (see the section on fourth quarter activities below). Most of the work to date has been on techniques for utilization of the satellite data, and progress in this area is reported below.

In the absence of any definitive data relating particular species to ice habitats the approach adopted has been to attempt to develop methods of statistically discriminating different ice conditions from LANDSAT data simply to learn what methods might be useful. In order to accomplish this in detail, some means of determining approximate ice thickness from the data is required. No methods are presently known by which this can be done (although a possible approach is given below). Therefore, as a starting point the ice has been divided into only two categories: 'thick' ice, which has high reflectivity and appears in tones of light gray on band 7 of the LANDSAT imagery, and open water or 'thin' ice, which ranges from black through the darker gray tones. Using these, it is possible to statistically define the floe size distribution and, equally important, the distribution of spacing between floes. It is anticipated, based upon the available data, that these will be important factors in defining ice habitats.

It is intended that in the remainder of the study digital tapes of the LANDSAT data will be used to produce the results described below. However, another method was adopted for the first attempt simply to test the idea with available equipment. In this method, a scanning microdensitometer is used to establish the film density along a number of lines on a 70mm negative transparency of a LANDSAT image. The density variation is recorded as a continuous curve on a strip chart recorder. The resolution of the system is thought to be about the same as that of the satellite images, but this still needs to be esablished. The scanning and recording speeds are known, so that distances along the curve can be scaled against distances on the image. Sharp changes in film density between thick ice floes and thin ice or open water are readily identified on the curve. The exact density value at which the transition is to be defined is determined by comparison of observed densities of thick ice and thin ice-open water areas on the image with the density scale which is supplied as part of the marginal information on the negative. Once this decision level is established, the path distances over thick ice and thin ice or open water can be determined by simply measuring the distances along the curve over which the density value is above or below the standard for the transition. The results can then be summarized to numerically define differences in ice conditions in different areas. Note that these steps can be done by computer directly from the digital tapes of the data.

As an example, Figure 7 shows LANDSAT image number 1228-22273-7, acquired on March 8, 1973. The scene covers part of the southeastern Chukchi Sea, with Point Hope just west of the center of the northeast quadrant. Outlined on the picture are six areas, 35 km x 35 km in size, which were used for this study. Each area was scanned twelve times by the microdensitometer, six scans each in a north-south and east-west direction. The density level curves were processed as outlined above, and some results are summarized in Table I. The preliminary nature of these values must be emphasized, because several important questions are still to be investigated before any detailed interpretation is attempted. Among these are:

(1) Which band (or combination of bands) will yield the most suitable data? In this example, band 7 was used because of its high contrast which simplifies the interpretation of the microdensitometer curves. However, no comparisons have yet been made with results from other bands.

(2) Is the number of scans adequate to supply a statistically significant data sample?

(3) What is an appropriate size for the sample area and need this be the same in all cases. Note that the size of the sample areas selected above was arbitrary.

TABLE I

SUMMARY OF STATISTICAL DATA

	THICK ICE						THIN ICE - OPEN WATER					
Area	% Path	Mean (mm)	σ_I	γ_I	Median (mm)	Mode (mm)	% Path	Mean (mm)	σ_W	γ_W	Median (mm)	Mode (mm)
1	75.1	10.31	19.85	.821	4	2-4	24.9	2.86	4.7	2.85	1.5	2-4
2	90.2	27.63	35.66	1.72	18	16-32	9.8	3.50	7.69	6.87	2.25	2-4
3	90.1	30.40	45.42	3.17	12	16-32	9.9	3.74	4.24	1.64	2	1-2
4	70.1	11.70	24.16	5.07	2	2-4	27.9	4.66	9.84	6.16	1	2-4
5	83.1	24.17	31.04	1.87	13	4-8	16.9	5.53	8.81	2.50	3.5	1-2
6	91.3	27.17	50.98	3.50	9	16-32	8.7	2.90	2.83	2.61	2	2-4

Key: Conversion scale, 1mm on chart = .114 km

$\sigma_{(I,w)}$ - standard deviation of (thick ice, thin ice-open water) path length

$\gamma_{(i,w)}$ - slewness

(4) Exactly how should the decision level for the transition between open water-thin ice and thick ice be established? This is obviously critical, because it absolutely determines the values of the measured path lengths.

Finally, there is an extensive literature relating to the statistical treatment of particle size distributions in sedimentary rocks. This is analogous in many ways to the problem under study, and it is anticipated that at least some of this will be useful in the interpretation of this data.

The range of values in Table I do serve to indicate that differences in ice characteristics can be detected and expressed quantitatively. As an example, areas 1 and 4 primarily cover ice which is typical of that deformed in the shear zone along the coast. These areas have lower values of percent of ice cover, mean, medium and mode of thick ice path, σ_i and median water path than do the remaining areas, and these values appear to reflect the greater deformation in these areas than in the pack ice of the remaining areas. Areas 2, 3 and 6 are all dominated by thick ice. However, at the time the image was acquired, tension fractures were developing in areas 2 and 3 and the pack ice was thus probably diverging, while area 6 was drifting relatively uniformly to the south-southeast at a velocity of about 9-10 km/day (Shapiro and Burns, 1975b). From Table I, it is apparent that the values which describe the characteristics of the thick floes are similar for the three areas, except that the median floe size for area 6 is lower than those of areas 2 and 3. However, there is a marked difference in the values of the mean, σ_w, median and mode for the open water-thin ice path lengths for these areas. For area 6, all of these values are quite similar, indicating that these path lengths are relatively uniform in size, while they are more variable for areas 2 and 3. This is probably related to the difference in the dynamic state of these areas. The tension fractures in areas 2 and 3 tend to form long leads of variable width, while the open water-thin ice distribution in the uniform drift field of area 6 would be expected to be more even.

These results are considered to be encouraging, but more work is needed both to answer the questions outlined above, and to provide a wider range of sample areas.

A second method under study for obtaining the data for establishing the classification involves using the Fourier transforming properties of spherical lenses. The technique has been investigated in connection with problems of pattern recognition on aerial photographs, and may also be applicable in the present study.

In theory, the technique is straightforward. A point source of monochromatic light from a lasar is passed through a spherical lens to form a plane wave. The beam then passes through a small area of the photographic image which is placed at the back focal plane of a second spherical lens. The light collected by the second lens forms a diffraction pattern in the front focal plane. This diffraction pattern, which is the Fourier transform of the illuminated photographic image, provides information about the spatial frequency distribution of the photograph. The geometry and intensity of the light distribution in the diffraction pattern relates directly to the size distribution and spacing of objects in the photograph. Thus, in theory it would be possible to quickly and conveniently obtained detailed information about sea ice states by applying the technique to photographic products of the LANDSAT data.

In practice, however, the accuracy and utility of the method is limited by the noise in the system. For this project, the necessary apparatus was set up using available equipment which is too crude for detailed work, but is thought to be adequate for judging if the method is sufficiently promising to justify further effort. Light from a lasar source was passed through a small part of a 70mm transparency of a LANDSAT image, generating a diffraction pattern which changed as the image was moved through the beam. This indicates that, in fact, the changing pattern was reflecting changes in the image which the beam was sampling. However, the noise level of the resulting pattern was far too high for usable data to be taken. Efforts to remove this noise have been partially successful, but there is some question as to whether the difficulties caused by noise from the film grain can be overcome. Experiments to examine this possibility are in progress, and if a satisfactory result is not obtained, the program will be dropped.

