THE 1980 WHALE MONITORING PROGRAM MACKENZIE ESTUARY

by

LGL LIMITED
environmental research associates
Sidney, British Columbia

for

ESSO RESOURCES CANADA LIMITED

CALGARY, ALBERTA

Errata Sheet for the Report of THE 1980 WHALE MONITORING PROGRAM, MACKENZIE ESTUARY.

Page	Correction
25	'Adago' should read 'Adgo' wherever it appears on the map.
44, 2nd para., 1st sent.	'...was very important to cultural....' should read '...has very important cultural....'
51, 3rd para., 4th sent.	'...df-1....' should read '...df=1....'
53, 2nd para., 1st sent.	'...(χ^2-1.11,....' should read '...(χ^2=1.11,....'
95	Add the following to heading of appendix table: 'East Mackenzie Bay Survey Lines'.

ANDREW ARCHIE ERIGAKTOAK, 1937 - 1980

THE 1980
WHALE MONITORING PROGRAM,
MACKENZIE ESTUARY

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This report is dedicated
to the memory of
Andrew Archie Erigaktoak (1937-1980).

We will miss his companionship,
good humour, and insights.

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ACKNOWLEDGEMENTS

Many persons made important contributions to the success of the 1980 Whale Monitoring Program. Within Esso, Mr. Mark Psutka, Mr. Cam Mancini, Mr. Dave Boone, and Mr. Cliff Kippen encouraged the study and provided information about operations. We are grateful to the individuals who took time in the course of their work to record valuable observations of whales; these persons are identified where their observations are presented.

Mr. Andrew Erigaktoak, for the sixth year, served very ably as an observer on survey flights and provided liaison during visits to whaling camps.

Pilots Mr. Jeff Mahoney and Mr. Charles Record at the Aklavik Flying Service provided safe, accurate flying.

We are grateful to the many families who provided generous hospitality during our visits to their camps; in particular, Mr. and Mrs. George Allen, Mr. and Mrs. Jacob Archie, and Mr. and Mrs. Bill Cockney.

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We are grateful to the U.S. Bureau of Land Management for permission to use information collected on their behalf by LGL.

We thank Drs. Rolph Davis and W. John Richardson (LGL Limited) for their analytical review of this report. Mrs. Jo-Anne Kruzynski and Mrs. Elizabeth White typed and helped assemble the report. Ms. Robin Hood prepared the illustrations.

EXECUTIVE SUMMARY

Each summer thousands of white whales (*Delphinapterus leucas*) migrate to the estuary of the Mackenzie River; large numbers are present from about late June to early August. While there, the whales are hunted by Inuit from Tuktoyaktuk, Inuvik, and Aklavik. The whale hunt and resulting whale products have important cultural, sociological, and nutritional benefits. From the outset of offshore drilling in the Mackenzie estuary, there has been concern about possible adverse effects on the whales and whale hunting. In recognition of this concern, Esso Resources Canada Limited has sponsored a whale monitoring program for the past nine years. The overall purpose of this program has been to prevent any serious effects on the whales and whale hunt. A major focus has been to detect potential disturbance to whales and whale hunting and to communicate any concerns to Esso for immediate mitigative action, if necessary. Since 1976, as operations have moved farther offshore, bowhead whales (*Balaena mysticetus*) have also been included in the studies.

Esso operations offshore in the Mackenzie estuary region in 1980 centered around the rebuilding of Issungnak O-61, an artificial island located in 19 m of water. Material for the island was dredged from adjacent areas by the suction dredge, *Beaver Mackenzie*. A barge camp was located at the construction site. Men and supplies were transported to and from Tuktoyaktuk, the base of operations, by boat and by helicopter.

The first white whales arrived in West Mackenzie Bay on 27 June in 1980. Although a break in the ice in Kugmallit Bay occurred on 30 June, no whales were seen there until 4 July.

More than 95% of the white whales gathered in Niakunak Bay, while less than 5% were in Kugmallit Bay. This difference appears to have been a consequence of the timing of the break-up of the landfast ice in relation to the migration.

The maximum estimated number of white whales in Niakunak Bay in 1980 was 4234; however, based on the pattern of change in abundance in other years, it is probable that a higher peak number was reached during a

period of poor weather when surveys were not possible. The maximum estimated number in Kugmallit Bay was only 120 in 1980. The total number of whales using the Mackenzie estuary probably is in the order of 7000.

The 1980 white whale harvest of 90 was 46 less than the 1972-1979 average; hunters from Tuktoyaktuk and Kugmallit Bay landed substantially fewer whales than normal because of the scarcity of whales and poor weather.

The sex ratio of the landed catch was 0.95 males : 1 female which is statistically different from the ratio of 3.42 males : 1 female in the 1974-1978 catch. The change in sex ratio probably is the result of decreased selectivity by hunters.

Vessel traffic, the main industrial activity in Kugmallit Bay in 1980, did not appear to have a significant effect either on the use of Kugmallit Bay by white whales, or on the success of whale hunters. A consideration of the overall relationship between white whales and Esso's operations indicates that there have been no serious interactions and that the Mackenzie whale herd is in good condition. Esso's willingness to avoid sensitive areas that have been identified in the course of these studies and to make certain operational adjustments probably has been of significant value in preventing adverse effects.

In 1980 large numbers of bowheads were present in the area near Issungnak artificial island during construction and subsequent operations, early August to mid-September. The main activity of bowheads in the south-eastern Beaufort Sea region appears to be feeding. Relatively large numbers of bowheads were observed north of Kugmallit Bay in 1976, 1977, and 1978, as well as 1980, but not in 1979. The well-documented presence of bowheads near island-building operations in 1980 suggests that their absence in 1979 owed to natural reasons rather than a response to Esso's activities.

PART 1

INTRODUCTION

Thousands of white whales (*Delphinapterus leucas*) and bowhead whales (*Balaena mysticetus*) migrate to the southeastern Beaufort Sea region each summer, after overwintering in the Bering Sea. The first whales of both species arrive in May (Fraker 1979; Braham et al. 1980), and most leave by early October. From late June to early August, large numbers of white whales congregate in the warm, shallow (<2 m) waters of the Mackenzie River estuary. While in these waters the whales appear to feed very little, and it seems most likely that they are there to take advantage of the warm water, which may be especially beneficial to the newborn calves. Although it is not yet certain why the whales gather in estuaries, these areas are clearly very important to them. In the estuary, white whales are hunted by Inuit from Aklavik, Inuvik, and Tuktoyaktuk. This activity has very important cultural, sociological, and nutritional benefits for the Inuit. Fraker (1977b) estimated that roughly one-third of the Inuit from Aklavik and one-quarter of the Inuit from Inuvik travelled to whaling camps; individuals from about 60% of the families in Tuktoyaktuk hunted whales in Kugmallit Bay. Since whale products may be traded or given to persons who did not participate in the hunt, probably a majority of the Inuit of the Mackenzie delta region are directly or indirectly affected by the annual whale hunt.

From May to September, most bowhead whales of the Western Arctic stock occupy the relatively shallow waters (<50 m) of the southeastern Beaufort Sea and possibly parts of Amundsen Gulf (Fraker and Bockstoce 1980). The summer range may be the bowheads' main feeding ground. The bowhead has not been hunted in the western Canadian Arctic for decades (Marquette and Bockstoce 1980), but each year Inuit hunt these bowheads as they travel past western and northern Alaska (Mitchell and Reeves 1980; Tillman 1980). Because the bowhead is generally regarded as rare-and-endangered, recently there has been a vigorous international debate about the Inuit hunt and possible adverse effects of offshore hydrocarbon exploration on this species.

From the outset of offshore oil and gas exploration in the Mackenzie estuary, there has been concern about possible adverse effects on white whales and the whale hunt. For this reason, Esso Resources Canada Limited has sponsored studies of whales since offshore operations began in 1972. Because white whales concentrate in some of the nearshore areas where exploration started, and because of the importance of the whale hunt to Inuit of the Mackenzie delta region, the studies have focused on white whales. However, since 1976, as Esso's activities have moved into deeper waters, bowhead whales have been included in the studies.

Esso's summer offshore 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. Barges transport this material when the excavation site is distant from the island location. Where the excavation site is adjacent to the island location, fill can be pumped directly from the dredge. Helicopters, fixed-wing aircraft, tugs, and other boats are used for transporting personnel, equipment, and materials. Construction of the first artificial island, Immerk, began in summer 1972 and was finished in 1973. By the end of 1980, 15 artificial islands plus the breakwater at Tuft Pt. had been constructed by Esso and another (Alerk P-23) had been started (Fig. 1).

Objectives

The overall purpose of the whale monitoring program is to prevent serious adverse interactions between Esso's operations and whales and Inuit whale hunting activities. To do this, information about whale activities and responses to industrial operations has been collected over several years. This information has assisted with planning, and in some instances on-location advice has been provided to prevent or minimize potentially adverse effects.

Specific objectives of the study were:

1. to determine the timing of use of the estuary by white whales and to assess the effects of spring break-up of the landfast ice on patterns of use;

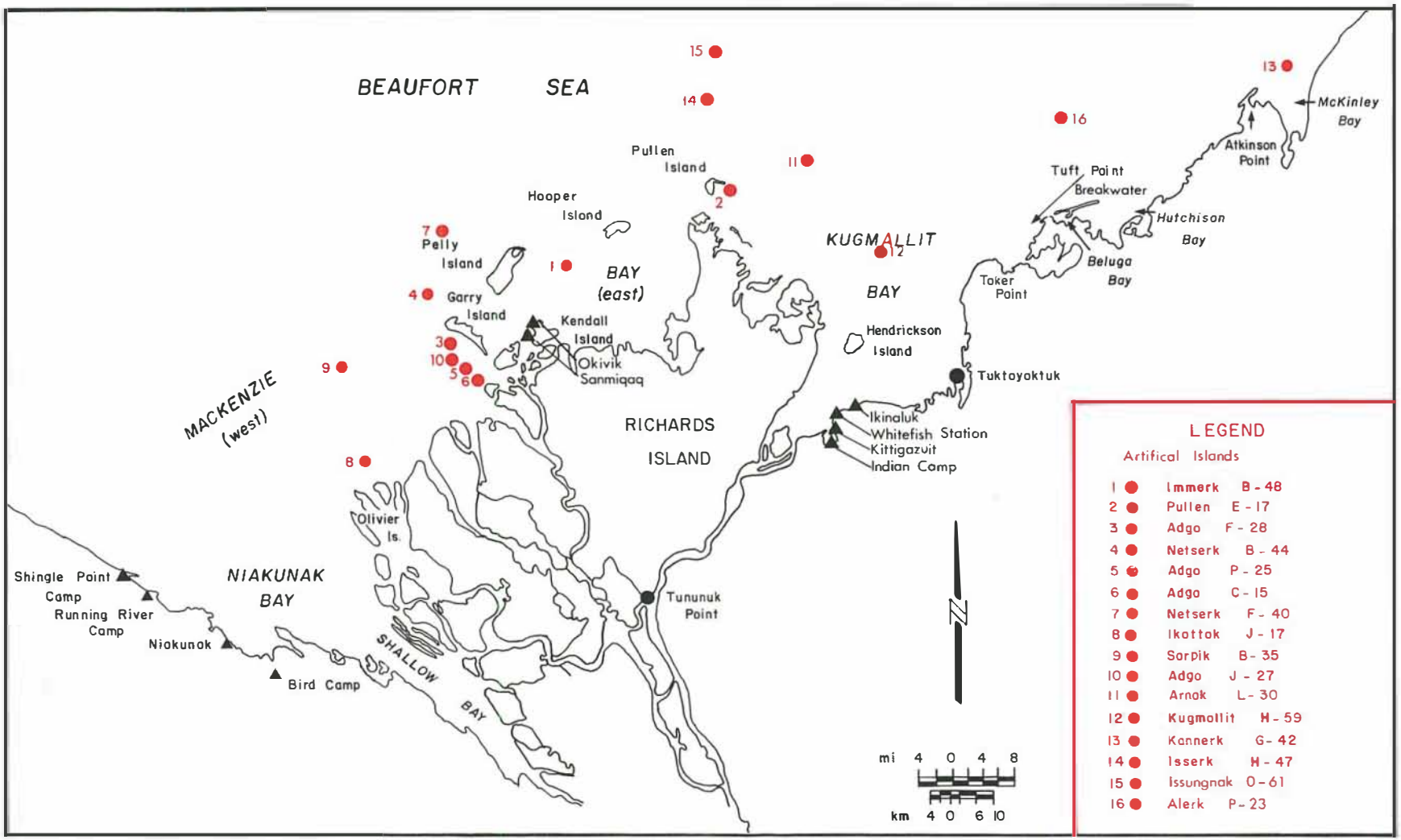


Figure 1. Location of Esso activities in the Mackenzie estuary region, summer 1980.

2. to assess the numbers of white whales using the estuary;
3. to determine the distribution and movement patterns of white whales in various parts of the estuary;
4. to observe the behaviour of white whales and their responses to Inuit hunting;
5. to gather information on the status of the Mackenzie white whale stock by taking biological samples from whales landed during the Inuit hunt;
6. to document the occurrence, movements, and activities of bowhead whales in the Mackenzie estuary region; and
7. to document and describe the behaviour of both bowhead and white whales in response to various offshore industrial activities.

PART 2

METHODS

The 1980 field program began on 19 June and continued to 13 August. Investigations focused on Kugmallit Bay and nearshore areas of adjacent parts of the Tuktoyaktuk Peninsula, which were within the main area of Esso's activities. To maintain the continuity of annual population estimates, surveys were also carried out in Niakunak Bay. Initially it had been planned to survey West and East Mackenzie Bays systematically throughout the summer, in order to better determine the pattern of use of these areas by white whales. However, at Esso's request, effort was redirected after mid-July to surveys for both bowhead and white whales in the Issungnak area (Fig. 2), in view of potential long-term activities in this area.

Study Area

We have defined the Mackenzie estuary study area as that area included in systematic surveys (Fig. 2). Additional areas are covered during the spring migration reconnaissance surveys.

To facilitate discussion we further divided the area into eight sub areas (Fig. 2):

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 survey area, the eastern boundary defined by Garry Island and a line running north of the western tip of Garry Island to the survey area perimeter;
4. East Mackenzie Bay - the area landward of the Barrier Islands;
5. Barrier Islands - Garry, Pelly, Hooper, and Pullen Islands;

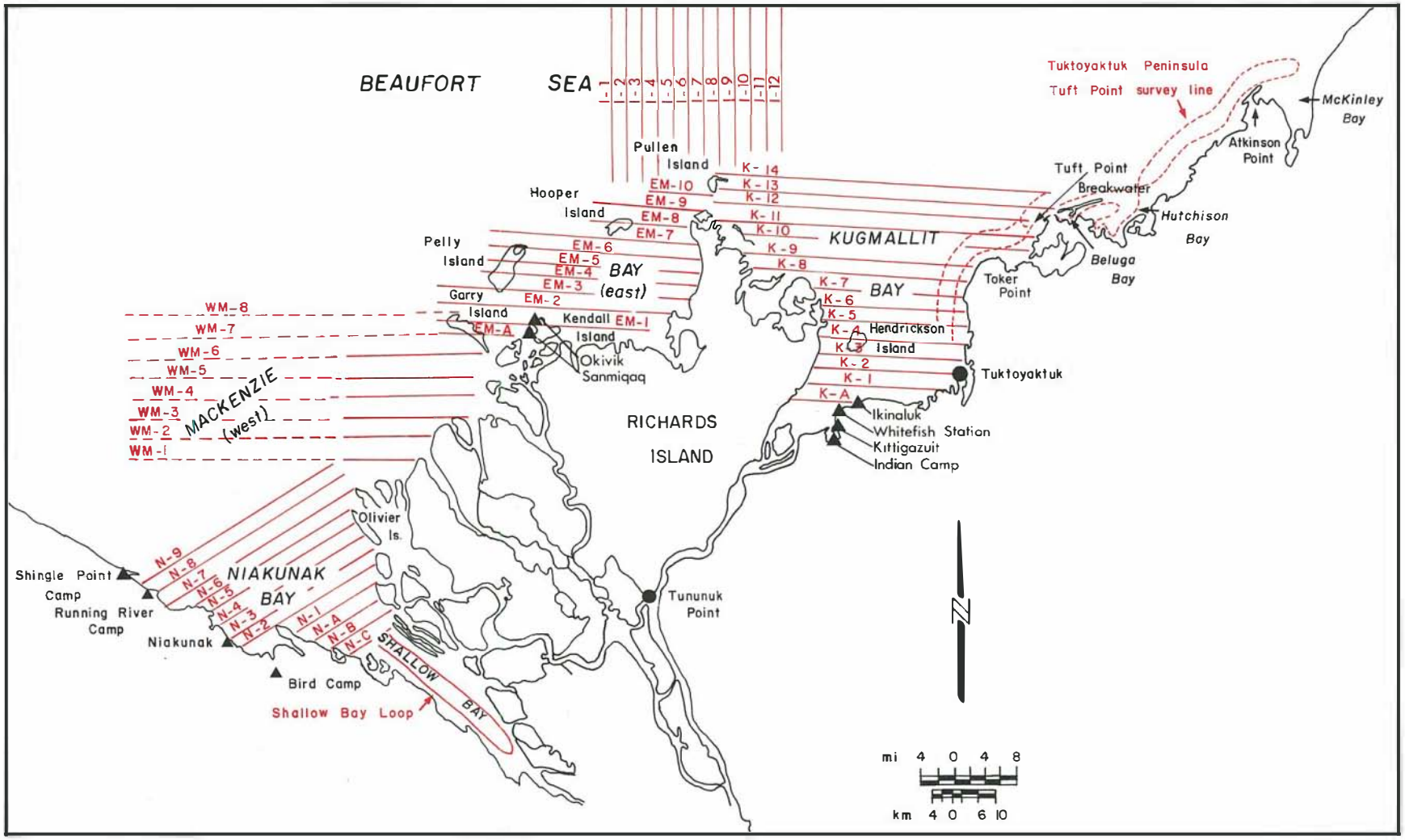


Figure 2. Standard survey lines Mackenzie estuary and Tuktoyaktuk Peninsula, 1976-1980.

