THE 1979 WHALE MONITORING PROGRAM MACKENZIE ESTUARY

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SUMMARY

Large numbers of white whales *(Delphinapterus leucas)* migrate to the Mackenzie River estuary each summer. While the whales are there, they are hunted by Inuit from Aklavik, Inuvik, and Tuktoyaktuk. The whale hunt and resulting whale products play a very important role in the local culture and economy. From the outset of offshore oil and gas exploration in the Mackenzie estuary region, concern has been expressed about possible major adverse effects on the whales or whale hunting. In recognition of this concern, Esso Resources Canada Limited (formerly Imperial Oil Limited) has supported studies of white whales for the past eight years. The major focus of the studies has been to detect potential disturbance to whales and Inuit whale hunting by exploration activities and to communicate any concerns to Esso for immediate mitigative action. Since 1976, as operations have moved farther offshore, bowhead whales *(Balaena mysticetus)* have been included in the studies.

The first whales arrived in West Mackenzie Bay by 20 June, at least six days earlier than they had been recorded in the estuary during the preceding seven years. However, the landfast ice barrier did not break-up until 1 July in Kugmallit Bay, and the first whales were not observed there until 2 July.

Because the whales had access to West Mackenzie and Niakunak Bays at least 10 days earlier than to Kugmallit Bay, more than 90% of the whales gathered in the former areas. The minimum number of whales estimated to be present in Niakunak and West Mackenzie Bays was 6683 on 30 June. Because not all whales had arrived by this date, we believe that at least 7000 whales used the estuary in 1979. The maximum number estimated in Kugmallit Bay was less than 500.

The total 1979 harvest of white whales was 120, which is low compared with the mean of 138 for the previous seven years. However, this number is within the range observed from 1972 to 1978.

Island construction, exploratory drilling, and related activities had no detectable effect on whale distribution, movement, or pattern of use of the estuary. Minor interference with whale hunting may have resulted from occasional barge traffic in the Garry Island area and from aircraft use of the landing strip on Garry Island. Possible further disturbance from aircraft was eliminated by suspending the use of the Garry Island spit until hunting ceased.

An analysis of whale sightings contained in logbooks of 10 commercial whaling cruises from 1891 – 1906 indicates that the summer range of the bowhead includes the southeastern Beaufort Sea east from approximately the Canada-USA boundary seaward to the 50 m isobath and possibly Amundsen Gulf. Sightings recorded during Esso studies in 1976–1978 suggest that a similar pattern of bowhead distribution and movement still obtains. However, only two observations of a total of seven bowheads were reported in 1979; this is a much smaller number than was seen in 1976–1978. The reason for the fewer sightings is unknown.

PART 1

THE 1979 WHALE MONITORING PROGRAM, MACKENZIE ESTUARY

1.1 INTRODUCTION

Large numbers of white whales *(Delphinapterus leucas)* migrate to the estuary of the Mackenzie River each summer. The period spent in the warm water of the estuary probably is of major importance to the whales, perhaps to newborn calves in particular, but the reasons for this are not yet clear. Inuit from Aklavik, Inuvik, and Tuktoyaktuk hunt the whales in the estuary. This activity and the resulting whale products are important to the local culture and economy. From the outset of offshore oil and gas exploration, concern has been expressed about possible adverse effects to white whales and whale hunting. In recognition of this concern, Esso Resources Canada Limited (formerly Imperial Oil Limited) has supported studies of white whales since 1972.

Bowhead whales *(Balaena mysticetus)* also occur in the eastern Beaufort Sea. Since 1976, as Esso operations have moved farther offshore, bowheads have been included in the studies.

This report presents and discusses the findings of the 1979 whale monitoring program. For a more general and comprehensive treatment of the biology of whales in the Beaufort Sea and the details of earlier studies, the reader is referred to *The 1977 Whale Monitoring Program, Mackenzie Estuary, N.W.T.* (Fraker 1977b) and to Beaufort Sea Project Technical Report No. 4, *Bowhead and White Whales in the Southern Beaufort Sea* (Fraker et al. 1978), both of which present relatively complete reviews of knowledge of both bowhead and white whales in the study region. In addition, reprinted in Part 4 of this report is a recent journal paper on the summer range of the bowhead whale, based on an analysis of sightings made from whaling ships that operated in the Beaufort Sea from 1891 to 1906 and a comparison with data collected from 1976 to 1978.

The study area lies immediately offshore of the outflow channels of the Mackenzie River (Figure 1). Adjacent terrestrial areas are mainly of deltaic or glacial origin. The warm, fresh, turbid discharge water from the Mackenzie River strongly influences the character of the estuary. Because of the Mackenzie discharge, water throughout all but the most seaward areas is fresh in summer. The basic pattern of currents is determined by the river outflow which joins the northeastward coastal flow resulting from the Coriolis force. This generally northeastward movement is sometimes temporarily modified by winds. Further offshore in the Beaufort Sea gyre, there is a wind-generated, clockwise circulation.

Esso's summer offshore exploration activities in the Mackenzie Estuary region centre around the construction and operation of artificial islands that are used as platforms for exploration drilling. Construction of artificial islands requires the use of dredges for excavating granular fill for the islands together with tugs, barges, and boats for transporting personnel, equipment, and materials. When the excavation site is distant from the island location, barges are required to transport the fill material; where the excavation site is adjacent to the island location, fill is pumped directly from the dredge. In some cases, the material comes from both near the site and from a distance. Construction of the first artificial island, Immerk, began in summer 1972 and was finished the next year. Since Immerk, 14 other artificial islands have been constructed by Esso (Figure 1).

Offshore activities in summer 1979 centred on two operations: finishing exploratory drilling on Adgo J-27, an artificial island southwest of Garry Island, and completing the construction of Issungnak O–61, 26 km north of Pullen Island (Figure 1).

Although drilling operations at Adgo J-27 ended on 12 July, the drilling rig was not moved off the island until 10 August. During the open-water period, various materials had to be taken to and from the island. This was done using a shallow-draught jet barge, helicopters (Bell 206 and 212), and a Twin Otter fixed-wing aircraft (Figure 1). Usually, the helicopter operated between the rig and the airstrip on northwestern Garry Island, while the Twin Otter carried materials between Garry Island and other places.

Under some circumstances, the helicopter transferred loads between the rig and Tununuk Point. The jet barge carried loads between the rig and Tununuk Point or Tuktoyaktuk. When travelling to Tununuk Point throughout the summer or to Tuktoyaktuk early in the open-water season, the barge followed the channel past Kendall Island. After the ice left the area seaward of the Barrier Islands, the barge used an offshore route to travel to Tuktoyaktuk.

Construction of Issungnak 0–61 involved on-site dredging plus the hauling of additional material from Tuft Point. Most of the material for building the island was excavated adjacent to the site by the suction dredge *Beaver Mackenzie.* Material for the working surface of the island was sand hauled from Tuft Point, where it was excavated by the cutter dredge *Arctic Northern.* Operations at Tuft Point commenced on 14 July, and the *Beaver Mackenzie* moved onto location at Issungnak on 22 July.

Personnel involved in the Issungnak operations were housed nearby in a camp on the barge *Arctic Breaker* (Figure 1). Boats transported supplies, and aircraft carried both men and materials. Typically, a Twin Otter was used for air transport to Tuft Point and Pullen Island. A Bell 212 helicopter operated between Pullen and Issungnak.

1.2 PURPOSE

The main purposes of the 1979 whale monitoring program were to:

1. document the distribution and abundance of white whales in the Mackenzie estuary and the success of Inuit hunters in relation to Esso exploration activities, and

2. provide on-location advice to Esso supervisors regarding the concentrations and movements of white whales in relation to the timing and location of operations in order to minimize potential adverse effects on whales or whale hunting.

1.3 OBJECTIVES

The primary objectives of the 1979 study were to:

1. monitor white whale movements and concentrations in the Mackenzie estuary,

2. reduce potential adverse interactions between white whales and Esso offshore island-building activities by providing on-location advice,

3. monitor Esso activities near Garry Island in relation to white whales and whale hunting as requested in Land-Use Permit N76J360,

4. ascertain the Inuit harvest of white whales, and

5. prevent potential interference with the hunt that might result from Esso activities.

Secondary objectives were to:

1. obtain additional information on the patterns and timing of white whale arrival and departure,

2. expand the existing data base on white whales in the Mackenzie estuary through the continued estimation of whale numbers and observation of distribution and movements,

3. compare whale behaviour with respect to numbers of whales present and movement patterns in order to gain a more complete picture of whale usage of the area,

4. study the effects of Inuit hunting on the distribution and behaviour of white whales,

5. gain additional insights into the biology of the whales in the estuary through the collection of samples and measurements from animals harvested by hunters,

6. document and describe encounters between industrial traffic and whales to gain a better understanding of the behavioural reactions of white whales to this type of disturbance,

7. observe the distribution and abundance of white whales in offshore waters north of the Mackenzie estuary study area, and

8. document the occurrence and movements of bowhead whales in the Mackenzie estuary region.

1.4 SCOPE OF WORK

The 1979 field program began on 20 June and continued to 12 August. The investigation

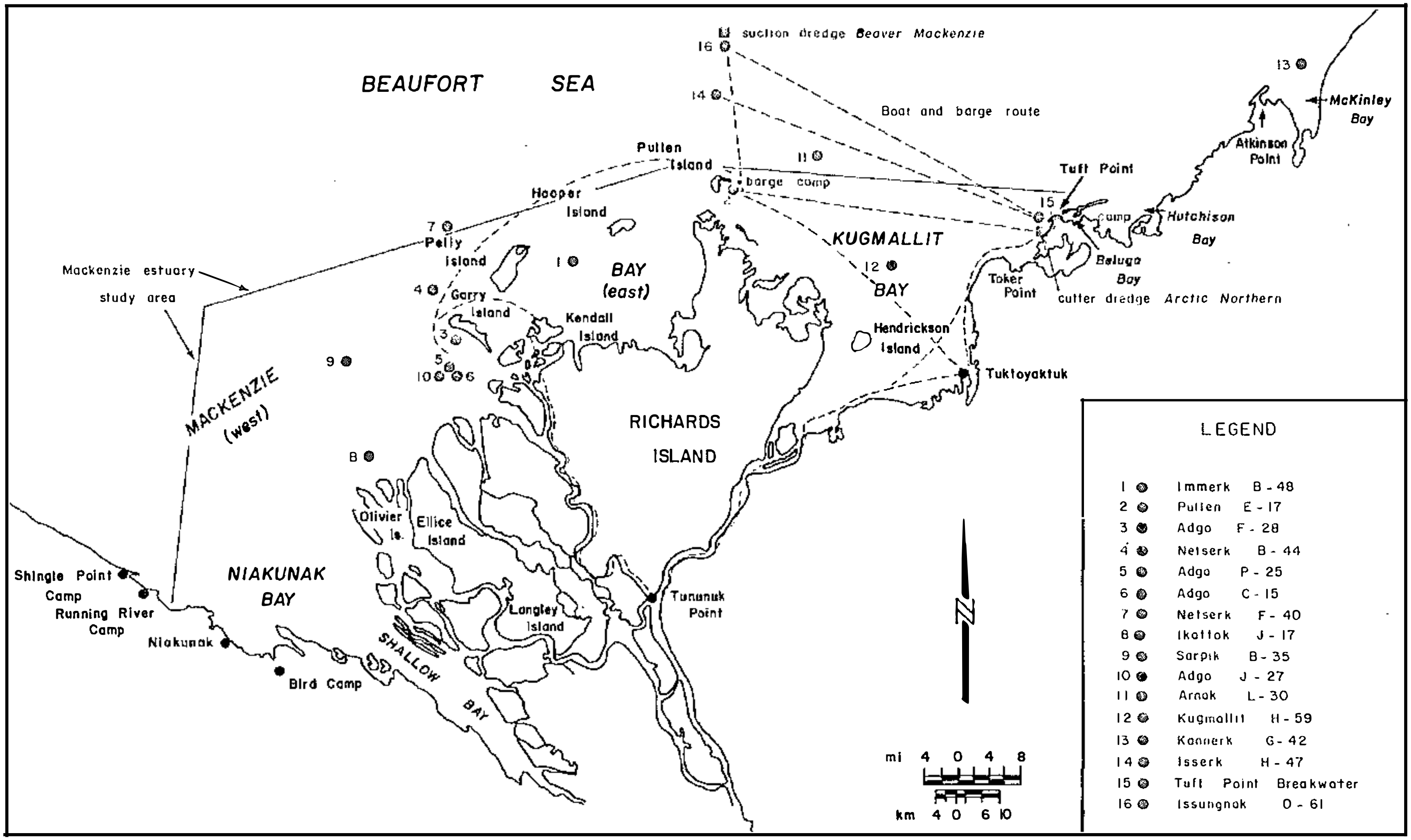

Figure 1. Location of Esso activities in the Mackenzie estuary region, summer 1979.

focused on the two main areas of activity by Esso: the Garry Island region and Kugmallit Bay (Figure 1). The movement of whales in relation to Esso activities was also monitored in the Tuft Point/Tuktoyaktuk Peninsula region. The whales in Niakunak Bay were studied to determine their distribution and abundance and their response to Inuit hunting. Bowhead and white whales were studied in waters north of the Mackenzie estuary study area during three offshore surveys and from sightings made by industry personnel.

The Mackenzie estuary has been operationally defined, for the purpose of whale studies (Fraker 1976, 1977a, b, 1978; Fraker et al. 1978, 1979), as the area extending from the mouths of the outflow channels of the Mackenzie River to the outer perimeter of the area included in regular, systematic surveys (Figure 1). This does not coincide exactly with the area that would be defined biologically or oceanographically as an estuary, and it is used here as a convenient geographical term.

To facilitate the discussion of the whale data, the Mackenzie estuary has been subdivided into six areas:

1. Shallow Bay – the seaward boundary being between the mouth of West Channel and the southern tip of the Olivier Islands;

2. Niakunak Bay – the portion of West Mackenzie Bay lying north of Shallow Bay with the seaward boundary defined by a line running from Shingle Point to the outermost part of the Olivier Islands;

3. West Mackenzie Bay – the seaward boundary defined by the outer perimeter of the estuary study area, the eastern boundary defined by Garry Island and a line running north of the western tip of Garry Island to the study area perimeter;

4. East Mackenzie Bay – the area landward of the Barrier Islands;

5. Barrier Islands – Garry, Pelly, Hooper, and Pullen Islands; and

6. Kugmallit Bay – the seaward boundary extending approximately between Pullen Island and Warren Point.

In this report frequent mention is made of results from previous years' studies, although the reports supporting these statements are not always cited. Results of the 1972–1974 seasons are described in Slaney (1973, 1974, and 1975, respectively), and results from 1975–1978 are described in Fraker (1976, 1977a, 1977b, and 1978, respectively).

1.5 METHODS

Methods used during the 1979 whale program were the same as those of previous years and included intensive systematic aerial surveys, reconnaissance aerial surveys, and frequent visits to hunting camps and the communities where hunters reside. An Inuit observer, Andrew Erigaktoak, participated in the 1979 program by acting as a second observer on flights and providing liaison during camp visits. The study was carried out under a permit granted by the Fisheries and Marine Service.

1.5.1 Systematic Surveys

Systematic surveys were designed to obtain data on the distribution, relative abundance, behaviour, and movement patterns of white whales. Transect lines across the survey areas were established at 3.2–km intervals except for the 'loop' extending into Shallow Bay (Figure 2) and the entire West Mackenzie Bay survey which had lines spaced at 4.8–km intervals. A standard flight track was also established for the Tuft Point/Tuktoyaktuk Peninsula region (Figure 2). Survey lines were established in Kugmallit and Niakunak Bays in 1976 and in East and West Mackenzie Bays in 1977. The West Mackenzie Bay survey area was reduced in size in 1979 for safety and so that both East and West Mackenzie Bays could be surveyed without having to refuel the aircraft; however, surveys conducted before 10 July, while there was extensive ice cover, followed the standard survey lines. The parts deleted to form the 'modified' survey are shown as dashed lines on Figure 2.

Surveys were conducted as often as weather allowed. Which area was selected depended on how recently it had been surveyed and its importance to the whales or its relevance to Esso operations. Because of changes in weather, it was not always possible to complete each survey on each attempt, and therefore, the area covered on a survey varied from time to time. In Niakunak and Kugmallit Bays, the areas where most whales can be expected to be present (i.e. the concentration area) are consistent and well known. One can be reasonably confident of being able to detect changes in abundance as long as the concentration areas are surveyed.

A float-equipped Cessna 185 was used for the whale surveys conducted in the estuary. An altitude of 305 m and an airspeed of 193 km/h were maintained on all flights. Times were recorded to the closest 15 sec at the start and finish of each line and at landmarks along the way; total numbers of whales observed were recorded during each 15-sec interval so that sightings could be plotted to within approximately 0.8 km. The survey flights were timed so that the sun was either in front of or behind the aircraft to minimize interference from glare on the water to observers looking out the sides. Observation conditions on each survey were rated according to the following scheme:

EXCELLENT: No glare or water disturbance to interfere with whale observations.

GOOD: Small amount of glare and/or a few whitecaps which cause a minor amount of visual interference.

FAIR: Glare and/or whitecaps which cause significant visual interference.

POOR: Severe winds generate rough water; there may be glare, and air turbulence may interfere with both navigation and whale observation.

The visibility conditions that prevailed during each survey were taken into account in interpreting the results. Generally, estimates of numbers mentioned in the text are those from surveys conducted under excellent or good visibility conditions, unless otherwise noted. However, surveys flown under fair or poor conditions still provided valuable data on distribution, movements, and behaviour.

From an altitude of 305 m, it is possible to see whales up to 2 or 3 km away under favourable wind and light conditions. To keep the surveys consistent, only those whales within a 0.8 km-wide strip along either side of the aircraft were counted. In order for each observer to confine his counts to the 0.8-km strip, the aircraft was flown over a 0.8-km aircraft runway, and the struts were marked so that the projected area on the water viewed between the floats and the strut marks at a 305-m altitude was 0.8 km wide. These markings were further checked using an inclinometer and triangulation.

The two observers, one in the right front seat and the other in the left rear, used Seiko Liquid Quartz digital watches which were synchronized before each survey. Because the aircraft flew at an airspeed of 193 km/h, approximately 0.8 km was covered during each 15 sec. Cassette tape recorders were used to record the data as well as observations on directions of movement and behaviour. Shortly after each survey, the tapes were transcribed onto a standard form, and data on distribution, abundance, behaviour, and direction of travel were plotted onto individual maps for each survey.

Three systematic aerial surveys were also conducted north of the Mackenzie estuary in offshore waters of the Beaufort Sea during the open-water period. North-south flight lines were located at 9.6-km intervals from Hooper Island to Warren Point and extended approximately 64 km into the Beaufort Sea to cover an area outside the normal study area. These surveys were flown in a twin engine Cessna 337 at an altitude of 305 m and an airspeed of 262 km/h. The two observers occupied the two rear seats and each surveyed a 0.8-km-wide transect strip.

1.5.2 Reconnaissance Surveys

Reconnaissance aerial surveys were used to answer questions about the presence or absence of whales in a given area, to concentrate attention on a particular area or activity, or to rapidly survey a large area where a systematic survey would have been impractical. These surveys were flown at altitudes of 305 to 610 m.

1.5.3 Counting and Estimating Numbers of White Whales

In the highly turbid water of the Mackenzie estuary, white whales become invisible just a few centimetres beneath the surface. Although the turbidity decreases over the course of the summer, this appears to have no significant effect on our ability to detect whales in the heavily used nearshore areas. An accurate estimate depends on knowing what proportion of all the whales in an area is at the surface; unfortunately, this is not known. Calves are not included in the estimates because the dark calves are not reliably detectable in the turbid water, even at the surface.

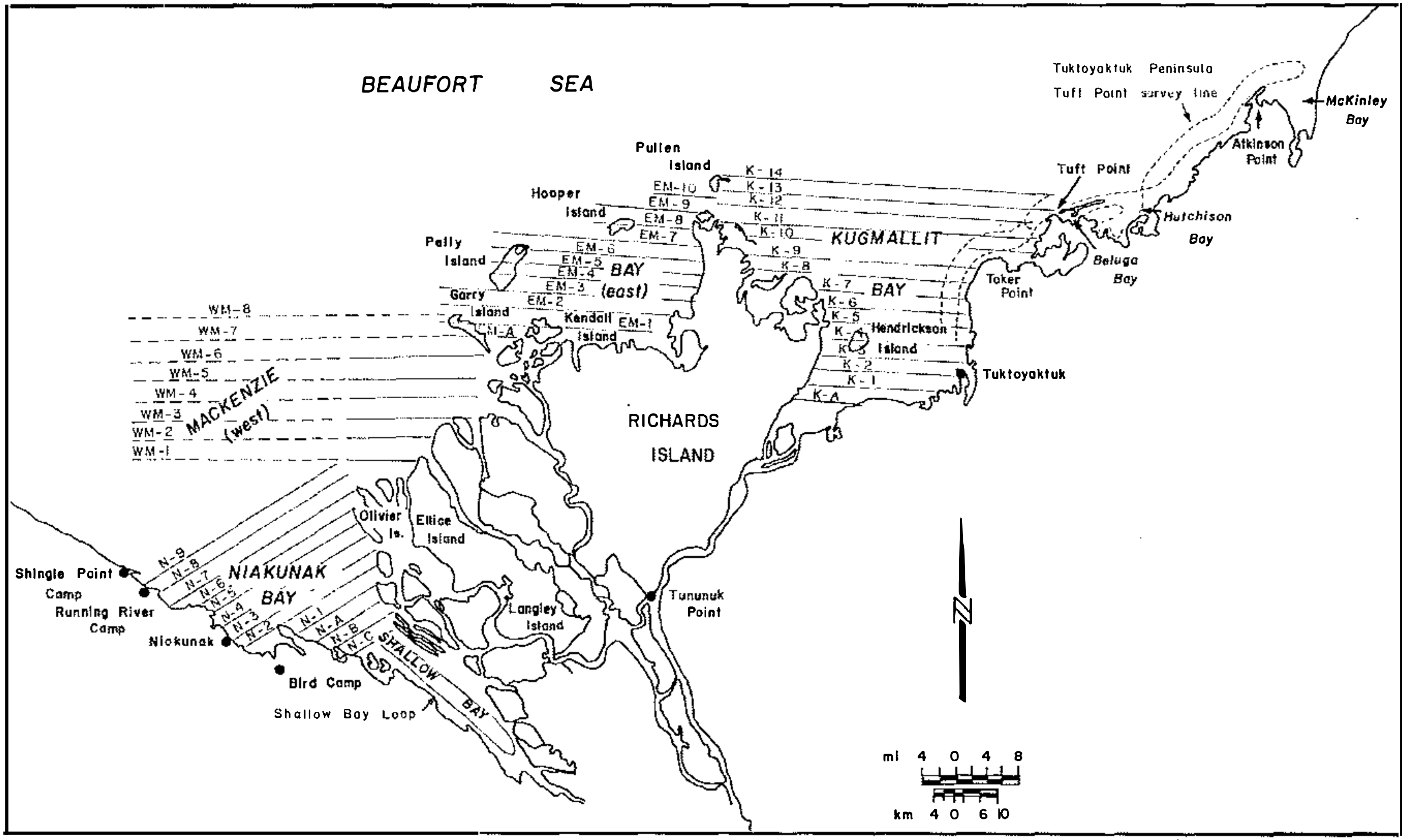

Figure 2. Standard survey lines, Mackenzie estuary and Tuktoyaktuk Peninsula, 1976–1979. Dotted lines indicate survey lines before modification (see text).