It was noted above that the problem of estimating ice thickness from satellite data has not been solved. For the purpose of this project, however, a detailed knowledge of the thickness distribution of the pack ice is not required. Instead, the need is to determine thicknesses of the ice which set limits on its utility as habitat. Walrus can apparently break through ice up to 25 cm thick, so that, for the present, this is taken as the upper limit of thickness which it would be desirable to measure from the satellite data. A possible approach to making such a measurement is provided by the density curves described above.

LANDSAT imagery is acquired over any point for four consecutive days at the latitude of the Arctic Coast, and for three days at the latitude of St. Lawrence Island. Several sets of such consecutive images exist in which a lead or polynya is observed to be in the initial stages of formation on the first image, and then continues to grow throughout the time covered by the remaining images of the set. If new ice is forming as the lead or polynya opens, then obviously the ice thickness will grade from zero at the edge of open water to some greater thickness of the edge of the older ice. This thickness will depend upon the ambient air temperature. Given some value for the temperature, it is possible to estimate the ice thickness at some point in the lead or polynya, as a function of the time since its origin by using data on ice thickness growth versus temperature (see, for example, Stehle, 1965). When this is established, a density curve can be measured across the new ice. As noted above, gray levels associated with ice tend to become lighter as the ice thickens, and this should be reflected in the density curve up to the limit of light penetration into the ice. Thus, if the curve changes smoothly across the traverse, it may be reflecting thickness changes while it should flatten if the limit is reached.

If the procedure can be successfully applied, then a possibility of identifying ice thicknesses up to 25 cm exists. This is because from the growth curves it appears that at ambient air temperatures common along the Arctic slope in winter, ice thicknesses of up to 25 cm would be expected to form over a new lead within the time frame of four consecutive LANDSAT passes. This, therefore, would provide the necessary test data.

C. Ringed Seal Distribution

Aerial surveys of ringed seals were conducted between 10 and 18 June 1975. These surveys were in the areas of landfast ice between Point Lay and Barter Island. The timing, census procedures and survey areas coincided as closely as possible with a similar effort undertaken between 8 and 15 June 1970 (Burns and Harbo, 1972).

The 1975 surveys were undertaken for several reasons. During the winter of 1974-75, ice conditions in the Chukchi Sea, as far south as Bering Strait, were more severe than usual. Ringed seals were uncommonly numerous in the southern Chukchi Sea. Conversely, indications from several sources were that numbers of ringed seals in some areas of the Beaufort Sea were down (Lentfer, personal communication; Ehredt, personal communication). A downward trend has been reported for the past several years in the eastern Beaufort Sea and in Amundson Gulf (Smith and Stirling, 1975; Stirling et al., 1975).

Survey tracks flown in 1970 and 1975 are shown in Figures 8 and 9. The distribution of ringed seals along tracks flown on the most favorable days of each year is shown in Figures 10, 11, 12 and 13. Sea ice conditions were markedly different in these years.

In 1970, the fast ice east of Barrow was extensive, very flat over broad areas and well covered by drifted snow. Dispersed, breeding seals were rather evenly distributed throughout the entire area and aggregations of seals were confined to a small number of extensive cracks. It appeared that these favorable ice conditions over such a broad area resulted from the presence of several hundred fresh water ice floes which were grounded during October and November 1968 along the 28m depth contour between approximately 146°W and 156°W (McKay, 1969). At least 200 of these floes still existed in 1970 although many of the smaller ones had broken up and were pushed into more shallow water. The main line of floes present in 1970 was grounded in 16 to 24 meters of water and in most cases marked the seaward boundary of landfast ice. These islands protected the area inshore from drifting pack ice, permitting the development of flat, stable ice.

Ice conditions in this same area during the spring and early summer of 1975 were entirely different. The fast ice was very rough and irregular. It appeared that during the process of freezing small floes had been driven toward shore and were piled up and consolidated by freezing into an extensive cover largely dominated by low, pressure ridges. The most extensive areas of flat ice occurred approximately 17 km from shore in the area between Point Barrow and Lonely. Other limited areas of thick flat ice were randomly distributed in the rough ice between Barrow and Barter Island.

The condition of the landfast ice in the Chukchi Sea between Barrow and Point Lay in the two survey years was different in two respects. In June 1970 the fast ice did not extend very far from shore and approximately 30 to 40% of that which was present was very rough. In June 1975 the reverse was true. There was unusually extensive shore ice along the entire coast in some areas extending out more than 40 km from shore, and large areas of the ice were flat. The only regions where rough, pressured ice predominated were near points of land and along the seaward margin.

The distribution of ringed seals reflects the ice conditions which prevailed.

As noted above, in the Beaufort Sea during June 1970, ringed seals were rather evenly distributed throughout the fast ice (Figure 10). Large aggregations were encountered only along occasional cracks and infrequently along the seaward margin of the fast ice. In 1975, the distribution of seals was quite different in that there were restircted areas of flat ice in which large numbers of seals were present in aggregations and extensive areas dominated by rough ice in which very few if any seals were sighted (Figure 11).

The total area of fast ice in the Beaufort Sea was comparable in both years. Although statistical analyses of the 1975 surveys have not been completed, it appears there were significantly fewer ringed seals than in 1970.

In the Chukchi Sea during June 1970 there were few seals per square mile of track line, and the total area of landfast ice was comparatively small (Figure 12). In 1975 seal density was higher and the total area of favorable fast ice habitat was much greater. Ringed seals were rather evenly distributed near shore, but occurred in large aggregations along the seaward margin (Figure 13).

The LANDSAT imagery of the survey area arrived too late for any attempt to correlate the distribution and density of seals with specific features of the ice cover to be made for this report. If possible, this will be accomplished in the next quarter.

D. The 'Ice Remnant'

Previous study of the natural history of ribbon seals (Phoca (Histrigshoca) fasciata) indicated that they make use of an unusual feature of the late-spring sea ice cover in the Bering Sea. Ribbon seals remain in association with ice until it seasonally disappears from the Bering Sea in mid- to late-June. Some ribbon seals migrate north through Bering Strait, but most appear to remain in Bering Sea and to become pelagic when the ice disintegrates. In early June of 1968 a significant number of ribbon seals were observed in association with a band of sea ice which persisted in the eastern Bering Sea far to the south of the main body of receding pack ice.

Investigation of the limited information available concerning winds, currents and the build-up of sea ice over the winter and early spring months led to the suggestion that, 'the occurrence of a disjunct band or remnant of seasonal ice, far south of the normally receding ice edge, may be a normal annual occurrence....' (Burns, 1969). There was no opportunity to verify this until satellite imagery covering the appropriate areas during late May and June became available. Data were acquired in 1973 by the DAPP system, and in 1974 and 1975 by the NOAA weather satellite. These confirmed the existence of such remnants in each year. Data from Muench and Ahlnas (1976) shows the formation, movement, and disintegration of these during 1974. Figure 14, a composite of two images acquired by a NOAA satellite on May 22, 1974, gives a view of the ice conditions in Bering Sea after the formation of a large remnant. A more detailed view of this feature is shown in Figure 15, prepared from LANDSAT images acquired on June 1, 1974.

As noted, it is known that the ice remnants are utilized by ribbon seals, and they are probably of importance to other marine mammals, birds and plants as well. Further biological studies of these features are planned when ship time is available.

In addition, it is important to determine whether the remnants follow any predictable, repetitive drift pattern if the possible impact of offshore development on them is to be estimated. At present, therefore, an attempt is being made to calculate the average geostrophic wind fieled in this area using weather data acquired over several years. Muench and Ahlnas (1976) have indicated that most of the ice movement which they observed in the Bering Sea can be accounted for in this manner. The results will, however, be evaluated in light of available oceanographic information. Finally, satellite data will be used to track the movements of the ice remnants. These data sources should be adequate to answer the question posed above.