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

7. Tuktoyaktuk Peninsula coastal area - the nearshore area along the Tuktoyaktuk Peninsula extending seaward for approximately 10 km; and

8. Issungnak area - the area from 69°48' to 70°05' N latitude and between 133°52' and 134°44' W longitude.

Systematic Surveys

Systematic surveys were designed to obtain data on the distribution, relative abundance, behaviour, and movement patterns of whales. Transect lines across the survey areas were spaced at 3.2-km intervals except in West Mackenzie Bay where lines were spaced at 4.8-km intervals (Fig. 2). A standard flight track was flown along the Tuktoyaktuk Peninsula. The standard survey lines were first established in Kugmallit and Niakunak Bays and off the Tuktoyaktuk Peninsula in 1976, in East and West Mackenzie Bays in 1977, and in the Issungnak area in 1980. The West Mackenzie Bay survey area was reduced in size by 70 percent in 1979 for safety reasons and so that both East and West Mackenzie Bays could be surveyed without refueling the aircraft; however, surveys conducted on or before 2 July in both 1979 and 1980, while there was extensive ice cover, followed the original survey lines (except over ice-covered areas). The parts deleted to form the 'modified' survey are shown as dashed lines on Figure 2. North-south survey lines in the Issungnak area were spaced 8.0 and 9.6 km apart in 1978 and 1979, respectively, and routinely extended to approximately 80 km offshore. Because more intensive coverage was desired around the artificial island, in 1980 a systematic survey was designed with lines spaced 3.2 km apart (Fig. 2).

Surveys were conducted as often as weather allowed. The area chosen for coverage during each survey depended on how recently each area had been surveyed, its importance to whales, and 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 actual area surveyed was variable.

A float-equipped Cessna 185 aircraft was used for all surveys except those of the Issungnak area. 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 during each 15-sec interval were recorded 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 glare on the water for 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. Estimates of numbers mentioned in the text are those from surveys conducted under excellent or good visibility conditions, unless otherwise noted. 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 conditions. To keep the surveys consistent and comparable, only those whales within a 0.8 km-wide strip along either side of the aircraft were counted. In order for each observer to accurately determine the width of the strip at the water surface, the aircraft was flown perpendicular to a 0.8 km runway at an altitude of 305 m, and the wing struts were marked so that the area projected on the water, between the floats and the strut marks, was 0.8 km wide. These marks were further

checked by computing the appropriate angles of view and by measuring the actual angles with an inclinometer.

The two observers, one in the right front seat and the other in the left rear, used digital watches which were synchronized before each survey. Cassette tape recorders were used to record all data. Data were transcribed onto standard forms and plotted onto maps.

Three systematic aerial surveys were conducted in the Issungnak Island area, on 24 July and 5 and 9 August. These surveys were flown in a twin-engine Cessna 337 at an altitude of 305 m and an airspeed of 262 km/h; other procedures were identical to those outlined above.

Reconnaissance Surveys

Reconnaissance aerial surveys were used to rapidly survey large areas when systematic surveys would have been impractical. These surveys were flown at altitudes of 305 to 610 m.

During recent years it has become apparent that the timing of break-up of the landfast ice across the Mackenzie estuary in relation to the migration of white whales can have a profound effect on the number of white whales using various parts of the estuary. Because the number of white whales using Kugmallit Bay, the main area of Esso's current operations, appeared to have been greatly reduced from 'normal' levels during 1978 and 1979 owing to ice conditions, we studied the spring migration movement in some detail in 1980. Reconnaissance flights in single-engine aircraft were used to evaluate ice conditons and check for the presence of whales within the estuary. Offshore flights in twin-engine aircraft were used to observe the relative numbers of whales moving along the ice edge toward the estuary. Temporal patterns of ice cover in the southern Beaufort Sea were plotted using field observations as well as NOAA (U.S. National Oceanic and Atmospheric Administration) -6 satellite imagery.

Estimation Procedures

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 (Fraker et al. 1979), this appears to have no significant effect on our ability to detect whales in the heavily used nearshore areas. An accurate estimate of the number of whales depends on knowing what proportion is at the surface; unfortunately, this proportion is not precisely known.

Sergeant (1973) watched white whales from a cliff near Churchill, Manitoba, and observed that they spend 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 that 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. 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. It must be emphasized that the resulting figures should be treated as relative indices rather than unbiased estimates of absolute abundance. Calves are not included in the estimates because the dark calves are not reliably detectable in the turbid water, even at the surface.

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 was 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. To date no attempt has been made to calculate

appropriate visibility factors for the Mackenzie estuary; to do this radio transmitter tags would be required to study the behaviour of individual whales to determine the proportion of time spent below the surface during various activities.

Estimates of the number of white whales in the Mackenzie estuary may be affected by 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 usually conducted the surveys during the first part of the period when the whales are in the estuary and when the highest numbers have been recorded. The exception to this was in 1977, when 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 the transect width was 1.6 km or 50% of the surveyed area. Thus, an extrapolation coefficient of two was applied to the survey results to allow for whales assumed to have been present in 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. For the few surveys where only one observer was present, the extrapolation coefficient was doubled to allow for the additional unsurveyed area.

Limited information is available on the proportion of the time that bowhead whales spend beneath the surface, and it appears that the proportion depends on the whale's activity (Würsig et al. 1981). We have made no attempt to extrapolate from our survey results to estimate the total number of bowheads within the survey area.

Visits to Hunting Camps

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

It was occasionally 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.

Observations By Industry and Other Personnel

Important observations were made by various persons 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 3

RESULTS AND DISCUSSION

Spring Migration of White Whales

Beginning in April, white whales of the Mackenzie stock leave wintering grounds in the Bering Sea and proceed north and northeast along the northwest coast of Alaska, entering the Beaufort Sea near Pt. Barrow (Fraker 1979). Most of the whales travel eastward across the Beaufort Sea following a far offshore route that takes them to Amundsen Gulf and the adjacent part of the southeastern Beaufort Sea. In late June or early July, these whales travel southwestward toward the Mackenzie estuary, following the edge of the landfast ice lying off the Tuktoyaktuk Peninsula. In addition, a relatively small number of late-migrating white whales may go directly to the estuary without first travelling farther east.

A reconnaissance survey on 19 June 1980 showed large amounts of landfast ice present across the Mackenzie estuary, precluding access for the white whales. During a survey of the ice edge on 21 June we located a total of only 21 whales, most of which were about 90 km north of Shingle Pt. (Fig. 3a); we saw no others along the ice edge from the Alaska-Yukon border to Baillie Islands. In contrast, on 25 June, 235 white whales were seen along the edge of the landfast ice, and most were headed toward the estuary (Fig. 3b). On a brief reconnaissance survey along the ice edge in West Mackenzie Bay on 27 June, we counted 246 whales. At 1500 h on that date the landfast ice in Mackenzie Bay was still intact (Fig. 4a), but by 2000 h the ice barrier had been breached (Fig. 4b) and whales were swimming into the estuary toward Niakunak Bay.

The migration of white whales to the estuary was still in progress on 29 June when 296 were observed swimming along the ice edge, most toward West Mackenzie Bay (Fig. 3c). Landfast ice still precluded access to Kugmallit Bay on that date.

A small crack in the ice appeared in Kugmallit Bay, just north of Hendrickson Island, on 30 June; however, no animals were seen entering the bay, nor were any whales seen along the ice edge between Kugmallit Bay and McKinley Bay (Fig. 3d). On 6 July no whales were seen during a survey of the ice edge east from Kugmallit Bay to Baillie Islands.

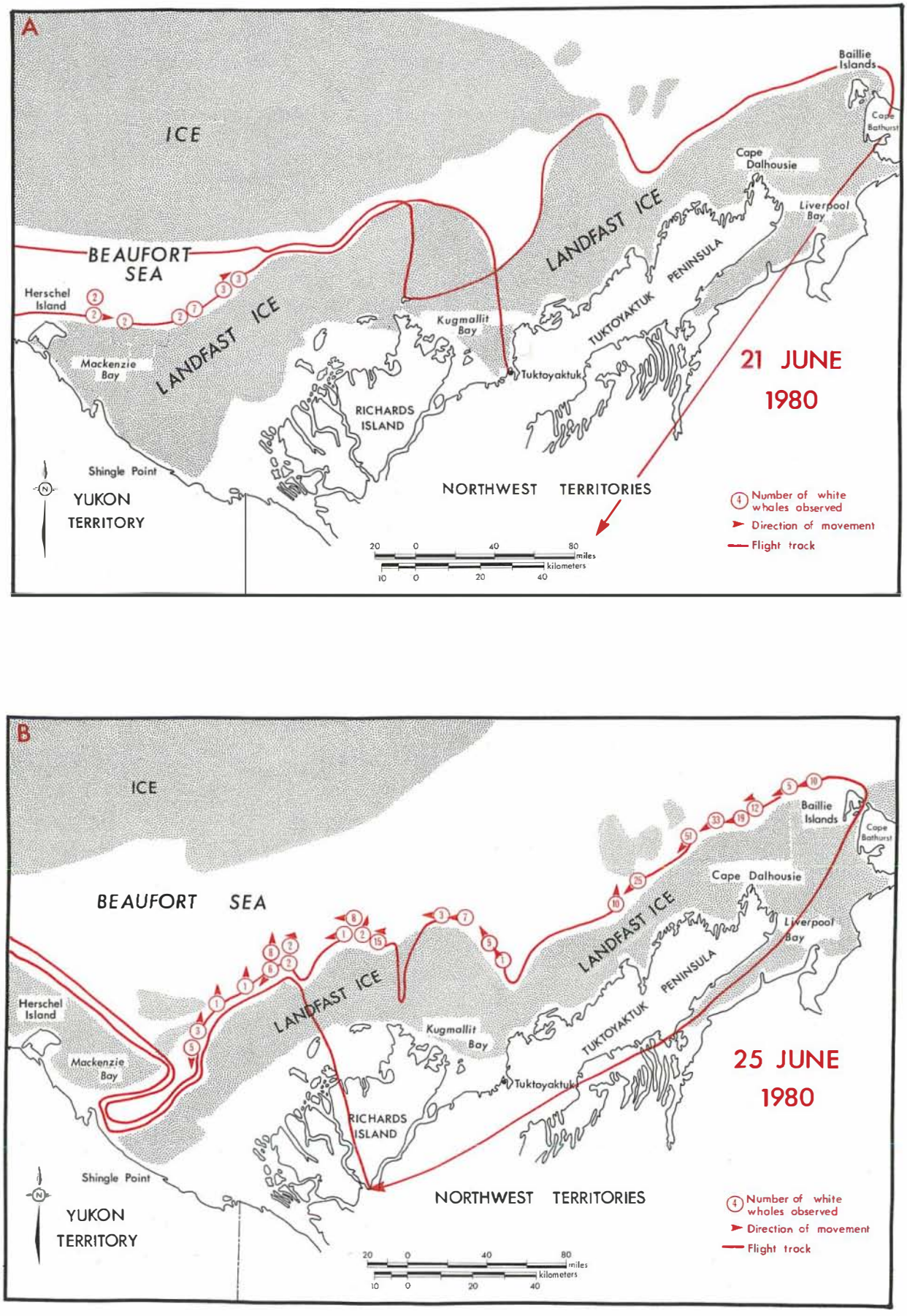
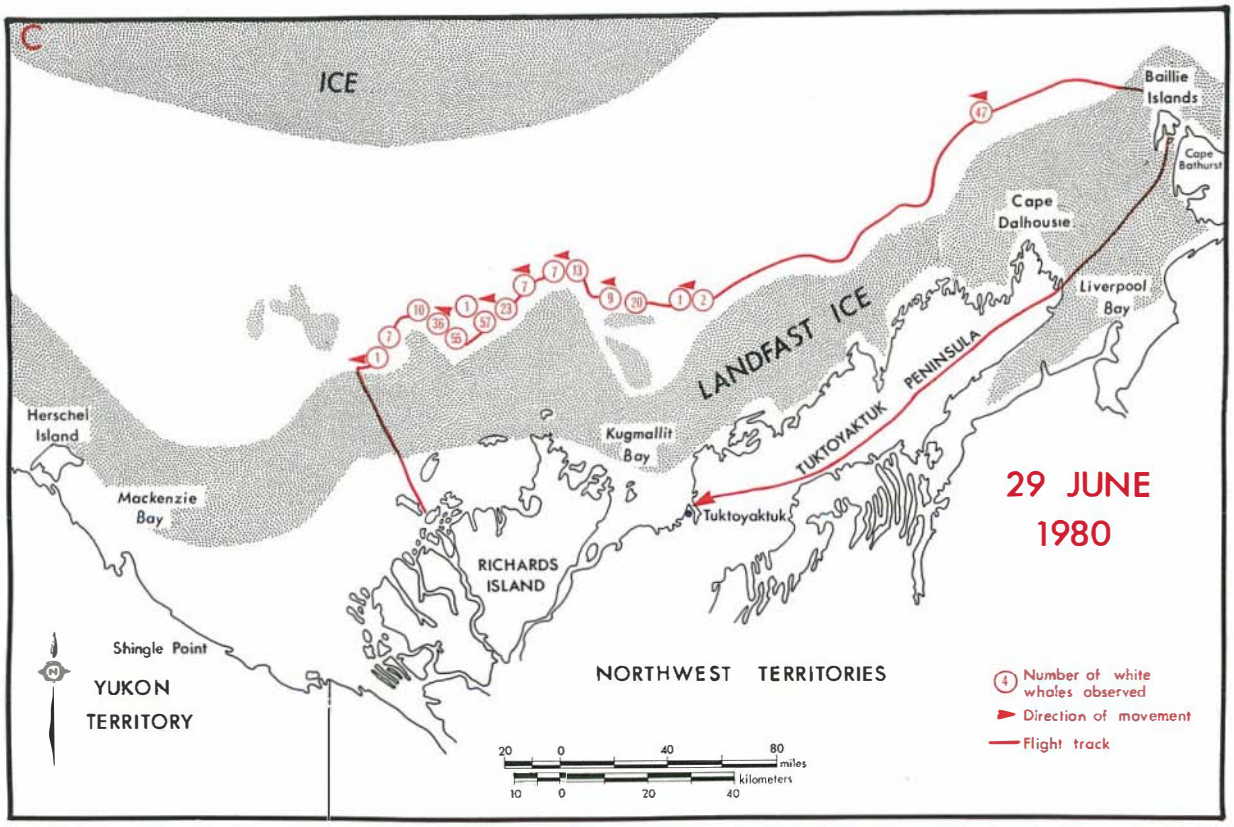
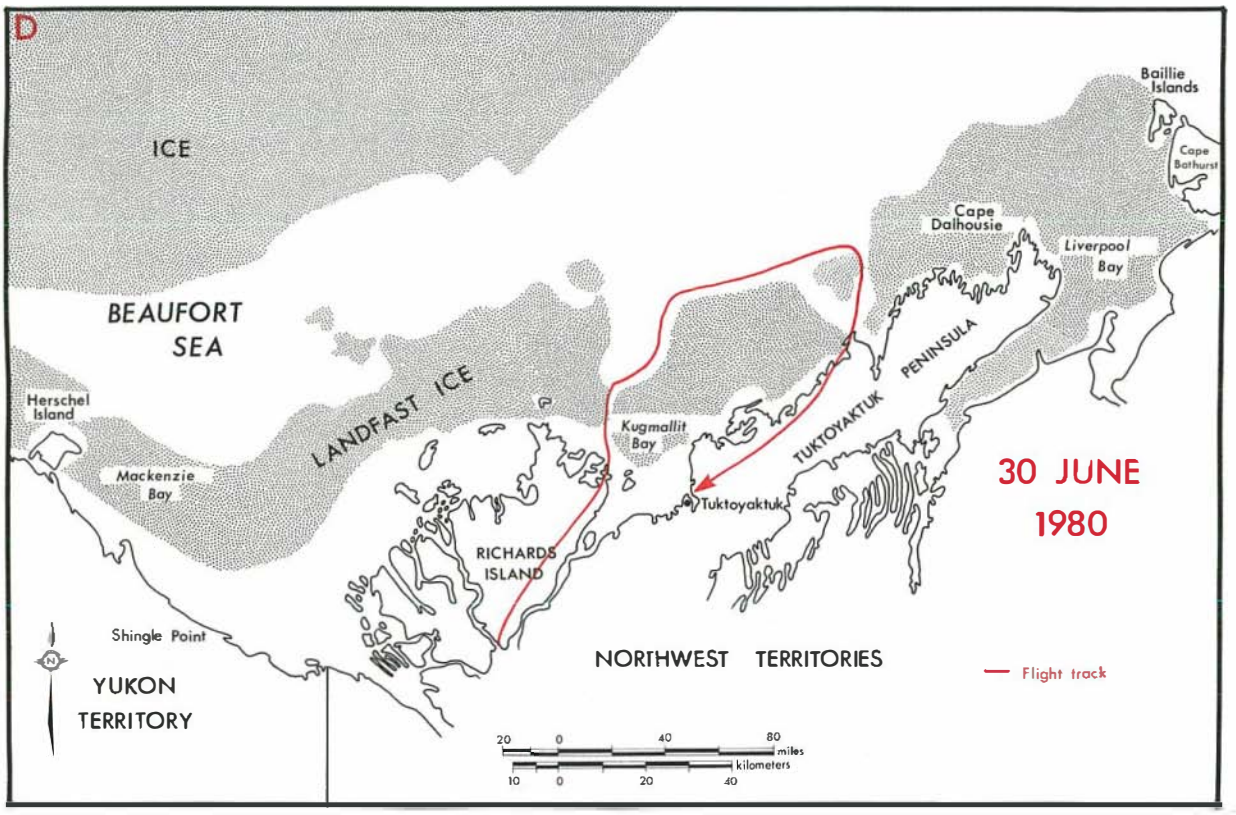