Sergeant (1973) watched whales from a cliff near Churchill, Manitoba, and observed that they spent about one third of the time at the surface; thus, he applied a visibility factor of three to his counts to arrive at an estimate of total numbers. Sergeant's visibility factor assumes that only an instantaneous count of whales in any given area is made. However, as the period of observation increases, a greater number of whales will be seen as they come to the surface. If we had restricted the counts in this study to a narrow strip at right angles to the flight track, a method which would have approximated an instantaneous count, whales would have been recorded as absent from areas where they occurred in low density. This procedure would have been unacceptable because distribution was just as important as abundance in this study. By viewing objects while flying over land under survey conditions, Fraker (1976) determined that any given point is in view for about 15 sec under the standard observation technique used in this and previous studies (Fraker 1976, 1977 a, b; Fraker et al. 1978, 1979). To compensate for the fact that the assumption of an instantaneous count of whales was not met, Sergeant's visibility factor was reduced from three to two, and this factor has been applied consistently in whale studies in this area since 1975 (Fraker 1976, 1977a, 1977b, 1978; Fraker et al. 1979). This factor probably results in conservative estimates of total whale numbers, and it must be emphasized that the resulting figures should be treated as relative indices rather than unbiased estimates of absolute abundance. The most important feature of such surveys is that the methods be consistent so that results are comparable within and between years. Usually it is apparent that whales are continually surfacing and submerging out of sight. But in a few instances most whales have been observed to remain at the surface, and apparently few have been beneath the surface where they could not be seen. When a larger-than-normal proportion of the whales were at the surface, the numbers of whales observed have been strikingly larger than the numbers usually seen. In such cases, no visibility factor has been applied.

Estimates of the number of whales in the Mackenzie estuary may be affected by potential variables other than the proportion of whales at the surface. Different observers and the use of different aircraft could also affect the number of whales counted. These possible sources of variation have been minimized, since the same two persons (Andrew Erigaktoak and Mark Fraker) sitting in the same seats of the same type of aircraft have conducted the surveys during the first part of the period when the whales are in the estuary (when the highest numbers are recorded) in 1976, 1978, and 1979. In 1977, other observers conducted most of the surveys of Niakunak Bay and East and West Mackenzie Bays (Fraker et al. 1979).

The transect lines in Kugmallit, Niakunak, and East Mackenzie Bays were 3.2 km apart, and because the two observers, one on each side of the aircraft, surveyed 0.8-km-wide strips, one half of the water surface area was viewed on each survey. Therefore, an extrapolation coefficient of two was applied to the survey results to allow for the whales assumed to have been present in the remaining one half of the area that was not viewed. Because the survey lines were 4.8 km apart in West Mackenzie Bay, one third of the area was surveyed and the extrapolation coefficient was three. If only one observer was present on a survey, the extrapolation coefficient was doubled to allow for the additional unsurveyed area.

1.5.4 Camp Visitations

All occupied whaling camps were visited every two to four days to ascertain hunting effort and success, to collect biological data, and to learn of any possible interference with hunting by exploration activities.

1.5.5 Biological Data Collection

Occasionally, it was possible to obtain samples and measurements from whale carcasses. Because butchering occurs promptly after a whale is landed, only a few carcasses can be examined. In many cases, even a minimal set of observations (consisting of total length, sex, and tooth samples) was difficult to obtain. Length was measured in a straight line from the tip of the snout to the tail notch.

1.5.6 Study of Spring Ice Conditions

The movement of white whales to the Mackenzie estuary region was studied in relation to ice conditions. Images from the TYROS-N satellite were used to examine temporal changes in ice cover within the Southern Beaufort Sea.

1.5.7 Observations by Industry Personnel

Important observations were made by various persons operating on boats, in aircraft, or from the barge camps. These observations were recorded on standard forms and were submitted at the end of the field season. Data recorded included species and numbers of whales, location, date and time, direction of movement, distance from and reaction to vessels, and remarks on feeding or other behaviour.

PART 2
WHITE WHALE MOVEMENTS, DISTRIBUTION, AND ABUNDANCE

2.1 WHITE WHALE MOVEMENTS AND DISTRIBUTION

2.1.1 Spring Migration and Arrival of the Whales at the Mackenzie Estuary

In 1979, the first whales observed to enter West Mackenzie Bay were seen as they moved through a breach in the landfast ice on 20 June. TYROS-N satellite imagery indicated that the first break in the band of landfast ice across the estuary occurred on 19 June, and therefore the first whales may have arrived on that date. The earliest date when whales had been recorded within the estuary previously was 26 June in both 1973 and 1975.

In 1973 frequent surveys of the area from Herschel Island to Cape Dalhousie were flown from 26 May through June. Although whales were reported by other scientists to be present in Amundsen Gulf by early June that year and ice conditions would have allowed them to travel from late May onwards (Fraker et al. 1978; Fraker 1979), none were seen in the area between Herschel Island and Cape Dalhousie until 19 June. Before the landfast ice broke in 1973 large numbers of whales had moved into the area offshore of the Mackenzie estuary study area.

On 20 June 1979, we saw 15 whales entering West Mackenzie Bay through an opening in the landfast ice (Figure 3a). Only two whales, moving southeastward, were seen along the landfast ice north of the Yukon. Along the edge of the landfast ice north and east of the Mackenzie estuary, in contrast, there were 225 whales, all but four headed westward. Approximately 240 whales were observed during a brief survey of the landfast ice edge from north of Atkinson Point to Baillie Islands on 22 June. All were near Baillie Islands and all were headed westward. Most of these whales were in a single group estimated to contain about 200 whales.

On 1 July, 64 whales were observed swimming westward along the ice edge from the Mackenzie estuary east to Baillie Islands (Figure 3b). This is considerably less than the number seen during earlier surveys. There were also 37 whales in West Mackenzie Bay near the inside edge of the landfast ice, but what they were doing is unknown. The ice was sufficiently broken up in Kugmallit Bay by 1 July that whales could have entered there, and some probably did since they were seen near Hendrickson Island the next day both by hunters (Mr. Bill Cockney, pers. comm.) and by us. But on 1 July, the whales seen north of the Barrier Islands had apparently moved past Kugmallit Bay on to Niakunak Bay (Figure 3b).

The pattern of break-up of the landfast ice apparently strongly influenced the distribution of whales within the estuary in 1979. During the last 10 days of June, the whales arriving at the estuary could enter only West Mackenzie Bay. On 30 June, a minimum of 5948 whales were estimated to be in Niakunak Bay and there were an additional 735 (minimum) in West Mackenzie Bay. Thus, before any whales had been observed in Kugmallit Bay, the majority (over 6600) were already present in West Mackenzie and Niakunak Bays. No more than about 500 were ever estimated to be present in Kugmallit Bay in 1979 (see section 2.1.4), although in most previous years, an estimated 2000 to 2500 whales have been present there. Apparently, the large difference in timing of the break-up of ice in West Mackenzie Bay and in Kugmallit Bay determined the distribution of whales within the Mackenzie estuary in 1979.

In 1978, there was a similar disparity in the distribution of whales within the estuary, and this was also attributable to ice conditions. However, in 1978 many whales moved from Niakunak Bay to Kugmallit Bay in mid-July, soon after the break-up of ice north of Richards Island made travel between the two areas possible. This did not happen to any large extent, if at all, in 1979 for reasons that are not clear. In 1979, the ice north of Richards Island did not leave until about 8 July, 18 days after the first whales entered the estuary. In 1978, the movement of whales from Niakunak 8ay to Kugmallit 8ay was first possible on 13 July, only eight days after the first whales arrived in the estuary. Whether whales move from the west part of the estuary to the east may depend on how soon after arrival free travel within the estuary is possible.

2.1.2 Niakunak Bay

The first whales arrived in Niakunak 8ay on 19 or 20 June 1979, at least six days earlier than they had previously (1973 and 1975) been recorded present. Estimated numbers rose steadily over the next 10 days, so that a minimum of 5948 whales was estimated on 30 June (Figure 4; Table 1; Appendix 1). Large numbers were maintained until at least 4 July. Subsequently there was a decline so that only about 1000 whales were estimated on 12 and 20 July. As is typical, the number of whales present declined in early August so that only 256 were estimated to be in Niakunak 8ay on 9 August.

Compared to 1978, there was a more gradual rate of increase in numbers in 1979. Because of the late date (5 July) on which the ice broke up in 1978, whales apparently had gathered offshore of the landfast ice, before they could enter the estuary. In 1979, the ice broke early (19 June) compared to 1978 (5 July), and consequently the buildup of maximum numbers in Niakunak Bay was more protracted in 1979. Peak numbers occurred in Niakunak Bay on 9 July in 1978, four days after the first whales entered, but in 1979 the peak occurred 10 days after (Figure 4).

The apparent stability of the number of whales in Niakunak Bay during much of July (after the initial period of high numbers) is undoubtedly an artifact resulting from the low frequency of surveys (Figure 4; Table 1). In 1977, when more survey effort was directed at this area, fluctuations were evident in the number of whales present during July (Fraker et al. 1979). These fluctuations resulted from movements of the whales between Niakunak and West Mackenzie Bays, and this probably occurred in 1979 also.

The extent of the concentration area in Niakunak Bay this year was similar to that seen in 1976, 1977, and 1978 except that whales (100) went farther into Shallow Bay than had been seen in previous studies (Figure 5). As in 1978 but not 1977, a small area on the southwest side of the bay was utilized initially. As the number of whales in the bay increased, so did the extent of the concentration area. The fact that the whales penetrated more deeply into Shallow Bay in 1979 than had been seen previously probably is related to the pattern of hunting activity. In 1979, eight whales were taken during the first 10 days that whales were present, but because these were taken quickly and within about 1 km of the point where the river channel near Bird Camp enters Niakunak Bay, the whales were exposed to a minimum of disturbance. Usually the hunting takes place over a much wider area than it did in the first part of the 1979 hunting period in Niakunak Bay (see section 2.1.6).

2.1.3 West and East Mackenzie Bays

West and East Mackenzie Bays were included in this year's study in order to monitor the activities related to drilling on Adgo J-27 and to monitor the subsequent movement of the drilling rig and materials to Tuktoyaktuk and Tununuk Point (Figure 1). The area surveyed in 1979 in West Mackenzie Bay was initially the same as that surveyed in 1977, the only other year when systematic surveys were carried out (Fraker et al. 1979), but the extent of coverage was reduced by 70% after 2 July (see section 1.5.1, Figure 2). The area surveyed in East Mackenzie Bay was identical in 1977 and 1979.

Whales first entered West Mackenzie Bay on 19 or 20 June (Figure 3a), however, most of the arriving whales continued on into Niakunak Bay. The maximum number of whales in the bay was estimated at 2364 on 2 July. The numbers remained high until 15 July, after which there was a steady decline until only an estimated 12 whales were present on 5 August.

In examining the changes in numbers in 1977 and 1979 (Figure 4; Table 2; Appendix 1), it must be recalled that the 1979 survey area, after 2 July, was only about 30% of the 1977 area. However, in both years the data indicate that there were two peaks of up to an estimated 2500 whales. The first peak occurred after the peak in Niakunak Bay by a few days (1979) to two weeks (1977). Certainly many of the whales using West Mackenzie Bay come from Niakunak Bay; movement between these two areas was clearly observed during the more intensive study of this area conducted in 1977 (Fraker et

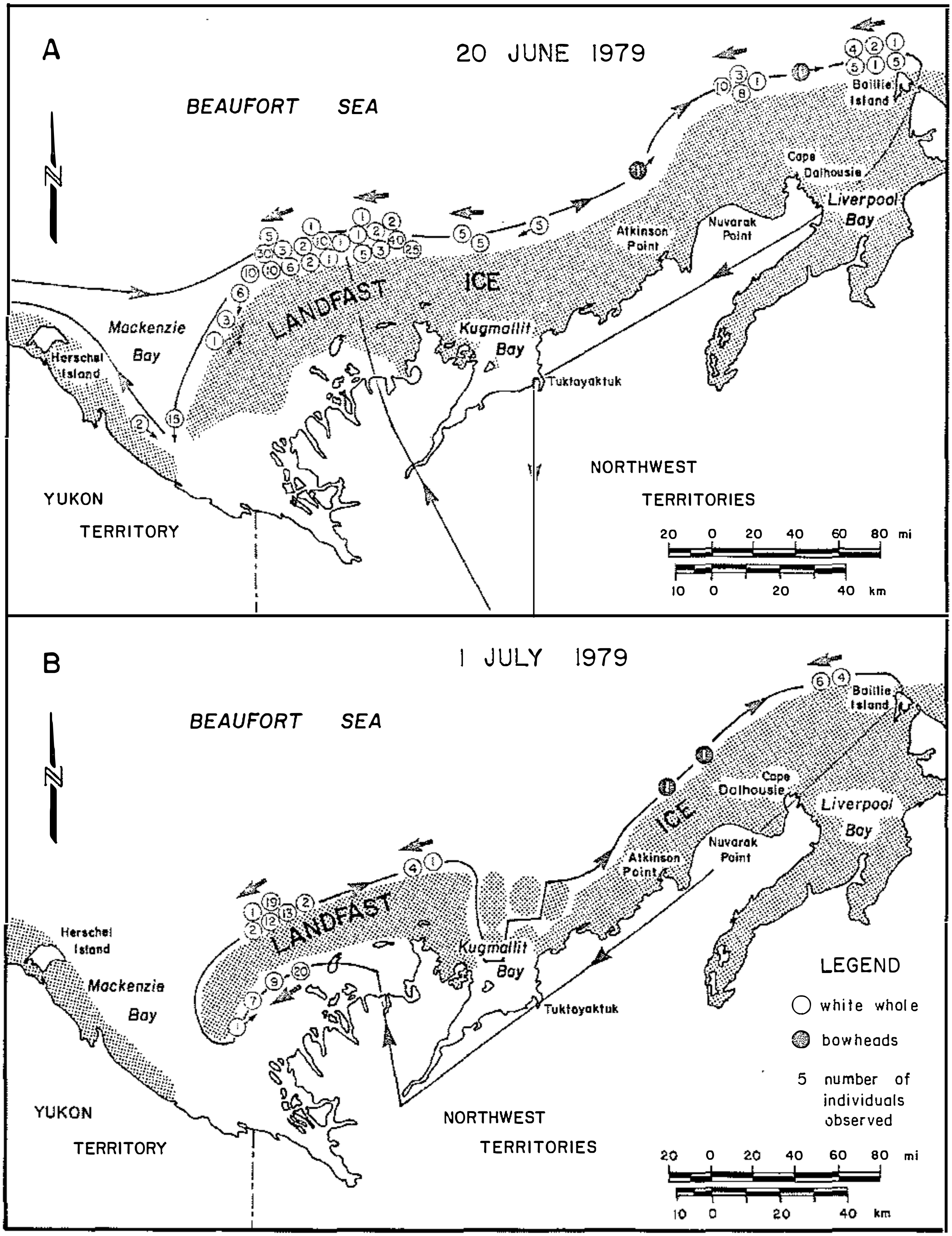

Figure 3. Results of spring migration surveys along the landfast ice, 1979.

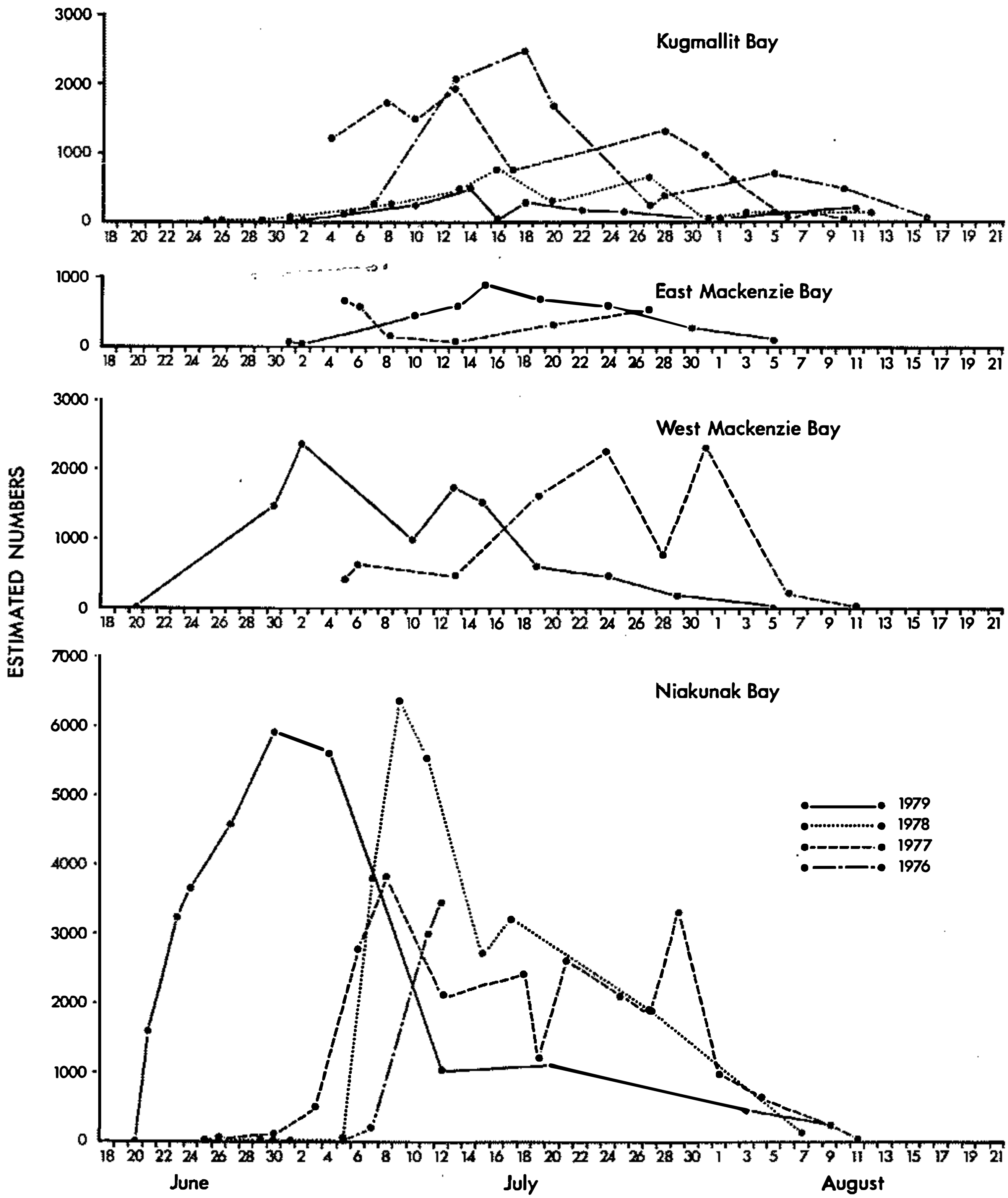

Figure 4. Changes in estimated numbers of white whales within the Mackenzie estuary, June—August 1976—1979. Data used are from systematic surveys done under good or excellent conditions. Results from partial surveys were used if the area surveyed included the primary areas used by whales.

Table 1. Summary of whale surveys in Niakunak Bay, 1979.

Date	Lines Flown	Observation Conditions	Whales Observed	Extrapolation Coefficient*	Visibility Factor	Estimated Numbers
21 June	N-C to N-9	Good	200	4	2	1,600
23June	N-C to N-9	Excellent	820	2	2	3,280
24June	SB Loop to N-9	Excellent SB Loop to N-4, Good N-5 to N-9	914	2	2	3,656
27 June	SB Loop to N-9	Excellent SB Loop and N-5 to N-9, Good N-C to N-4	1,149	2	2	4,596
29June	Reconnaissance SB Loop Only	Good	80	–	–	–
30June	SB Loop to N-9	Excellent	2,974	2	–†	5,948
4 July	N-1 to N-9	Good	703	4	2	5,624
12 July	SB Loop to N-7	Good	253	2	2	1,012
20July	SB Loop to N-9	Excellent SB Loop to N-A, Good N-1 to N-9	275	2	2	1,100
3 August	N-A to N-1, N-4 to N-9	Excellent N-A to N-1, N-5 to N-9, Good N-4	112	2	2	448
9 August	N-7 to N-9	Excellent	64	2	2	256

* For systematic surveys, an extrapolation coefficient of two was used to include the unsurveyed areas. This was increased to four when only one observer was present.

† Behaviour indicated a larger than usual proportion of the whales were at the surface this day.

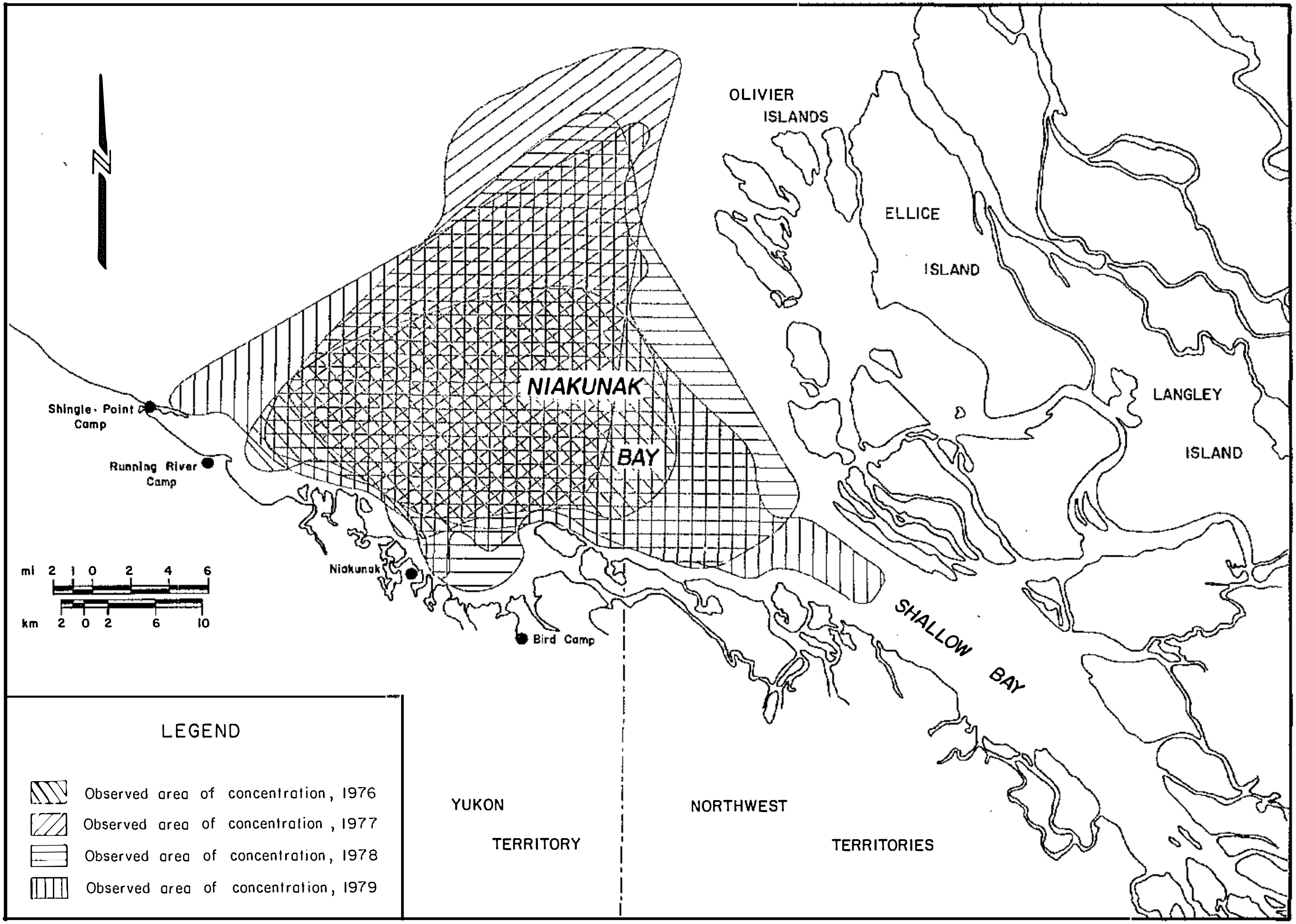

Figure 5. The extent of the Niakunak Bay white whale concentration area, 1976–1979.