REFERENCES CITED

Burns, J. J., 1965, The walrus in Alaska, Alaska Dept. Fish & Game, Juneau, 48 pp.

Burns, J. J., 1967, The Pacific bearded seal, Alaska Dept. Fish & Game, Juneau, 66 pp.

Burns, J. J., 1969, Marine mammal investigations, Alaska Dept. Fish & Game, Juneau, 25 pp.

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., 1971, Biology of the ribbon seal, *Phoca* (*Histriophoca*) *fasciata*, in the Bering Sea (Abstract), Proc. 22nd Alaska Sci. Conf., p. 135.

Burns, J. J., G. C. Ray, F. H. Fay and P. D. Shaughnessy, 1972, Adoption of a strange pup by the ice-inhabiting harbor seal, *Phoca vitulina largha*, J. Mammal, 53:594-598.

Crowder, W. K., H. L. McKim, S. F. Ackley, W. D. Hibler III, and D. M. Anderson, 1974, Mesoscale deformation of sea ice from satellite imagery, Proc. Interdisciplinary Symposium on Advanced Concepts and Techniques in the Study of Snow and Ice Resources, Monterey, Calif., December 1973.

Fay, F. H., 1974, The role of ice in the ecology of marine mammals of the Bering Sea, in Oceanography of the Bering Sea, D. W. Hood and E. J. Kelly, eds., Inst. Mar. Sci., Univ. Alaska, Fairbanks, p. 393-399.

Gol'tsev, V. N., 1968, Dynamics of coastal walrus rookeries in connection with distribution and numbers of walruses, Izv. TINRO 62:205-215.

Hibler, W. D. III, S. F. Ackley, W. K. Crowder, H. L. McKim and D. M. Anderson, 1974, Analysis of shear zone deformation in the Beaufort Sea using satellite imagery, in The Coast and Shelf of the Beaufort Sea, ed. J. C. Reed and J. E. Sater, Arctic Inst. of North America, 285-296.

Kleinenberg, S. E., A. V. Yablokok, V. M. Bel'kovich and M. N. Tarasevich, 1964, Belukha (Delphinapterus leucas): A monographic investigation of the species, Akad. Nauk SSSR, Inst. Morfol. Zhivotnikh, Moscow, 456 pp (Israel Prog. Sci. Transl. 1969).

McKay, R. A., 1969, Sea ice activity and pressure ridge growth in the vicinity of surcharged grounded ice islands Unak 1 and Unak 2, ms. Rept. Inst. Arctic Environ. Engin., Univ. of Alaska, Fairbanks, 78 pp.

McLaren, I. A., 1958, The biology of the ringed seal (Phoca hispida Schreber) in the eastern Canadian Arctic; Fish. Research Bd. Can., Ottawa, Bull. 118:97 pp.

Muench, R. D. and K. Ahlnas, 1976, Ice movement and distribution in the Bering Sea, March-June 1974, J. Geophys. Res. (in press).

Shapiro, L. H. and J. J. Burns, 1975a, Major late-winter features of ice in northern Bering and Chukchi seas as determined from satellite imagery, Univ. of Alaska, Fairbanks, Sea Grant Report No. 75-8.

Shapiro, L. H. and J. J. Burns, 1975b, Satellite observations of sea ice movement in the Bering Strait region, in Climate of the Arctic, edited by G. Weller and S. A. Bowling, Univ. of Alaska, Fairbanks, pp. 379-386.

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.

Stehle, N. S., 1965, Ice engineering, growth rate of sea ice in a closed system: Tech. Rept. R396, U. S. Naval Civil Eng. Lab., Port Hueneme, Calif., 21 pp.

Stirling, I., R. Archibald and D. DeMaster, 1975, The distribution and abundance of seals in the eastern Beaufort Sea, Beaufort Sea Tech. Rept. #1, Victoria, Canada, 58 pp.

Tikhomirov, E. A., 1961, Distribution and migration of seals in waters of the Far East, in Transactions of the Conference on Ecology and Hunting of Marine Mammals, E. H. Pavlovskii and S. K. Kleinenberg, eds., Akad. Nauk SSSR, Ikhtiol. Comm., Moscow, p. 199-210.

Tikhomorov, E. A., 1964, Distribution and biology of pinnipeds in the Bering Sea, Izv. TINRO, 52:272-280.

VII, VIII. DISCUSSION AND CONCLUSIONS

The results given above are merely descriptions of work in progress. The field work which will provide most of the ground truth for the project has just begun, and until these results are analyzed, even preliminary conclusions will not be available. An exception to this is the discussion of the correlation between certain mammal species and ice conditions in the Bering and Chukchi seas during March and April.

Finally, other work is in progress which has not been reported on. This includes collection and organization data from previous surveys and incidental sightings of species under study, and preparation of maps of ice conditions from satellite data.

IX. NEEDS FOR FURTHER STUDY

To date, we have examined only a small portion of the available imagery and analyzed short-term changes in ice cover for a few selected areas. Results of these analyses have been correlated with information about mammal distribution. The major tasks are yet to be accomplished. These include analysis of seasonal changes in sea ice, detailed studies of each of the major sea ice habitats as indicated by LANDSAT imagery from several successive years, and correlation with a rapidly increasing body of information concerning the marine mammals.

Specific aspects which should be examined include study of the formation, extent, persistence and disintegration of the ice front, persistent polynya, major shear zones and landfast ice over several years. Changes in the 'quality' of these habitats must be correlated with annual differences in their use by marine mammals, such as is being done at present for ringed seals.

Correlations of quality of ice habitats with distribution and movements of marine mammals are extremely important. Why are polar bears only sporadically abundant in northern Bering Sea? It is known that the winter of 1975-76 was a heavy ice year in northern Bering Sea and that polar bears were unusually abundant as far south as St. Lawrence Island. In most years, they occur in low numbers near this island. What ice conditions account for these annual differences? It also appears that particular year classes of some species of seals are poorly represented in the samples acquired for other studies. This is the result of unusually low survival of pups. How is this related to quality of the specific ice habitat utilized by the seals during a year when survival of pups is poor? Conversely, what conditions prevail during years of average or good survival?

In view of the rudimentary stages of sea ice habitat studies in the Bering, Chukchi and Beaufort seas, work presently in progress should be continued until such time as a reasonable understanding of the major habitat associations and dynamics of the seasonal ice cover is achieved.

X. SUMMARY OF 4TH QUARTER ACTIVITIES

As indicated previously, ground truth verification of sea ice conditions, distribution and seasonal activity patterns of marine mammals and mammal-ice associations are obtained from many different sources.

Field programs planned for the fourth quarter (April-June) which will provide data for this project are as follows:

(1) The cruise of the Soviet research vessel Zagoriani in the central Bering Sea. F. H. Fay, a co-principal investigator, will be aboard this vessel from 15 March to 30 April. Information will be obtained on the distribution and density of walrus and ribbon seals as well as the ice conditions in areas where they occur.

(2) The American research vessel Surveyor will be operating in eastern Bering Sea during March and April. The Surveyor will be working in the ice front and will be engaged in surface surveys of all marine mammals, but primarily spotted seals. Personnel will include Lloyd F. Lowry, Kathryn Frost and Edward S. Muktvyuk (see annual report for project number 231).