Figure 3. Results of spring migration surveys, 1980





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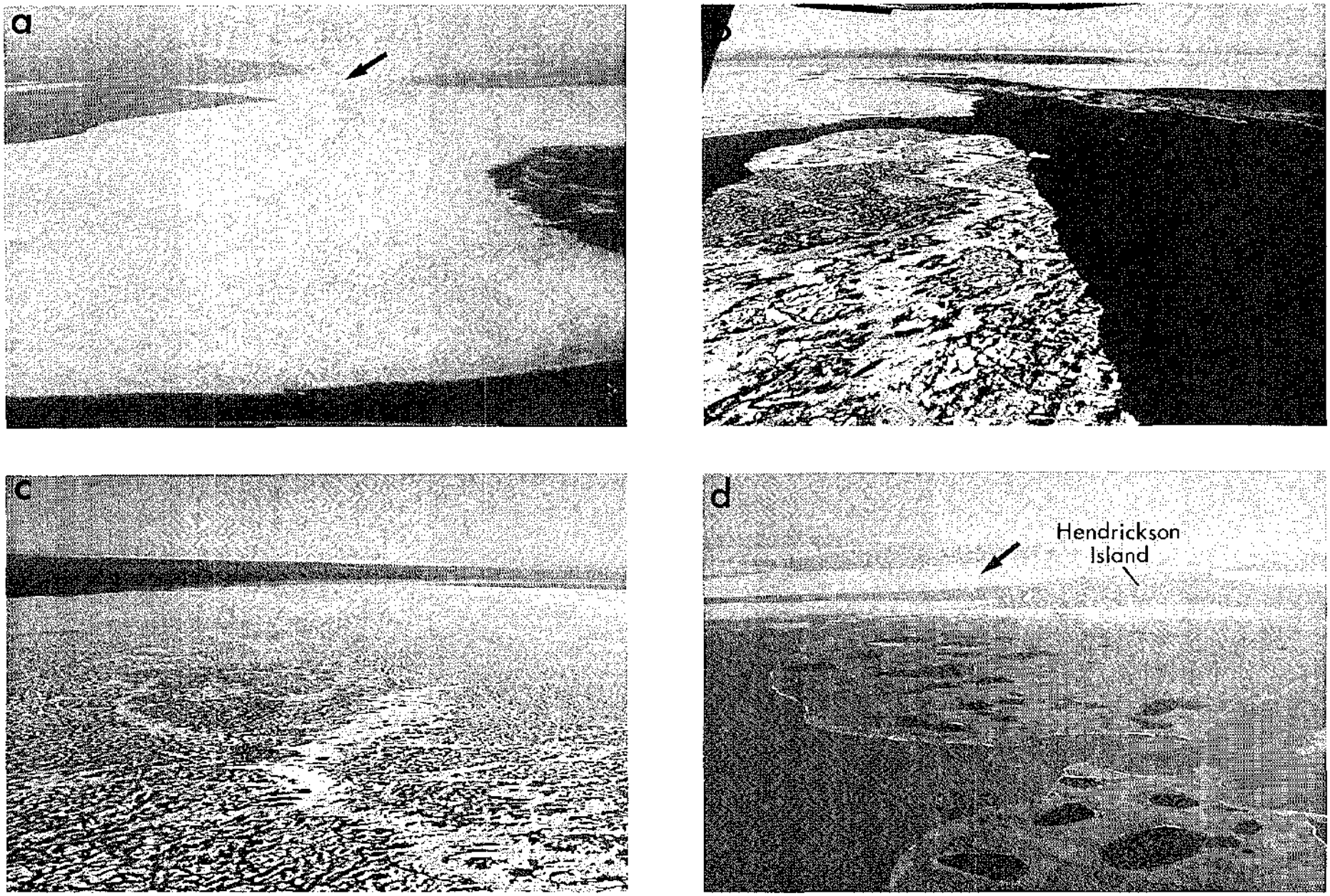

Figure 4. Observations of the break-up of landfast ice in the Mackenzie estuary, June 1980. a. Ice in West Mackenzie Bay as seen from the Yukon coast at 1500 h, 27 June; arrow marks point where ice fractured a short time later. b. The ice as it was breaking up at 2000 h, 27 June; whales were first observed entering the estuary at this time. c. The ice in West Mackenzie Bay as seen looking toward the Yukon coast, 30 June. d. The ice in Kugmallit Bay 30 June; arrow points to fracture.

The timing of the movement of white whales from the Amundsen Gulf region to the area near the Mackenzie estuary has varied between years. For example, in 1979, white whales were first seen entering West Mackenzie Bay on 20 June. In contrast, in 1977 no whales were found in the estuary until 30 June (Fraker et al. 1979) -- even though the landfast ice in West Mackenzie Bay was first breached on 15 or 16 June (Fraker 1979). In 1980, we first saw whales offshore of the estuary on 21 June; none were seen along the ice to the east on that date. The timing of the movement toward the estuary may be related to ice conditions in the southeastern Beaufort Sea and Amundsen Gulf. In 1977, when the movement was relatively late, Amundsen Gulf contained extensive open-water areas by late May (Fraker 1979), but in 1979, when the movement was early, Amundsen Gulf was completely ice-covered well into July (M.A. Fraker unpubl.).

Three mechanisms appear to be involved in the deterioration and eventual break-up of landfast ice in the Mackenzie estuary region (Dey 1980):

1. erosion of ice by heat from the Mackenzie River water (temperature and volume of discharge both being important),
2. melting owing to heat from insolation, and
3. mechanical forces resulting mainly from wind (but also river current).

In 1980, erosion by warm river water and melting caused by insolation were the dominant factors in West Mackenzie Bay: the landfast ice barrier was breached when the ice finally weakened to the extent that the outflowing river current was able to transport some of this ice seaward (Fig. 4b). During the next several days, the ice in this area continued to weaken and be carried seaward, thus widening the gap (Fig. 4c). In contrast, in 1978, strong southerly winds dislodged a large piece of the landfast ice in West Mackenzie Bay resulting (on 5 July) in the first access for the whales (Fraker 1978). Mechanical forces, probably resulting mainly from wind, appeared to be responsible for the fracturing and break-up of ice in Kugmallit Bay in 1980 (Fig. 4d).

In certain years, such as 1973 (Slaney 1974; Fraker 1979) and 1978 (Fraker 1978), offshore surveys have been carried out before the whales have had access to the estuary. In those years whales congregated seaward

of the landfast ice where large amounts of turbid river water were flowing out beneath the landfast ice. On the limited reconnaissance survey along the ice edge on 27 June, we saw 246 whales which were in turbid water near the narrowest point in the ice. Thus it appeared that again in 1980 the whales gathered in an area where the flow of river water probably was large and where the ice would first be breached. However, no whales were observed north of the Kugmallit Bay ice in 1980 or in 1978 or 1979, although about 100 were observed there in 1973 (Slaney 1974). In 1978, strong north winds pushed ice from the transition zone (Marko 1975; Fraker 1979) against the landfast ice north of Kugmallit Bay (Fraker 1978). This may have resulted in conditions that were unfavourable to whales, but the reasons why whales did not gather there in 1979 and 1980 are not apparent.

The pattern of break-up of the landfast ice in the Mackenzie estuary region is of great importance with regard to white whales (and whale hunting), because it appears to govern the numbers of whales that occupy certain parts of the estuary in any given year. In 1972 (Slaney 1973), 1978 (Fraker 1978), 1979 (Fraker and Fraker 1979), and 1980, the late break-up of ice in Kugmallit Bay appears to have resulted in the use of that area by only small numbers of whales. In contrast, the landfast ice in West Mackenzie Bay consistently breaks-up relatively early, and the largest number of whales typically is found in the western part of the estuary (i.e., Niakunak and West Mackenzie Bays). However, in 1973, 1976, and 1977, large numbers of whales were present in both the east and west sides of the estuary. (Surveys in 1974 and 1975 were not sufficient to ascertain the distribution patterns in those years).

In summary, the main part of the migration of white whales to the Mackenzie estuary in 1980 began sometime between 21 and 25 June and was nearly complete by 30 June.

Distribution of White Whales

Niakunak Bay

At 2000 h on 27 June 1980, white whales were first observed swimming into West Mackenzie Bay through a break in the landfast ice north of Shingle Point, and they probably entered Niakunak Bay early on the next day. During a systematic survey of Niakunak Bay on 28 June, 127 whales were

counted, for a total estimate of 508 (Table 1; Fig. 5; Appendix 1). Because of only fair survey conditions, the 28 June figure must be considered a minimum estimate. The first reliable survey, done three days later, resulted in an estimate of 4160 white whales. Nine days later, on 10 July, the maximum estimate (4234) for this area was obtained. Nearly 3000 whales were estimated to be present on 15 July, but on 25 July only an estimated 152 whales were present.

Owing to unfavourable weather, only a limited survey effort was possible in Niakunak Bay early in 1980, and as a consequence we probably were unable to detect some major changes in whale numbers. Given the rapid increase in numbers that typically occurs within a few days after the first whales enter the estuary (Fig. 5), followed by a gradual decline, it is quite likely that peak numbers occurred during the 2-9 July period when poor weather precluded surveys.

The location and extent of the Niakunak Bay concentration area in 1980 were within the limits determined in previous years (Fig. 6). No southeastward extension into Shallow Bay was observed in 1980, possibly because of the pattern of hunting activity. In 1980, hunting activity was spread over a wide geographical area, including the area north of Tent Island, although the hunting period was very short (of 19 whales for which a date of kill is known, 15 were taken in the first 10 days that whales were present). In 1979 the hunting period in Niakunak Bay was much longer, but all eight whales that were landed in the first 10 days of the 1979 season were taken within a very small area about one kilometre from the mouth of the river channel near Bird Camp. During this early period in 1979 about 100 whales penetrated deeply into Shallow Bay. The larger area disturbed by hunting in 1980 may have discouraged such a movement.

Every year or two, a few whales are reported to swim considerable distances up channels of the Mackenzie River. Typically the reports are of one or two individuals. However, in 1980 an unusually large number of whales entered the West Channel and some travelled up-river at least as far as Aklavik (90 km from the mouth of West Channel). The estimates of the total number of whales that entered the river range from 20 to 100. Inuit in the Aklavik area killed 10 and landed eight whales near the settlement

Table 1. Results of systematic whale surveys in Niakunak Bay, 1980.

Date	Lines flown	Observation conditions	Whales observed	Extrapolation coefficient *	Visibility factor	Estimated numbers
28 June	N-B to N-8	Fair	127	- **	- **	- **
30 June	N-B to N-8	Fair	77	-	-	-
1 July	N-B to N-9	Good	1040	2	2	4160
3 July	N-B to N-9	Fair	592	-	-	-
10 July	N-B to N-10	Good	1036	2 (N-B to N-9) 3 (N-10)	2	4234
15 July	N-B to N-9	Excellent (N-B to N-3) Good (N-4 to N-9)	695	2	2	2780
25 July	N-B to N-9	Good	19	4	2	152

* For most (lines N-B to N-9) systematic surveys an extrapolation coefficient of two was used to allow for the unsurveyed areas. Line N-10 is 4.8 km from N-9 and so the extrapolation coefficient for whales seen on this line is three. The extrapolation coefficient is doubled if only one observer was present on the survey (25 July).

** No population estimate was calculated for surveys done under fair conditions.

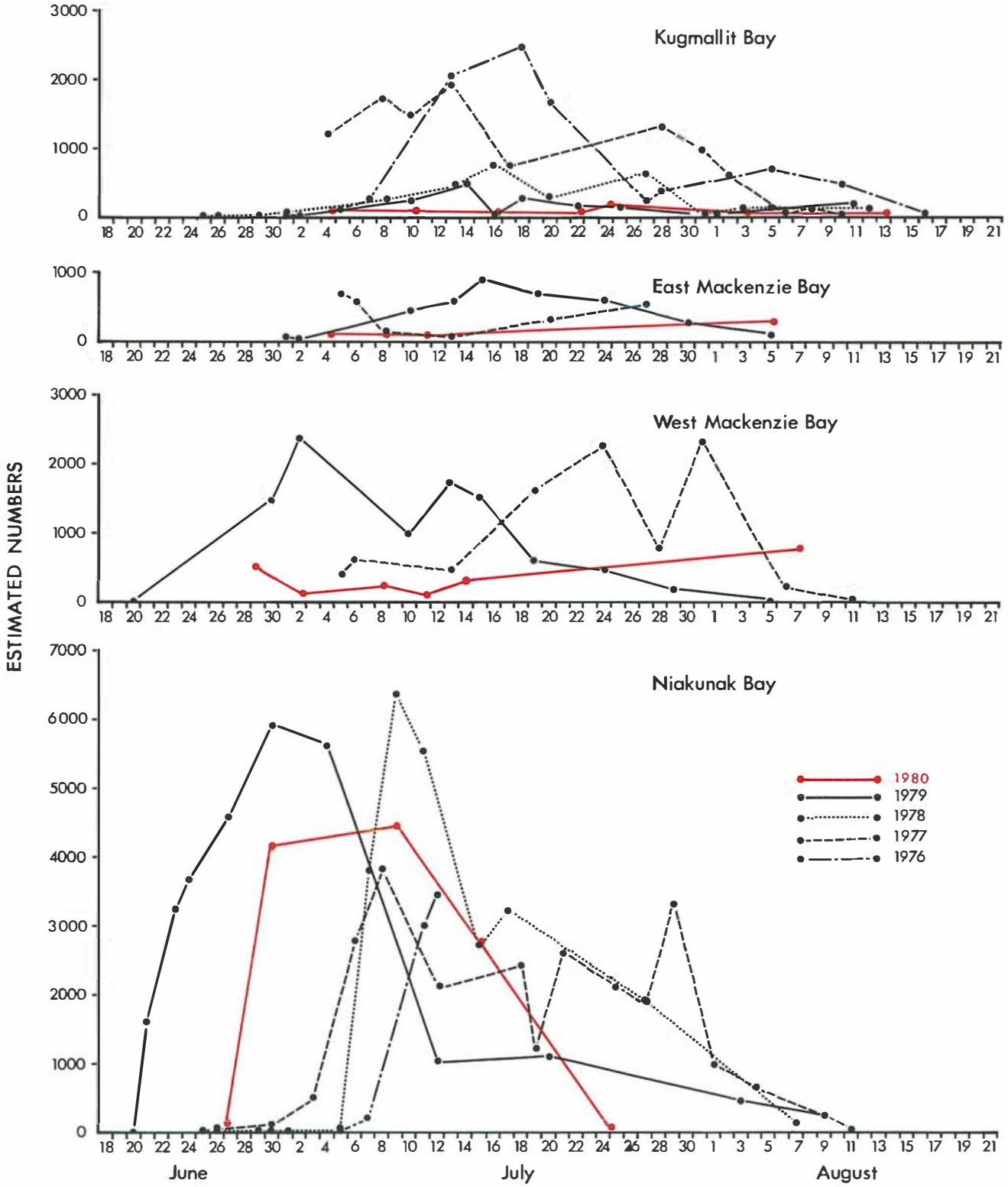

Figure 5. Changes in estimated numbers of white whales within the Mackenzie estuary, June-August 1976-1980.