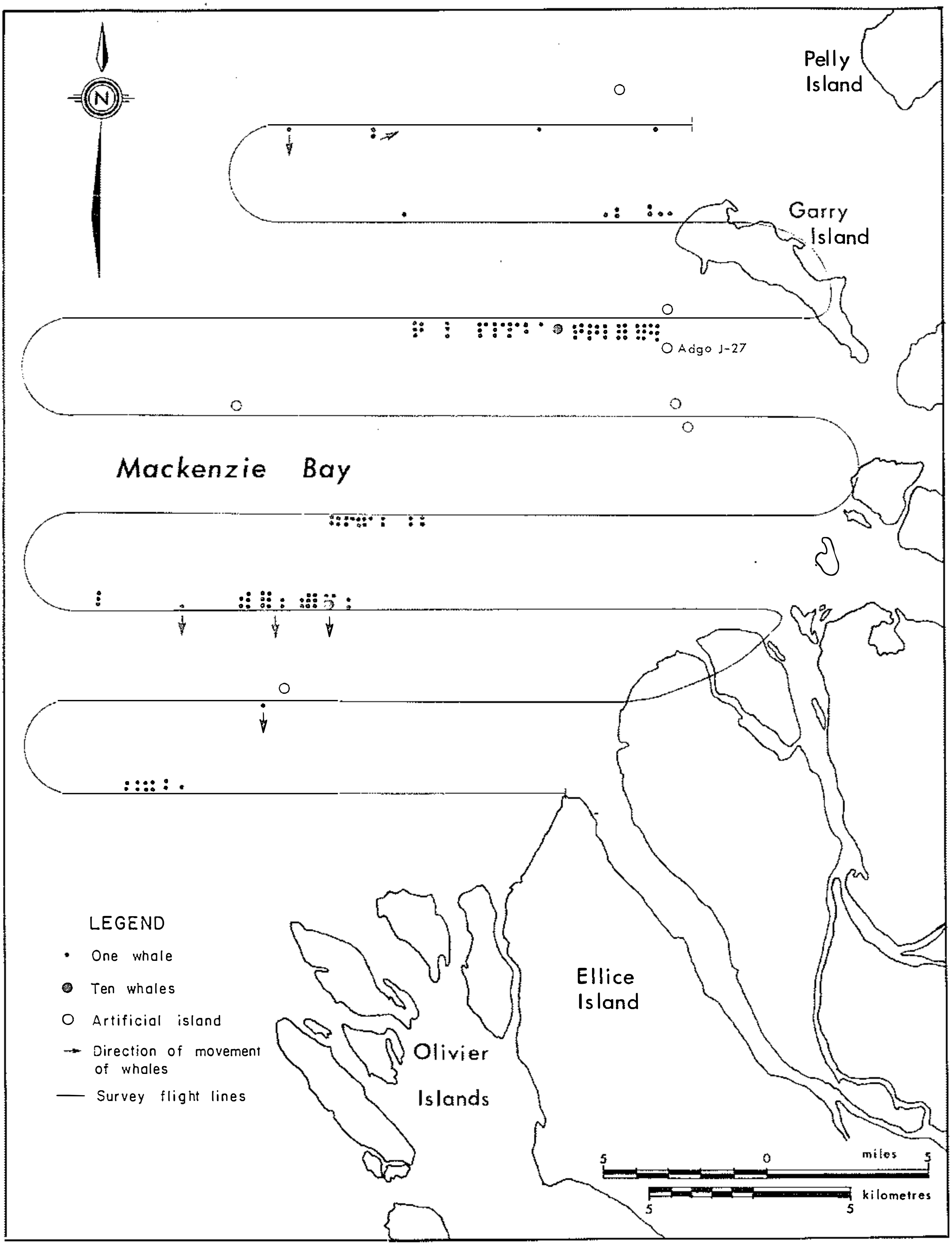

Figure 6. Distribution and abundance of white whales in West Mackenzie Bay, 13 July 1979.

Table 2. Summary of whale surveys in West Mackenzie Bay, 1979.

Date	Lines Flown	Observation Conditions	Whales Observed	Extrapolation Coefficient*	Visibility Factor	Estimated Numbers
20 June	Reconnaissance	Excellent	0	–	–	–
30 June	WM-1 to WM-8	Excellent	245	3	2	1,470
2 July	WM-1 to WM-8	Excellent	394	3	2	2,364
10 July	WM-1 to WM-8 (modified†)	Good	162	3	2	972
13 July	WM-1 to WM-8 (modified)	Excellent	145	6	2	1,740
15 July	WM-1 to WM-6 (modified)	Good	253	3	2	1,518
19 July	WM-3 to WM-6 (modified)	Excellent	97	3	2	582
24 July	WM-1 to WM-6 (modified)	Excellent	40	6	2	480
29 July	WM-1 to WM-6 (modified)	Good	33	3	2	198
5 August	WM-5 to WM-6 (modified)	Excellent	2	3	2	12

*For systematic surveys, an extrapolation coefficient of three was used to correct for the unsurveyed area. This was increased to six when only one observer was present.

†Modified means that the lines were shortened (see section 1.5.1 and Figure 2).

al. 1979). Large numbers were maintained for approximately three weeks in both 1977 and 1979; however, in 1979 the whales arrived earlier and left earlier. In both years, only very small numbers were present in early August.

In 1979, the highest densities of whales were observed in the area between the Olivier Islands and the west part of Garry Island, as shown in the survey results of 13 July 1979 (Figure 6). Whales were not seen in the area directly south of Garry Island or up to 10 km seaward of the outer islands of the delta in 1979 or 1977 (Fraker et al. 1979).

The whales apparently use West Mackenzie Bay differently than they do Niakunak Bay. Much of their time is spent travelling, rather than associating in gams or remaining stationary. During the nine surveys flown in 1979, an average of 40% of the whales seen were in transit, but on two dates, 13 and 24 July, most of the whales were stationary or in gams. On 13 July gams of whales were seen in the eastern part of West Mackenzie Bay west of Garry Island (Figure 6). Similar aggregations have been observed here in other years (Fraker et al. 1979).

Observations made during this and previous studies of East Mackenzie Bay indicate that the whales usually arrive here later and in smaller numbers than in Niakunak and Kugmallit Bays[1] (Figure 4).

Unfortunately, systematic surveys have been conducted here in only 1977 and 1979, and

†The relatively high numbers seen on 5 July 1977 resulted from a temporary aggregation near Garry Island of whales that had just arrived at the estuary. In that year, the whales entered through a break in the landfast ice that was just north of Pelly Island (instead of north of Shingle Point as in 1979). These whales left the Garry Island area after a few days and apparently continued on to Niakunak Bay.

therefore we cannot yet be certain about the pattern of use of this area.

The largest numbers of whales in East Mackenzie Bay have always been observed in the southwestern part near Garry, Pelly, and Kendall Islands, and this was true also in 1979. No whales were seen in the southern part of East Mackenzie Bay on 2B June, but about 50 were present on both 1 and 2 July (Figure 4; Table 3; Appendix 1). The whales subsequently increased in number, and the 1979 maximum of 876 was estimated during a complete survey on 15 July. Subsequently, numbers declined to an estimated 116 whales on 5 August.

2.1.4 Kugmallit Bay

By 1 July 1979, the ice in Kugmallit Bay had fractured sufficiently to allow whales to enter, but on that date a reconnaissance survey failed to locate any whales entering the bay (Figure 3). Even though there were several clear avenues through the ice to the Hendrickson Island area, on 1 July whales were observed swimming westward past Kugmallit Bay. The first whales observed in Kugmallit Bay were seen near Hendrickson Island on 2 July by hunters (Mr. Bill Cockney, pers. comm.) and by us.

From 2 July, there was a gradual increase until the peak on 14 July, estimated to be 496, after which there was a decline. However, at least 188 whales were estimated to be present on 11 August (Figure 4; Table 4; Appendix 1).

The general profile of the change in numbers of whales in Kugmallit Bay appears to be characterized by a peak in mid-July, followed by a decline, a second increase, and a final decline. This pattern is suggested by data from 1976—1978, even though the numbers of whales in Kugmallit Bay have differed greatly during this period. Because of limitations in the survey technique, it is difficult to be certain that the changes that occurred in 1979 followed the same pattern.

The maximum estimated number of whales in Kugmallit Bay has been low during 1978 and 1979, compared with 1976 and 1977 (Figure 4). This year's peak of 496 was only about 20% of the 1976 maximum. The later break-up of the landfast ice was undoubtedly the main cause of the reduced maximum number recorded in 1979.

As in 1979, initial ice conditions created a disparate distribution of whales within the estuary in 1978. But in 1978 there was apparently a movement of perhaps 400 whales from Niakunak Bay to Kugmallit Bay during the period from 13—16 July. If there was a similar movement of whales in 1979 it was not detected. Several whales were observed moving southeast along the Richards Island coast on 14 July; these might have come from the western part of the estuary. On the other hand, other whales were seen moving toward Hendrickson Island from other directions, suggesting that at least some of the whales seen coming into the Hendrickson area may have been driven away by the hunting activity that had occurred earlier in the morning and that resulted in at least three landed whales (see section 2.1.6). Since the whales in Kugmallit Bay are subjected to much more disturbance than are whales elsewhere in the estuary (nearly 75% of the harvest occurs there and most of the industrial activity in the Beaufort Sea is based at Tuktoyaktuk), human activities cannot be eliminated as a possible cause of any variations noted there.

The number and density of whales seen in Kugmallit Bay in 1979 were so low that it was not possible to define a concentration area. In addition, gamming behaviour (stationary aggregations of up to approximately 20 individuals; see Fraker et al. 1979), which may be characteristic of concentration areas, was not observed during our surveys in Kugmallit Bay this year. Most of the whales seen in Kugmallit Bay were within the area included in the concentration area as defined by studies made during 1976—1978 (Figure 7).

The timing and location of whales along the coast of the southern Tuktoyaktuk Peninsula were similar in 1979 to that seen in previous years. From mid-July to mid-August, small numbers of white whales were seen moving along the coast of the Tuktoyaktuk Peninsula (Table 5). On 22 and 23 July, approximately 100 whales, including several neonate calves, were observed in Hutchison Bay. Because these whales were diving and gulls were flying nearby, we suspect that the whales were feeding.[2]

[2] Whales were assumed to be feeding if there were gulls nearby for three reasons. First, gulls associated only with whales that were diving in place (see Fraker 1978). Whales in the concentration areas are not associated with gulls, and only very rarely do the whales taken in these areas by hunters contain food in the stomachs. Second, whales accompanied by gulls are usually seen in locations where migrating fish can be expected (Fraker 1977b). Third, in 1976 a hunter detected a small group of whales near the mouth of Blow River by the presence of gulls. He shot and landed one whale; examination of its stomach revealed six burbot *(Lota lota)*.

Table 3. Summary of whale surveys in East Mackenzie Bay, 1979.

Date	Lines Flown	Observation Conditions	Whales Observed	Extrapolation Coefficient †	Visibility Factor	Estimated Number
28 June	EM-A, EM-2 to EM-4*	Good	0	–	–	–
1 July	EM-A to EM-4*	Excellent	14	2	2	56
2 July	EM-A to EM-4*	Excellent	10	2	2	40
10 July	EM-A to EM-4	Good EM-A & EM-2 to EM-4, Fair EM-1	102	2	2	408
13 July	EM-A to EM-10	Excellent EM-1, 3, 5, 7, 9, & 10, Good EM-2, 4, 6, & 8	71	4	2	568
15 July	EM-A to EM-10	Good	219	2	2	876
19 July	EM-A to EM-6	Good	165	2	2	660
24 July	EM-A to EM-6	Excellent	73	4	2	584
30 July	EM-A to EM-10	Excellent - Good	59	2	2	236
5 August	EM-A to EM-10	Excellent	29	2	2	116

*The presence of ice over large areas on these dates obviated the necessity of flying all survey lines.

†For systematic surveys, an extrapolation coefficient of two was used to correct for the unsurveyed area. This was increased to four when only one observer was present.

Table 4. Summary of whale surveys in Kugmallit Bay, 1979.

Date	Lines Flown	Observation Conditions	Whales Observed	Extrapolation Coefficient *	Visibility Factor	Estimated Numbers
24 June	Reconnaissance	Excellent	0	–	–	–
27 June	Reconnaissance	Good-Fair	0	–	–	–
1 July	Reconnaissance	Good	0	–	–	–
2 July	K-A to K-7	Excellent	16	2	2	64
10 July	K-1 to K-9	Excellent K-1 to K-5 & K-8 to K-9, Good K-6 to K-7	55	2	2	220
14 July	K-1 to K-11	Excellent K-1 to K-8, Good K-9 to K-11	124	2	2	496
16 July	K-A to K-5 & K-8	Good	3	2	2	12
18 July	K-A to K-10	Good	84	2	2	336
22 July	K-A to K-10	Excellent	43	2	2	172
25 July	K-A to K-10	Excellent	16	4	2	128
31 July	K-1 to K-6	Good K-1 to K-4. Fair K-5 to K-6	0	–	–	0
1 August	K-1 to K-13	Excellent K-1 to K-12, Good K-13	26	2	2	104
6 August	K-4 to K-14	Good K-4 to K-11 & K-13, Fair K-12 & K-14	13	2	2	52
11 August	K-9 to K-14	Good	47	2	2	188

* For systematic surveys, an extrapolation coefficient of two was used to include the unsurveyed areas. This was increased to four when only one observer was present.

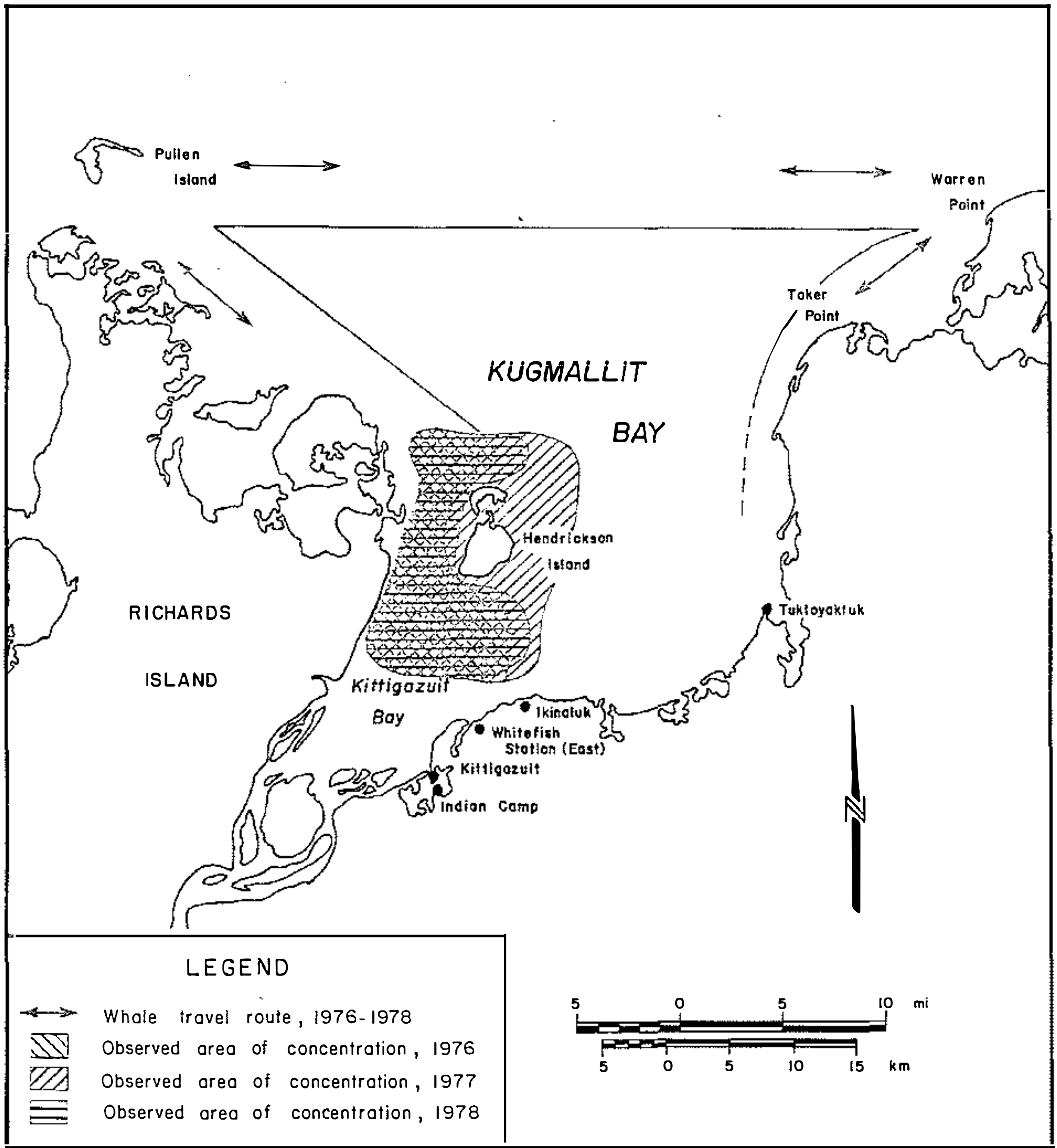

Figure 7. The extent of white whale high-use areas in Kugmallit Bay, 1976–1978.

Table 5. Results of reconnaissance surveys along the Tuktoyaktuk Peninsula, 1979.

Date	Total Number of Whales	Number of Moving Whales and Direction of Movement	Location	Additional Comments
14 July	37	9 – NE 20 – SW	N of Warren Point	No whales in Hutchison or Beluga Bays.
16 July	7	7 – SW	N and S of Tuft Point	No whales in Hutchison or Beluga Bays.
1B July	26	2 – N 12 – W	N and S of Tuft Point	No whales in Hutchison or Beluga Bays.
22 July	13	4 – N	Warren Point	Approx. 100 whales feeding in Hutchison Bay; many calves present; no whales in Beluga Bay.
23 July				Approx. 100 whales in Hutchison Bay; no whales in Beluga Bay.
25 July	5	1 – SW 3 – E 1 – N	Warrent Point	No whales in Hutchison or Beluga Bays.
31 July	2	2 – SW	N of Tuft Point	No whales in Hutchison or Beluga Bays.
6 August				No whales in Beluga Bay.
B August	3	N/A*	Mouth of McKinley Bay	Feeding
	6	2 – N 2 – NE 1 – W 1 – SW	N of McKinley Bay	
	16	N/A	Between Nuvorak Pt. and Cape Dalhousie	Feeding
11 August	9	N/A	NW of mouth of Hutchison Bay	Feeding
	2	2 – NE	N of McKinley Bay	

* N/A means not applicable.

Table 6. Distances flown and whales observed on offshore surveys, 1978 – 1979.

Date	Distance (km)	Whales Observed	Whales/km
26 July 1978	960	157	0.164
29 July 1978	1166	218	0.187
2 August 1978	690	2	0.003
8 August 1978	690	5	0.007
21 July 1979	1064	5	0.005
2 August 1979	480	26	0.054
8 August 1979	915	26	0.028

Whales, presumed to be feeding, were also seen at other locations along the Tuktoyaktuk Peninsula. Near Tuft Point, industry personnel made several observations of whales which were probably feeding. (see Appendix 2).

2.1.5 Results of Offshore Surveys

It is clear that large numbers of white whales leave the Mackenzie estuary to spend part of the open-water period in other parts of the southeastern Beaufort Sea region. However, the timing, location, and function of movements to areas outside of the Mackenzie estuary are not known. It is important to gain more information about the presence of whales outside of the estuary in order to obtain a more complete picture of the whales' ecology and the implications of exploration and development.

We conducted four offshore surveys in 1978 and three in 1979. In both years, the basic survey area lay between Hooper Island and Warren Point and extended offshore for approximately 64 km; there were, however, deviations from this in order to investigate particular situations. Parallel north-south lines were flown in both 1978 and 1979; the intervals between the lines were 8 km in 1978 and 9.6 km in 1979. In both years changes in the weather affected how much of the survey area was covered on each survey attempt. Table 6 gives the distances flown and whales seen on each survey in 1978 and 1979.

In 1979 a total of 57 white whales were observed on the three surveys (Figure 8). Most were moving north or east, away from the estuary; similar results were obtained in 1978. However, the number of whales seen in 1978 was much greater; 157 and 218 whales were observed during similar surveys flown on 26 and 29 July 1978, respectively. The number of whales observed on the offshore surveys may be related to the timing of the surveys relative to the date when the whales arrive at the estuary. In 1979 the first offshore survey was done on the 32nd day after whales had first been observed in the estuary while in 1978 the first survey was on the 22nd day. Possibly an earlier survey in 1979 would have recorded more whales.