(3) Extensive aerial surveys will be conducted in the ice front during April. These surveys will be undertaken to assess the distribution, density and total number of spotted seals in the front. The surveys will also produce information about the distribution of other species including whales, ribbon seals, bearded seals, walruses and sea lions. Personnel involved in the aerial surveys will include John J. Burns, Samuel J. Harbo Jr., and Lewis H. Shapiro. Flights are being planned to coincide with the timing of LANDSAT-2 passes over the survey areas.

(4) Intensive studies of ringed seals and polar bears will be conducted during March and April on the ice of the Chukchi

Sea. A helicopter and fixed wing support aircraft will be operating out of Cape Lisburne. This effort will provide ground truth information concerning characteristics and changes in the extensive shear zone which occurs along the northwest coast. Information will also be obtained on the distribution and density of bears and seals as well as migration of bowhead and belukha whales. Mr. Thomas J. Eley (Project RU 230) will be in charge of this effort.

(5) In May a collection of ringed seals will be obtained from the Beaufort Sea north of Colville River. Seals will be collected from leads at the edge of the shore fast ice. This effort will provide ground truth information about characteristics of the fast ice, leads and adjacent drifting ice during the May passes of LANDSAT-2. This field work will be conducted by John J. Burns and other investigators as yet not designated.

Each of these programs involves personnel who are either involved with this project (RU 248/249) or who have agreed to record information in a manner which is directly usable to this project.

Finally, the studies of ice classification discussed above will be continued.

FIGURE CAPTIONS

Figure 1. Distribution of reproductive adults of the pagophilic pinnipeds in the northern Bering and Chukchi seas during March and early April (from Burns, 1970).

Figure 2. "Average" ice conditions in the northern Bering and Chukchi seas during March and April, 1973 and 1974 (from Shapiro and Burns, 1975a).

Figure 3. Shear zone off Cape Lisburne, March 8, 1973. Photo from LANDSAT image E-1228-22270. Scale 1:1,000,000.

Figure 4. Area just north of Bering Strait, with Chukchi Peninsula in lower left. Photo from LANDSAT image E-1623-22160, April 7, 1974. Scale 1:1,000,000.

Figure 5. Convergence zone north of St. Lawrence Island, March 6, 1973. Photo from a mosaic of LANDSAT images E-1226-22165, 22171, 22174. Scale 1:1,000,000.

Figure 6. Marginal zone of pack ice in the Bering Sea, March 23, 1973. Photo from a mosaic of LANDSAT images E-1243-22134, 22131. Scale 1:1,000,000.

Figure 7. LANDSAT image E-1228-22273-7 with sample areas indicated.

Figure 8. Flight lines of ringed seal survey, June 1970.

Figure 9. Flight lines of ringed seal survey, June 1975.

Figure 10. Ringed seals sighted on best survey day east of Pt. Barrow, June 1970.

Figure 11. Ringed seals sighted on best survey day east of Pt. Barrow, June 1975.

Figure 12. Ringed seals sighted on best survey day southwest of Pt. Barrow, June 1970.

Figure 13. Ringed seals sighted on best survey day southwest of Pt. Barrow, June 1975.

Figure 14. Pack ice "remnant" southwest of St. Lawrence Island. Photo from NOAA 2/3 satellite image acquired May 22 1974.

Figure 15. Pack ice "remnant" southwest of St. Lawrence Island, June 1, 1975. Photo from a mosaic of LANDSAT images E-1678-22220, 22213, 22211. Scale 1:1,000,000.

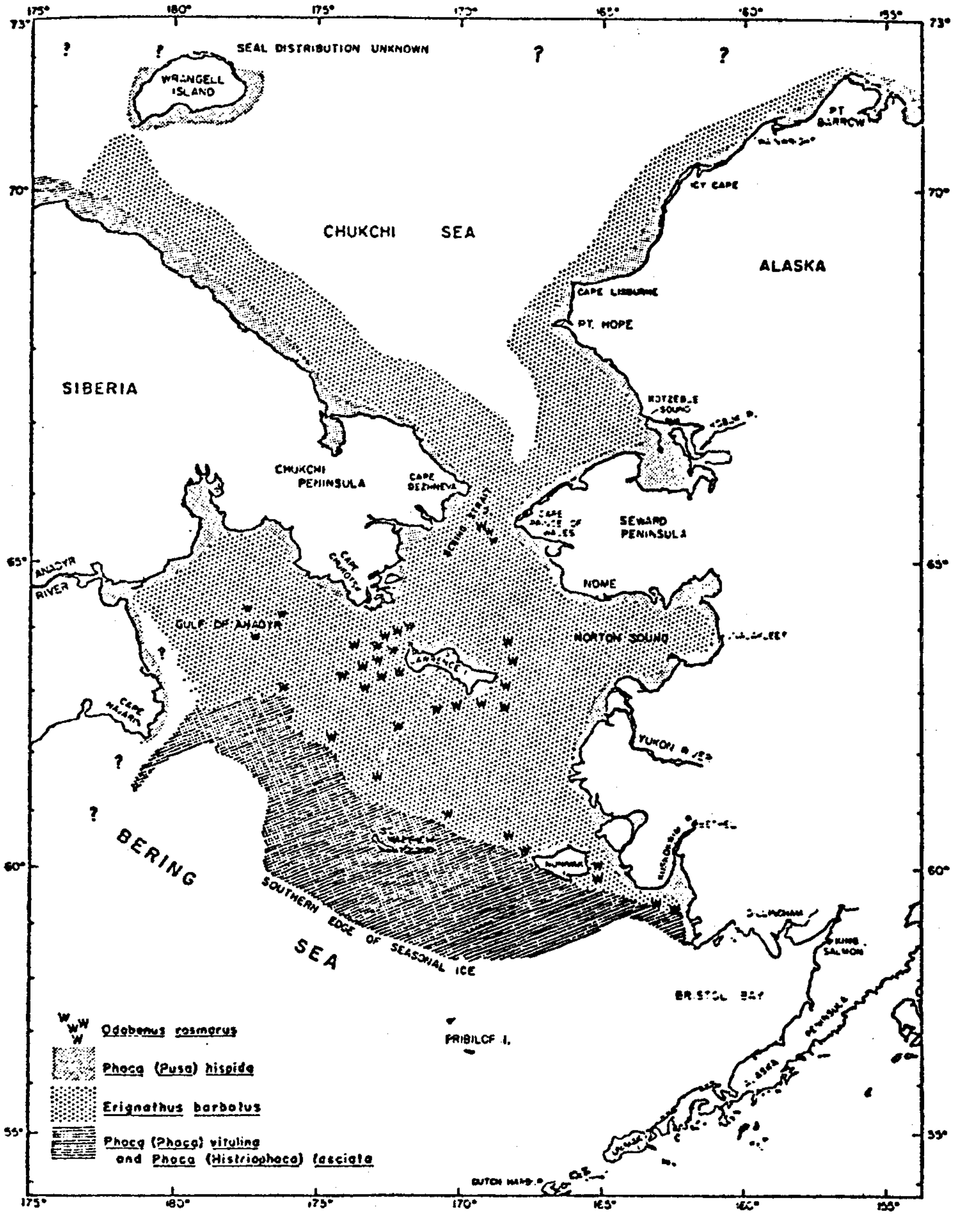
SEAL DISTRIBUTION UNKNOWN
WRANGELL ISLAND
CHUKCHI SEA
ALASKA
SIBERIA
CAPE LISBURNE
PT. HOPE
CHUKCHI PENINSULA
SEWARD PENINSULA
NOME
NORTON SOUND
GULF OF ANADYR
YUKON RIVER
BERING SEA
SOUTHERN EDGE OF SEASONAL ICE
BRISTOL BAY
PRIBILOF I.
Odobenus rosmarus
Phoca (Pusa) hispida
Erignathus barbatus
Phoca (Phoca) vitulina
and Phoca (Histriophoca) fasciata