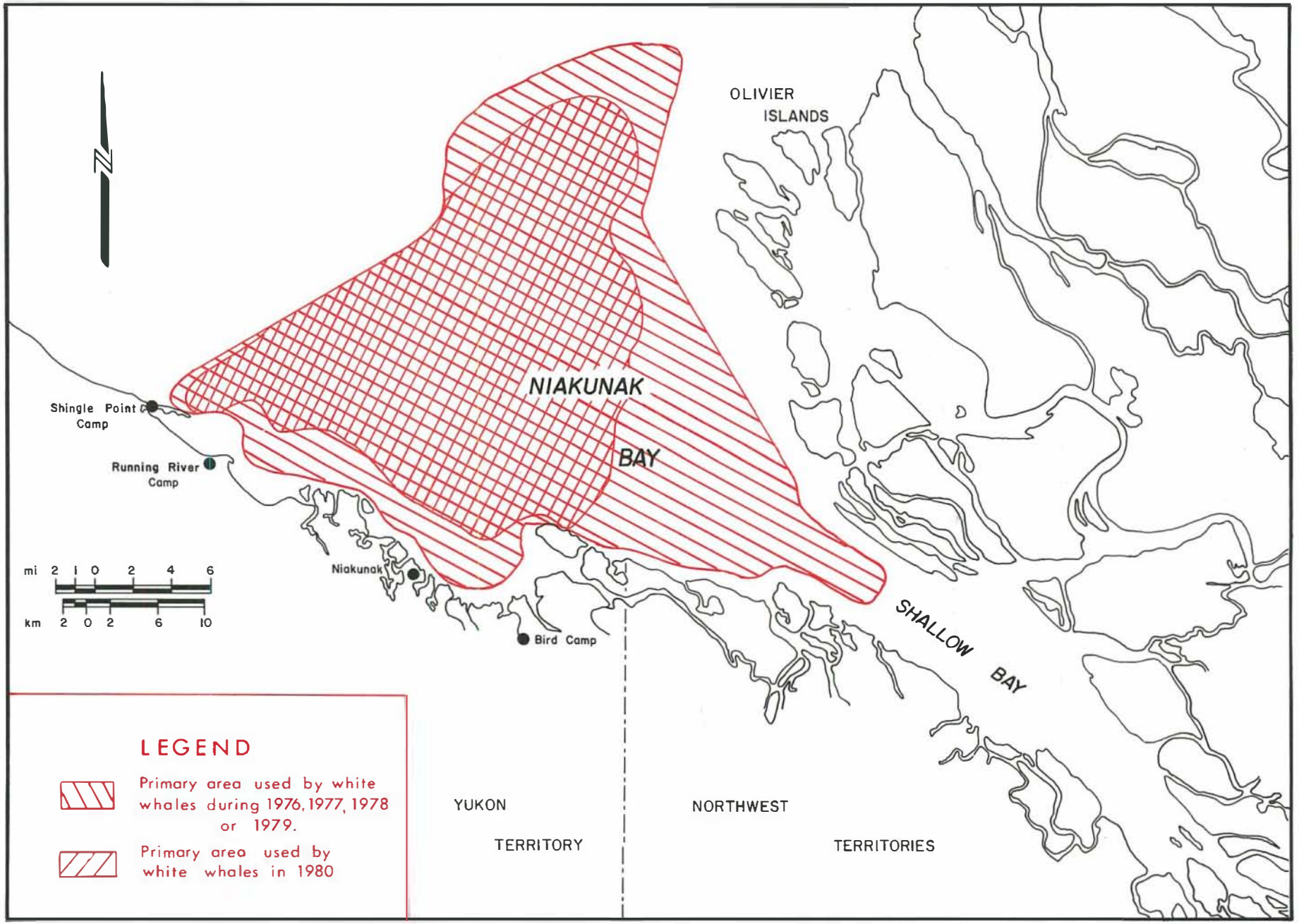

Figure 6. The extent of the Niakunak Bay white whale concentration area, 1976-1980.

on 14 July. The reasons why so many whales moved so far up-river are unknown.

West Mackenzie Bay

During the first two West Mackenzie Bay surveys (29 June and 2 July), we covered all of the survey area that was ice-free; after 2 July the area covered was reduced to the nearshore part of the first six lines, as had also been done after 2 July in 1979 (Fig. 2). In 1977, the only other year this area was examined in detail, all of the original survey lines were flown throughout the study period. The modified coverage flown in 1979 and 1980 was only about 30% of the original survey area, but included the nearshore region that sometimes is used intensively by whales.

Few whales were observed in West Mackenzie Bay in late June and July 1980 (Table 2; Appendix 1). Surveys on 19 and 21 July were hampered by low cloud ceilings, but the fact that we saw only 19 whales on the 19th and none on the 21st indicates that very few were present within the surveyed area on those days. However, our last survey, on 7 August, produced an estimate of 900 white whales. These animals were fairly concentrated and few were moving (Fig. 7). Of the whales observed before 19 July most were moving; very few of the observed whales were moving on or after 19 July (Table 3). On or before 5 July many of the moving whales were headed toward Niakunak Bay (to the S, SW, or W); after 5 July, there was no clear movement pattern.

Early in the summer, West Mackenzie Bay is used as a travel route by whales migrating to the shallow nearshore concentration area in Niakunak Bay. As the initial aggregations disperse, West Mackenzie Bay is used by animals leaving Niakunak Bay. Whales may gather in relatively dense aggregations in the nearshore parts of West Mackenzie Bay after the estuary has warmed and the level of use of Niakunak Bay has declined. The reduced amount of movement recorded after mid-July 1980 probably reflects a change in the use of West Mackenzie Bay from a travel route to an area where whales gather.

East Mackenzie Bay

It has never been possible to devote a large amount of survey effort to East Mackenzie Bay, and therefore the pattern of utilization of

Table 2. Results of systematic whale surveys in West Mackenzie Bay, 1980.

Date	Lines flown	Observation conditions	Whales observed	Extrapolation coefficient *	Visibility factor	Estimated numbers
29 June	WM-1 to WM-8	Excellent	51	3	2	306
2 July	WM-1 to WM-7	Good	16	3	2	96
5 July	WM-1 to WM-6 (modified ††)	Fair	61	- †	- †	- †
8 July	WM-1 to WM-3 (modified)	Fair	2	-	-	-
9 July	WM-1 to WM-6 (modified)	Good	30	3	2	180
11 July	WM-1 to WM-6 (modified)	Good	12	3	2	72
14 July	WM-1 to WM-6 (modified)	Good	51	3	2	306
19 July	WM-1 to WM-6 (modified)	Fair	19	-	-	-
21 July	WM-1 to WM-6 (modified)	Fair	0	-	-	-
7 August	WM-1 to WM-6 (modified)	Excellent	150	3	2	900

* An extrapolation coefficient of three was used to correct for unsurveyed area.

† No population estimate was calculated for surveys done under fair conditions.

†† Modified means that the lines were shortened (see Fig. 2).

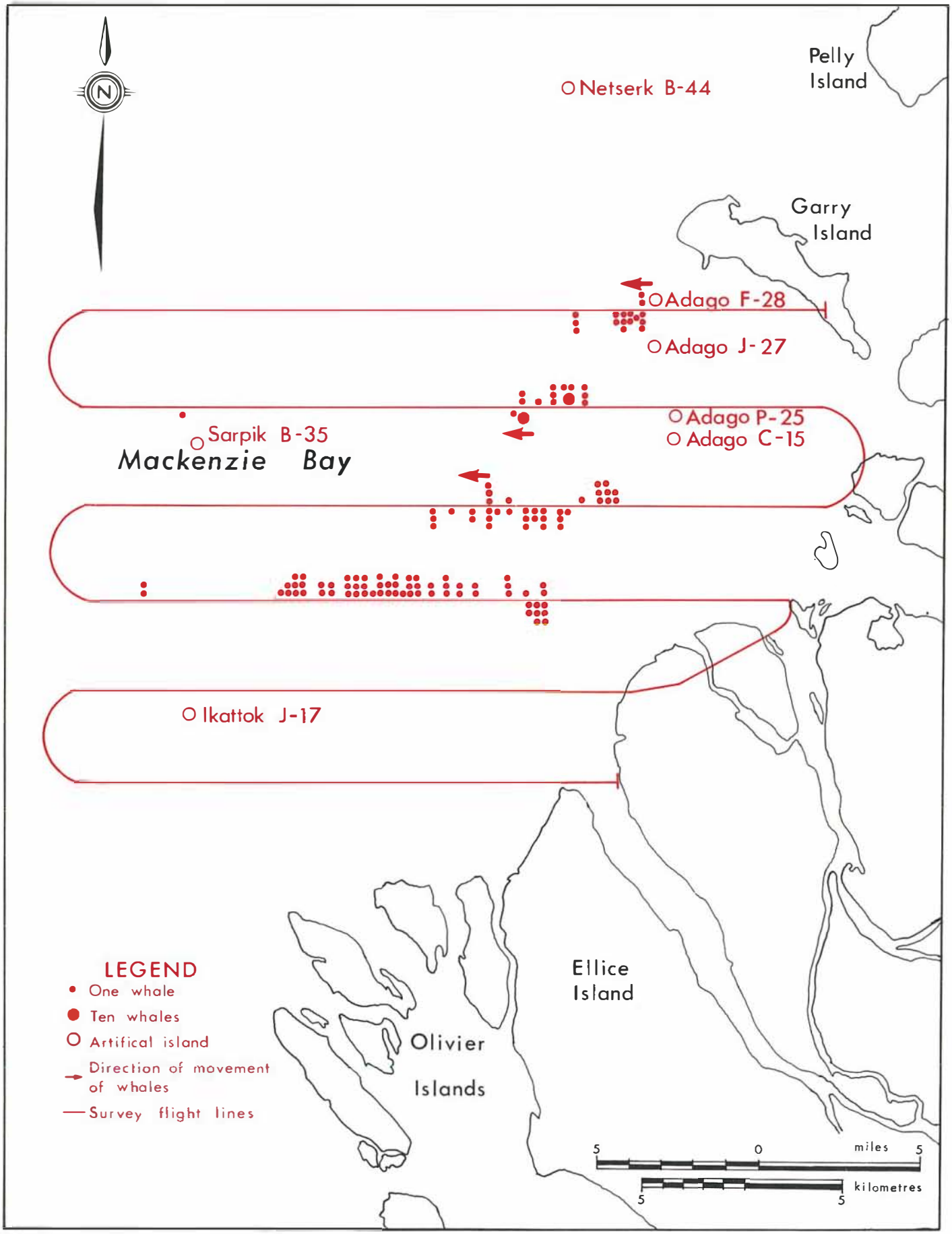

Figure 7. Distribution and abundance of white whales in West Mackenzie Bay, 7 August 1980.

Table 3. Number and direction of movement of white whales in West Mackenzie Bay, 1980.

Date	Total number of whales observed	Number of moving whales and direction of movement	% observed whales that were moving
29 June	51	12 - S 9 - W 2 - SW 2 - NE	49
2 July	16	6 - SE 1 - E	44
5 July	61	50 - SW 5 - W 4 - NE 2 - N	100
8 July	2	1 - W 1 - E	100
9 July	30	21 - E 5 - S 1 - W 1 - N	93
11 July	12	8 - E 2 - N 1 - SE	92
14 July	51	8 - W 4 - NE 2 - NW 2 - E	31
19 July	19	NA*	0
21 July	0	NA	0
7 August	150	20 - W	13

* NA - not applicable as no moving whales were observed.

this area by whales is only partially understood. In general, East Mackenzie Bay has tended to be used later in the season and by fewer whales than the other parts of the estuary (Fig. 5). However, if the landfast ice north of this area fractures relatively early, as in 1973 and 1977, then large numbers of whales may use this area as a travel route to reach Niakunak Bay early in the season. We saw only small numbers of whales in East Mackenzie Bay in 1980 (Table 4; Appendix 1). The largest estimate was 316 on 5 August; this was at about the same time (7 August) that we observed the largest numbers in West Mackenzie Bay.

The area in East Mackenzie Bay used most frequently by the whales is just off the north end of Garry Island and between Garry, Pelly, and Kendall Islands. Most of the whales seen on 5 August were in the Garry-Pelly-Kendall area (Fig. 8), which was part of the area utilized by many animals in 1977 (Fraker et al. 1979) and 1979 (Fraker and Fraker 1979).

Kugmallit Bay

Relatively few whales were present in Kugmallit Bay in 1980. The largest number estimated was only 120 (Table 5), in contrast to the 2000-2500 animals that have used this area during some years (1973, 1976, 1977). The low numbers appear to have resulted mainly from the timing of ice break-up, which occurred after most whales had migrated past Kugmallit Bay.

Although the ice barrier across Kugmallit Bay fractured on 30 June, no white whales were reported there until 4 July, when M. Lawrence (Fisheries and Marine Service, Winnipeg, pers. comm.) counted 24 individuals south of Hendrickson Island. On 5 July, we estimated that only 44 whales were in the southern part of the bay (Table 5; Fig. 5; Appendix 1). The number of whales in Kugmallit Bay remained low throughout July and the first half of August (Table 5). (A few whales can be present as late as September.) As in 1979, there were too few observations of white whales in Kugmallit Bay in 1980 to define a concentration area. The extent of this area probably is well defined based on the study results of 1976-1978 (Fig. 9).

We conclude that the late break-up of the landfast ice in Kugmallit Bay, in relation to the timing of the whales' migration to the estuary, was

Table 4. Results of systematic whale surveys in East Mackenzie Bay, 1980.

Date	Lines flown	Observation conditions	Whales observed	Extrapolation coefficient *	Visibility factor	Estimated numbers
5 July	EM-A to EM-6	Good	0	2	2	0
9 July	EM-A to EM-10	Good	10	2	2	40
11 July	EM-A to EM-4 EM-6 to EM-7	Good	3	2	2	12
19 July	EM-A to EM-10	Fair	6	- †	- †	- †
5 August	EM-A to EM-10	Good-Excellent	79	2	2	316

* An extrapolation coefficient of two was used to correct for the unsurveyed area.

† No population estimate was calculated for surveys done under fair conditions.

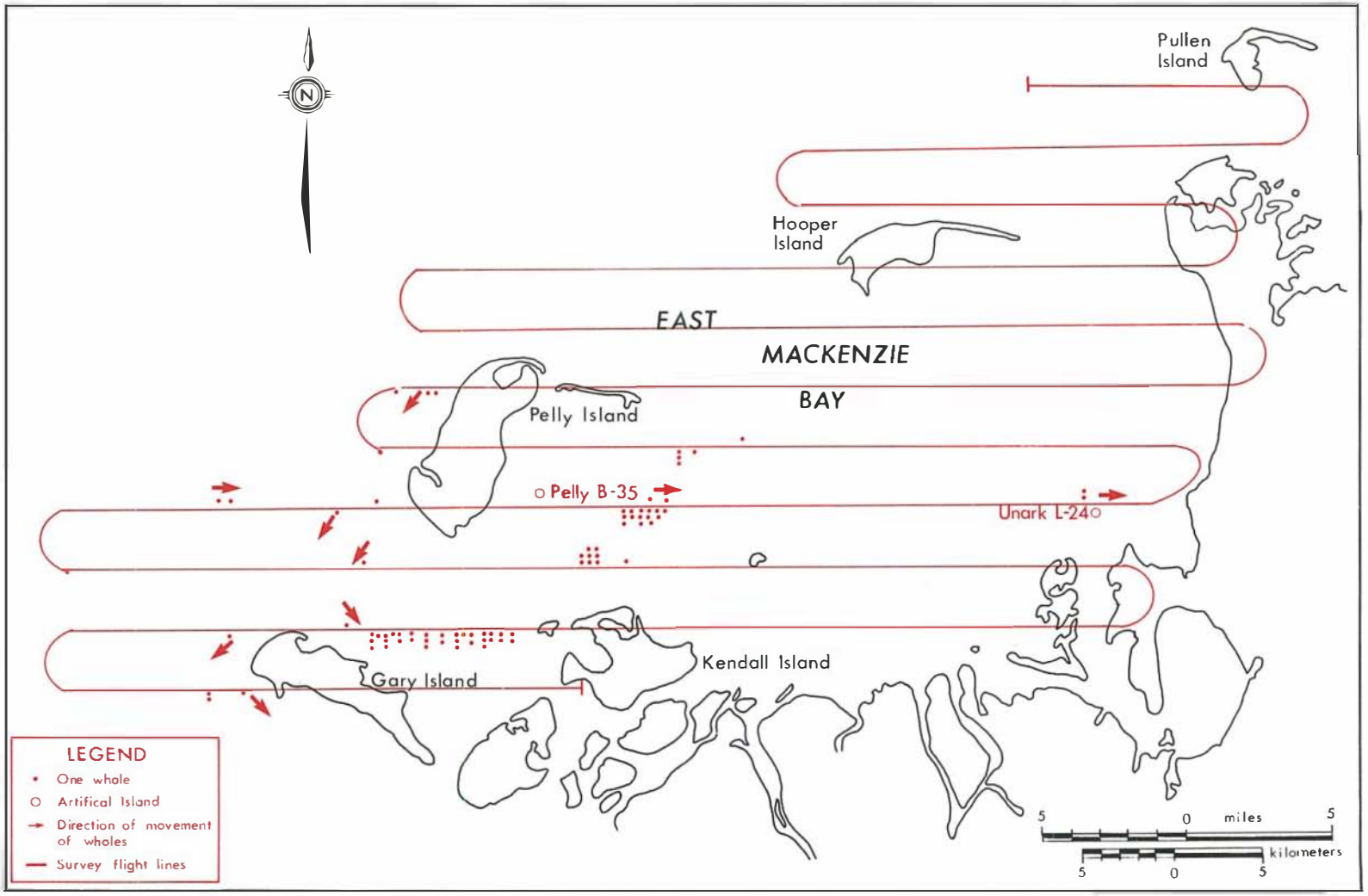

Figure 8. Distribution and abundance of white whales in East Mackenzie Bay, 5 August 1980.