Few whales remain in the Mackenzie estuary after early August. Probably the whales move away to feed, with some returning to the estuary. Most of the whales observed along the Tuktoyaktuk Peninsula in August 1979 were apparently feeding (Table 5). In late July 1973, pilots reported seeing hundreds of whales in floe ice about 320 km north of the estuary. The ice edge is apparently an important feeding area for marine mammals in the eastern Arctic (Sekerak and Richardson 1978), and this might be true in the Beaufort Sea, also. Previous studies have indicated that most whales moving along the Tuktoyaktuk Peninsula in late July and August were moving southwestward, toward the estuary. But in 1979, few whales were seen heading southwest in this area; few whales were seen moving north or northeast in this area as well. The question of where the thousands of white

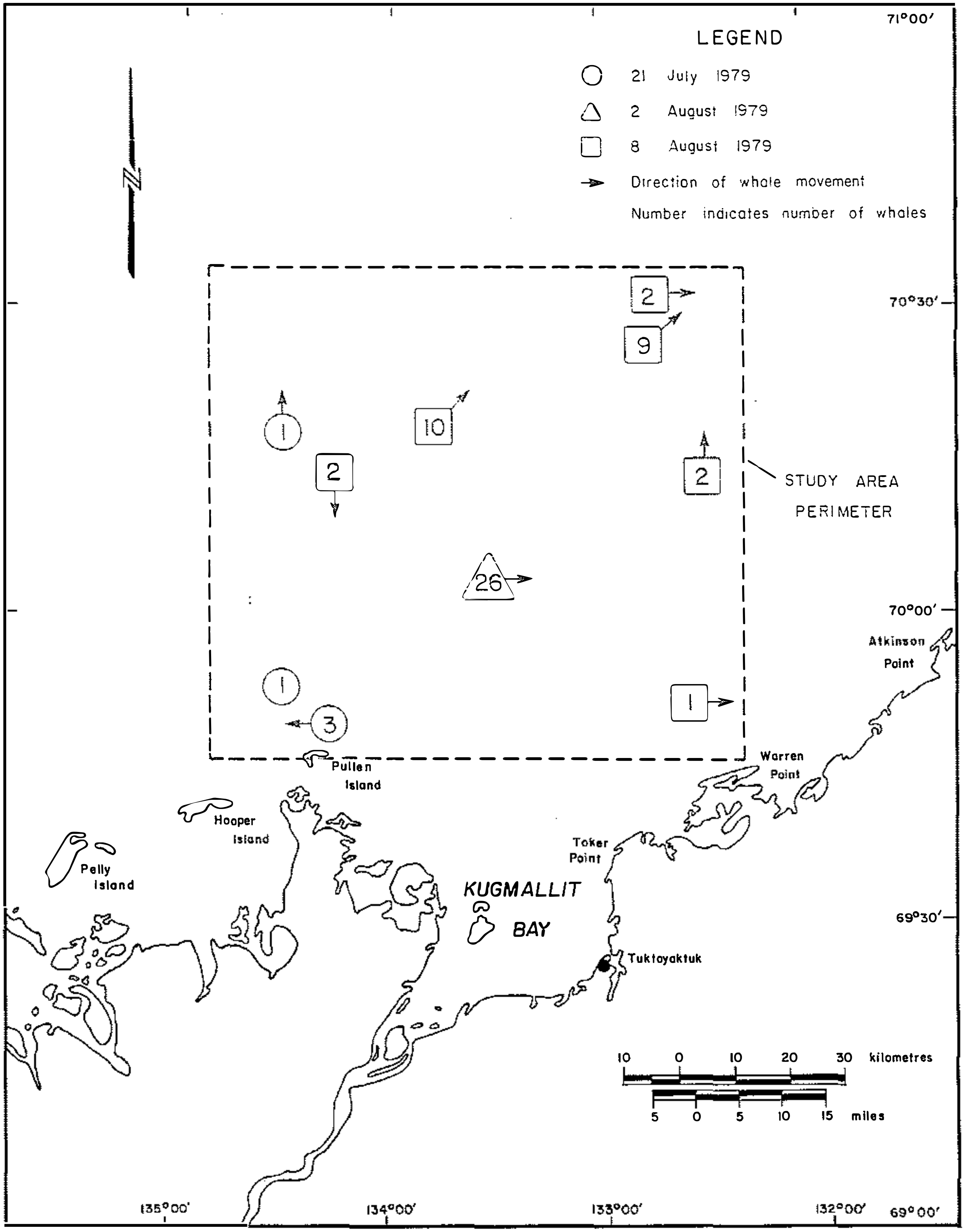

Figure 8. Observations of white whales made during offshore surveys, July and August 1979.

whales go after leaving the Mackenzie estuary remains open and requires further study.

2.1.6 Response of White Whales to Hunting

On two occasions in 1978, aerial observations of Niakunak Bay detailed the reaction of white whales to hunting. Whales within 0.8 km of the hunters actively avoided them, whereas whales farther away appeared not to be disturbed. There was also an indication that short periods of intensive hunting in Kugmallit Bay may have been responsible for the early decline in numbers observed there. However, because of the very late break-up of ice in 1978, barge traffic related to the start-up of exploration activities commenced at the same time as hunting, and thus it was not possible to separate out the effects of these two factors on the early decline of the whales. Results from observations in Kugmallit Bay in 1979 provide additional information on the effects of hunting on the behaviour, distribution, and abundance of white whales.

There were important differences in the patterns of hunting in Kugmallit Bay during 1978 and 1979. The most significant is that hunting started as soon as the whales appeared in the bay in 1979, while in 1978 windy weather kept the hunters in camp until 16 July, at least eight days after whales arrived. In addition, there were fewer whales present to be hunted in 1979. In 1978, 81 whales were taken from a maximum estimated number of 780 (10.4%), whereas in 1979, 80 whales were taken from a maximum estimate of 496 (16.1%). Taking into consideration whales that were killed-and-lost (see section 3.4), approximately 15.5% of the peak number of whales in Kugmallit Bay in 1978 were killed, compared with 24% in 1979. In addition to the whales that are killed, others are either chased or disturbed by the hunting activity. Furthermore, in Kugmallit Bay, the whale concentration area near Hendrickson Island is relatively small and completely accessible to hunters. Looking at the situation in another way, in 1978 and 1979, of the total number of whales estimated to have been in the estuary, only 10% or less were in Kugmallit Bay, yet these animals sustained nearly 75% of the harvest.

No gamming behaviour was observed during surveys of Kugmallit Bay in 1979; gamming was seen on three different dates in 1978. Because it may be an important social behaviour (Fraker et al. 1979), the apparent absence of gamming may indicate that the whales sustained significant disturbance during the period when they were present in Kugmallit Bay.

The observation of low numbers of whales in the concentration area on 16 July (Figure 4) was made on the fourth day of intensive hunting; although the entire concentration area was not systematically surveyed on 16 July, there was a noticeable decline in the numbers of whales seen on the lines that were surveyed. No whales were sighted on a reconnaissance on that date done over that part of the concentration area not included in the systematic survey. During 13–16 July, 26 whales were taken, including 19 on 14 and 15 July. These whales represent 33% of the whales taken from Kugmallit Bay on known dates.[3] (Dates of some kills by Tuktoyaktuk hunters are unknown.) A single episode of intensive hunting activity may not be adequate to cause a detectable proportion of the whales to leave an area. Repeated encounters may be necessary. For example, on 22 July 1978, during the second period of intensive hunting, most of the whales that had been present in Kugmallit Bay were observed moving away from the Hendrickson Island area *en masse.* Although the number of whales subsequently increased in 1978, the number of whales declined and did not recover following the third period of intensive hunting. The decline noted in Kugmallit Bay on 16 July 1979 preceded the start-up of most of Esso's exploration activities. The limited barge traffic operated some distance from the whale concentration area (see section 5.4).

The unusual extent of southward movement into Shallow Bay in 1979, together with the low level of hunting activity in the Niakunak Bay area during the first 10 days when whales were present, is consistent with the contention that disturbance from hunting can affect the distribution of whales in that area. Because whales were so easily accessible near Bird Camp during this period, hunters had only to go a short distance into Niakunak Bay to obtain whales and the area disturbed was minimal. On 29 June, 100 whales were observed in Shallow Bay nearly as far as Reindeer Channel (10 km south of line N-C). The only other time that we have observed whales as far south in Shallow Bay was on 26 July 1975. The last whale taken in 1975 was killed on about 20 July, and Fraker (1976) felt that the movement of whales into Shallow Bay

[3] The number of whales killed and the amount of disturbance to which the whales in an area are subjected are assumed to be directly related. Although this relationship may be oversimplified, it is probably largely correct.

Table 7. Maximum estimated number of white whales, Mackenzie estuary, 1972 – 1979.

Year	Maximum Estimate
1972	1500 – 2000
1973	3500 – 4000
1974	3500 – 4000
1975	4000
1976	5500 – 6000
1977	5500
1978	6600
1979	7000

on the 26th was related to the cessation of hunting. Whether or not there was a similar movement of whales into Shallow Bay in 1979 after hunting ceased is unknown because of the limited survey effort that was possible in that area late in the 1979 season.

The decline in numbers in Kugmallit Bay between 25 and 31 July was not likely the result of hunting activity (Figure 4; Table 4). No whales were landed between 23 July and 16 August, and only one hunting party is known to have looked for whales during this time. They reported sighting a killer whale in the normal concentration area west of Hendrickson Island late on 30 July or early on 31 July. Having seen the characteristic black-white dorsal fin of the killer whale, the hunters returned to camp. No additional reports were received corroborating the sighting, and the 31 July survey did not reveal the presence of killer whales or white whales. Killer whales have been reported previously along the Arctic coast from Baillie Islands to Herschel Island (Barry 1967).

2.2 WHITE WHALE ABUNDANCE

The maximum number of whales estimated to be within the Mackenzie estuary has varied from year to year (Table 7). A large part of this variation is undoubtedly the result of variation in techniques, but since 1976 we have used a standard survey technique (see section 1.5.1). Other factors, such as weather conditions and behaviour of the whales, undoubtedly affect the estimates. However, a major concern about the estimation procedure is related to the 'visibility factor' (2X) by which the number of whales observed is multiplied in order to allow for the whales that are beneath the surface. Although we believe that this factor is conservative, it is largely arbitrary (see section 1.5.3).

During aerial surveys, whales usually can be seen surfacing and submerging, but occasionally it is clear that a larger-than-usual proportion of the whales are at the surface. Such situations are apparent at the time of the survey because most whales at the surface remain there and do not submerge. When the survey data are later compiled, the number of whales seen is much larger than usual. This phenomenon has been encountered only in Niakunak Bay and only on three occasions: 8 July 1977 (Fraker et al. 1979); 7 July 1978; and 30 June 1979 (Table 1). No change in the distribution pattern of the whales was evident on any of these three occasions so the extrapolation coefficient was not changed. Because an accurate estimate of the total number of whales in the Mackenzie estuary is important, particularly for understanding the implications of the harvest, the estimates made when most whales are at the surface are especially valuable. These are minimum estimates and are not subject to the uncertainty associated with the 2X 'visibility factor'.

On 30 June 1979, we counted a total of 2974 whales in Niakunak Bay. Multiplying 2974 by two (to allow for the whales in the 50% of the area that was not viewed), the minimum estimated number present in Niakunak Bay was 5948. On the same day, we counted 245 whales in West Mackenzie Bay; allowing for the two-thirds of this area that was not viewed, but not allowing for invisible individuals beneath the surface, the minimum estimate was 735 for West Mackenzie Bay. (To be certain that there would be no overestimates, no visibility factor was applied to the number counted in West Mackenzie Bay, even though many whales probably were beneath the surface.) Together, the minimum estimated number of whales in both Niakunak and West Mackenzie Bays totalled 6683. Because whales were still migrating to the Mackenzie estuary at this time (see section 2.1.1), the above estimate was made before all whales had arrived. Therefore, we believe that a minimum of 7000 whales used the Mackenzie estuary in 1979.

Although the number of whales in the Mackenzie estuary reaches a peak in late June or early July, it is not certain whether there are whales elsewhere in the southeastern Beaufort Sea at the same time. Thus, the proportion of the total number of Beaufort Sea whales that are in the Mackenzie estuary at any one time may be another factor affecting the maximum estimates.

Another factor that may affect population estimates is the possibility that different numbers of whales may migrate to the Beaufort Sea and Mackenzie estuary in different years. Although we suspect that the extensive migration of the Mackenzie stock of white whales means that these whales are distinct from those found along the coasts of western Alaska and Siberia during summer (Fraker 1980), it may be that whales throughout most or all of the western Arctic belong to a single population and that various components of this population summer in different areas in different years. This question will not be resolved until extensive tagging and/or biochemical genetics studies are carried out.

PART 3

HARVEST OF WHITE WHALES IN THE MACKENZIE ESTUARY

3.1 HUNTING PERIOD

The timing and length of the hunting period can differ substantially between different years and between different parts of the estuary. These differences depend on the dates of arrival and departure of the whales and on weather conditions. Annual differences have long been apparent, but detailed data are available for only 1978 and 1979 . In general, 1979 was a very early year and 1978 was late. By considering these two contrasting years, we gain a better idea of the time span during which hunting may occur.

Aklavik hunters and their families set up the first camps on Niakunak Bay on 26 June 1979. The first people from Inuvik set up camps on Kugmallit Bay on 30 June and at Kendall Island on about 4 July. As usual, Kendall Island was last to be populated. In all three areas, the camps were established at least one week earlier in 1979 than in 1978. The earliest date when most hunters can move out to the hunting camps is determined by the day on which their children finish school. Later dates of arrival can result from adverse weather, as in 1978.

The dates when the first whales were taken were also earlier in 1979 than in 1978 – by about one week for Niakunak Bay and the Kendall Island area and by nearly two weeks for Kugmallit Bay (Figure 9). Hunting was pursued actively for approximately two weeks this year, but then it abated with only an occasional whale being taken after 18 July. In Niakunak Bay, the hunting was evenly spread over the entire hunting period. During mid- and late July, Kendall Island hunters were plagued with persistent winds that prevented hunting on all but a few days. Hunting activity from the Kugmallit Bay camps was most intense during and immediately after the second weekend in July (14–15 July). Most hunting from Tuktoyaktuk was done as soon as the whales arrived (2–3 July) or during the second week (9–15 July).

The 1979 Northern Games were held in Inuvik from 19–24 July, and this significantly affected hunting activities. Most people left the camps early to attend the games, and with the completion of festivities, many either went to fish camps or simply stayed in town. So important were the Northern Games to some hunters and their families that they waited until after the games to go out whaling.

3.2 HUNTING CAMPS

The hunting camps used this year were the same as those used in the two previous years (Figure 1). Ikinaluk was used up to and including 1976 but has not been used since. Hunters have occupied both the north (Okivik) and south (Sanmiqaq) camps on Kendall Island for the past three whaling seasons; since 1977 Kendall Island has been more important as a site for hunters from Inuvik, as some have switched from Kugmallit Bay. A major reason for the change is the intensity of hunting activity in Kugmallit Bay where about 72% of the total harvest has been taken in the past eight years (see section 3.3).

Tuktoyaktuk hunters continue to make day trips from the settlement rather than establish a camp. They sometimes visit Hendrickson Island to wait for the wind to go down, to boil tea, or to cut up the whales if the water is too rough to tow them back to Tuktoyaktuk.

3.3 HUNTING SUCCESS

The whale harvest is closely examined each year for four reasons. First, hunting is the main use of the whale resource and it should be monitored so any effects of hunting can be determined. Second, minimizing effects of exploration on the hunt depends on understanding hunting technology and factors affecting the hunt. Third, monitoring permits possible interference with hunting by Esso activities to be detected and assessed. Fourth, white whales, like other species of whales, are difficult to study, and examination of harvested individuals is a major source of biological information. Because of these considerations, the number of whales taken in each area is tabulated; where possible the date and time of the kill, the hunters involved, the calibre of rifle used, the number of

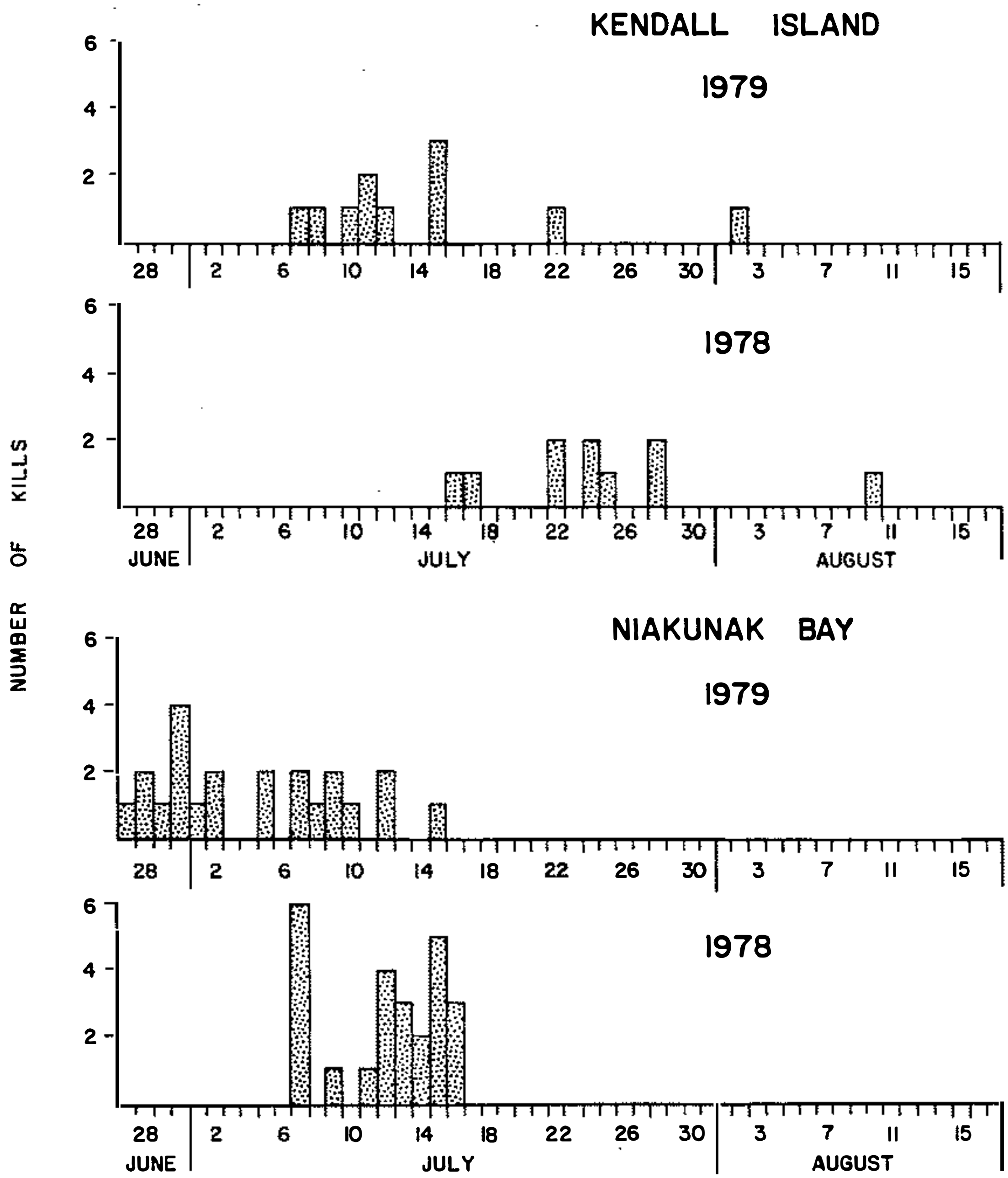

Figure 9. Known dates of whale kills in the Mackenzie estuary, 1978–1979.

shots taken, the length and sex of the whales, and the amount and type of any food in the stomach are recorded. All possible information is also recorded for whales that are struck-and-lost, along with the reason for the loss.

The numbers of whales taken in each area during 1979 were very similar to the numbers taken during 1978, and they were close to the seven-year (1972–1978) averages, except for the Kugmallit Bay camps (Table 8). The low number

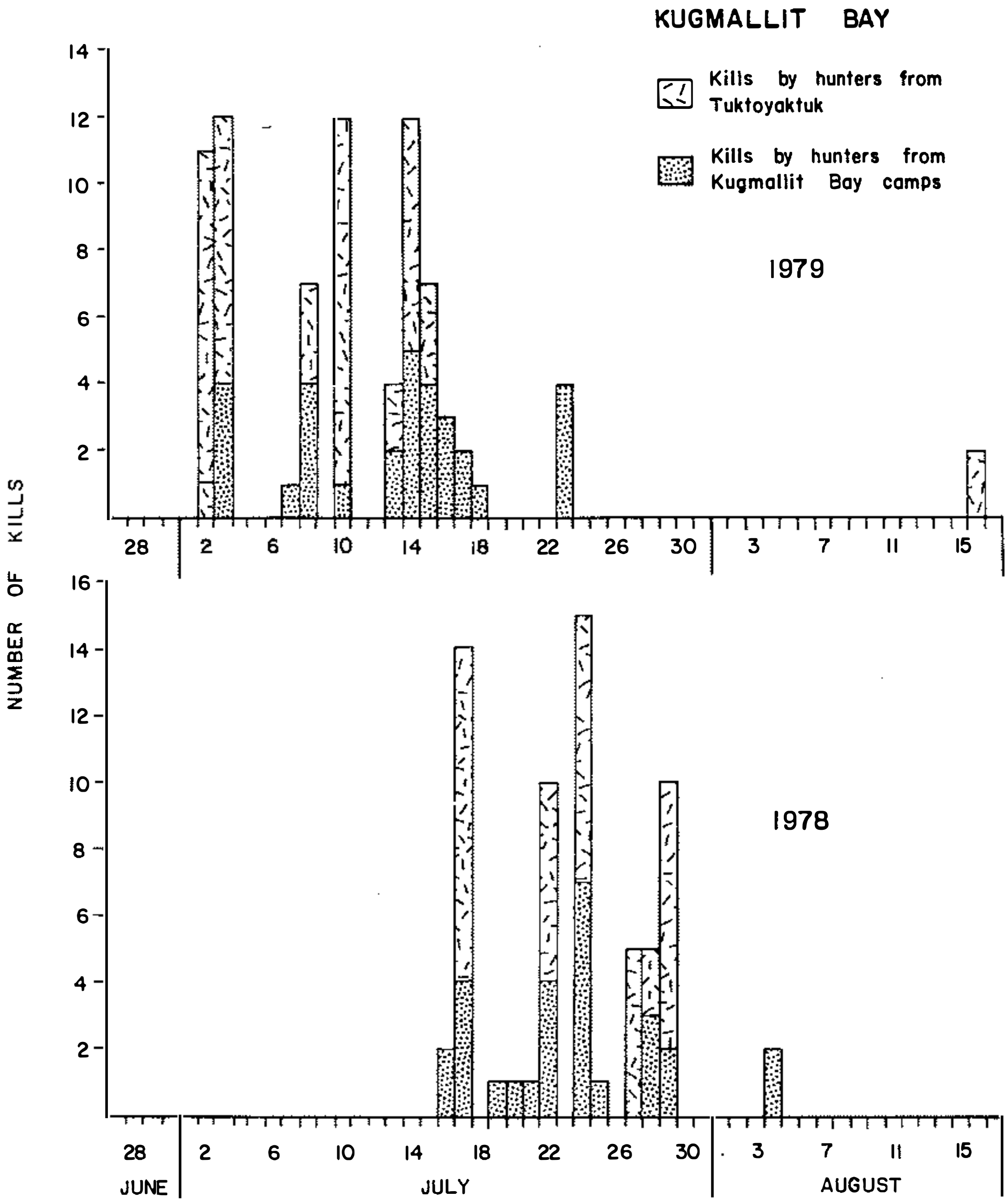

Figure 9. continued.

taken by hunters from the Kugmallit Bay camps was undoubtedly the result of a combination of factors. The late break-up of ice in Kugmallit Bay forestalled the early arrival of whales to that area. Once the whales did arrive, on 2 July, the weather made hunting impossible for much of the next week. There followed a period of intense hunting (33% of the whales taken in Kugmallit Bay on known dates were caught on 13–16 July), and the associated disturbance

Table 8. Numbers of white whales harvested in the Mackenzie estuary, 1972 – 1979. The number of whales landed is followed in parentheses by the percent of the total harvest.

	1972	1973	1974	1975	1976	1977	1978	1979	Mean Harvest 1972–1978
Tuktoyaktuk Community	45(40)	87(49)	40(33)	50(35)	51(33)	54(39)	53(44)	49(41)	54.3(39)
Kugmallit Bay Camps	31(27)	63(36)	50(41)	60(42)	59(38)	32(23)	28(23)	31(26)	46.1(33)
Kendall Island Camps	4(4)	7(4)	2(2)	3(2)	12(8)	30(21)	10(8)	12(10)	9.7(7)
Niakunak Bay Camps	33(29)	20(11)	30(25)	29(20)	32(21)	24(17)	30(25)	28(23)	28.3(20)
	113	177	122	142	154	140	121	120	138.4

may have caused the whales to leave the area earlier than usual. Only three whales were observed during the aerial survey on 16 July, and although the numbers increased again shortly afterward, the whales did not stay for long (Table 2; Figure 4). Several families did not arrive in the Kugmallit Bay camps until after the Northern Games were finished, and thus they missed the period of peak whale abundance. Hunters from Tuktoyaktuk generally were able to take advantage of the few good days when whales were present, and they obtained close to the average number of whales.