Figure 1

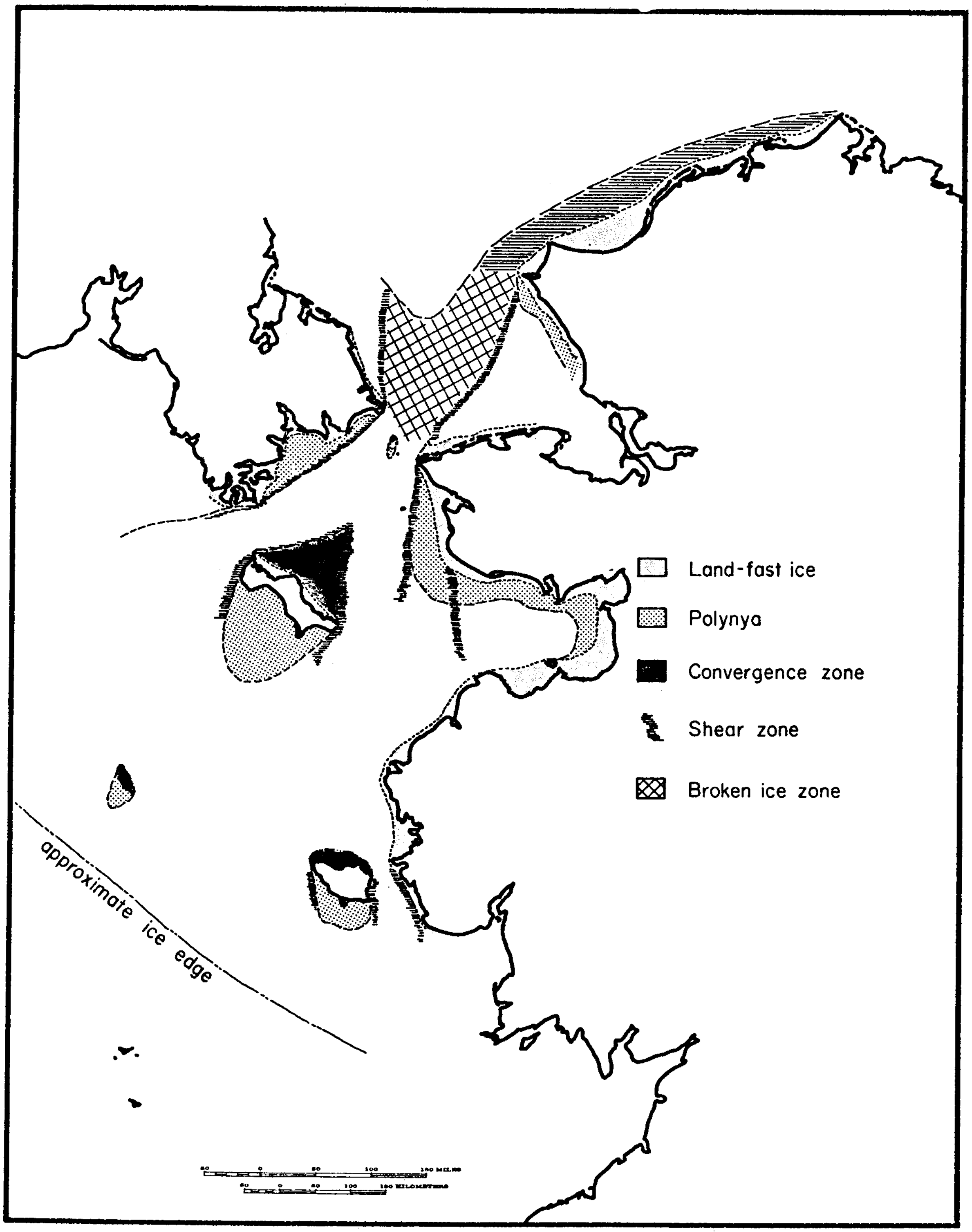
Land-fast ice
Polynya
Convergence zone
Shear zone
Broken ice zone
approximate ice edge