Table 5. Results of systematic whale surveys in Kugmallit Bay, 1980.

Date	Lines flown	Observation conditions	Whales observed	Extrapolation coefficient *	Visibility factor	Estimated numbers
5 July	K-1 to K-6	Good	11	2	2	44
10 July	K-A to K-9	Excellent (K-A to K-6) Good (K-7 to K-9)	5	2	2	20
12 July	K-2 to K-7	Good (K-2 to K-5) Fair (K-6 to K-7)	0	- †	- †	- †
16 July	K-1 to K-9	Good	0	2	2	0
22 July	K-1 to K-9	Good	0	2	2	0
24 July	K-1 to K-8	Good	15	4	2	120
28 July	K-1 to K-9	Fair	9	-	-	-
3 August	K-1 to K-9	Good	20	2	2	80
12 August	K-1 to K-9 K-11 to K-12	Good	15	2	2	60

* An extrapolation coefficient of two was used to correct for the unsurveyed areas. This was increased to four when only one observer was present (24 July).

† No population estimate was calculated for surveys done under fair conditions.

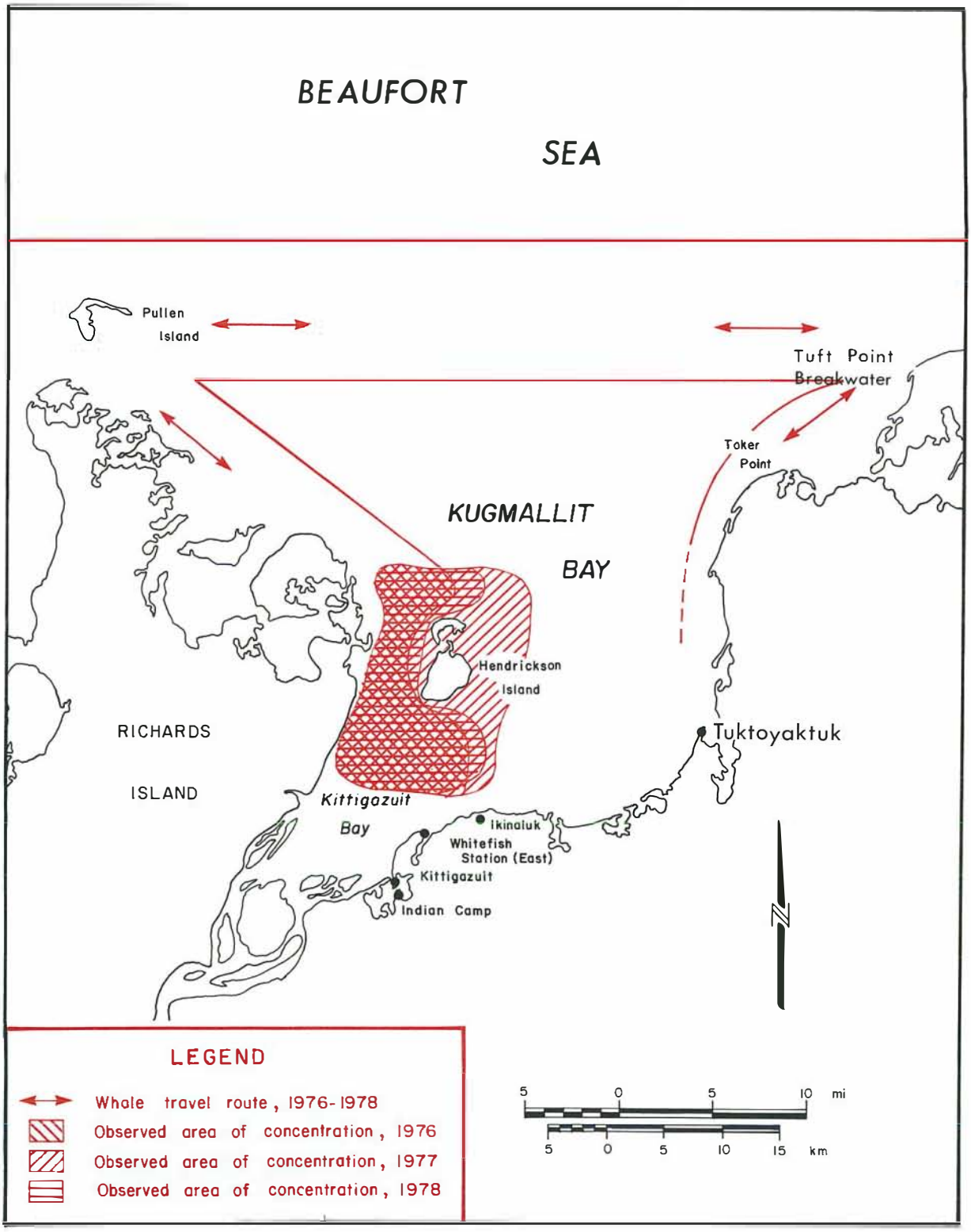

Figure 9. White whale high-use areas, Kugmallit Bay, 1976-1978.

mainly responsible for the low numbers in this area in 1980. Prior to 30 June (when the ice in Kugmallit Bay fractured) surveys along the edge of the landfast ice east of the Mackenzie estuary region showed that substantial numbers of white whales were migrating toward the estuary (Fig. 3). However, we saw no whales during surveys on 30 June or 6 July, indicating that the migration to the estuary was practically complete by the time that the ice broke in Kugmallit Bay. In 1972, as in 1978 and 1979, the whales were denied access to Kugmallit Bay until relatively late owing to ice, and low numbers were estimated to have used this area initially in those years. Thus, in four of seven years, the initial number of whales in Kugmallit Bay has been low, and in each case, ice conditions were identified as the cause. (The information available from 1974 and 1975 is insufficient to determine the numbers in Kugmallit Bay.)

An examination of the pattern of change in number of white whales in Kugmallit Bay also indicates that the number of whales that use the area in a given year is determined early in the season, and this lends further support to the idea that the abundance of whales in this area is related to the spring migration movement. The usual pattern of change in abundance of whales in the estuary is for peak numbers to be reached relatively quickly after the ice barrier is breached and the first whales arrive (Fig. 5). Thus, if high numbers of whales occur in Kugmallit Bay, they tend to do so early in the season. When the timing of break-up of the ice is late, relative to the whale migration, as in 1972, 1978, 1979, and 1980, only low numbers of whales are recorded.

Tuktoyaktuk Peninsula

White whales are frequently seen along the coast of the Tuktoyaktuk Peninsula during the latter part of July and August. This movement is not a continuation of the spring migration to the estuary, which occurs in late June and early July. Rather it appears to be a return to the estuary of whales that had been present earlier but that left, possibly to feed in offshore areas.

As expected, no whales were seen along the Tuktoyaktuk Peninsula in the first half of July (Table 6). Small groups of whales were often observed in the latter half of July and the first half of August (after

Table 6. Results of systematic whale surveys along the Tuktoyaktuk Peninsula, 1980.

Date	Easternmost point reached	Number of whales	Number of moving whales and direction of movment	Location	Remarks
10 July	Hutchison Bay	0	--	--	No whales in Hutchison or Beluga Bays
16 July	Hutchison Bay	0	--	--	No whales in Hutchison or Beluga Bays
20 July	Hutchison Bay	5	--	N of Warren Point	--
26 July	Cape Dalhousie	1	1 - SW	N of Warren Point	--
29 July	Cape Dalhousie	24	24 - SW	21 km SW of Atkinson Point	No whales in Hutchison or Beluga Bays
		8	8 - NW	N of Warren Point	
31 July	Atkinson Point	3		mouth of Hutchison Bay	feeding
3 August	Hutchison Bay	0	--	--	No whales in Hutchison or Beluga Bays
6 August	Cape Dalhousie	5	5 - W	19.5 km SW of Atkinson Point	--
		1	1 - W	N of Warren Point	--
11 August	McKinley Bay	3		21 km SW of Atkinson Point	feeding
		1	1 - E	N of Warren Point	17 whales and 2 calves feeding in Hutchison Bay
12 August	Cape Dalhousie	57	57 - SW	18 km SW of Atkinson Point	with 1 newborn calf
		1	1 - SW	38 km N of McKinley Bay	with 1 newborn calf
		65	60 - SW	12 km SW of Cape Dalhousie	3 whales in Hutchison Bay

which the study ended), and on 12 August we saw 123 whales in this area. We do not know how late in the year this coastal movement continues, but white whales can be present in the Mackenzie estuary in September, suggesting that this movement can continue until then. Whales observed along the Tuktoyaktuk Peninsula coast after mid-July usually are either feeding or travelling west toward the estuary.

Issungnak Area

The Issungnak area lies north of Richards Island and Kugmallit Bay (Fig. 2). Although much of the survey area is in deeper and more marine waters than those that characterize the Mackenzie estuary, the area north and west of Pullen Island is a coastal area. Construction of Issungnak O-61, which is located in about 19 m of water, began in 1978 and was completed to just above water in 1979; it was retopped and built up to about 5 m above water in 1980. A limited survey effort was undertaken in both 1978 and 1979 to examine use of this offshore region by whales.

In 1980 we surveyed the Issungnak area on 24 July and 5 and 9 August. Fifty-nine whales were seen on 9 August but only 20 and 7 were seen on 24 July and 5 August (Fig.10). More white whales were seen during the surveys in late July 1978 (157 and 218), but considerably fewer were seen in August 1978 (2 and 5) and during the 1979 surveys (5, 26, and 26) (Table 7). Despite much offshore activity during 1978, 1979, and 1980, only seven sightings of white whales have been reported by industry personnel and others for this area during these years. Most of the whales observed during offshore surveys or sighted by industry personnel and others were travelling; however, movements have been in all directions (Table 8) and no clear pattern has emerged.

It is clear that the number of whales in the concentration areas within the estuary is lower in the latter half of July than in the first half (Fig. 5), but where these whales go is uncertain. Many move offshore, perhaps out to the pack ice front to feed, and some of these return to the estuary. Information on the purpose of these movements is quite limited. In late July 1973, pilots reported seeing "hundreds" of white whales in pan ice about 320 km north of the estuary. In the eastern Arctic, the floe ice is known to be an important habitat for various species of seabirds and

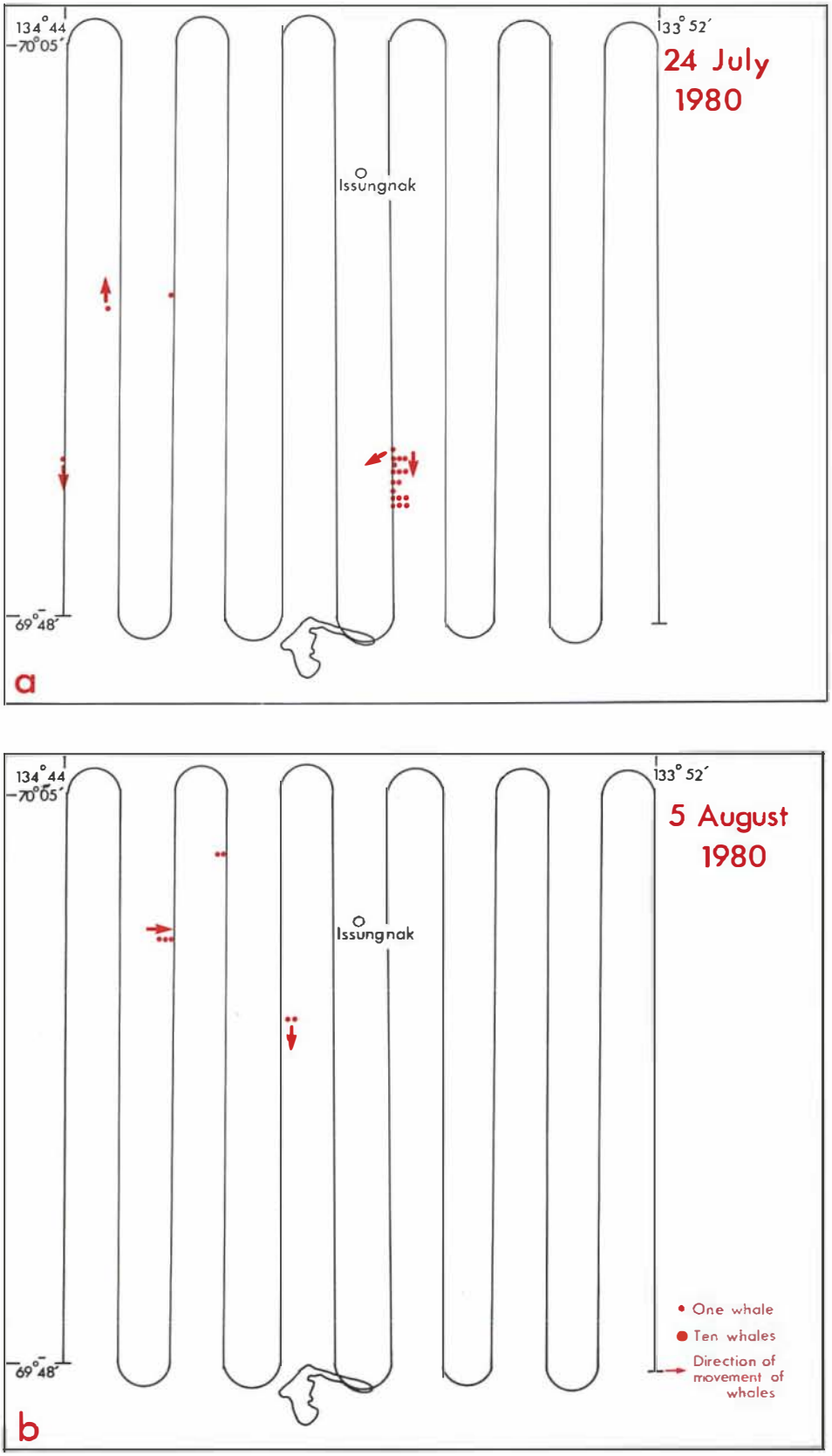

Figure 10. Observations of white whales in the Issungnak survey area, July and August 1980.

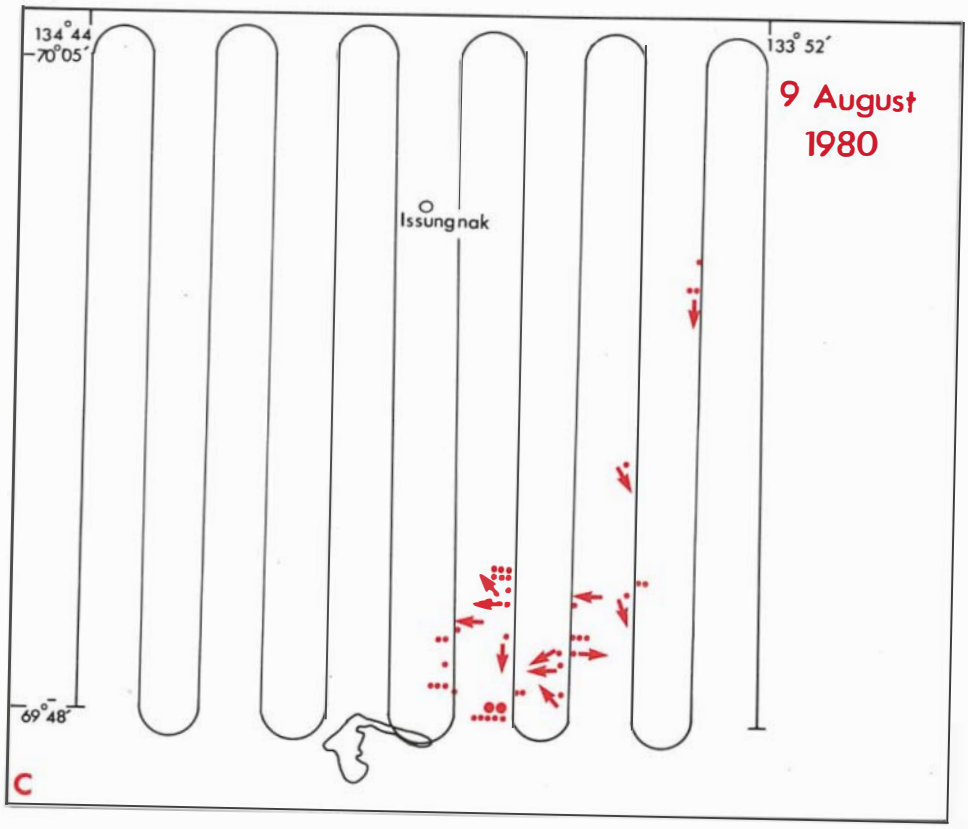

Figure 10. Continued

Table 7. Areas surveyed and white whales observed during offshore surveys, 1978-1980.