Four whales were caught in seal nets at Herschel Island this year between 16 and 28 July. Whales have been taken there in other years, but no detailed information is available for this area prior to 1979.

The maximum estimated number of whales present is not closely correlated with hunting success (r = -.776). Given good weather and the presence of whales in shallow water, Inuit hunters have the technology, knowledge, and skill to obtain whales even when few are present.

Two main factors can affect hunting success: the weather and the effort expended by the hunters. Because each of these factors has many dimensions, they are very difficult to measure. Therefore, a large amount of subjective judgment has been involved in the interpretation of year-to-year changes in the size of the harvest. As a first step in defining important variables to arrive at a more objective method of assessing the changes in the number of whales harvested, three measurable factors were selected. These are the number of hunters, the number of adults (hunters included), and the number of people (adults and children) that stayed at each of the whaling camps for part or all of the hunting season that year. These were then compared to the number of whales taken by each camp; only figures from 1978 were available for this analysis. A correlation coefficient was calculated to determine what proportion of the variation in the number of whales taken by the camps could be predicted using each measure. All three measures gave a high degree of prediction; the total number of people in camp gave an r value of 0.954, while for the number of hunters and for the number of adults, the r values were 0.909 and 0.948, respectively. These comparisons will have to be made for several years before useful conclusions can be drawn.

3.4 HUNTING LOSSES

For every 100 whales successfully landed, an estimated 50 are lost (Fraker 1980). Reasons for these losses have been compiled and are listed in Table 9. Although at this time we cannot reliably assess what percentages of the whales lost are attributable to the various reasons, it is possible to identify the major factors involved. Two factors, the type of available ammunition and harpooning after killing the whale, are clearly more important than the others. Hard-point bullets, which are increasingly more difficult to obtain, penetrate the blubber and flesh more effectively than the readily available expanding bullets. Of the ten ammunition manufacturers surveyed, two indicated they would supply hard-point bullets only if ordered in quantities of at least 500,000 rounds. The prohibitive size of the minimum order suggests that hard-point bullets will continue to be unavailable. The other major factor, that of harpooning after rather than before shooting the whale, is not easy to deal with because it involves a change in attitude on the part of the hunters. Harpooning afterward is preferred by most hunters because it is safer and easier.

Table 9. Reasons why whales are killed-and-lost (After Fraker 1980)

Reason	Remarks
MAJOR FACTORS	
Whale cannot be killed with available ammunition.	Currently available hunting ammunition consists of bullets that expand quickly and may not penetrate into vital areas of the whale. (See text for discussion.)
Whale is killed before it can be harpooned.	A whale shot before it is harpooned may be killed before the harpoon is attached. Such whales sink and are difficult to locate in the turbid estuary water.
MINOR FACTORS	
Rough water necessitates cutting loose the whale.	Wind may increase during a hunt so that waves break over the stern of a boat towing a whale. To keep the boat from sinking, the whale has to be cut loose.
Wounded whale evades hunters before it can be harpooned.	A wounded whale may evade hunters because they cannot detect the tract of the whale swimming underwater obscured by wind-generated waves.
Harpoon comes out of whale.	Under some conditions an alert hunter can set a second harpoon.
Harpoon line breaks.	A line may be accidentally severed by bullets or the the line may be weak.
Whale lost because of improper rifle calibre.	Rifles which shoot light, fast bullets tend to cause only superficial wounds that are not lethal.
Harpoon line too short.	Harpoon line may be too short to reach the whale from the boat.
Whale cannot be followed because of poor light.	Early in the hunting season, there is 24 h of sunlight per day, but later there may be inadequate light to enable wounded whales to be followed during certain times.

Harpooning before shooting is currently done by some concerned hunters because the chance of losing the whale is greatly reduced.

The effectiveness of different rifle calibres was examined in 1979 by calculating the mean number of shots required to kill a whale with each particular calibre (Table 10). Data from whales killed by two cooperating hunters using different calibre rifles were not included in the results. The .30/30 Winchester is clearly the most popular cartridge. Although this cartridge is considerably less powerful than the .270 or .308, hunters using the .30/30, on average, required only 0.7 more shots than those using the .270 and 2.2 fewer shots than those using the .308. These results may indicate hunters are more skilled in using the familiar .30/30 since this is the calibre rifle Inuit hunters have used the most. The large number of shots required by hunters using the .243 Winchester is probably indicative of the unsuitability of calibres using fast, light bullets. More data are required before reliable conclusions can be reached.

There are other changes in hunting materials and methods that could be made to reduce the number of whales lost, and these have been discussed by Fraker (1980). Certainly many hunters in the delta are aware of some of the problems and are concerned about making the changes necessary to bring about a reduction in the high proportion of losses. The high loss rate means that many whales are killed for no useful purpose and that the hunters' resources are expended without obtaining the desired whale products. In addition, whales in the three concentration areas are subjected to an unnecessary amount of disturbance. The significance to the whales of the concentration areas is not yet understood, but clearly these areas are of great importance (Fraker 1977; Fraker et al. 1978, 1979). Hunting activity in the concentration areas is necessary, but the additional disturbance from the extra hunting effort resulting from the high loss rate may have serious, insidious effects.

3.5 LENGTH AND SEX COMPOSITION OF THE HARVEST

The length and sex composition of the harvest provides some insights into the status of the Mackenzie stock of white whales. Alterations in either the average lengths or the ratio of males to females in the landed catch could indicate fundamental changes in the population. The harvest information can also be used to see if there is segregation of the whales within the estuary or over time according to age or sex. In considering these data, it must be kept in mind that the number of whales examined each year amounts to less than one percent of the total population and that the hunters bias their efforts toward taking large males.

The most striking feature of the catch is that the sex composition is heavily biased toward males (Table 11). The ratio is about 2.66 males per female, based on a sample of 149 males and 56 females examined from 1974 to 1979. This ratio is very different from 1:1, the ratio expected at birth ($z=6.43, p << 0.001$, normal-approximation-to-binomial test).

In 1979, there was a statistically significant increase, relative to 1974-1978, in the proportion of females in the harvest ($\chi^2 = 5.68$, df = 1, $p < 0.02$). We doubt that this represents a biologically signficant change in the population; when only a small proportion of the population is sampled, as with the Mackenzie white whales, there is a good chance that sampling errors will cause the observed sex ratios to differ from year to year. The harvest should be carefully monitored in subsequent years to determine if there is a trend. For the other analyses this year, except where indicated, no significance was attached to the higher percentage of females in the 1979 harvest and the data were lumped with those gathered in previous years.

The tendency to select males over females has occurred in several white whale fisheries (Sergeant and Brodie 1969). For data collected in the Mackenzie delta region, mainly during the 1950's, Sergeant and Brodie show a sex ratio of 94 males: 32 females. This ratio (2.94) is not significantly different from that of our recent (1974–1979) observations ($\chi^2 = 0.15$, df = 1, $p = 0.7$).

Several factors contribute to a bias toward males in the harvest. Most hunters avoid taking females accompanied by calves. Many hunters also select larger animals, which are often males. A possible spatial separation of the sexes may also contribute to the bias.

Figure 10 shows the effects of a harvest regime of 80% males, slightly more than the 73% for pooled data from 1974–1979, on sex composition of the herd under a very simplified set of assumptions. It assumes that annual recruitment into the huntable population exactly balances the number of animals killed each year in the hunt plus those lost to natural mortality, which is assumed to be the same for both sexes. It also assumes that there are no changes in the production of calves, and hence no increase in population size, despite the increasing proportion of females, and that the same biased selection of males continues even as the percentage of males decreases. Although these assumptions obviously cannot remain valid until the males are extirpated, and thus the assumptions exaggerate the possible rate and degree of change, it is clear that such selection could rapidly affect the sex composition of the Mackenzie white whale stock. Yet, until 1979, there was no indication of a change in the sex composition of the harvest. Although the 1979 data are statistically different from those collected during 1974–1978, they are only marginally different from those reported by Sergeant and Brodie (1969) for an earlier period (see above, $\chi^2 = 3.55$, df = 1, $0.05 < p < 0.1$).

On the basis of what is known about the social structure and behaviour of other odontocete whales, such as pilot and killer whales, it is likely that one male mates with several females. Breeding in white whales appears to take place once every three years (Brodie 1971); thus, slightly more than one third of the adult females (allowing for those that lost calves before weaning) need to be mated each year. Therefore, the tendency of the hunters to select males probably acts to increase the production of calves by increasing the proportion of females in the population. However, a high level of calf production can be maintained only as long as all eligible females can be mated by the available males.

Potentially acting against a high proportion of males in the harvest is the probability that as the proportion of males becomes greatly reduced, the hunters will tend to take a larger proportion of females, either deliberately or inadvertently. It is also possible that some sort of compensatory increase in non-hunting mortality of females (and/or decrease in non-hunting mortality of males) might tend to push the sex ratio of the population toward unity. It

Table 10. Number of shots required to kill a whale for rifle calibres used, Mackenzie estuary, 1979.

Rifle Calibre		Number of Kills Observed	Number of Shots to Kill Whale Mean ± SD
.270	Winchester	5	4.8 ± 2.3
.30/30	Winchester	30	5.5 ± 5.1
.308	Winchester	3	7.7 ± 4.5
.243	Winchester	3	10.0 ± 8.9

Table 11. Sex of harvested whales, Mackenzie estuary, 1974 – 1979.

Year	Number of females examined	Number of males examined	% females
1974	7	16	30
1975	4	13	24
1976	7	36	16
1977	8	13	38
1978	7	35	17
1979	23/56	36/149	39

Table 12. Means and standard deviations of lengths of harvested whales according to sex, Mackenzie estuary, 1974 – 1979.

Year	Males			Females		
	$\bar{x}$	SD	N	$\bar{x}$	SD	N
1974	423.3	±58.9	16	368.6	±28.4	7
1975	429.9	±34.2	13	366.8	±17.3	4
1976	429.8	±29.4	35	414.0	±28.5	7
1977	436.6	±31.7	12	365.0	±18.1	3
1978	424.8	±23.1	18	358.8	±17.0	4
1979	423.7	±26.6	25	374.9	±32.7	17

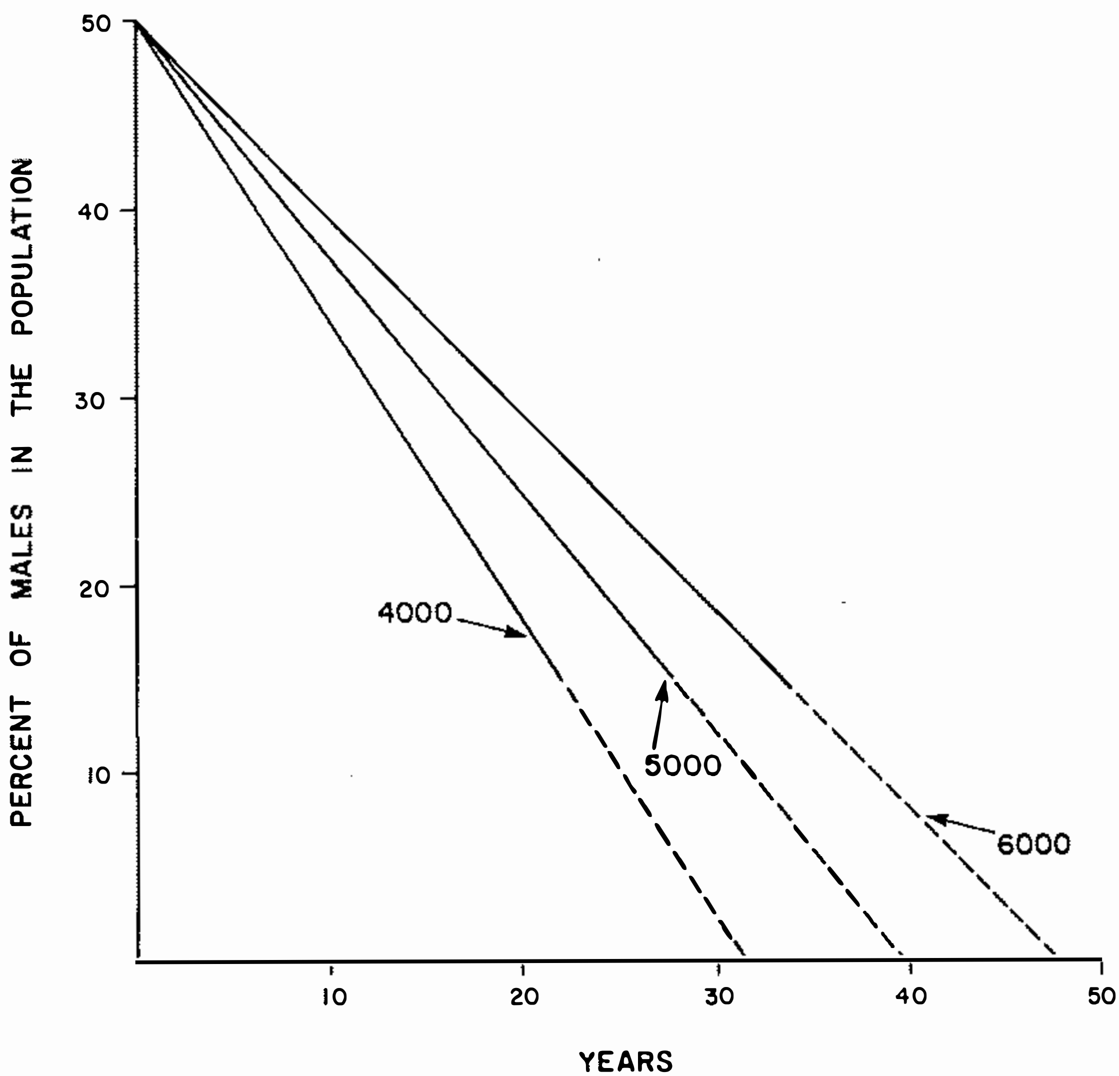

Figure 10. Hypothetical change in sex composition of whale stocks of three sizes; assuming constant stock. size, an initial sex ratio of unity, annual removals of 168 males and 42 females, and recruitment of 210 (sex ratio 1:1) replacements. (From Fraker 1980)

is significant that this selection for males has occurred at a similar rate for at least the past 25 years, yet it is still possible for hunters to take predominantly males. Unfortunately, there is no means for determining the sex ratio of the Mackenzie stock at large.

The yearly mean lengths of male whales landed and measured during the past six years have varied from 423.3 to 436.6 cm (Table 12; Figure 11). There is no year-to-year trend in lengths of harvested males, and an analysis of variance indicates no statistically significant difference between years ($F = 0.346$; df = 5, 113; $p > 0.20$).

The yearly mean lengths of female whales landed and measured during the same period have ranged from 358.8 to 414.0 cm (Table 12; Figure 11); these differences are statistically significant ($F = 3.04$; df = 5, 36; $p < 0.05$) because of the unusually high mean length in 1976 (Table 12). Few females were measured in any year, and the differences between annual

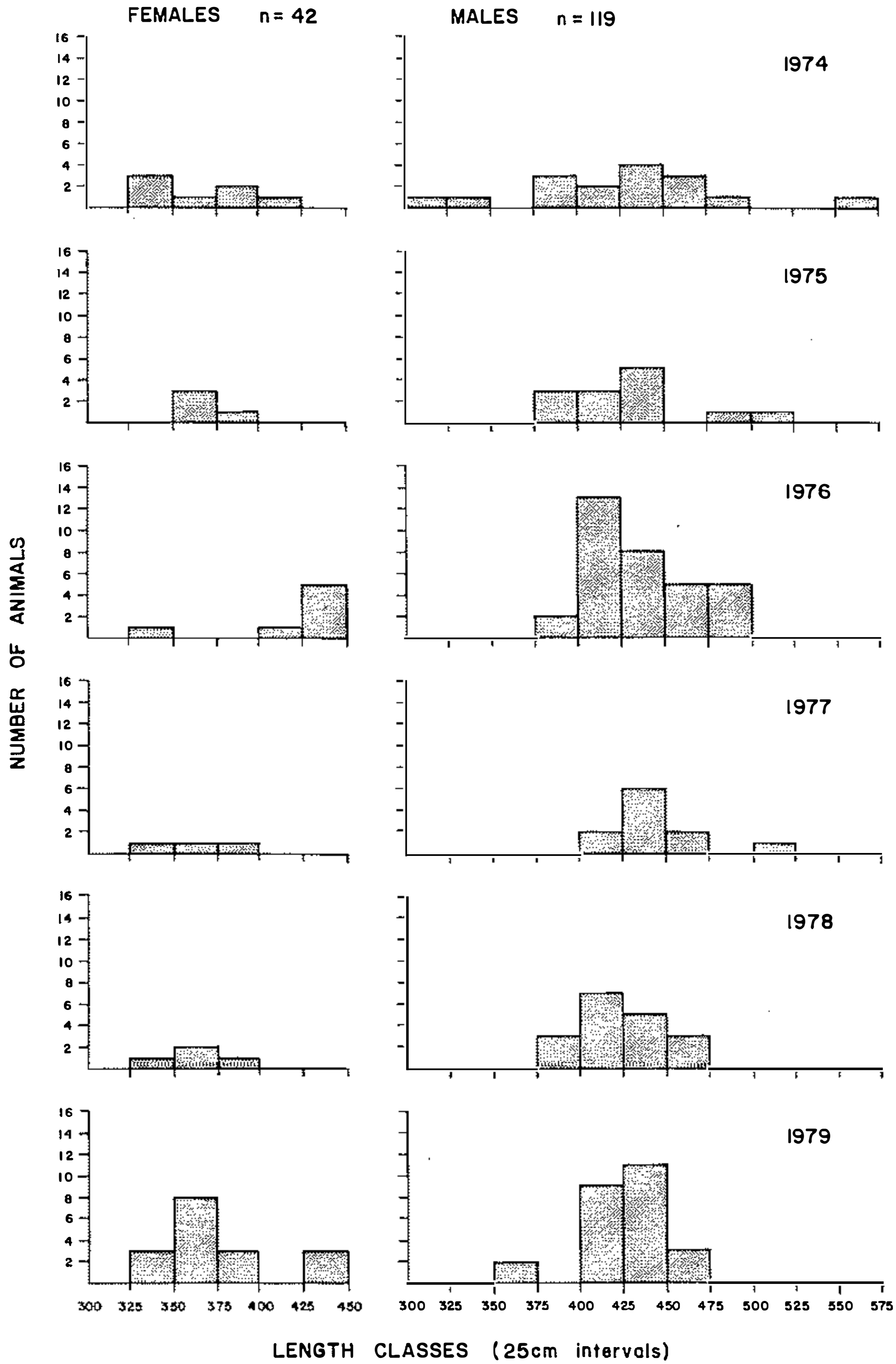

Figure 11. Length frequencies of whales harvested in the Mackenzie estuary, 1974–1979.

mean lengths are not biologically significant.

White whales might segregate themselves geographically or temporally according to age or sex. To examine the possibility of geographical segregation within the Mackenzie estuary according to age (= length), the available lengths of females and males harvested from different areas during 1977 through 1979 were compared (Table 13). Comparing the lengths of whales harvested in Niakunak and Kugmallit Bays and near Kendall Island, there were no statistically significant differences ($F= 2.135$, $df = 2, 22$, $0.10 < p < 0.20$ for males; $F= 1.912$, $df=2, 14$, $0.10 < p < 0.20$ for females). The percentage of harvested whales that were females was similar in Niakunak and Kugmallit Bays (Table 14; $\chi^2 = 0.005$, $df = 1$, $p > 0.9$) and so the data from these areas were summed. However, the percentage of the harvest that was females was greater near Kendall Island than in the two other areas combined (Yates corrected $\chi^2 = 6.10$, $df = 1$, $0.01 < p < 0.025$).

To test for temporal segregation, the 1978 and 1979 hunting periods were divided into two equal parts: 27 June to 14 July and 15 July to 2 August for 1979, and 7 to 17 July and 18 to 29 July for 1978. Dates of kills were unavailable for other years. As Table 15 clearly indicates, there was no temporal effect on the sex ratio of the harvest ($\chi^2 = 0.02$, $df = 1$, $p > 0.8$), nor was there an apparent temporal segregation according to age (= length) ($t = 0.377$, $df = 23$, $p > 0.50$ for males; $t = 1.365$, $df = 15$, $0.10 < p < 0.20$ for females).

Temporal segregation according to sex has been found for white whales in western Greenland (Degerbøl and Nielsen 1930) and in Tugur Gulf in the Sea of Okhotsk (Kleinenberg et al. 1964), for grey whales (Rice and Wolman 1971), and for humpback whales (Dawbin 1966), but not for white whales within the Mackenzie estuary. However the statistically greater percentage of females in the harvest taken by Kendall Island hunters suggests that geographical segregation according to sex may occur.

Table 13. Mean lengths of harvested whales according to sex and area, Mackenzie estuary, 1977 – 1979.

Area	Males		Females	
	$\bar{x}$	N	$\bar{x}$	N
Kugmallit Bay	430.60	11	371.25	5
Kendall Island	390.14	2	361.84	7
Niakunak Bay	424.94	12	396.85	5

Table 14. Sex of harvested whales according to area, Mackenzie estuary, 1977 – 1979.

Area	Males Killed	Females Killed	% Females
Kugmallit Bay	36	13	26.5
Kendall Island	8	11	57.9
Niakunak Bay	40	14	25.9

Table 15. Sex of harvested whales according to date of harvest, Mackenzie estuary, 1978 – 1979.

	Males Killed	Females Killed	% Females
First Half Hunting Period	44	19	30.2
Latter Half Hunting Period	27	11	28.9

PART 4

BOWHEAD WHALES

4.1 SPRING MIGRATION

Available data indicate that bowhead whales migrate far offshore in the Beaufort Sea en route from wintering grounds in the Bering Sea to summering grounds in the southeastern Beaufort Sea region (Fraker 1979; Braham et al. 1980). It is consistent with this hypothesis that a small number of late-migrating whales should leave the pack ice, intercept the lead along the Tuktoyaktuk Peninsula, and follow it east. This could explain the two eastward-moving bowheads that were seen on 20 June 1979 (Figure 3a). Both were swimming along the seaward edge of the landfast ice, one north of Atkinson Point and the other about 20 km west of Baillie Islands. Another eastward moving bowhead was along the edge of the landfast ice north of Atkinson Point on 22 June. Two more bowheads were seen along the landfast ice north of Nuvorak Point on 1 July (Figure 3b); these whales were separated by about 20 km. One was headed northeast, the other southwest.

The most obvious explanation for the presence of northeastward-moving bowheads along the landfast ice lying off the Tuktoyaktuk Peninsula is that they were on the last leg of their spring migration. However, another explanation is possible for 1979. In other recent years (1973–1978), there have been large amounts of open water in Amundsen Gulf in June (Marko 1970; Fraker 1979, unpubl. data). In 1979, in contrast, Amundsen Gulf was completely ice covered until early July. Thus, bowheads observed along the ice edge in 1979 may have been feeding or searching for food.