Figure 2

Figure 3

Figure 4

Figure 5

Figure 6

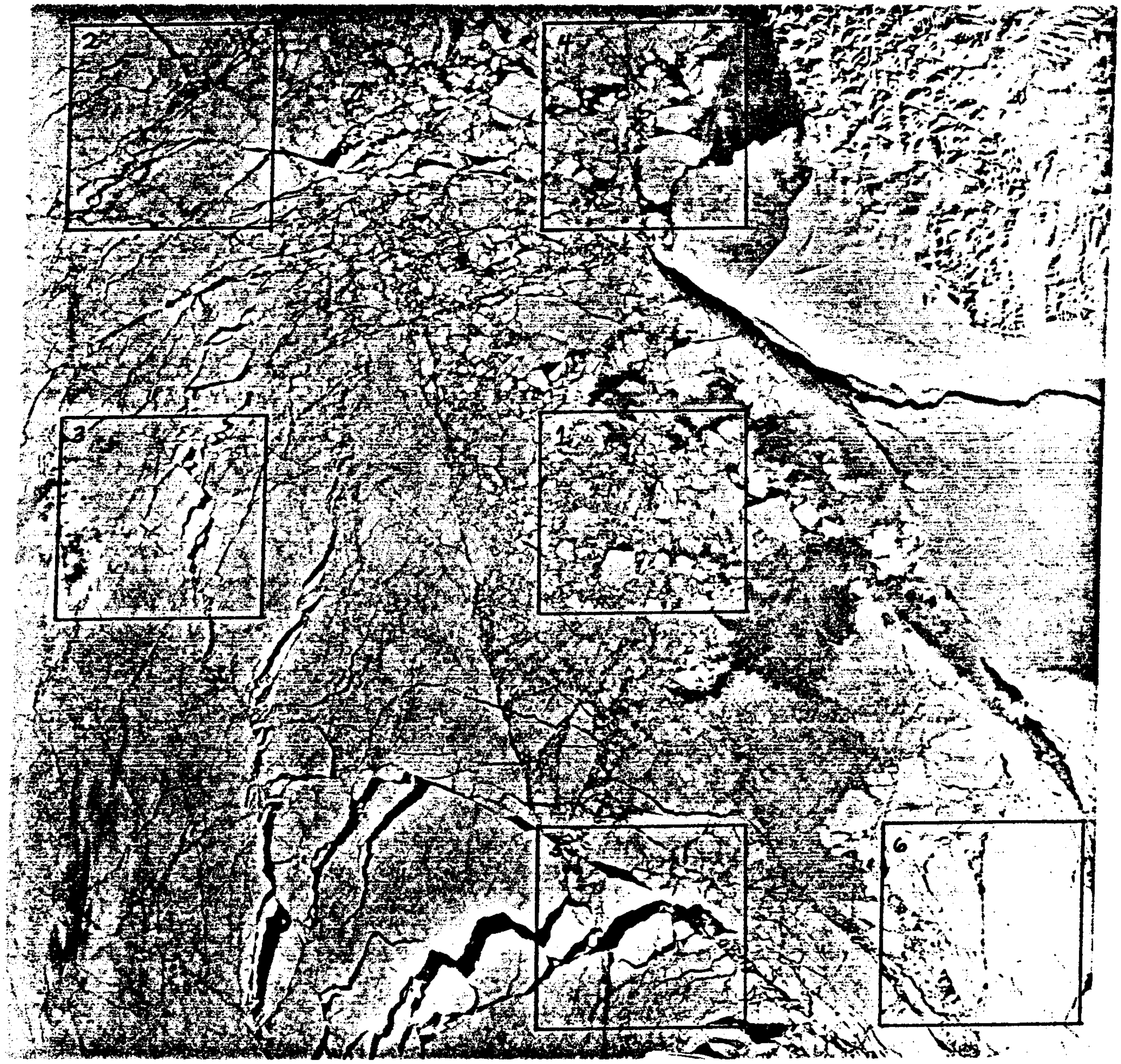

Figure 7

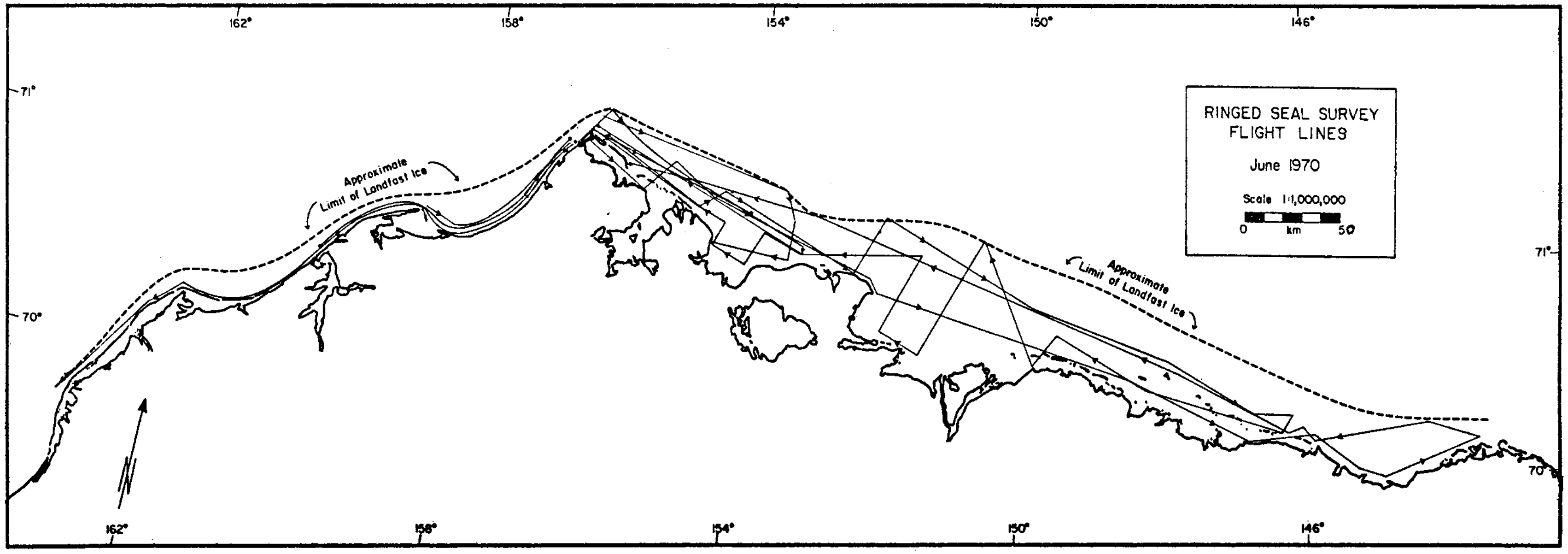
RINGED SEAL SURVEY
FLIGHT LINES
June 1970
Scale 1:1,000,000
0 km 50
Approximate
Limit of Landfast Ice
Approximate
Limit of Landfast Ice
162°
158°
154°
150°
146°
71°
70°
N

Figure 8

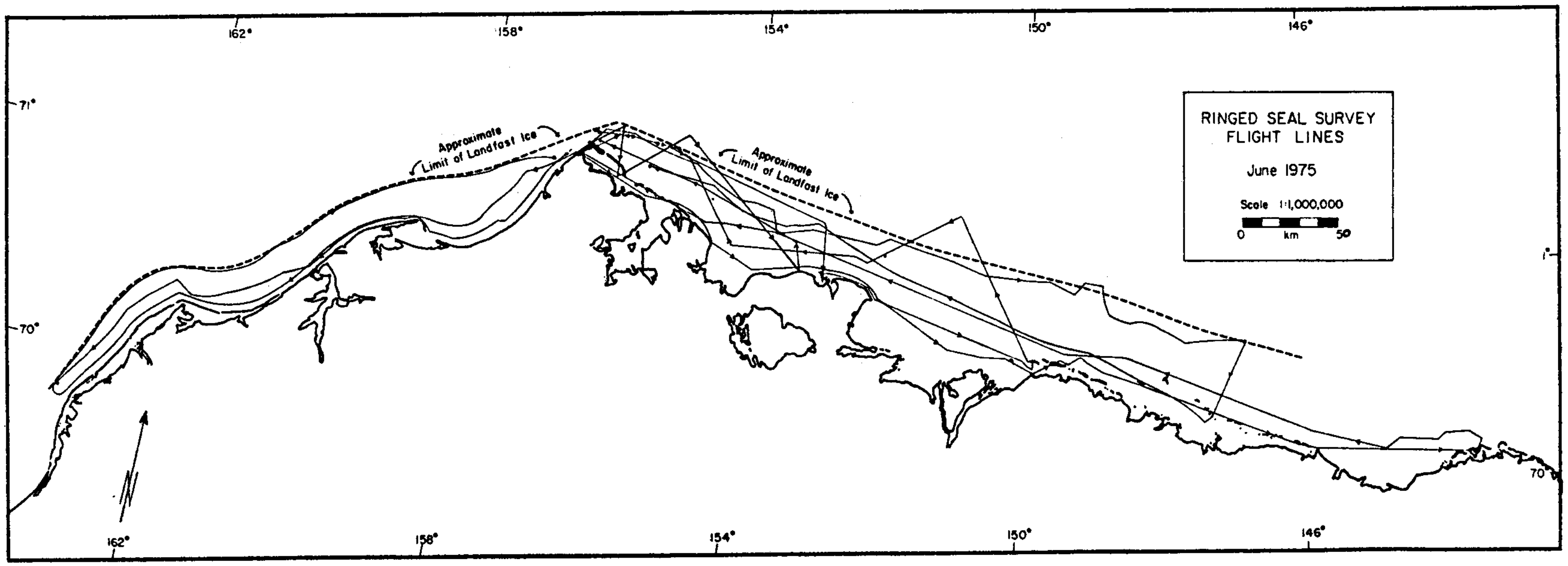
RINGED SEAL SURVEY
FLIGHT LINES
June 1975
Scale 1:1,000,000
0 km 50
Approximate Limit of Landfast Ice
Approximate Limit of Landfast Ice
162°
158°
154°
150°
146°
71°
70°