Date	Area (km^2)	Whales observed	Whales/km^2
26 July 1978	1536	157	0.102
29 July 1978	1866	218	0.117
2 August 1978	1104	2	0.002
8 August 1978	1104	5	0.005
21 July 1979	1702	5	0.003
2 August 1979	768	26	0.034
8 August 1979	1464	26	0.018
24 July 1980	340	20	0.059
5 August 1980	680	7	0.010
9 August 1980	680	59	0.087

Table 8. Orientations of white whales observed offshore of the Mackenzie estuary, 1978-1980. Data are sightings reported by industry and other personnel and observations during systematic whale surveys.

Orientation	Number of observations
N	11
NE	8
E	16
SE	7
S	11
SW	8
W	10
NW	4

marine mammals, and white whales have been seen to feed beneath ice in the eastern arctic during late summer (Finley and Johnston 1977). Finley (1976) observed a large movement of white whales out of Creswell Bay into an area off Fury Point coincident with the arrival of pan ice in this area. Approximately 2 days later, when the pan ice drifted out, the whales returned to Creswell Bay. It is possible that the Mackenzie whales behave similarly. There is some indication that a few white whales may travel farther east and also into the Eskimo Lakes in the latter part of the open-water period (Appendix 2; Fraker et al. 1978).

The whales offshore may travel singly, in small groups (typically 2-6), or in larger groups of up to 50-100 (Fig. 10).

Fall Migration of White Whales

Little information is available about the fall migration of white whales out of the Beaufort Sea. Fraker et al. (1978) saw about 2000 westward-moving individuals near Herschel Island and a group of about 100 along the ice edge about 200 km north of Prudhoe Bay, all on 21 September 1972. Johnson (1979) saw approximately 75-100 westward-migrating white whales 50-300 m seaward of Pingok Island, Alaska, on 15 September 1977, and approximately 35 white whales moving west about 150 m offshore of Thetis Island, Alaska, on 23 September 1978. On 1 October 1979, NARL (n.d.) reported an observation of 500-1000 white whales along the ice edge at 73°24'N, 155°37'W, which is about 250 km north of Pt. Barrow; apparently, a similar sighting was made on 20 September 1978 about 16 km from this location.

During 1980, LGL maintained field camps and daily seawatches at King Pt., Yukon Territory, from 16 August to 13 September, and at Herschel Island, Yukon Territory, from 23 August to 11 September (Würsig et al. 1981). White whales were observed only twice, both times at King Pt. On 19 August approximately 200 animals swam past King Pt., and on 24 August a group of perhaps 10 swam by. All were moving northwest along the coast. Nolan Solomon (pers. comm.), a resident of Kaktovik, Alaska, said that 10 white whales had been taken along the coast near that settlement on about 20 August 1980; the taking of white whales at Kaktovik is an infrequent occurrence.

If a substantial portion of the fall migration were to take place along the coast, many more sightings would be expected. Despite a limited amount of survey effort along the ice edge north of Alaska, more whales have been seen there than near the more surveyed coast. The very limited information about the fall out-migration of white whales suggests that most migrate offshore, possibly along the ice edge, rather than along the coast.

Numbers of White Whales

The maximum estimate of white whales in the Mackenzie estuary in 1980 occurred on 10 July. On that date, 1036 whales were seen in Niakunak Bay, giving a total estimate of 4234 whales. On 9 July, 180 whales were estimated to be present in West Mackenzie Bay and 40 in East Mackenzie Bay; since most of these were headed away from Niakunak Bay, they were added to the total count. On 10 July, 20 whales were estimated to be present in Kugmallit Bay. Altogether approximately 4500 white whales were computed to have been present in the Mackenzie estuary at the time of the peak estimate.

The peak estimate of whale numbers has been obtained within a few days after the first whales enter the estuary in past years (Fig. 5). The maximum time taken to achieve peak numbers was 10 days, in 1979, a year in which the arrival of the first whales was especially early. In 1980 the peak estimate was obtained on 10 July, 14 days after the first whales arrived, although a similar estimate had been made on 1 July. During the intervening eight days, poor weather hampered our survey effort, and it is likely that a larger number were present at some point during that period. Therefore, 4500 probably is an underestimate of the peak number of whales using the estuary in 1980.

Estimates of the maximum number of white whales within the Mackenzie estuary at any one time have varied greatly from year to year (Table 9); the 1980 maximum of 4500 is much lower than that obtained in 1979 (7000). However, the 1979 maximum estimate was made on a day when a larger-than-usual proportion of the whales were remaining at the surface. No visibility factor needed to be applied, eliminating the uncertainty inherent in that method of calculating abundance. In addition, observation conditions were excellent. We believe that the difference in estimates in 1979 and 1980 was a sampling artifact.

Table 9. Maximum estimated number of white whales, Mackenzie estuary, 1972-1980.

Year	Maximum estimate
1972	1500-2000
1973	3500-4000
1974	3500-4000
1975	4000
1976	5500-6000
1977	5500
1978	6600
1979	7000
1980	4500

Less variation in the estimated maximum has been observed since 1976, when a standard survey technique was adopted. Many of the year-to-year differences may be the result of

1. interference with the observations owing to weather,
2. whales spending more or less time at the surface and, therefore, affecting the validity of the visibility factor (2X),
3. differing proportions of the total population being present within the surveyed area at a given time, and/or
4. different numbers of whales coming into the estuary each year.

We doubt that there has been any substantial difference in the number of whales in the estuary and, therefore, factors 1-3 above probably explain most of the variation.

White Whale Behaviour

Since 1977 an attempt has been made to record whale behaviour during systematic surveys; the effort expended has not been consistent from day to day or from year to year. Unfortunately these behaviours are most common where there are large numbers of whales, situations in which most time must be spent doing abundance estimates. The behaviours that have been recorded include:

gamming - an aggregation of up to approximately 20 whales remains in place at the surface; occasionally their heads point in toward the centre as in a rosette.

splashing - a part of the whale's body is forcibly brought down onto the water producing a splash. During surveys it is often not possible to make detailed observations of behaviour; 'splashing' is a composite category that includes tail-lobbing, flipper-slapping, head-slapping, and breaching.

tail-lobbing - the tail is raised out of the water and forcibly struck against the water's surface.

head-slapping - the animal forcibly strikes the water with its head.

breaching - most of the whale's body leaves the water and then falls back in, creating a large splash.

spy-hopping - the whale raises its head out of the water, while its body is oriented tail downward. The eyes clear the water surface, and it appears that the whale is gaining a vantage so that it can look around it.

During 28 of the surveys done in the study area from 1978 to 1980, there have been 206 observations of one or more of the behaviours listed above; during the remaining 59 surveys we did not notice any of these behaviours. The majority of the observations (88%) were made in Niakunak Bay (Table 10). Splashing (72 observations) and gamming (72 observations) were most common; tail-lobbing was least common (1 observation).

Although the behaviour of several odontocete species has been studied in captivity, the behaviour of only a few odontocetes has been examined in the wild. Würsig and Würsig (1979, 1980) studied the bottlenose dolphin (*Tursiops truncatus*) and dusky dolphin (*Lagenorhynchus obscurus*) in Argentina, Saayman et al. (1973) studied the Indian Ocean bottlenose dolphin (*Tursiops aduncus* Ehrenburg) in South Africa, and Norris and Dohl (1980) examined the Hawaiian spinner dolphin (*Stenella longirostris*) in Hawaii. All of these studies primarily involved observations from shore camps, a situation which allows longer and more intensive observation than is possible during our aerial surveys and ensures that the animals are undisturbed by the observers. Many of the behaviours seen in white whales (tail-lobbing, head-slapping, and spy-hopping or nose out) have also been reported for most of the abovementioned species. Nothing similar to gamming has been described for any of these four species, although a similar behaviour has been reported for the sperm whale, *Physeter catodon* (Caldwell et al. 1966).

Suggested functions of aerial (splashing) behaviours include strengthening school cohesiveness (Norris and Dohl 1980; Würsig and Würsig 1980), signaling to neighbouring groups that feeding is occurring (Würsig and Würsig 1980), confining prey fish (Saayman et al. 1973; Würsig and Würsig 1980), and communicating information to other members of the group (Würsig and Würsig 1979). Since little feeding occurs in the estuary, it is unlikely that the splashing observed during our aerial surveys is used in confining prey fish or signaling neighbouring groups that feeding is occurring. Splashing would be more likely to strengthen group cohesiveness and/or to be a means of communicating within or between groups. Spy-hopping may provide white whales with information about the environment

Table 10. Observations of white whale behaviours according to locality within Mackenzie estuary, 1978-1980.

Area	Behaviour	Number of observations
Niakunak Bay	Gamming	66
	Splashing	61
	Head-slapping	2
	Tail-lobbing	1
	Breaching	40
	Spy-hopping	11
Kugmallit Bay	Gamming	5
	Splashing	3
	Head-slapping	1
	Breaching	4
West Mackenzie Bay	Gamming	1
	Splashing	7
	Head-slapping	2
East Mackenzie Bay	Splashing	1
	Head-slapping	1

above the water. In Niakunak Bay none of the above behaviours was observed when fewer than 1600 whales were estimated to be present, and if one observation was made during a survey, usually at least one more was recorded. (There were five surveys with just one observation.) In Niakunak Bay, if one type of behaviour was observed, in every case, at least one other type was recorded as well. This suggests that gamming and the splashing behaviours probably serve a social function in white whales.

Harvest of White Whales

The harvest of white whales by Inuit in the Mackenzie estuary was very important to cultural, nutritional, and social dimensions. In fact, the primary reason for the Esso whale monitoring program was a response to concerns about possible adverse effects of offshore exploration activities on the hunt. In addition, it is important for the hunters and government, as well as Esso, to understand the effects of hunting on the white whales that use the estuary. It is also important to understand what kinds of 'normal' factors affect the hunting season and level of harvest. An examination of the harvested whales has provided valuable information about the status of the herd and how it is being affected by current levels of hunting mortality. Finally, the frequent contact between the whale researchers and the hunters has served to promote communication. For all of the above reasons, we have placed considerable emphasis on gaining information about many aspects of the white whale hunt in the Mackenzie estuary.

Timing of the Hunt

In 1980 the first whales were taken in the estuary on 4 July and the last on 23 August (Fig. 11). These dates fall generally within the dates of first and last kills recorded in 1978 and 1979. (One white whale whale was landed at Shingle Point on 7 September 1979.) Variations in the timing of hunting from year to year and from area to area result from differences in weather, timing and pattern of ice break-up, timing of use of the estuary by whales, and the period when hunters occupy the camps.

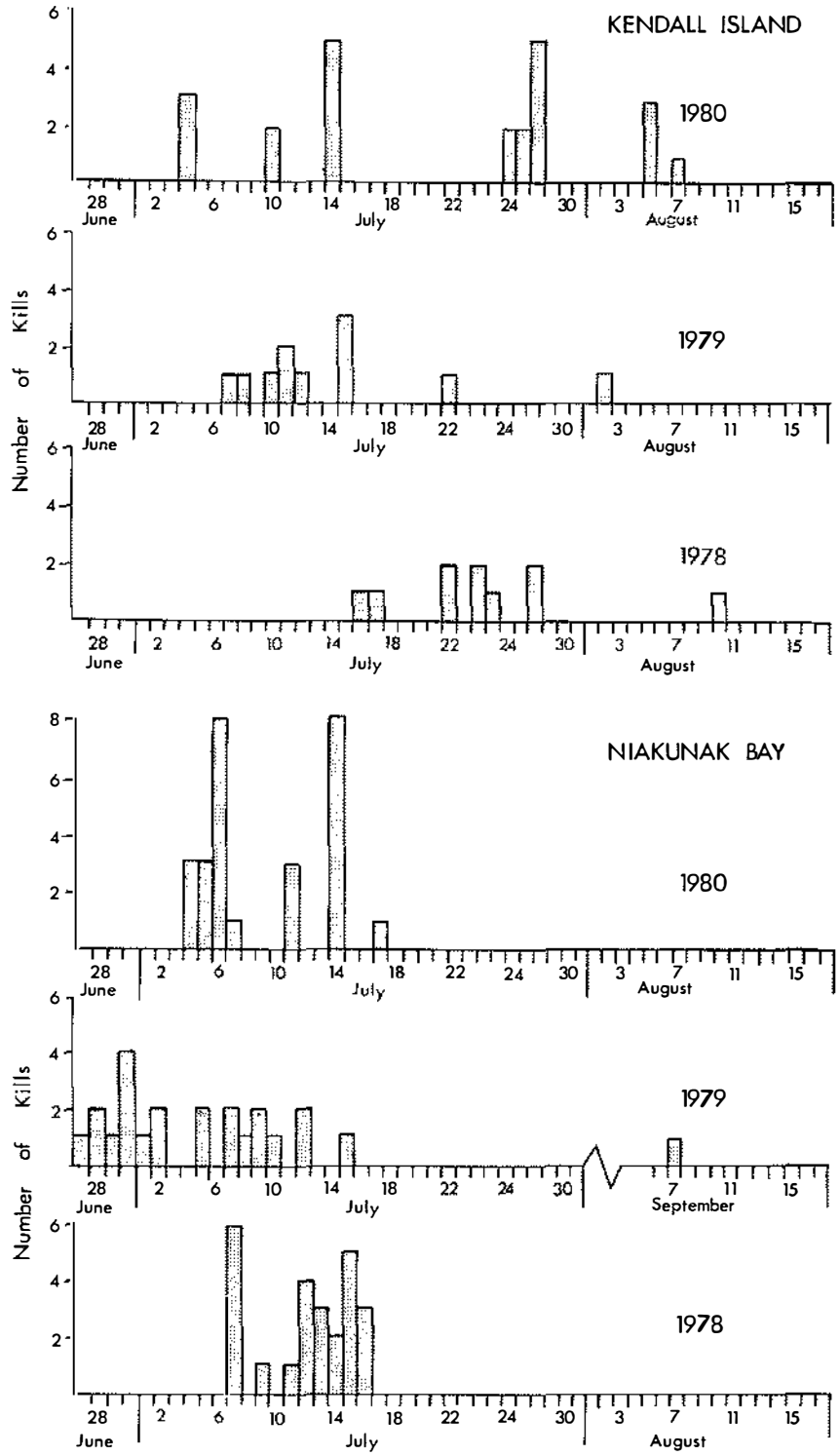

Figure 11. Dates of known white whale kills, Mackenzie estuary, 1978-1980.

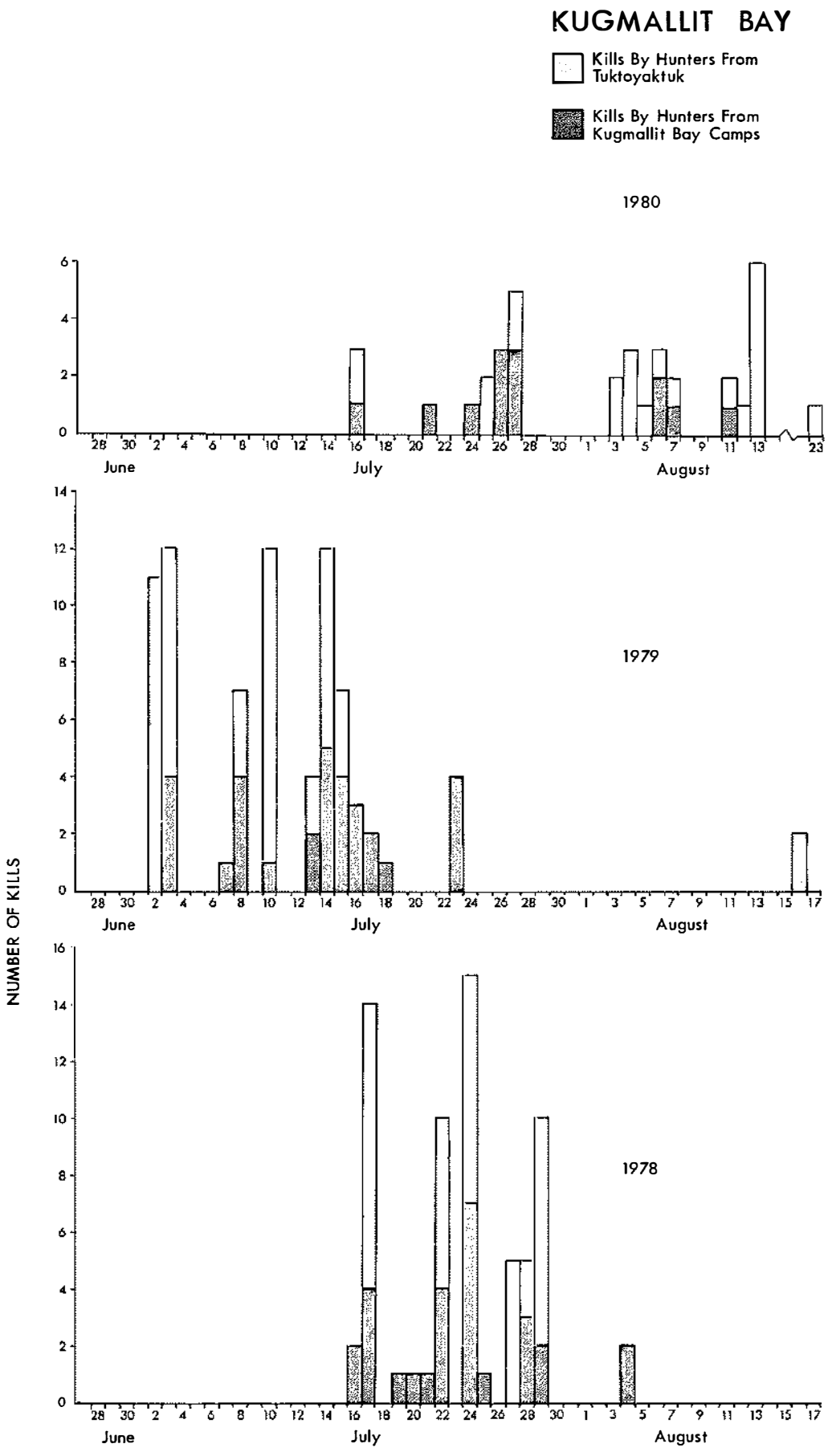

Figure 11. Continued

In 1980 the first camps were set up in each of the three main hunting areas at about the same time. Aklavik residents first moved to the Niakunak Bay camps on 29 June. Inuvik hunters and their families first arrived at the Kugmallit Bay camps on 28 June, and at the Kendall Island camps on 29 June. Traditionally Kendall Island has been occupied considerably later than the other two areas, and thus the 1980 pattern differed from that in most other years.