4.2 SUMMER RANGE

Little new information on the bowheads' summer range was gained in 1979, because only two sightings were recorded. One bowhead was observed 70 km north of Warren Point during an aerial survey on 8 August. Capt. J.W. Kavanagh (*Imperial Sarpik,* pers. comm.) reported seeing at least six bowheads moving west in 12.6 m of water on 9 September at approximately 69° 51'N lat., 133°34'W long., which is about two thirds of the distance from Tuft Point to Issungnak artificial island. When the *Sarpik* was within about 800 m, the whales sounded (dove). Using sightings from Esso whale monitoring programs (1976–1978) and observations contained in ten logbooks of cruises of whaleships in the eastern Beaufort Sea from 1891–1906, Fraker and Bockstoce (1980) have stated the current understanding of the bowheads' summer range. This paper is printed here in full with the permission of the editor of *Marine Fisheries Review,* where it will appear in early 1980.

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SUMMER DISTRIBUTION OF BOWHEAD WHALES IN THE EASTERN BEAUFORT SEA

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Abstract. The pattern of distribution of the western Arctic stock of bowhead whales on its summer range in the eastern Beaufort Sea region was examined using sightings made from commercial whaleships (1891–1906) and recent (1974–1978) observations. The results indicate that Amundsen Gulf and the southern Beaufort Sea east of Herschel Island north to a depth of about 50 m are important to bowheads. There is a westward shift of the range of the stock over the summer from the Cape Bathurst area and Amundsen Gulf to the Mackenzie delta region. The summering area is probably an important feeding ground.

INTRODUCTION

Nearly all bowhead whales *(Balaena mysticetus)* of the western Arctic stock migrate each spring from wintering grounds in the Bering Sea to summering grounds in the eastern Beaufort Sea and Amundsen Gulf where they stay for up to four months (Fraker et al., 1978; Fraker, 1979). The whales begin their spring journey soon after ice conditions permit (late April) and they remain on the summering grounds until near freeze-up. Although the summering area must be of major significance in the ecology of these animals, little is known about its geographical extent or the reason for its importance.

Our purpose is to describe the geographical area used by the bowheads during the July-September period (based on the locations of sightings and kills made by commercial whalers near the turn of the century and on recent observations) and to suggest an explanation of the significance of this area to these animals.

METHODS

Whaleship Observations (1891–1906)

Because there are few recent sightings of bowheads from the eastern Beaufort Sea and Amundsen Gulf, the best information about bowhead distribution comes from logbooks kept by commercial whalers who operated extensively in this region from 1890 to about 1910 (Bockstoce 1977). The locations and dates of sightings and captures have been extracted from original logbooks (held by the Whaling Museum, Old Dartmouth Historical Society, New Bedford, Massachusetts; the Providence (Rhode Island) Public Library; and Harvard University) of vessels operating in the eastern Beaufort Sea from 1891 to 1906 (Table 1). The only logbooks selected were those of cruises which took place entirely in the eastern Beaufort Sea region, and thus were preceded and followed by overwintering in the Arctic. We selected these records to ensure that the searches by the whalers spanned the greatest possible time period in this region. Because of ice conditions to the west, near Point Barrow, Alaska, vessels from "outside" were unable to arrive in the eastern Beaufort Sea before August, and vessels intending to leave the Arctic had to pass Point Barrow by early September (Cook, 1926; Bodfish, 1936; Bockstoce, 1977). We used data from only one cruise per year in order to minimize biases which might have resulted from peculiar conditions of particular years. We would have preferred to use data from one cruise from each year of the commercial fishery in the Beaufort Sea, but unfortunately, for certain years documents meeting our requirements have not survived.

Commercial whalemen, when cruising in waters familiar to them, generally determined their position from landmarks. They usually recorded their position once each day in the logbooks, but under foggy conditions position was determined less often. In plotting data from the logbooks, we sometimes had to estimate the ship's position on a given day using previous and subsequent positions, information on the ship's speed and course, and the recorded water depth. We have firsthand familiarity with the region and believe that most records have been plotted to an approximate accuracy within 20 km (10 naut. mi.). Observations from uncertain locations were omitted.

Table 1. Vessel, logbook keeper, year, and wintering location (prior to cruise of the eastern Beaufort Sea whaling grounds).

Vessel	Logbook Keeper	Year	Wintering Location
Mary D. Hume	H.H. Bodfish	1891	Herschel Island
Mary D. Hume	H.H. Bodfish	1892	Herschel Island
Newport	H.H. Bodfish	1894	Herschel Island
Newport	H.H. Bodfish	1895	Herschel Island
Mary D. Hume	G.B. Leavitt	1896	Herschel Island
Beluga	H.H. Bodfish	1898	Langton Bay
Beluga	H.H. Bodfish	1899	Baillie Islands
Narwhal	G.B. Leavitt	1903	Herschel Island
Karluk	Unknown	1905	Herschel Island
Alexander	J.A. Tilton	1906	Herschel Island

Recent Observations (1974–1978)

Recently, several persons have recorded sightings of bowheads in the eastern Beaufort Sea, and these data provide additional insight into the whales' use of certain areas and the timing of their movements.

From 1976 to 1978, sightings were recorded on whale sighting forms supplied to personnel working for Esso Resources Canada Limited on offshore oil and gas exploration projects in and near the Mackenzie estuary; other sightings were made during aerial surveys of whales in the Mackenzie region. Additional observations were obtained from the field notes of various scientists and from interviews with local inhabitants. Most records included date, location, estimated numbers, and direction of movement (if any).

RESULTS

Whaleship Observations (1891–1906)

To conveniently discuss the observations, the study region has been divided into three areas: the Mackenzie Zone, the Bathurst Zone, and Amundsen Gulf (Figure 1). Most (67%) of the captures and sightings made from commercial whaling vessels occurred in the Bathurst Zone, with 27% and 6% made in the Mackenzie Zone and Amundsen Gulf (Table 2).

The whalers' period of observation generally extended from the second week in July, when the ships were first able to leave winter quarters, to the latter half of September, when the ships were made ready for overwintering (Cook, 1926; Bodfish, 1936; Bockstoce, 1977). Most (64%) observations of bowheads were made in August (Table 2). Substantial numbers were also encountered in the latter half of July (9%) and the first half of September (16%). Thus, the main period of activity of the whaleships was from mid-July to mid-September.

Nearly all observations made before mid-August were from the Bathurst Zone and Amundsen Gulf (Figure 2; Table 2). After mid-August substantial numbers of whales were also recorded in the Mackenzie Zone. The apparent absence of whales from the latter area early in the season probably is real. Most vessels overwintered at Herschel Island (Table 1) and passed through the Mackenzie Zone while travelling to the whaling grounds; in addition, they usually returned to Herschel once or twice during the summer for supplies or repairs. Whales in Amundsen Gulf were observed only in August. Whales were seen in the Mackenzie Zone through September with a single record from early October. Figure 1 and Table 2 both demonstrate a westward shift in the range of the bowhead population during the course of the season. As described below, the records in Amundsen Gulf in the latter parts of the season reflect an eastward shift in hunting effort during the 1900's rather than a pattern of temporal change in whale distribution.

A large reduction in the whale stock is indicated by the number of observations per year before and after 1900 (see Bockstoce, 1980). During the seven cruises preceding 1900, there were 259 observations (37/cruise), whereas during the three cruises after 1900, there were only 24 observations (8/cruise). However, all records from Amundsen Gulf were made after 1900. Thus, the prosecution of the hunt appears to have been carried further east late in the whaling era, after this stock of bowheads had been greatly reduced.

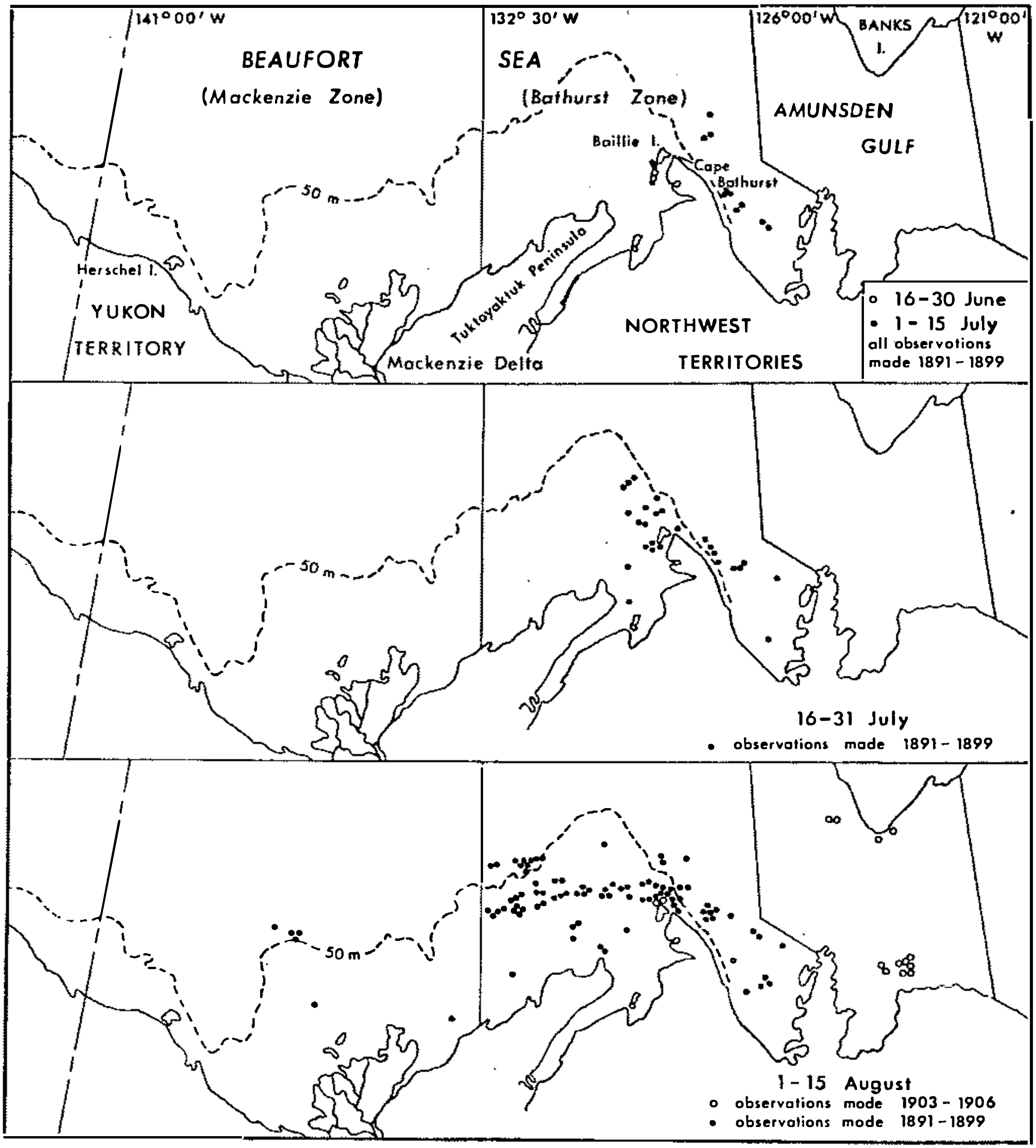

Figure 1. Locations of bowhead whale observations made from whaleships, 1891–1906. Each symbol represents an observation of one or more whales.

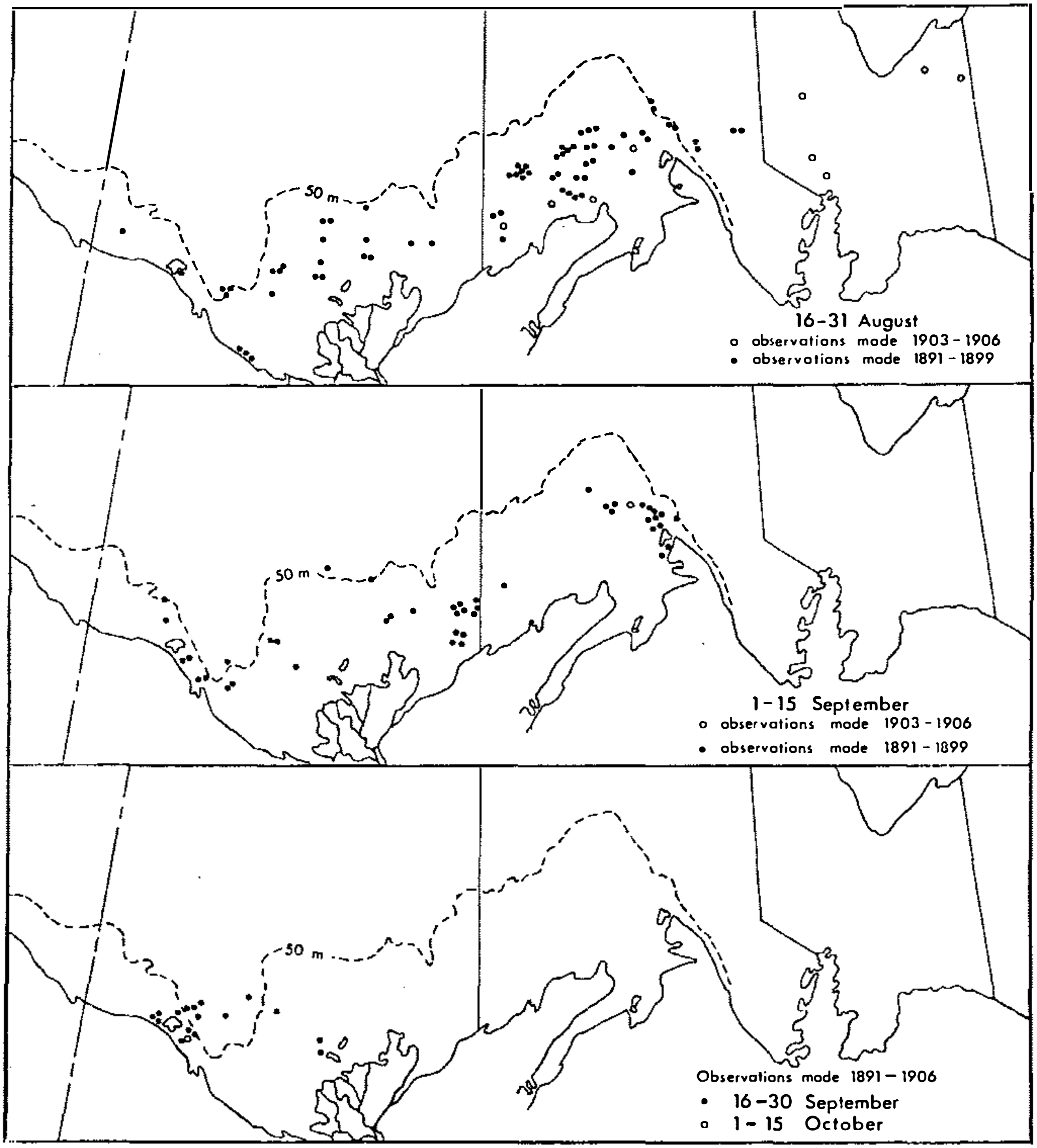

Figure 1. Continued.

Table 2. Area, time period, and number of bowhead whale observations made from whaleships, 1891–1906.

Area	Time Period								Totals
	16-30 June	1-15 July	16-31 July	1-15 Aug.	16-31 Aug.	1-15 Sept.	16-30 Sept.	1-15 Oct	
Amundsen Gulf	–	–	–	12	5	–	–	–	17
Bathurst Zone	2	13	26	86	47	16	–	–	190
Mackenzie Zone	–	–	–	6	24	28	17	1	76
Totals	2	13	26	104	76	44	17	1	283

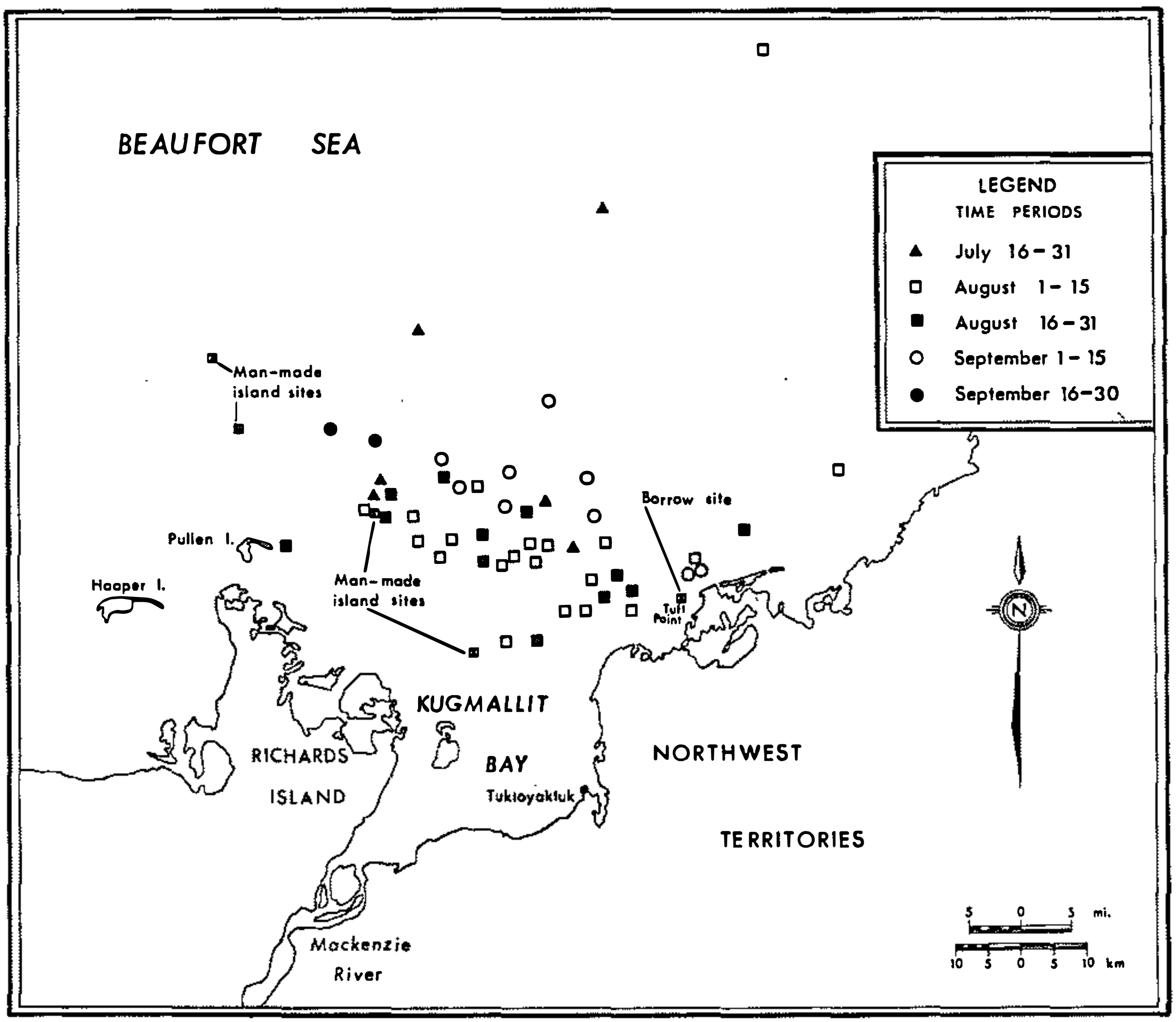

Figure 2. Bowhead whale observations in the Mackenzie estuary region of the Beaufort Sea, 1976–1978.

Recent Observations (1974–1978)

Bowhead whales have been seen regularly in and north of Kugmallit Bay from 1976 to 1978 by personnel on boats and by aerial surveyors (Figure 2). Boat activities began by about mid-July in all years and aerial surveys began by 1 July. The first observations in this region were on 3 August in 1976 and on 26 July in both 1977 and 1978. Aerial surveys continued to mid-August in each year, and boats continued to operate offshore until late October in 1976 and 1977 and to the end of September in 1978. The last dates on which whales were observed were 16 September in 1976, 17 September in 1977, and 14 September in 1978. Because there was a good potential to make observations before and after the time span during which whales were seen, the first and last dates of observations probably define fairly accurately the period during which bowheads were in this area.

The directions of movement of bowheads in the Mackenzie estuary region differed between the periods 26 July–31 August and 1–17 September (Figure 3). Because of the small number of observations (N= 38) and the low numbers observed travelling in certain directions, the observations from each of these periods were catagorized as having either an easterly or a westerly component and a 2 x 2 contingency table was constructed. There was a statistically significant difference in directions of movement between the early and late time periods (Yates' corrected $\chi^2 = 4.83$, df = 1, $p < 0.05$).

The directions of movement also appear to differ from a uniform distribution within each time period, but there are too few observations for a meaningful statistical analysis. From 26 July – 31 August, more whales were oriented N-ENE than in any other directions; but in September, most were oriented W-NNW (Figure 3).

There has been a relatively large number of recent observations of bowheads along the Yukon coast between Shingle Point and Kay Point during August and September (Figure 4). Each of these sightings was of one to seven individuals. Most were within 3.2 km (2 mi.) of the shore. On 13 September 1976, a minimum of 33 was observed in the area between Shingle Point and Kay Point (William Koski, Biologist, LGL Limited, Edmonton, Alberta, T5N 1P6, pers. commun., 14 September 1976).

Mr. Don McWatt (resident, Aklavik, N.W.T., XOE OAO, pers. commun., July 1976), on about 31 August 1975, observed four bowheads as he walked along the beach from Sabine Point to Shingle Point. They were swimming southeastward along the coast at the rate of a man walking. The whales were observed for about an hour, during which time they made several dives, each with an estimated duration of 10–15 min. Mr. McWatt suspected that these animals may have been feeding.

Not shown on Figure 4 are observations made by Mr. and Mrs. George Allen (residents, Aklavik, N.W.T., XOE OAO, pers. commun., July 1976) who regularly camp at

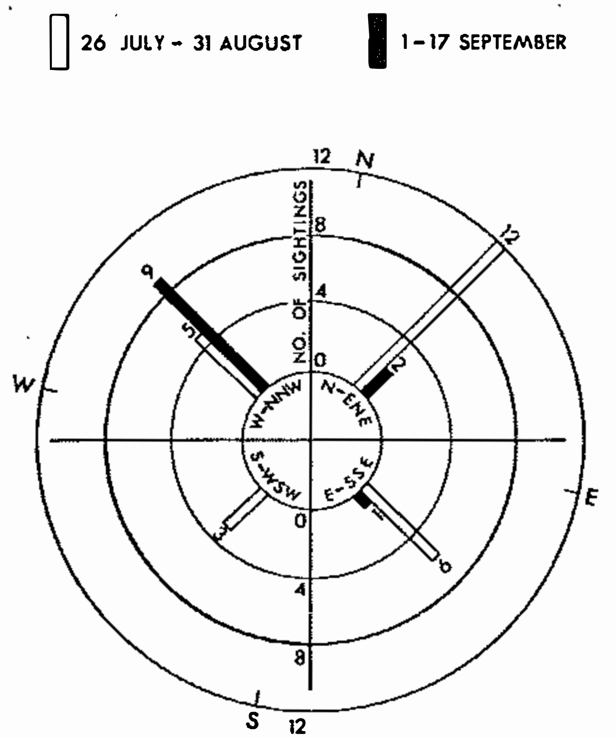

Figure 3. Direction of movement and time period of bowhead whale observations in the Mackenzie estuary region, 1976–1978.

Shingle Point and travel along the Yukon coast from early July to about mid-September. They say that bowheads usually appear in this area in late August or early September. Commonly the bowheads approach to within a few metres of the beach.