Figure 9

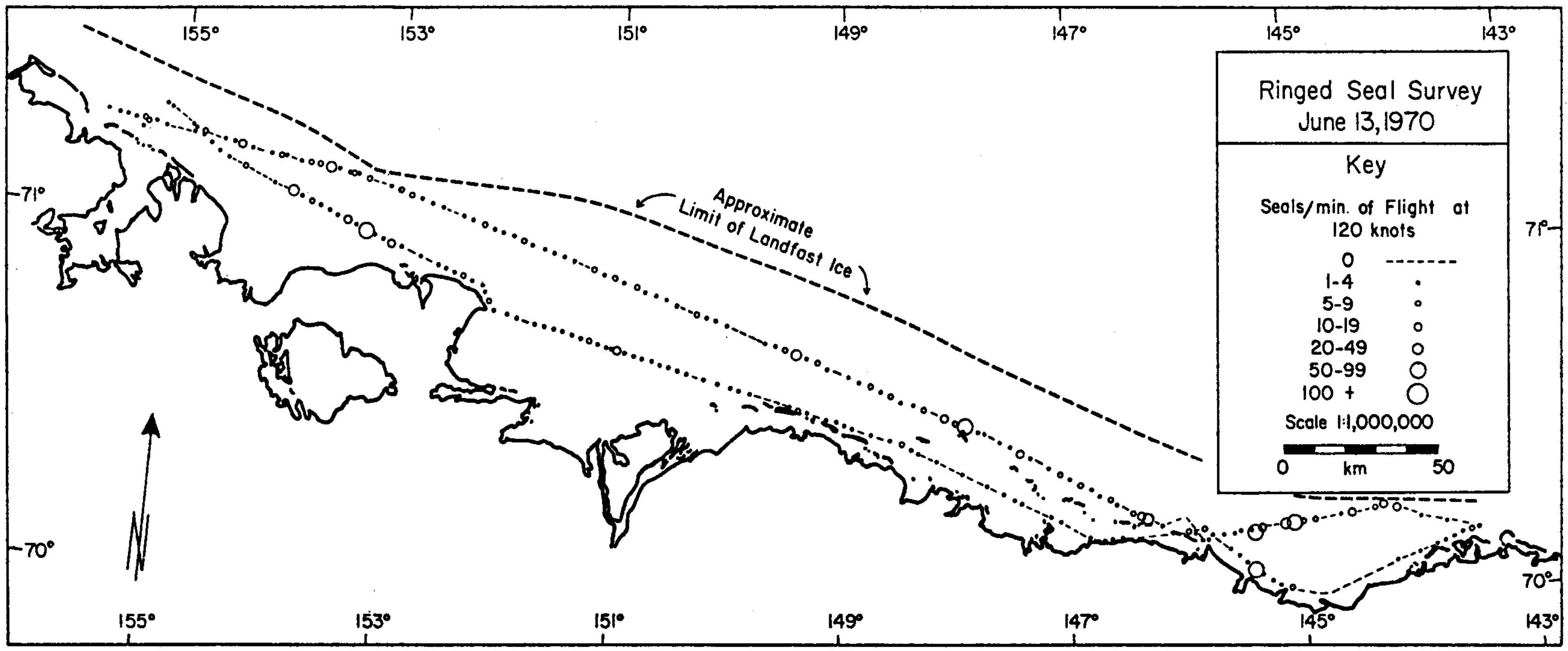
Ringed Seal Survey
June 13, 1970
Key
Seals/min. of Flight at 120 knots
0
1-4
5-9
10-19
20-49
50-99
100 +
Scale 1:1,000,000
0 km 50
Approximate Limit of Landfast Ice
N
155°
153°
151°
149°
147°
145°
143°
71°
70°

Figure 10

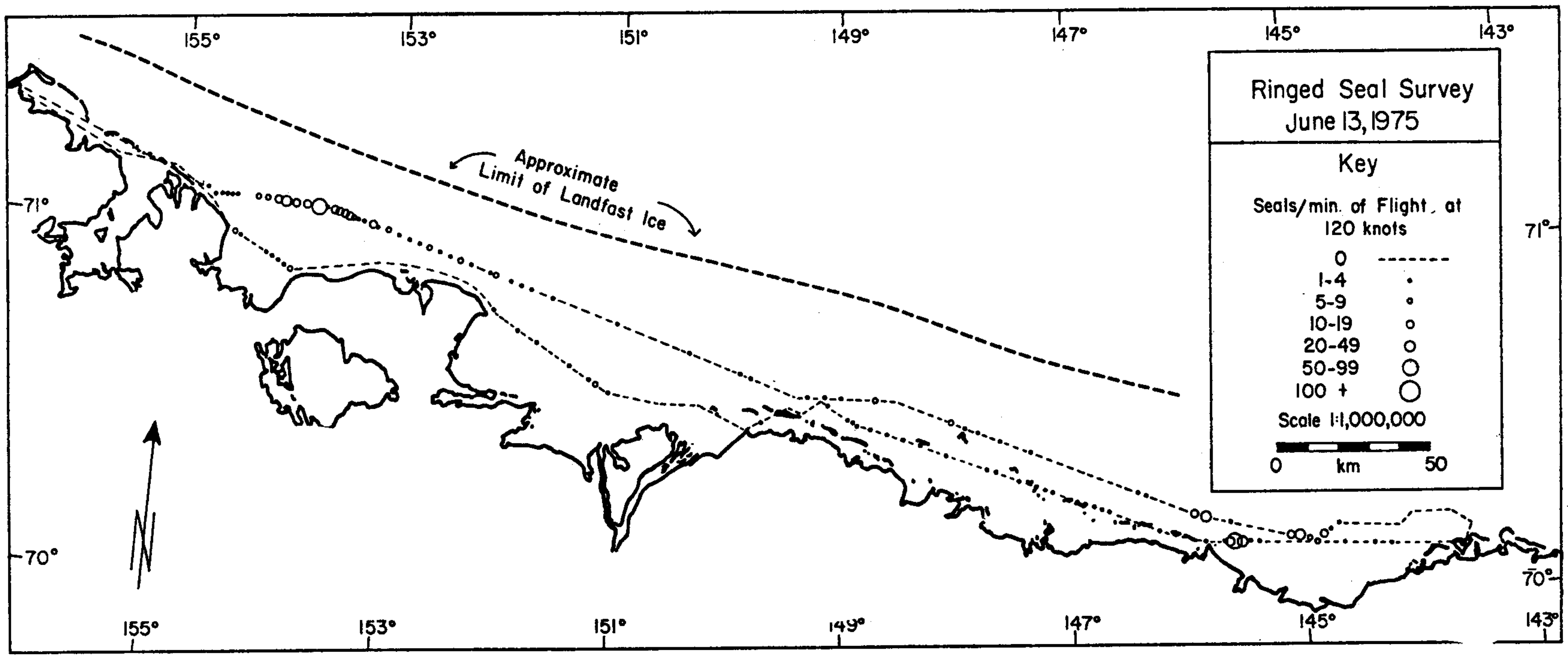
155°
153°
151°
149°
147°
145°
143°
71°
70°
Approximate
Limit of Landfast Ice
Ringed Seal Survey
June 13, 1975
Key
Seals/min. of Flight, at
120 knots
0
1-4
5-9
10-19
20-49
50-99
100 +
Scale 1:1,000,000
0
km
50