The first whales from Niakunak Bay were landed on 4 July (Fig. 11), five days after the first hunters arrived. Kendall Island hunters also got their first whales on 4 July, the earliest recorded date on which whales have been taken there. The first whales from Kugmallit Bay were taken late in 1980, on 16 July, 18 days after the first hunters arrived in camp and 12 days after the first success in the other two areas. In 1978 the first whale from Kugmallit Bay was also landed on 16 July. In that year windy weather delayed hunting until that date; in 1980 sporadic hunting attempts were made on several days before the first whale was landed, although the weather during this period was generally unfavourable.

The date on which the first whale is taken is usually the first day of good weather after the whales have arrived. In 1980, seven days elapsed between the arrival of the whales and the first successful hunt in Niakunak Bay and at Kendall Island; in Kugmallit Bay the time between the known arrival of the whales and the landing of the first whale was 12 days. The delayed starts in all three areas resulted at least partly from poor weather. The early (compared with 1978 and 1979) commencement of hunting at Kendall Island was possible because the hunters had arrived earlier in 1980 than in 1978 or 1979. The date when the camps were set up also affected the time of the first successful hunt in Niakunak Bay in 1979; although the whales had returned by 20 June, the whalers did not arrive until the 27th. Most hunters have school-age children, and the end of the school term (late June) determines when they can move out to the camps.

The hunting period was short in Niakunak Bay and much longer at Kendall Island and in Kugmallit Bay. Whales were landed on six days over a 14-day span in Niakunak Bay, on eight days over a 35-day span at Kendall Island, and on 16 days over a 39-day period in Kugmallit Bay. The taking of whales near Aklavik may have helped to shorten the hunting period in Niakunak Bay in 1980, since this satisfied the requirements of some hunters who would have travelled to Niakunak Bay later. There was poor weather for most of the hunting period at Kendall Island, but the hunters used the few days of good weather there to obtain twice their usual number of whales. Weather also protracted the hunting period in Kugmallit Bay; however, a major reason for the long season there was the low number of whales in Kugmallit Bay in 1980.

Hunting Camps

The same hunting camps have been used for the past four seasons (Fig. 1). Aklavik hunters and their families set up camps at Shingle Point, Running River, Niakunak, and Bird Camp on Niakunak Bay. Inuvik hunters occupied Whitefish Station, Kittigazuit, and Indian Camp on Kugmallit Bay and Okivik and Sanmiqaq on Kendall Island. The poor hunting in Kugmallit Bay in 1980 caused several Inuvik hunters to switch to the Kendall Island camps.

A few hunters from Tuktoyaktuk occasionally stayed overnight on Hendrickson Island in 1980, but most continued the usual practice of making day trips from their settlement.

Hunting Success

The number of whales landed during the hunting season depends on the number of days of calm weather, the amount of effort expended by the hunters, and the number of whales that come into shallow water. These factors are not only difficult to measure, but are often inter-related.

In 1980 the number of whales landed by hunters in the whaling camps, combined with those taken by Tuktoyaktuk hunters, totalled 82, with an additional eight whales taken near Aklavik on 14 July (Table 11). The eight landed near Aklavik were taken by persons who would have gone to the Niakunak Bay whaling camps had they not been successful so close to home. These eight whales are included as part of the harvest for the Niakunak Bay camps (Table 11, Fig. 11).

This year's total harvest of 90 whales was well below the annual average of 136 for the preceding eight years (1972-1979); however, according to the 'outliers' test (Johnson and Leone 1964), the difference was not statistically significant [$r_{11} = 0.359$; $0.20 > p > 0.10$ (Beyer 1966)]. Only hunters from the Niakunak Bay camps took the usual number of whales (Table 11). The 1980 Kendall Island catch was much higher than the 1972-1979 average, largely because a number of hunters shifted from Kugmallit Bay to the Kendall area. In 1980, 24 hunters used the Kendall Island camps; five hunters used those camps in 1978, and 14 hunters in 1979.[1] The harvests by hunters from Tuktoyaktuk and from the Kugmallit Bay camps were well below average. Some of the differences can be explained by the number of hunters involved; only 16 hunters used the Kugmallit Bay camps in 1980 compared to 23 hunters in 1979 (the data are incomplete for the Kugmallit Bay camps in 1978 and for Tuktoyaktuk in 1978, 1979, and 1980). However, the low number of whales taken in Kugmallit Bay in 1980 was mainly the result of the small number of whales present there. Hunters from Kugmallit Bay camps said that there were often more hunters than whales in the shallow water around Hendrickson Island this year, and that the whales were harder to catch. Mr. H. Chicksi, the whale monitor for the Whitefish Station area, was quoted as saying that "When the weather was good, ten to fifteen boats were hunting, but there were few belugas to hunt" (DFO 1980). Several hunters commented that they would see a whale once and then it would not surface again in the shallow water. The decreased time spent at the surface may reflect a change in behaviour that resulted from hunting disturbance.

In an effort to establish a quantitative index of success that includes some aspect of hunting effort, the number of whales landed in each camp was compared to the number of hunters, the number of adults (including hunters), and the total number of people (adults and children) who used that

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[1] In 1977, an estimated one-third of the Inuit population of Aklavik and one-quarter of the Inuit population of Inuvik, for a total of approximately 267 people, travelled to whaling camps (Fraker 1977b). Tuktoyaktuk hunters usually make only day trips for hunting and do not set up camps. In 1977, about 60% of Tuktoyaktuk families were involved in hunting whales. People other than those who directly participate in the hunting activities are involved through the purchase or receipt of whale products.

Table 11. Numbers of white whales harvested in the Mackenzie estuary, 1972-1980. The number of whales landed is followed in parentheses by the percent of total harvest.

	1972	1973	1974	1975	1976	1977	1978	1979	1980	Mean harvest 1972-1979
Tuktoyaktuk Community	45(40)	87(49)	40(33)	50(35)	51(33)	54(39)	53(44)	49(41)	23(26)	53.6(39.4)
Kugmallit Bay Camps	31(27)	63(36)	50(41)	60(42)	59(38)	32(23)	28(23)	31(26)	14(16)	44.2(32.5)
Kendall Island Camps	4(4)	7(4)	2(2)	3(2)	12(8)	30(21)	10(8)	12(10)	24(27)	10 (7.4)
Niakunak Bay Camps	33(29)	20(11)	30(25)	29(20)	32(21)	24(17)	30(25)	28(23)	29(23)*	28.2(20.7)
	113	177	122	142	154	140	121	120	90	136.0

* Includes 8 whales taken near Aklavik on 14 July.

camp for at least one night during the hunting season. Interviews with hunters provided the data for the comparisons. The 1980 data showed that the number of whales landed was highly correlated with the number of hunters in camp ($r = 0.920$, $n = 7$), but was more weakly correlated with the number of adults in camp ($r = 0.712$, $n = 5$) and with the total number of people in camp ($r = 0.762$, $n = 6$). This is in contrast to the data from 1978, which showed a high degree of correlation between the numbers of whales landed and each of the same three measures of hunting effort [$r = 0.909$, $n = 5$, $r = 0.948$, $n = 5$, and $r = 0.954$, $n = 5$, respectively (Fraker and Fraker 1979)].

Hunting Loss

It is estimated that about one-third of the white whales killed in the Mackenzie estuary are not retrieved or are lost before landing (Hunt 1979; Fraker 1980). To assess the effects of calibre of rifle on this loss rate, we examined the mean number of shots required to kill a whale for each of several calibres currently used by hunters (Table 12). Although an analysis of variance did not reveal statistically significant differences between the four calibres tested ($F = 2.864$; $df = 3,174$; $0.05 < p < 0.10$), the .243 Winchester required, on average, 3 or 4 more bullets to kill a whale than did the heavier calibres; the .30/30 calibre is most popular (Table 12).

Sex Composition

The most striking feature of the white whale harvest before 1980 was the predominance of males (Table 13). In 1974-1978 an average of 3.42 males per female (146 animals examined) was taken; in 1979 this ratio was 1.57 males per female (59 animals examined). In 1980, 44 of the 86 landed whales for which sex was determined were females; this was the only year in nine years of study when more females than males were landed in the Mackenzie estuary. The sex ratio of the 1980 catch was not statistically different from the sex ratio of the 1979 catch ($\chi^2 = 2.09$, $df = 1$, $0.1 < p < 0.2$), but the sex ratio of the combined 1979-1980 harvest was statistically different from the sex ratio of the 1974-1978 harvest ($\chi^2 = 17.97$, $df = 1$, $p << 0.001$). The sex composition of the combined 1979-1980 catches was also statistically different ($\chi^2 = 12.59$, $df = 1$, $p < 0.001$) from the sex composition of white whales collected in the Mackenzie delta region during the

Table 12. Mean number of shots required to kill a whale according to rifle calibre. Data from interviews with hunters from 1978-1980 were used in the analysis.

	Rifle calibre			
	.243	.30/30	.30/60	.270
Mean number of shots to kill a whale	9.27	5.96	5.67	5.08
Standard deviation	±5.75	±4.67	±3.14	±3.60
Number of whales killed	15	131	6	26
Number of hunting parties known to have used calibre	7	31	5	9

Table 13. Sex of harvested white whales, Mackenzie estuary, 1974-1980.

	Number of males examined	Number of females examined	Males per female
1974	16	7	2.29
1975	13	4	3.25
1976	36	7	5.14
1977	13	8	1.62
1978	35	7	5.00
1979	36	23	1.57
1980	42	44	0.95

1950's when 2.94 males per female were landed, with 126 animals examined (Sergeant and Brodie 1969).

The ratio of males to females landed did not differ between the first half (4-30 July) and the latter half (31 July-23 August) of the 1980 hunting period (χ^2 - 1.11, df = 1, 0.25 <p< 0.50). However, there were significant differences in the sex ratio of the whales landed in the three concentration areas. The sex ratio of whales taken in Kugmallit Bay (12 of 36 were males) was not statistically different from that of whales taken near Kendall Island (11 of 22 were males; χ^2 = 1.85, df = 1, 0.10 <p< 0.2). The combined harvest in these two areas included a significantly greater percentage of females than did the harvest in Niakunak Bay (17 of 20 were males; Yates corrected χ^2 = 10.492, df = 1, p <0.005). In 1979, Kendall Island hunters landed a higher percentage of female whales than did hunters in either Niakunak or Kugmallit Bays (Table 14).

Seaman and Burns (1980) report on the harvests of white whales from along the coast of western Alaska during 1977, 1978, and 1979. Many of these were taken in nets or in organized drives, methods not used currently in the Mackenzie estuary. Unlike the Mackenzie harvest method, the Alaskan methods would not be selective for large animals, which tend to be males. The Alaskan data did not differ between years (χ^2 = 1.06, df = 2, 0.25 <p< 0.50), and therefore, we have pooled these data. A total of 106 males and 89 females were taken in the western Alaska harvest in 1977-79 -- a ratio of 1.19:1. This ratio was not significantly different from the 1:1 ratio expected at birth (χ^2 = 1.49, df = 1, p≈0.25), or from the 1979-1980 ratio of the landed catch in the Mackenzie estuary (χ^2 = 0.01, df = 1, p> 0.90), but it was different from the Mackenzie data for 1974-1978 (χ^2 = 19.29, df = 1, p <<0.001). Sergeant (1973) suggested that an increase in the proportion of males in the white whale harvest at Churchill, Manitoba, was the result of increased selection for larger animals (which are mostly males) by the hunters. It appears that hunters in the Mackenzie estuary have been less selective in their hunting in the past two years, mainly as a necessary response to poor weather and a scarcity of whales.

We do not believe that the change in sex composition in 1979-80 reflects a fundamental change in the sex composition of the Mackenzie stock

Table 14. Sex of harvested white whales according to locality within the Mackenzie estuary region, 1977-1980.

Year	Locality	Number of males harvested	Number of females harvested
1980	Kugmallit Bay	12	24
	Kendall Island	11	11
	Niakunak Bay	17	3
1979	Kugmallit Bay	17	9
	Kendall Island	2	9
	Niakunak Bay	17	5
1978	Kugmallit Bay	15	4
	Kendall Island	6	0
	Niakunak Bay	14	3
1977	Kugmallit Bay	4	0
	Kendall Island	0	2
	Niakunak Bay	9	6

at large. If such a change had taken place, one would expect a more gradual increase in the proportion of females taken. An annual removal of 204 animals (assuming a harvest of 136 with 68 struck and lost), even if they were all of one sex, from an estimated population of 7000 could not radically alter the sex ratio of the entire population in two years.

Length Composition

Overharvesting of whale populations could lead to changes in the length composition of the harvested animals. No such changes in length have been noted in Mackenzie estuary white whales. The mean lengths of males landed have varied from 423.3 cm in 1974 to 438.2 cm in 1980 (Table 15, Fig. 12). However, there has been no consistent trend, and an analysis of variance indicates no statistically significant differences between years ($F = 0.602$, $df = 6, 154$, $p > 0.20$). For the same period mean lengths of landed females have varied from 358.8 cm in 1978 to 414.0 cm in 1976 (Table 15, Fig. 12). Again no trend is obvious and between-year differences are not significant ($F = 2.203$; $df = 6, 77$; $0.1 < p < 0.2$).

Seasonal and geographic differences in lengths (≈ages) of the harvested animals were evident. To examine seasonal differences, the hunting period was divided into two parts -- 4 to 30 July and 31 July to 23 August. The mean length of males caught in the first and second halves of the 1980 hunting period were 429.4 ± 52.07 cm and 466.7 ± 35.02 cm, respectively ($t = 2.11$, $df = 39$, $0.02 < p < 0.05$). No such difference was found for females: 398.9 ± 45.07 cm vs 386.2 ± 39.54 cm, respectively; $t = 0.908$, $df = 39$, $0.3 < p < 0.4$.

Lengths (and thus ages) also differed significantly on a geographic basis for both males and females in 1980 (Table 16). The largest males, on average, were taken near Aklavik while the largest females came from near Kendall Island. The smallest whales, male and female, were from Niakunak Bay. Although the differences between areas in 1980 were statistically significant for both males ($F = 3.43$, $df = 2, 37$, $0.025 < p < 0.05$; Aklavik data were not included in analysis) and females ($F = 4.33$, $df = 3, 38$, $0.01 < p < 0.025$), no such differences were apparent in 1979.

Table 15. Lengths of harvested white whales according to sex, Mackenzie estuary, 1974-1980.

Females				Males			
Year	Mean length (cm)	Standard deviation	n	Year	Mean length (cm)	Standard deviation	n
1974	368.8	±28.36	7	1974	423.3	±58.94	16
1975	366.8	±17.28	4	1975	429.9	±34.20	13
1976	414.0	±28.52	7	1976	429.8	±29.35	35
1977	365.0	±18.06	3	1977	436.6	±31.70	12
1978	358.8	±17.00	4	1978	424.8	±23.08	18
1979	374.9	±32.70	17	1979	423.7	±26.64	25
1980	393.6	±42.77	42	1980	438.2	±50.14	42

Table 16. Mean length of male and female harvested whales, according to locality within the Mackenzie estuary region, 1980.

	Females			Males		
	Mean length	Standard deviation	n	Mean length	Standard deviation	n
Kugmallit Bay	378.9	±35.67	22	463.7	±37.69	12
Kendall Island	426.2	±36.84	11	430.0	±41.39	11
Niakunak Bay	366.0	*	3	419.6	±52.16	17
Aklavik	401.5	±55.86	6	488.0	†	2

* All three females harvested in Niakunak Bay were 366 cm long.

† Both males harvested near Aklavik were 488 cm long.