DISCUSSION

The whalemen made the majority (67%) of their sightings and captures in the Bathurst Zone, particularly near Cape Bathurst (Figure 1). The lesser importance to them of the Mackenzie Zone is particularly significant because most cruises began from Herschel Island (Table 1), and the vessels hunted while passing through this area en route to the Cape Bathurst "whaling ground" (Cook, 1926). It was not until after mid-August that many whales were recorded from the Mackenzie Zone (Table 2). The failure of the whalers to find whales west of the Cape Bathurst area until after July adds support to the theory that this stock undertakes its eastward spring migration relatively far offshore, rather than along the coast (Braham and Krogman, 1977; Fraker el al., 1978; Fraker, 1979).

The observations from Amundsen Gulf were all made after the turn of the century (Figure 1). Until that time, the whalers had concentrated their attention on the productive whaling ground near Cape Bathurst and westward to near Herschel Island. But as the number of whales in the stock was reduced, the whalers extended

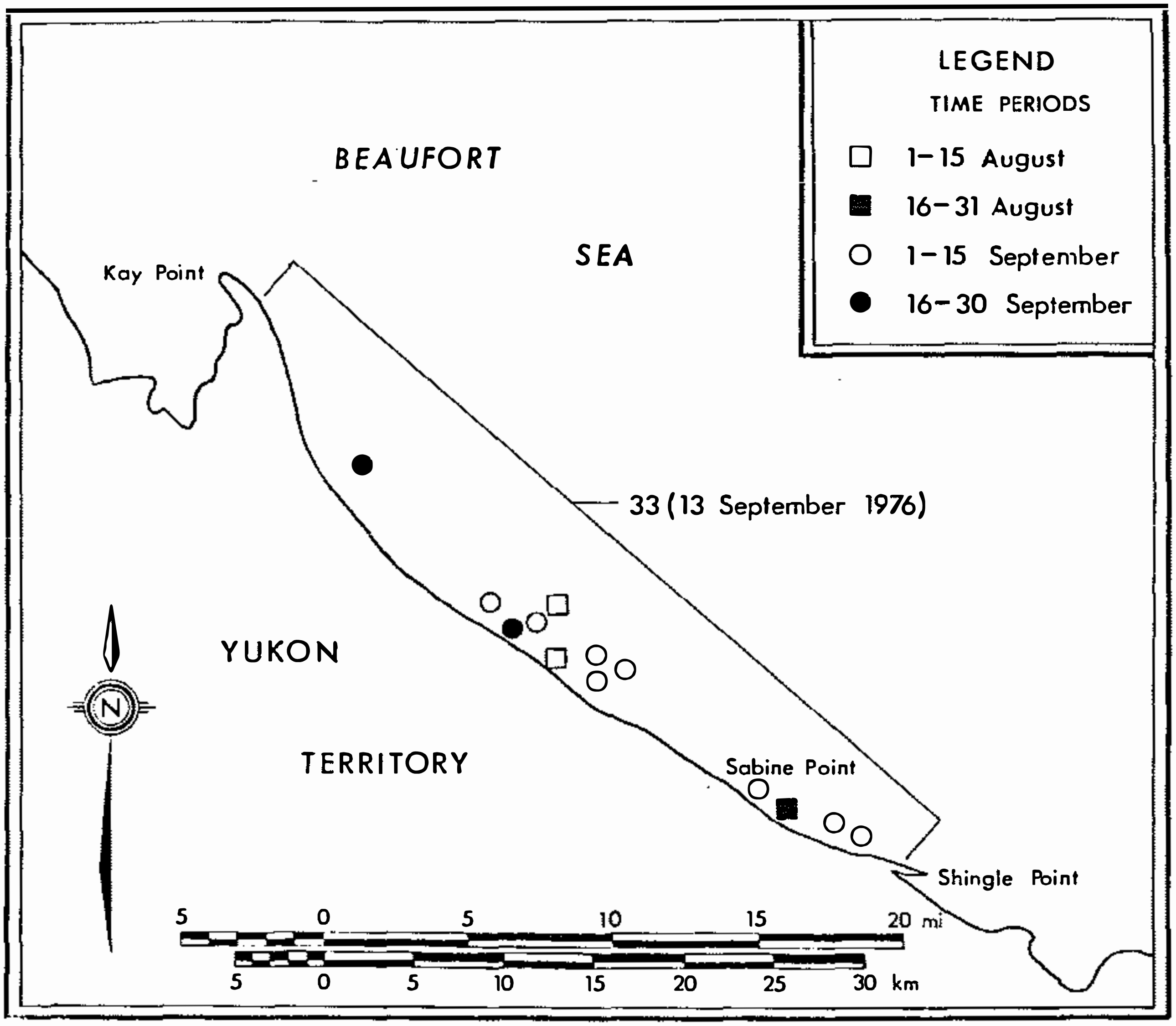

Figure 4. Recent bowhead whale observations along the Yukon coast, 1973 – 1976. Each symbol represents an observation of one or more individuals, except for a minimum of 33 whales which were observed on 13 September 1976 between Kay Point and Shingle Point.

their searches eastward. Cook (1926) also hunted further eastward during this period, but not before, and he reported several sightings near Nelson Head in August of 1903 and 1905. Cook's sightings have been plotted by Fraker et al. (1978).

During the 1900's more observations (17) were made in Amundsen Gulf than in the formerly productive areas of the Bathurst Zone (7) (Figure 1). Thus it is possible that at least certain parts of Amundsen Gulf (e.g. near Cape Parry, Nelson Head, and Cape Lyon) may have been proportionately (according to size) as important as the heavily used parts of the Bathurst Zone. Sightings from Amundsen Gulf did not appear in the 1890's data, apparently because the whalers did not need to travel that far east to catch whales. This assumes, as seems likely to us, that animals of the western Arctic stock used the entire summer range and that there were no substocks restricted to limited areas. The currently available data are insufficient to define well the distribution within Amundsen Gulf or to estimate the relative importance of various parts of this area compared to the Bathurst Zone.

If the Amundsen Gulf area is under-represented in our sample, the Bathurst Zone and, to a lesser extent, the Mackenzie Zone are over-represented. This kind of bias is common in fishery-type data because of the tendency for fishermen (and whalers) to locate particularly productive areas which they continue to exploit. Tradition and uncertainty inhibit them from switching to other areas. Capt. Bodfish, on the other hand, frequently sought new whaling grounds, extending his searches beyond those of most of his contemporaries; because six of his logbooks provided data for this study, the degree of bias in Figure 1 and Table 2 is reduced.

In the Bathurst Zone, bowheads were observed out to a depth of about 50 m or 25 fathoms (Figure 1). It was in this "20–25 fathom ground" that Capt. Bodfish was particularly successful in pursuing bowheads (Bodfish, 1936; Bockstoce, 1977). Bodfish was a careful and observant individual who not only searched a wide area, but also was comparatively systematic in recording his observations. For example, he took soundings of depth where whales were taken, and the observations which are farthest north of the Tuktoyaktuk Peninsula on Figure 1 were his. Thus, his observations are particularly important in defining the probable extent of the outer boundary of the summering grounds in this area.

The data clearly indicate a westward shift of the bowhead population as the open-water season proceeded (Figure 1; Table 1). Within the Bathurst Zone, the earliest records(late June and early July) were concentrated near Cape Bathurst, but later (August and early September) records tended to be farther west. Although the vessels which had overwintered at Herschel Island operated first in the Mackenzie Zone, no whales were sighted there until early August, and most were observed in the latter half of August and in September (Table 2). The latest record, from near Herschel Island, was made on 2 October 1891.

The relatively few whalers' records from Amundsen Gulf were made only in August (Figure 1; Table 2). Recent records show that some bowheads are present in the eastern Beaufort Sea and Amundsen Gulf by mid-May (Fraker et al., 1978; Fraker, 1979). Thus, the lateness of the whalers' first observations was a consequence of their inability (owing to ice conditions) to reach this area early in the season, and the earliest dates do not reflect the time of arrival of the first whales in this region.

Observations during 1976–1978 suggest that the present pattern of use of the eastern Beaufort Sea by bowheads is similar to that recorded three-quarters of a century ago. Many of the recent sightings were made from vessels operating between Tuft Point, a source of granular fill material, and the sites of man-made islands (Figure 2); the locations and dates of these observations are similar to what would be expected from running a transect across the distribution shown in Figure 1.

The earliest recent sightings in the Kugmallit Bay area have come in the last week of July in 1977 and 1978 and in the first week of August in 1976; the earliest whalers' sightings in this area were in the latter half of August, with a single exception in the first half of the month (Figure 1). We doubt that there has been any change in the basic pattern of utilization of this area by bowheads. It seems likely that the western part of the study area was poorly searched in early August by the whalers because they were expending most of their effort near Cape Bathurst and in the "20–25 fathom ground" which was highly productive at this time (Figure 1; Table 2). The latest observations by the whalers in this area were in the first half of September, and this fits well with the mid-September dates when the latest recent observations were made.

Directions of movement differed significantly between the 26 July–31 August period and the 1–17 September period in 1976–1978 (Figure 3). During the earlier period, animals moved in all quadrants, but particularly those with an easterly component. Why such a large proportion should head eastward at this time is not clear. In September, nine of 12 sightings were of bowheads moving W-NNW. Whales moving in these directions would eventually leave the Beaufort Sea, and we suspect that such movements are part of the fall migration.

The data available on direction of movement may not be representative because of the relatively small number of observations or because of movements which were too far offshore to be recorded. However, the strong tendency of September movements to be W-NNW suggests that these were migrational movements.

Bowheads apparently spend little time in the Beaufort Sea north of Alaska. The whalers passed through this area regularly en route to the eastern Beaufort Sea, but they rarely encountered whales there. As whalers left the whaling grounds late in the season they sometimes saw whales. These whales were apparently making a passage westward at this time, and logbook entries such as "...whales going quick..." were typical.

The eastern Beaufort Sea region is clearly of major significance to bowhead whales, but the reasons for this are unknown. We believe that the most reasonable hypothesis is that this constitutes an important feeding area. The occurrence of long migrations to summer feeding grounds is common among the great whales (Dawbin, 1966; Rice and Wolman, 1971; Small 1971; Matthews, 1978). One way to assess this conjecture is to examine the relationship between bowhead distribution, as shown in Figure 1, and biological productivity.

In examining the relationship between productivity and distribution of Antarctic whales, Gulland (1974) compared whale abundance (from harvest records) with primary productivity and zooplankton standing crop. He found a closer correspondence with zooplankton standing crop, presumably because whales eat zooplankton.

Between 1971 and 1975, Grainger (1975) studied zooplankton abundance in the southern Beaufort Sea from about the Alaska-Yukon border to the eastern tip of the Tuktoyaktuk Peninsula and north to about 71°N latitude. He found the highest zooplankton standing crops north of the Tuktoyaktuk Peninsula, within the area which Figure 1 indicates to be highly important to bowheads. Unfortunately, neither the area near Cape Bathurst nor Amundsen Gulf, both of which may be of particular importance to the bowheads, has been studied.

Along the Yukon coast, where there are several recent records of bowheads, there are few data on zooplankton abundance. However, in the nearshore areas from Herschel Island to Shingle Point, Hsaio et al. (1977) found levels of primary productivity four to 10 times higher than elsewhere in the southern Beaufort Sea, and this may be reflected in the abundance of zooplankton in this area, upon which bowhead whales depend.

In discussing the major factors influencing primary production in the southeastern Beaufort Sea, Grainger (1975) identified the attenuation of light by turbidity as the limiting factor in the Mackenzie River plume, and a lack of nitrate in waters outside the turbid plume. The Mackenzie contributes a relatively large amount of nitrate to the Beaufort Sea system, but this is quickly consumed when the turbidity diminishes to the point that the water becomes euphotic. Although the overall circulation of water offshore in the Beaufort Sea is clockwise, there is a generally northeastward movement of water in the southeastern Beaufort Sea owing to the Coriolis force (Herlinveaux and de Lange Boom, 1975). Mackenzie River water tends to flow northward as it discharges into the Beaufort Sea, but it is drawn northeastward into the general coastal movement so that it flows parallel to the Tuktoyaktuk Peninsula toward Amundsen Gulf. The further the water gets from the river mouth, the lower the turbidity, the greater the penetration of light, and the greater the primary productivity, until the nitrates are depleted. The volume of water discharged from the Mackenzie is greatest in late June to mid-July, and turbidity is also highest at this time (Fraker et al., 1979). Thus the Mackenzie River turbidity plume affects the largest area early in the open-water period. As river flows diminish during the summer, the turbidity of the water decreases and the zone of highest productivity probably retreats toward the Mackenzie delta area. This hypothetical shift in the area of highest productivity would correspond to the gradual westward shift of the bowhead whale population which is seen in both the whalers' and the recent observations. A time lag in the growth of zooplankton populations in response to increased primary productivity would, of course, be expected. Therefore, we would not predict an exact correspondence between primary production and whale distribution.

CONCLUSIONS

The whaling records clearly indicate that the Bathurst Zone seaward to about the 50 m contour is of major importance to the bowhead whales as a summering ground (Figure 1). The role of Amundsen Gulf in the summer range is less clear, but at least some parts of it (e.g. near Cape Parry, Cape Lyon, and Nelson Head) may also be significant. The summering area probably represents a very important feeding ground. This conjecture is supported by the existing data on zooplankton standing crop and primary productivity in the southeastern Beaufort Sea. However, data on productivity are greatly limited with respect to location and time of collection (annually and seasonally). Each season, the initial distribution of bowheads in the eastern Beaufort Sea region is in Amundsen Gulf and the adjacent waters near Cape Bathurst. Over the open-water period, there is a gradual westward shift in the animals' range, and this shift may be related to a shift in the area of high productivity. Recent observations in the Mackenzie delta region indicate that the pattern of use of this area by bowheads has not changed over the three-quarters of a century which has elapsed since the whaling era.

Because the data on whale distribution and on primary and secondary productivity are limited in several respects, we believe that our conclusions should be taken as hypotheses. These hypotheses require testing by systematic studies of whale distribution and biological productivity, and by a more comprehensive analysis of the whaling records. The latter approach is currently being pursued by Bockstoce.

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PART 5

THE IMPACT OF EXPLORATION ACTIVITIES ON WHALES AND WHALE HUNTING

5.1 INTRODUCTION

Since 1972, when Esso began offshore exploration, there has been concern about possible impact on white whales and whale hunting; therefore, Esso has sponsored a monitoring program for the past eight years. Throughout these studies a basic objective has been to detect possible interference with white whales and Inuit hunting and to communicate any concerns and recommendations to Esso supervisors.

Esso has utilized the information gained from previous and ongoing whale monitoring programs in locating and scheduling specific logistic and exploration activities. In a number of instances, operational plans and schedules have been adjusted to prevent possible adverse effects. Readers are referred to previous reports (Slaney 1973, 1974, 1975; Fraker 1976, 1977a, 1978) for details of previous operations.

This year Esso was active mainly in two offshore areas. The underwater borrow operation at Tuft Point and associated nearby barge traffic to and from Issungnak were kept under observation (Figure 1). These activities have been closely monitored for the past four years. Because of the limited potential for disturbance to white whales by the activities at the Issungnak island site, 26 km north of Pullen Island, relatively little surveillance effort was expended in that area. Attention was also focused on the area near Adgo J-27 artificial island, southwest of Garry Island, where drilling and other activities continued into the summer (Figure 1). Drilling was completed on 12 July, and subsequently the rig and camp were dismantled and moved to Tuktoyaktuk; supplies were transported to either Tuktoyaktuk or Tununuk Point. The camp and large pieces of equipment were moved to and from Adgo J-27 by barge, but some smaller equipment, supplies, and personnel were brought by Twin Otter to Garry Island and then taken by helicopter to the artificial island (Figure 12). This meant that the landing strip on Garry Island was used once or twice each day. Land Use Permit N76J360, dated 5 April 1979, stipulated that helicopters travelling to and from Adgo J-27 should avoid (white) whale concentrations and that whale movements in the area should be monitored in order to direct the helicopter routing.

5.2 DRILLING ACTIVITIES AT ADGO J-27

Because of the limited amount of offshore drilling activity when and where white whales have been present, there have been few previous opportunities to observe whales close to active drilling operations. But in 1979, Esso Rig 3 drilled from Adgo J-27 artificial island as late as 12 July, so that it was possible to make observations of whales in relation to active drilling operations.

The normal pattern of whale movement and activity in East Mackenzie Bay and eastern West Mackenzie Bay, where Adgo J-27 artificial island is located, has not been well defined. Depending on where the landfast-ice barrier fractures, whales may travel through this area on their way to Niakunak Bay when they first arrive in the estuary, and East and West Mackenzie Bays continue to serve as whale travel routes throughout the time that the whales are in the estuary. In the shallow-water areas, the whales occasionally are seen gamming or remaining nearly stationary; thus their behaviour in these areas is similar to that seen in the heavily used concentration areas of Niakunak and Kugmallit Bays where they gather first.

In early July, drilling from Adgo J-27 was suspended for several days while tests were conducted, but it was resumed briefly from about 2300 h on 11 July to 1300 h on 12 July. Before, during, and after this period, we flew surveys of the adjacent area (Table 16). No whales were observed closer than 4.8 km from the artificial island on 10 July, the day before drilling resumed. Although some of these were moving (west, southwest, and southeast), the majority were stationary. But during the survey on 12 July, which was conducted more than 12 h after drilling had been under way, whales were observed within 4.8 km of Adgo J-27. Again, many whales were stationary. We saw whales within 0.8 km on 13 July, about 30 h after drilling had ceased; most were stationary (Figure

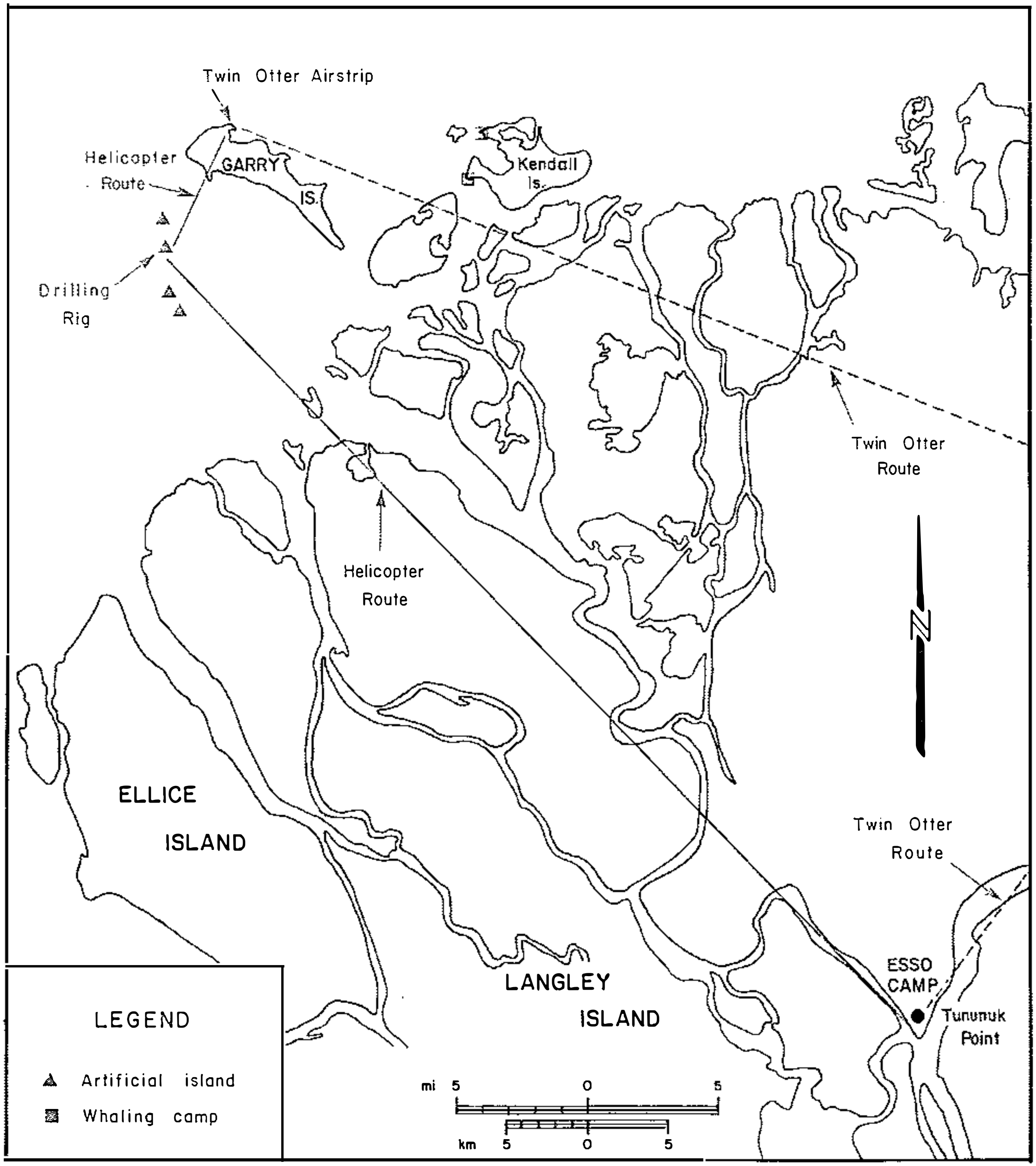

Figure 12. Location of Esso activities near Garry Island, summer 1979.

Table 16. Presence of whales near Adgo J–27 before, during, and after drilling, July 1979. Drilling occurred during the survey period on 12 July. A minus sign (–) indicates that whales were absent; a plus sign (+) indicates that whales were present; NS indicates that the area was not surveyed.

Distance from Island (km)	Dates: 10 July	12 July	13 July	14 July	15 July
0-0.8	–	–	+	–	–
0.8-1.6	–	–	+	–	–
1.6-3.2	–	–	+	+	–
3.2-4.8	–	+	+	NS	+
4.8-6.4	+	+	+	NS	+
6.4-8.0	+	+	+	NS	+
8.0-9.6	+	+	+	NS	+

6). One day later the closest whales were more than 3.2 km away from the island.

During early July, industry personnel also observed whales close to the island. About 20 approached to within about 10 m on 4 July; however, it is not known whether drilling was underway at that time (Appendix 2). During a period when Rig 3 actually was drilling from Adgo J-27, Mr. Al Gronvall (Esso Resources Canada Limited, pers. comm.) saw numerous whales within 100–150 m of the island. Gronvall also observed the whales spy-hopping.[4]

It appears that drilling did not keep whales from coming as close as 150 m to Adgo J-27 early in July and as near as 3.2 km on 12 July. They were seen even closer than 3.2 km after, but not before, drilling in the second week of July (Table 16). Thus, it is not clear if the whales were disturbed by the drilling, but any effect was apparently small.

Previously, Fraker (1977a, 1978) observed that whales closely approached stationary operations, such as barge camps and dredges, but were frightened by moving barges (up to 2.4 km in water <2 m deep). The observations made of white whales near Adgo J-27 in 1979 are consistent with the idea that they are relatively tolerant of stationary operations.

There was concern by government that helicopter activities in support of operations at Adgo J-27 might disturb nearby whales (Figure 12), and, thus, it was stipulated in the land-use permit that whale concentrations were to be avoided. When the whales were seen near (<10 km) Adgo J-27, they were usually seaward of the artificial island. On the basis of results of surveys flown in 1977 (Fraker et al. 1979), when no drilling was conducted in this region, few, if any, whales would have been expected in the nearshore areas southwest of Garry Island, although it is possible that the 1979 Esso activities had some influence on white whale distribution. Only in early July 1979 were whales seen between Adgo J-27 and Garry Island. Some disturbance occurred on 6 July when a helicopter, en route from Adgo J-27 to Garry Island, approached six whales; the whales dove when the helicopter came within 50 m (Appendix 2). We believe that helicopter traffic from Adgo J-27 resulted in only a minor amount of disturbance to white whales, largely because of the small area affected by the helicopter and the relatively small number of whales there.