Figure 11

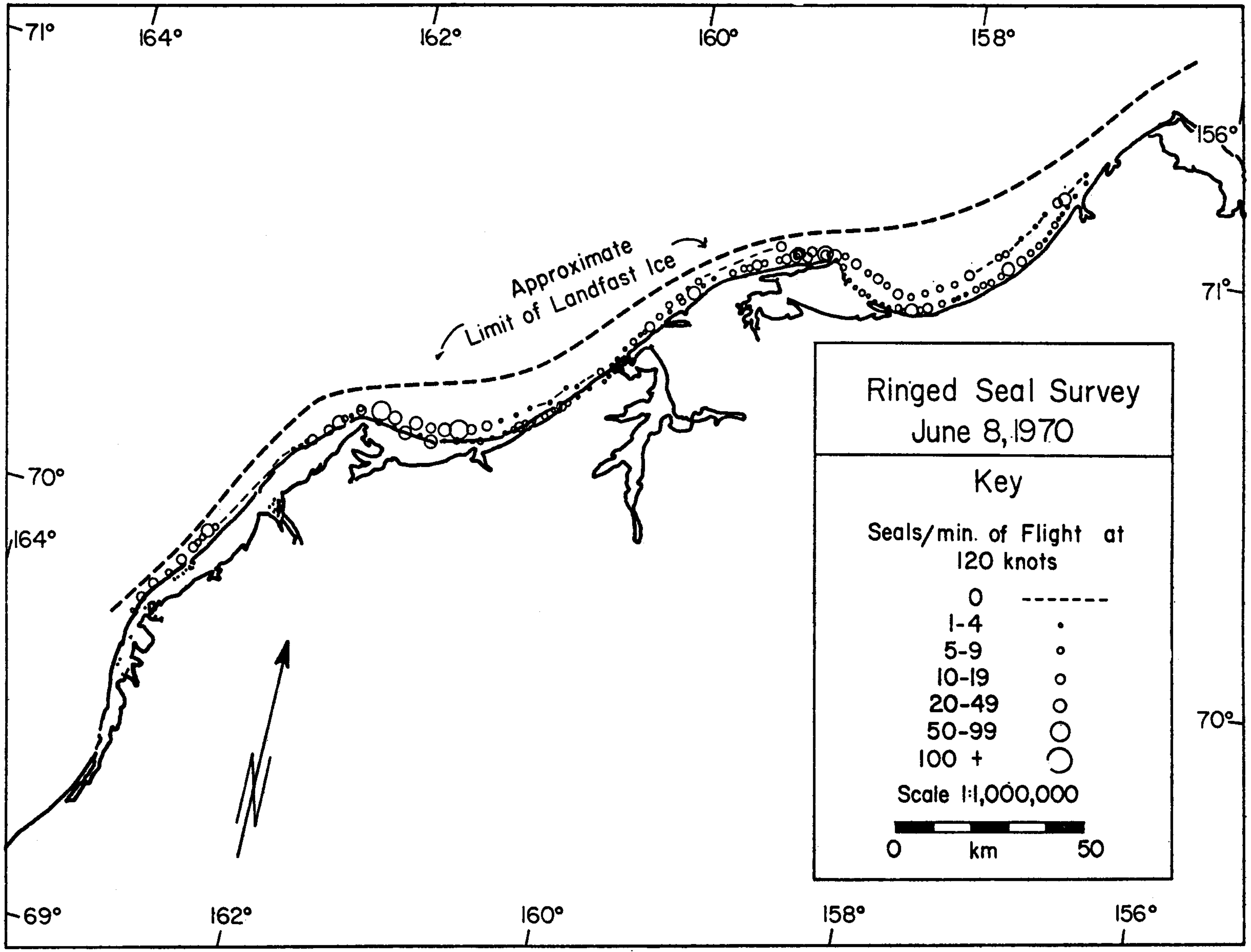
71°
164°
162°
160°
158°
156°
70°
69°
Approximate
Limit of Landfast Ice
Ringed Seal Survey
June 8, 1970
Key
Seals/min. of Flight at
120 knots
0
1-4
5-9
10-19
20-49
50-99
100 +
Scale 1:1,000,000
0
km
50

Figure 12

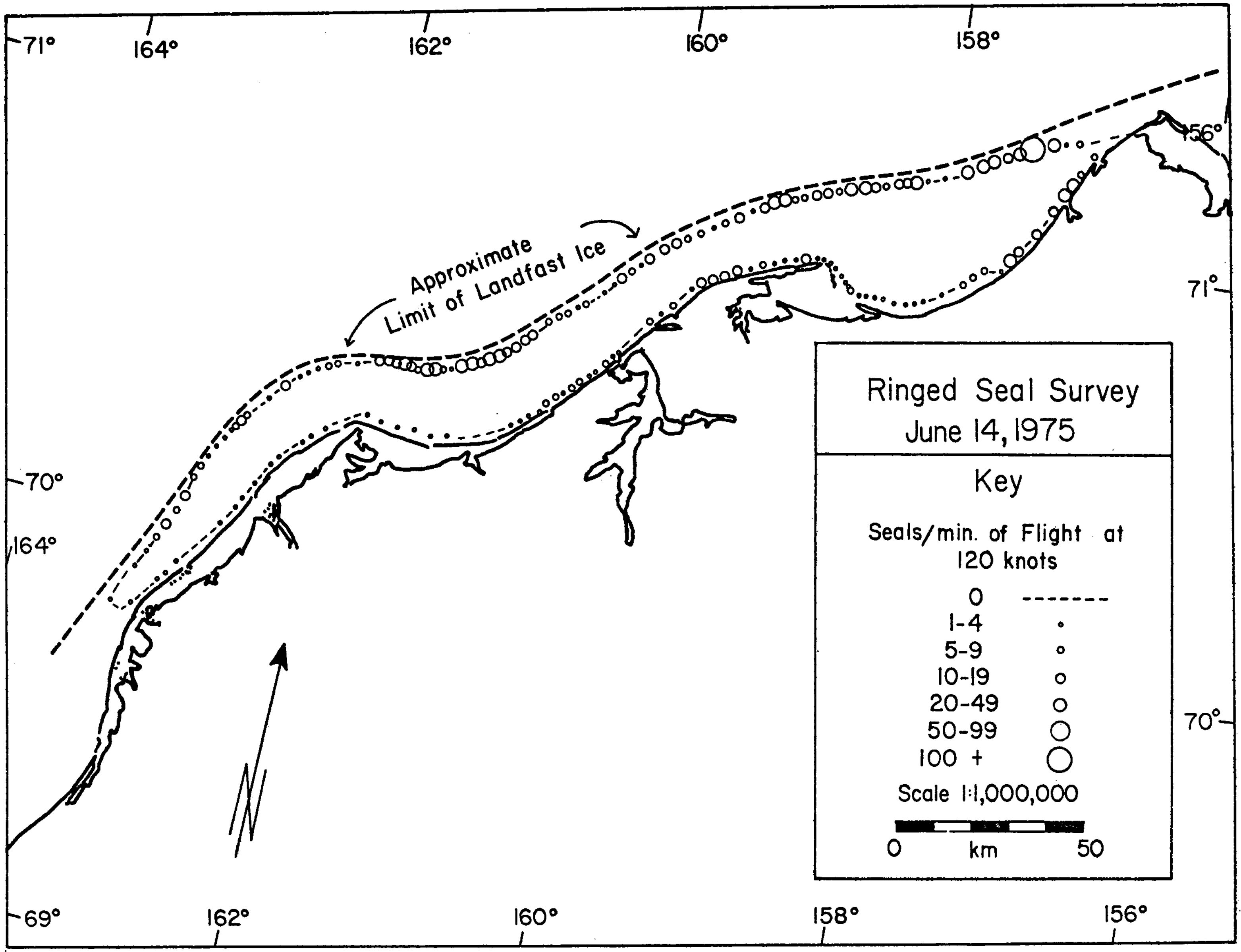
71°
164°
162°
160°
158°
156°
71°
70°
164°
70°
69°
162°
160°
158°
156°
Approximate
Limit of Landfast Ice
Ringed Seal Survey
June 14, 1975
Key
Seals/min. of Flight at
120 knots
0
1-4
5-9
10-19
20-49
50-99
100 +
Scale 1:1,000,000
0
km
50

Figure 13

Figure 14

Figure 15

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