During the last few days of July, some Inuit from Kendall Island, hunting for whales near the north end of Garry Island, reported possible interference with white whales by Twin Otters

[4] Spy-hopping is a behaviour that has been observed frequently in many species of whales. It consists of the whale emerging vertically part of the way out of the water, as though it were attempting to see as far as possible.

Table 17. Reaction of white whales to helicopters, in relation to altitude and whales' activity, 1978–79. A plus sign (+) indicates that there were one or more instances in which whales reacted to the helicopter; a minus sign (–) indicates that there were one or more instances in which whales did not react to the helicopter; NO indicates no observations were made in that situation. Data from Appendix 2 and Fraker (1978).

Whales' Activity	Altitude of Helicopters (m)						
	0–50	50–100	100–150	150–200	200–250	250–300	Over 300
Feeding	NO	NO	–	–	NO	NO	–
Moving (Swimming, Travelling)	+	NO	+	–	–	NO	–

using the Garry Island airstrip. The hunters were waiting on the spit on the northeast side of Garry Island for the water to calm and the whales to come into the shallower water. They reported that just as a group of white whales was approaching the northeastern tip of the island, a Twin Otter took off and the whales did not come into the bay. Because the Kendall Island hunters were still anxious to secure whales, the whale biologist in the field recommended on 30 July a temporary halt to use of the Garry Island landing strip. This suggestion was implemented on 31 July. Tununuk Point was designated as the transfer point, and the helicopter temporarily operated between there and Adgo J-27 (Figure 12). On 2 August, the hunters were successful in landing one more whale. By 9 August, interest in whaling had dwindled at both Kendall Island camps. By this date, most of the hunters either had left or were preparing to leave, and Twin Otters resumed using the Garry Island airstrip. It is not certain that the Twin Otters' use of the north Garry airstrip significantly disturbed the whales, although some of the hunters felt that this was true. More detailed observations would be required to determine the nature of any effect.

Reports were received from some Kendall Island hunters that barge traffic between Adgo J-27 and Tuktoyaktuk was delaying the entrance of the whales into the area where hunting could occur. Two delays of approximately 30 minutes duration were reported. Barges were requested to pass farther offshore of Garry Island; no additional effects were reported.

5.3 REACTION TO HELICOPTERS

In the past few years a limited number of observations of the reaction of white whales to helicopters have been made (Table 17). Because the total number of observations is only 14 and because judgment is often necessary in order to say whether or not a reaction occurred, any statements made must be regarded as tentative. Observations were made from Bell 212 helicopters, which are medium-sized, twin-engine, turbine-powered machines. Altitude is probably a significant factor in the type and degree of reaction. No whales were observed reacting to helicopters that were at an altitude of more than 150 m, but at altitudes lower than 150 m, the response varied. Sometimes there was no response. The whales' activity appeared to have an effect on whether or not they reacted to the helicopter at altitudes of less than 150 m. Whales that were feeding seemed to be less sensitive than whales that were moving. This was also found to be true regarding the reaction of whales to barge traffic (Fraker 1978). We have also noticed that feeding whales appear more tolerant of fixed-wing aircraft than whales doing something else. The few observations to date do not allow any generalizations regarding the effect of water depth or size of group on reaction to helicopters.

5.4 ACTIVITIES IN KUGMALLIT BAY

Seventy-five percent of the whale harvest and most industrial marine traffic occur in Kugmallit Bay. Thus, the whales there are subjected to a larger amount of disturbance than are whales in other parts of the estuary. Because it occurs within the heavily used concentration area and because it is directed toward the whales, hunting activity undoubtedly causes most of the disturbance to the whales. To date the only clearly documented instance of reaction of whales to intensive hunting activity was observed in July

1978 when a mass movement of whales out of Kugmallit Bay was observed in apparent response to more than five hunting parties. There were also indications that hunting activity affected the whales' use of Kugmallit Bay during 1979 (see section 2.1.6).

We suspect that the low numbers of whales in Kugmallit Bay in 1978 and 1979 were a consequence of the pattern of break-up of the landfast ice and not of hunting or industrial activities. A test of this hypothesis will probably be possible in 1980, assuming that the landfast-ice barrier across the outer part of the estuary breaks so that the whales have access to both West Mackenzie and Kugmallit Bays simultaneously. We predict that the number of whales in Kugmallit Bay should be closer to the 2000–2500 estimated in 1976 and 1977.

There was a decline from an estimated 496 whales on 14 July to only 12 whales on 16 July, but this was not associated with Esso's activities (see section 2.1.6). During this period, Barge Camp 208 and the dredge *Arctic Northern* moved from Tuktoyaktuk to Tuft Point, but dredging did not start until 16 July. The activities closest to the whale concentration area (i.e., vessels moving from Tuktoyaktuk) were more than 10 km away, well beyond the maximum distance of audibility of tugboat sounds (3300 m) calculated by Ford (1977). Sounds from dredging at Tuft Point, 34 km from the concentration area, have a theoretical audibility range of 4000 m or less (Ford 1977).

The seismic exploration vessel *Arctic Surveyor* was active in southern Kugmallit Bay on 16 July. Its activities began two hours after our survey which resulted in an estimate of only 12 whales. Although we would not recommend that a seismic vessel operate close to a whale concentration area during the period that whales are present or hunting is being carried out, the activities of the *Arctic Surveyor* in 1979 had no apparent effect on the use of Kugmallit Bay by whales because the whales had previously left the area.

In addition to Esso, several other companies operate within Kugmallit Bay. These include Canmar, Arctic Transportation Ltd., and Northern Transportation Company Ltd. Details of their activities are unknown, and, therefore, we cannot rule out industrial activities as contributing to the decline in the number of whales in Kugmallit Bay. However, disturbance of the small number of whales by intensive hunting is probably the main factor that resulted in the decline in the abundance of whales in Kugmallit Bay in mid-July.

In 1976, approximately 100–150 whales were present for about two weeks in the Hutchison Bay and Beluga Bay area, apparently as a result of disturbance from the dredging operations and associated activities near Tuft Point; therefore, close attention has been paid this area in each subsequent year. This year there was a brief aggregation of whales in the west end of Hutchison Bay. No whales were seen there on 18 July, but on the morning of 22 July, about 100 whales, including several calves, were present. They were also present on the evening of 22 July. Many of these whales were diving and a few gulls were flying overhead indicating that the whales were feeding. On 25 July no whales were seen in this area. The short stay of the whales and their behaviour indicate that they had not been disturbed by activities at Tuft Point. The intermittent use of this area as a feeding ground was further indicated in talks with several Inuit. This is in contrast to the situation found in 1976 when a much larger amount of barge traffic near Tuft Point may have impeded movement and resulted in an aggregation of whales in this area.

5.5 EFFECTS ON WHALE HUNTING

Twelve whales were taken by hunters using Kendall Island. This is slightly more than the 1978 harvest figure of 10. The number of hunters at Kendall Island in 1979 was similar to the number in 1978. The 1979 harvest may have been reduced by one or a few whales as a result of disturbance from aircraft or barge traffic (see section 5.2).

The harvest in Kugmallit Bay was near normal. Hunters from Tuktoyaktuk landed 49 whales, about 5 less than the 7-year mean of 54.3 and well within the range seen in previous years. Inuvik hunters, operating from camps on Kugmallit Bay, landed 31 whales; this is similar to the totals of 32 and 28 taken in 1977 and 1978, respectively, but lower than previous levels (Table 8).

The harvest in Niakunak Bay was remote from Esso operations and, therefore, was unaffected. The planned use of the barge route through Reindeer Channel and Shallow Bay was revised in order that the large concentration of whales and the hunting activities in Niakunak Bay could be completely undisturbed by Esso operations.

5.6 EFFECTS OF OFFSHORE EXPLORATION ON BOWHEAD WHALES

Bowhead whales were observed in substantial numbers in the Mackenzie estuary region in 1976 when there were 16 sightings of 47 whales (possibly including some duplicate sightings of the same individuals). In 1977 there were 28 sightings of at least 101 whales, and in 1978 there were 8 sightings of 63 whales. However, in 1979 there were only 2 sightings of 7 individuals (see section 4.2). The reasons for these variations are unknown but should be investigated.

PART 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

1. White whales first arrived at the Mackenzie estuary (West Mackenzie Bay) on 19 or 20 June 1979, the earliest recorded date of arrival. Whales were not recorded in Kugmallit Bay until 2 July.

2. Based on a count of white whales made under particularly good survey conditions, the minimum number of whales in the Mackenzie estuary in 1979 was approximately 7000. This estimate includes no adjustment for whales that may have been below the surface at the time of survey.

3. Because the landfast ice barrier was breached in West Mackenzie Bay about 10 days earlier than in Kugmallit Bay, more than 95% of the white whales in the estuary occupied the western part of the estuary (mainly Niakunak Bay) in the first week of July and less than 5% occupied Kugmallit Bay. A similar distribution was also recorded in 1978 and possibly 1972.

4. The geographical extent of the Niakunak Bay white whale concentration area observed in 1979 was largely unchanged from previous years. However, in 1979, substantial numbers of whales penetrated into Shallow Bay as far as Reindeer Channel; this was the greatest use of Shallow Bay that has been recorded during the eight years of study. The concentration area near Hendrickson Island in Kugmallit Bay was used by too few whales in 1979 to permit a concentration area to be defined; most whales were seen within the concentration area already defined in previous studies.

5. Hunting camps were established in the last week of June on Niakunak Bay, the first week of July on Kugmallit Bay, and the second week of July at Kendall Island.

6. The total number of white whales landed in 1979 was 120, approximately 18 below the recent average but within the limits observed since 1972. The proportion of females in the harvest increased in 1979 compared to previous years, but this probably does not reflect a biologically significant change in the population.

7. During aerial surveys, we observed white whales as close as 800 m from an actively used artificial island, Adgo J-27, in West Mackenzie Bay. Industry personnel reported that whales approached the artificial island as close as 100–150 m while drilling was under way.

8. Hunters reported that take-offs and landings by a Twin Otter at the north Garry Island spit may have interfered with the movement of white whales into East Mackenzie Bay. To eliminate this possible source of disturbance, aircraft traffic was re-routed temporarily. There was a limited amount of disturbance from a barge that occasionally moved through East Mackenzie Bay past Kendall Island.

9. No disturbance or interference with white whales was seen in relation to operations at Tuft Point. White whales were observed close to activities there; some whales probably were feeding.

10. Because of intensive hunting activity (75% of the total harvest) in the Hendrickson Island concentration area in Kugmallit Bay, white whales there are subjected to substantially more disturbance than are those elsewhere within the estuary. This situation has been exacerbated in 1978 and 1979 when only small numbers of whales used Kugmallit Bay. Furthermore, industrial marine traffic from Esso and several other companies is greatest in Kugmallit Bay. Thus, the potential for adverse effects from hunting and/or industrial activities is currently greater in Kugmallit Bay than elsewhere in the Mackenzie estuary.

6.2 RECOMMENDATIONS

1. The white whale monitoring program should be continued each year during the period when whales are present, as long as offshore exploration continues. As with previous programs, future studies should include the following aspects:

   (a) Because of the great influence that ice can have on the distribution and relative abundance of whales in the Mackenzie estuary, ice conditions and the movement of whales to the Mackenzie region should receive continued attention.

   (b) Aerial surveys of the major concentration areas in Kugmallit and Niakunak Bays should be conducted during late June or early July in order to maintain a continuous series of comparable data on population size.

   (c) Advantage should be taken of opportunities to gain more data related to the reproduction of white whales and to the possible biological significance of the concentration areas and other parts of the estuary.

   (d) All offshore exploration activities that could potentially affect white whales should be monitored in order to prevent adverse interactions between whales and Esso activities.

   (e) The Inuit hunt should be monitored in order to document the harvest.

   (f) Communication should be maintained with the hunters so that possible disturbance from Esso activities can be prevented or minimized.

   (g) To further improve the understanding of the relative importance of disturbance of whales by Esso activities, further studies of the reactions of whales to Inuit hunting should be conducted.

   (h) An Inuit observer should be employed to serve as a second observer on whale surveys and to provide liaison at the whale hunting camps.

2. If marine traffic more intensive than that of 1977, 1978, or 1979 operates in the Tuft Point region, activities in this area should be monitored carefully.

3. Future operations in the Garry Island area should be monitored intensively. If future exploration and/or development is planned for the Garry Island area, a better understanding of the whales' use of that area should be developed by systematic surveys.

4. Marine seismic activities should not be carried out in or near white whale concentration areas during the period when whales are present.

5. Because of the very high importance of underwater sound to marine mammals, we recommend that unstudied aspects of underwater sound production and propagation be investigated. Such a study should ideally include sounds of drilling from artificial islands, seismic exploration, aircraft, barges, and boats.

6. A close liaison should be maintained with all other industry and government whale research programs in the Beaufort Sea region to ensure data compatibility, maximum information exchange, and cost effectiveness of programs.

7. Because bowhead whales have been observed near Esso operations in the deeper offshore waters in the Beaufort Sea in 1976, 1977, and 1978, possible effects of exploration on this endangered species should be studied. Many valuable data can be gathered from vessels and aircraft operating offshore, and personnel should be provided with whale sighting forms to ensure that an orderly record is kept of sightings of both bowhead and white whales. The unsystematic data gathered by industry personnel should be supplemented by systematic aerial surveys of the offshore region where Esso is operating and of adjacent areas.

8. Eight years of uninterrupted white whale data have been collected during Esso-supported programs. If Esso is considering a long-term presence in the Mackenzie estuary region, the following variables should be monitored annually:

   (a) length and sex of whales taken in the harvest;

(b) age of whales taken in the harvest; and

(c) reproductive data (ovaries and reproductive conditions) from female whales taken in the harvest.

The purpose for collecting the above data is to be able to detect changes in the status of the population and, insofar as possible, to distinguish changes that may result from industrial activities and from the Inuit hunt.

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Appendix 1. Number of whales counted during aerial surveys in the Mackenzie estuary, by survey line and area, 1979. NS means that line was not surveyed on that date.

Dates	Kugmallit Bay Survey Lines															Totals
	K–A	K–1	K–2	K–3	K–4	K–5	K–6	K–7	K–8	K–9	K–10	K–11	K–12	K–13	K–14	
2 July	0	16	0	0	0	0	0	0	NS	NS	NS	NS	NS	NS	NS	16
10 July	NS	0	0	3	24	14	8	6	0	0	NS	NS	NS	NS	NS	55
14 July	0	0	0	0	9	6	37	48	8	7	5	4	NS	NS	NS	124
16 July	0	0	0	0	0	3	NS	NS	0	NS	NS	NS	NS	NS	NS	3
18 July	0	2	0	0	0	54	14	0	0	3	11	NS	NS	NS	NS	84
22 July	0	0	0	13	3	7	0	0	0	20	0	NS	NS	NS	NS	43
25 July	0	0	0	0	0	7	9	0	0	0	0	NS	NS	NS	NS	16
31 July	NS	0	0	0	0	0	0	NS	NS	NS	NS	NS	NS	NS	NS	0
1 August	NS	0	0	0	14	5	0	0	0	0	0	1	2	4	NS	26
6 August	NS	NS	NS	NS	0	0	0	0	1	3	6	3	0	0	0	13
11 August	NS	NS	NS	NS	NS	NS	NS	NS	NS	0	0	0	28	7	12	47
Totals	0	18	0	16	50	96	68	54	9	33	22	8	30	11	12	427

Appendix 1. Continued.

Dates	West Mackenzie Bay Survey Lines								Totals
	WM–1	WM–2	WM–3	WM–4	WM–5	WM–6	WM–7	WM–8	
30 June	51	30	18	78	37	16	11	4	245
2 July	69	66	38	59	34	20	54	54	394
10 July	42	27	39	11	28	8	2	5	162
13 July	10	1	39	18	0	64	8	5	145
15 July	16	39	34	51	43	70	NS	NS	253
19 July	NS	NS	21	32	31	13	NS	NS	97
24 July	0	17	3	3	8	9	NS	NS	40
29 July	1	5	2	3	9	13	NS	NS	33
5 August	NS	NS	NS	NS	0	2	NS	NS	2
Totals	189	185	194	255	190	215	75	68	1371

Appendix 1. Continued.

Dates	East Mackenzie Bay Survey Lines											Totals
	EM-A	EM–1	EM–2	EM–3	EM–4	EM–5	EM–6	EM–7	EM–8	EM–9	EM–10	
1 July	0	0	5	0	2	NS	NS	NS	NS	NS	NS	7
2 July	0	0	4	0	6	NS	NS	NS	NS	NS	NS	10
10 July	0	45	2	52	3	NS	NS	NS	NS	NS	NS	102
13 July	0	11	18	7	15	0	15	0	4	1	NS	71
15 July	20	19	40	38	27	23	9	14	13	8	8	219
19 July	16	11	30	56	24	24	4	NS	NS	NS	NS	165
24 July	8	8	6	23	14	10	4	NS	NS	NS	NS	73
30 July	6	1	0	5	13	12	2	2	16	0	2	59
5 August	8	0	0	8	1	0	2	6	0	0	4	29
Totals	58	95	105	189	105	69	36	22	33	9	14	735

Appendix 1. Continued.

Dates	Niakunak Bay Survey Lines													Totals
	SB loop	N–C	N–B	N–A	N–1	N–2	N–3	N–4	N–5	N–6	N–7	N–8	N–9	
21 June	0	0	0	0	0	0	42	39	58	44	9	1	7	200
23 June	0	0	0	13	72	70	182	135	172	92	39	30	15	820
24 June	NS	0	0	0	36	100	168	216	145	128	52	61	8	914
27 June	0	0	0	0	32	106	134	164	176	238	151	86	62	1149
30 June	0	0	12	135	107	129	124	283	609	644	404	370	157	2974
4 July	NS	NS	NS	NS	3	35	70	98	87	115	136	88	71	703
12 July	0	0	0	0	0	1	0	0	10	146	96	NS	NS	253
20 July	0	0	0	0	0	0	0	29	52	36	36	69	53	275
3 August	NS	0	0	0	0	NS	NS	0	0	0	54	37	21	112
9 August	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	24	16	24	64
Totals	0	0	12	148	250	441	720	964	1309	1443	1001	758	418	7464

Appendix 2. Observations of white whales made by industry personnel, 1979.

Date Time	Location	Numbers	Direction of Movement	Observations	Observer
2 July 1345	6 miles east of Kendall Island	6	NE	No apparent reaction to Bell 212 helicopter 91 m ASL.	Mr. Randy Klohn Okanagan Helicopters
3 July 1115	6 miles east of Kendall Island	25	milling around	No apparent reaction to helicopter at 152 m ASL. On a return trip 20 minutes later there appeared to be fewer whales. On subsequent trips, more whales were seen in the same area.	Mr. Randy Klohn Okanagan Helicopters
4 July 0400	Adgo J-27	20	—	While the rig was in operation, whales were seen within 10 m of the rig and barge camp.	Mr. Randy Klohn Okanagan Helicopters
4 July 1115	Adgo J-27	12	NW	Feeding* whales showed no reaction to helicopter at 122 m ASL.	Mr. Randy Klohn Okanagan Helicopters
5 July 2010	Adgo J-27	4	2 NW 2 SE	Feeding whales showed no reaction to helicopter at 122 m ASL.	Mr. Randy Klohn Okanagan Helicopters
6 July 1400	Adgo J-27	6	SE	Whales were moving towards the rig as the helicopter took off. When the helicopter was 50 m from whales, they suddenly dove.	Mr. Randy Klohn Okanagan Helicopters

Appendix 2. Continued.

Date Time	Location	Numbers	Direction of Movement	Observations	Observer
15 July 1550	Hooper Island	several groups, each with about 10 whales	S	Whales, moving parallel to shore about 400 m out, showed no apparent reaction to helicopter at 305 m ASL.	Mr. Randy Klohn Okanagan Helicopters
15 July 1600	Pullen Island	40	S	Whales were moving. Many were close to the surface. No reactions to helicopter at 305 m ASL.	Mr. Randy Klohn Okanagan Helicopters
18 July 0700	Tuft Point	~20	NNE	Whales were feeding 800 m from shore. Water depth = 4.6 m.	Mr. Reg Labinsky Northern Construction Co.
18 July 1750	Between Pelly and Hooper Islands	~100	all directions	No reaction to helicopter at 305 m ASL.	Mr. Randy Klohn Okanagan Helicopters
20 July 1030	Tuft Point	60	W	Whales were feeding about 1600 m from shore. Water depth = 7.6 m.	Mr. Reg Labinsky Northern Construction Co.
20 July 1030	Tuft Point	22	E and W	Whales were feeding 400 m outside breakwater. No reaction as tug *Beverly Lambert* approached 1200 m away.	Mr. Jim Kean Northern Construction Co.

Appendix 2. Continued.

Date Time	Location	Numbers	Direction of Movement	Observations	Observer
20 July 1330	Tuft Point	20	SSW	Whales were feeding 400 m from dredge. Water depth = 7.6 m.	Mr. Reg Labinsky Northern Construction Co.
21 July 1500	Tuft Point	60	SSW	Whales were feeding between breakwater and beach. Water depth = 4.6 m.	Mr. Reg Labinsky Northern Construction Co.
22 July 0610	Short distance N of Tuktoyaktuk	30	SE	Whales were feeding. Water depth = 4.0 m.	Mr. W.J. Gilmore Northern Construction Co.
25 July 1400	Tuft Point	60	W	Whales passed by barge camp about 1600 m away. Water depth = 7.6 m.	Mr. Reg Labinsky Northern Construction Co.
28 July 1600	3 miles west of Pullen Island	3 in one group; 4th whale 15.2 m away	–	No reaction to helicopter at 305 m ASL. Water depth = 3.1–4.6 m.	Mr. David Boone Esso
9 August 1200	Tuft Point	over 100	S	Whales were feeding. No reaction to *Arctic Courier* 400 m away. Water depth = 7.6 m.	Mr. Dennis Josephson Northern Construction Co.
9 August 1440	Tuft Point	15	W	Whales were feeding, moving in several directions. Most were slowly going west. There were several calves in group. Water depth = 4.6 m.	Mr. Reg Labinsky Northern Construction Co.

Appendix 2. Continued.

Date Time	Location	Numbers	Direction of Movement	Observations	Observer
15 August 0845	Tuft Point	20	NNE	Whales passed by 150m from shore.	Mr. Reg Labinsky Northern Construction Co.
18 August 0030	Tuft Point	6–7	NE	Whales were playing 3 m from barge camp. There were gulls nearby. Water depth = 2.1 m.	Mr. Robert Ewell Northern Construction Co.
20 August 1025	Tuft Point	20	NNE	Whales were feeding, moving parallel to beach about 100 m out. Water depth = 3.7 m.	Mr. Reg Labinsky Northern Construction Co.
27 August 1430	entrance to Tuktoyaktuk Point harbour	3	NNE	Whales were feeding, moving north about 100 m from beach. Water depth = 3.7 m.	Mr. Reg Labinsky Northern Construction Co.

*Whales were assumed to be feeding as gulls were present nearby.