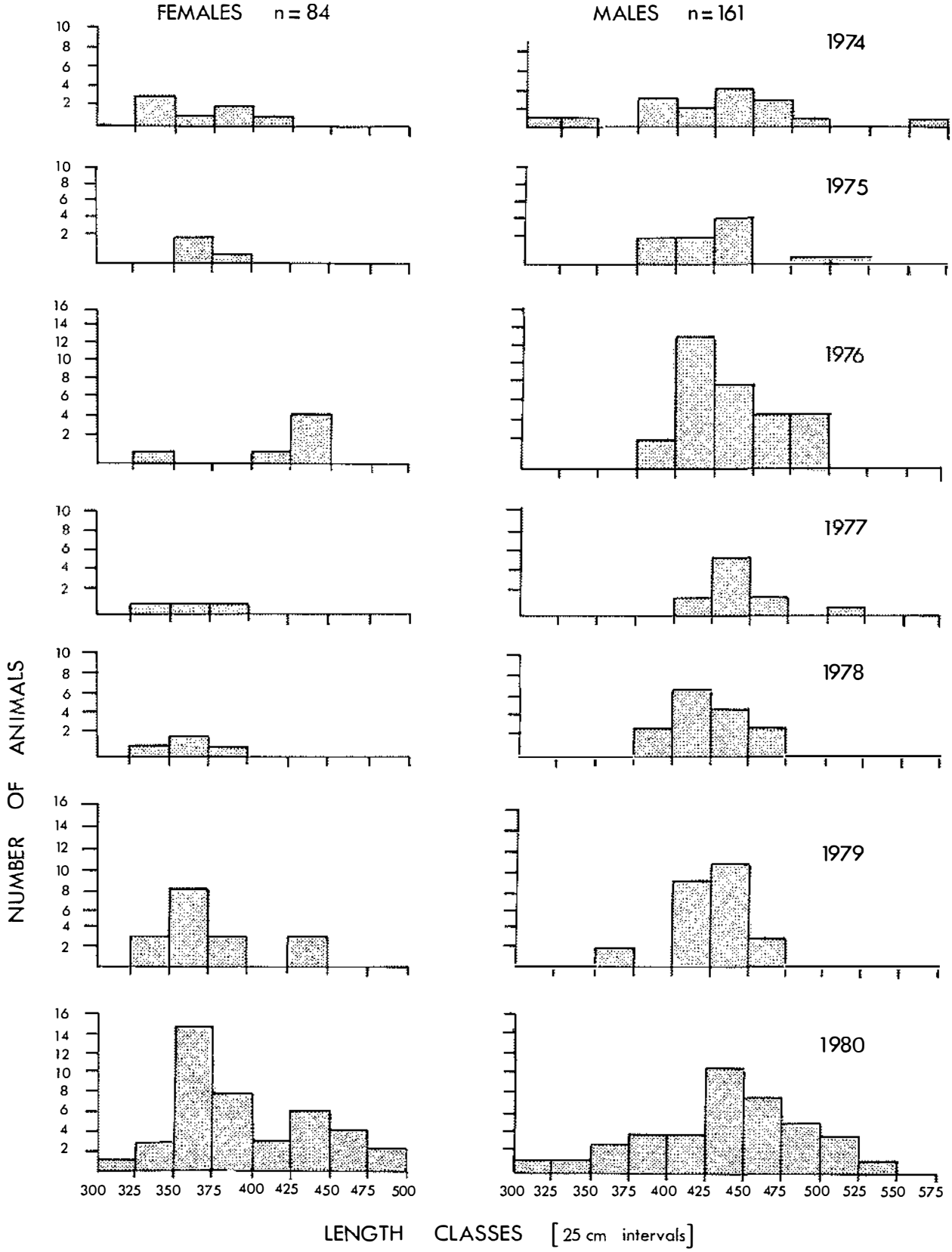


Figure 12. Length frequencies of white whales harvested in the Mackenzie estuary, 1974-1980.

One possible explanation for year-to-year and area-to-area changes in the percent females taken or in length (≈age) of males and females is that white whales segregate into small groups according to age and sex. This type of segreation has been reported within large schools of Hawaiian spinner dolphins (*Stenella longirostris*), another species of toothed cetacean; Norris and Dohl (1980) reported observing segregated groups of juveniles and mother-young pairs. A social structure of this sort probably occurs in other species, also. Inuit hunters speak of encountering small white whale aggregations of old males (large animals) or of females with calves while hunting, and aerial observations have been made of groups with no calves and other groups with one calf per adult. Random variation in the type of group hunted could then explain why a concentration area yields more males than females one year but not the next, or larger males one year than another. Because very small numbers of whales are taken in any given area on any one day and because more than one group may be hunted in a particular area on a particular day, it would be difficult to test this hypothesis. To what extent the possible segregation into small, homogeneous groups might explain the increased percentage of females taken in 1979 and 1980 is not known.

Bowhead Whales

Spring Migration

The spring migration of bowheads was delayed in 1980. Usually the first whales pass Pt. Barrow in the third or fourth week of April, and the migration continues through May and into June (Braham et al. 1980; Krogman 1980). But in 1980, the first whales were not observed at Barrow until 21 May; apparently the entire migration past Barrow took place in a period of about 13 days (Johnson et al. 1981), rather than the normal six-week period. Unusual ice conditions in the Bering Strait and along the northwest coast of Alaska caused the delay in migration (Johnson et al. 1981; D.K. Ljungblad, U.S. Naval Ocean Systems Center, San Diego, pers. comm.). Peculiar winds kept the ice packed tightly in this region until mid-May. Until then, large numbers of bowheads and white whales were observed in open-water areas immediately south of the Bering Strait.

There were no reports of bowheads in Canadian waters until 25 June in 1980, when two were seen 133 km northwest of Baillie Islands (Table 17). This was five weeks after the first whales were observed passing Barrow (Johnson et al. 1981), which is more than enough time for the whales to have made the journey. There were no other reported spring sightings in the southeastern Beaufort in 1980.

Summer Distribution and Movements

Using a combination of (1) sightings recorded in the logbooks of whaleships that operated in the Beaufort Sea around the turn of the century, and (2) recent (1974-1978) sightings from various sources, Fraker and Bockstoce (1980) attempted to describe the summer range of the bowhead whale. They concluded (1) that bowheads initially (May-June) occupied the southeasternmost part of the Beaufort Sea and Amundsen Gulf, after completing their eastward migration across the Beaufort Sea, (2) that the summer range occupied by the bowheads gradually extended westward over the summer, and (3) that the seaward limit of the range corresponded approximately to the 50 m depth contour. Prior to 1980, only a relatively modest amount of survey effort had been expended specifically on whale surveys offshore in the Beaufort Sea during summer (all funded by Esso during 1978 and 1979). In 1980, a total of five studies of bowhead whales in the Canadian Beaufort Sea were conducted; one was funded by Esso (this study), one by Dome Petroleum Limited (Renaud and Davis 1981), two by the U.S. Bureau of Land Management (Richardson 1981; L. Hobbs, U.S. Natl. Marine Fisheries Service, Seattle, WA), and one by the U.S. Natl. Marine Fisheries Service (D. Rugh, U.S. Natl. Marine Fisheries Service, Seattle, WA). The more extensive work in 1980 has produced considerable new information.

No bowheads were observed during the 24 July systematic survey of the Issungnak area (Table 18). Nor were any seen during late July surveys carried out north of the Tuktoyaktuk Peninsula (Larry Hobbs, U.S. Natl. Marine Fisheries Service, Seattle, WA, pers. comm.). However, 40-50 bowheads were seen 3 km east of Issungnak on 2 August (Table 17). Würsig et al. (1981) also reported seeing several both east and west of Issungnak on 3 and 4 August. However, during this same time period, neither Würsig et al. nor Hobbs could locate whales north of the Tuktoyaktuk Peninsula during

Table 17. Observations of bowhead whales made by industry personnel and others, 1980.

DATE TIME	LOCATION	NUMBER OF WHALES	DIRECTION OF MOVEMENT	OBSERVATIONS	OBSERVER COMPANY
25 June	133 km NE of Baillie Islands	2		'trapped' in small lead	B. Hough PCSP*
2 August	3 km W of Issungnak O-61	40-50	S	no reported reaction to Sarpik 610 m away; water depth = 11.3 m	E. Kehoe ERCL*
3 August	Issungnak O-61	7-12	NW	no reported reaction to J. Mattson 91 m away; water depth = 18 m	P. Harrison ATL*
4 August 1000	Issungnak O-61	8	SSW	whales come within 1000 m of Arctic Breaker (stationary); water depth = 20 m	B. Cox ERCL
4 August 1715	12 km SE of Issungnak O-61	24	E and W	no reported reaction to Arctic Hooper 402 m away	I. Rainsford ATL
4 August 1930	5 km from Issungnak O-61	20-30	NW		N. Sikkens ATL
5 August 0300	5-8 km W of Issungnak O-61	12	NW and E	whales were diving and may have been feeding; no reaction to Arctic Hooper 805-3200 m away	I. Rainsford ATL
6 August 0300	8 km W of Issungnak O-61	18	W	no reported reaction to Arctic Hooper 805-3220 m away	I. Rainsford ATL
6 August 0400	Issungnak O-61	6	W	whales appeared to be circling Beaver Mackenzie dredge, 400 m away; water depth = 24 m	A.M. Peters not reported
6 August 2030	Issungnak O-61	2	NNW	no reported reaction to helicopter 610 m above	E. Thurgar Dome Petroleum
7 August 0200	Issungnak O-61	4	NNE	whales approached to within 500 m of Beaver Mackenzie	G. Anderson not reported
7 August 1700	Issungnak O-61	2	E	whales come within 1600 m of Beaver Mackenzie;	B. Gojevic not reported
7 August 1900	Issungnak O-61	3	E	whales come within 3.2 km of Beaver Mackenzie	L. Anderson not reported
7 August 2200	Issungnak O-61	1	E	whales passed by Beaver Mackenzie 3.2 km away; water depth = 24 m	A. Thorpe not reported
8 August 1020	2 km SW of Issungnak O-61	2	ESE	no reported reaction to helicopter 610 m above	R. Klohn Dome Helicopters
9 August 0015	Issungnak O-61	1	E	whale passed by Beaver Mackenzie 3.2 km away	A. Thorpe not reported
9 August 0200	2 km W of Issungnak O-61	3	W	whales passed by Arctic Hooper 402 m away; seemed to be feeding	I. Rainsford ATL

Table 17. (Continued)

DATE TIME	LOCATION	NUMBER OF WHALES	DIRECTION OF MOVEMENT	OBSERVATIONS	OBSERVER COMPANY
10 August 1300	Issungnak O-61	2	E	whales passed by Beaver Mackenzie 3.2 km away	L. Anderson not reported
14 August 1400	E of Pullen Island	2	NNE	no reported reaction to Bell 206 helicopter 61 m above	B. MacDonald Kenting Helicopters
14 August 1400	N of Toker Point	3	E	no reported reaction to Bell 212 helicopter 91 m above	A. MacDonald Associated Helicopters
18 August	Issungnak O-61	4	S	no reported reaction to Arctic Pelly 402 m away; water depth = 17.7 m	A. Fergusson ATL
19 August 1208	16 km N of Toker Point	1	E	no reported reaction to Bell 212 helicopter	A. MacDougall Associated Helicopters
20 August	21 km NE of Hendrickson Island	13		no reported reaction to helicopter	T. Melynk ERCL
20 August 0500	124 km NNW of Cape Dalhousie	1	NNW	whale surfaced and blew approximately 10X, 30 sec apart when 402 m from Pandora II	W.J. Allan IOS
21 August 1400	56 km N of Baillie Islands	1	E	no reported reaction to Pandora II 305 m away	J.A. Clarkson IOS
22 August 2120	28 km NNW of Toker Point	10-20		no reported reaction to Sarpik 229 m away; water depth = 12-18 m	J. Vine ERCL
26 August 1830	48 km N of Cape Dalhousie	1	NE	no reported reaction to Pandora II 200 m away; water depth = 45 m	W.J. Allan IOS
28 August 1700	63 km NE of Baillie Islands	2			J.A. Clarkson IOS
28 August 1800	72 km NE of Baillie Islands	3	N	whales blew every 30 sec for about 5 minutes 805 m from Pandora II	W.J. Allan IOS
29 August 1510	48 km NE of Baillie Islands	5	SE	no reported reaction to Pandora II 200 m away; water depth = 50 m	J.A. Clarkson IOS
31 August	39 km N of Baillie Islands	3	SE	no reported reaction to Pandora II 915 m away	J.A. Clarkson IOS
31 August 1545	68 km N of Warren Point	2	E	no reported reaction to Nahidik 160 m away; water depth = 35 m	E. Keays CCG
31 August 1645	85 km N of Warren Point	2	E	whales blowing frequently 1500 from Nahidik	E. Keays CCG

Table 17. (Continued)

DATE TIME	LOCATION	NUMBER OF WHALES	DIRECTION OF MOVEMENT	OBSERVATIONS	OBSERVER COMPANY
31 August 1700	42 km NE of Baillie Islands	2	SE	no reported reaction to Pandora II 915 m away; water depth = 50 m	J.A. Clarkson IOS
31 August 2110	72 km NNE of Warren Point	2	E	no reported reaction to Nahidik 500 m away; water depth = 41 m	J. Hunter CCG
1 September 1830	74 km N of Cape Dalhousie	6	E	no reported reaction to Pandora II 805 m away	W.J. Allan IOS
11 September 1400	Issungnak O-61	1	W	whale approached barge camp to within 0.6 km	H. Grainger ERCL

* The following abbreviations were used for companies:

PCSP - Polar Continental Shelf Project, Tuktoyaktuk
ERCL - Esso Resources Canada Limited, Calgary
ATL - Arctic Transportation Limited, Inuvik
IOS - Institute of Ocean Sciences, Pat Bay
CCG - Canada Coast Guard
GSC - Geologic Survey of Canada

searches to approximately 25 km offshore. Assuming that the bowheads initially occupy areas to the east (Fraker et al. 1978; Fraker 1979; Fraker and Bockstoce 1980), these bowheads must have moved westward to north of the Mackenzie Delta at some distance offshore. The observations made from whaleships during the 1-15 August period (Fraker and Bockstoce 1980) also suggest an offshore westward movement of bowheads.

Systematic surveys of bowhead distribution in the Issungnak area were also carried out on 9, 11, 12, and 22 August (Fraker et al. 1981). These surveys showed that there were substantial numbers of bowheads within the surveyed area during all of the August surveys (Table 18, Fig. 13). There was a tendency for the whales to be distributed north of about the 18 m depth contour, which runs approximately through Issungnak 0-61. The densities of bowheads observed 'on-transect' during the five surveys in the 5-12 August period ranged from 0.028 to 0.055 whales/km^2 (Table 18). The slightly lower densities of whales seen during the Esso study probably resulted because more of the Esso survey area than the BLM survey area was in shallower water. The highest number seen during a BLM survey was 37, on 12 August, for an estimated total of 74 for the entire survey area.

The variation in densities of whales recorded during the BLM surveys of 9, 11, and 12 August probably is not significant. However, we suspect that the lower density recorded on 22 August does, in fact, reflect a decreased density, because by that time large numbers of bowheads were occupying the coastal region north of Kugmallit Bay and the Tuktoyaktuk Peninsula as far east as McKinley Bay (Würsig et al. 1981). At least some of these animals were known to have moved eastward; one group of three (two distinctively marked adults plus a calf) were observed about 20 km east of Issungnak on 7 August and were resighted on 20 August about 100 km east of the first location (Würsig et al. 1981). The fact that these animals remained together for about two weeks indicated that bowheads have some degree of stable social structure.

The observation of an eastward movement of these bowheads during August is corroborated by reports of bowheads sighted by industry and other personnel; the majority of these animals were reported to be eastbound (Table 19). Fraker and Bockstoce (1980) also noted a tendency for recent

Table 18. Observations of bowhead whales made during surveys of the Issungnak area, July-August 1980. Data are from this study (Esso surveys) and from Fraker et al. 1981 (BLM surveys).

Date	Number seen (on-transect)	Length of survey (km)*	Area surveyed (km^2)	Observed densities (Whales/km^2)	Distance of closest bowhead from island (km)**	No. seen within 5 km of the island***	No. seen 5-10 km from the island***
Esso Surveys							
24 July	0	425	684	0.000	—	—	—
5 Aug	19	425	684	0.028	4.8	1	4
9 Aug	21	425	684	0.031	0.8	12	11
BLM Surveys							
9 Aug	35	394	635	0.055	3.2	7	7
11 Aug	27	306	492	0.055	10.4	0	1
12 Aug	37	554	892	0.042	5.5	0	6
22 Aug	23	554	892	0.026	12.0	0	15

* In the case of the BLM surveys, the actual length (rather than the theoretical straight-line length) is given.

** The approximate distance of the closest bowhead detected by the aerial surveyors is given; other bowheads that were below the surface or otherwise not detected by the observers may have been present.

*** Includes off-transect sightings.

Table 19. Orientations of bowhead whales reported by industry personnel and others, August 1980. Data from Table 17.

Quadrant	Number of observations	
N-ENE	4	22
E-SSE	18	
S-WSW	8	12
N-NNW	4	

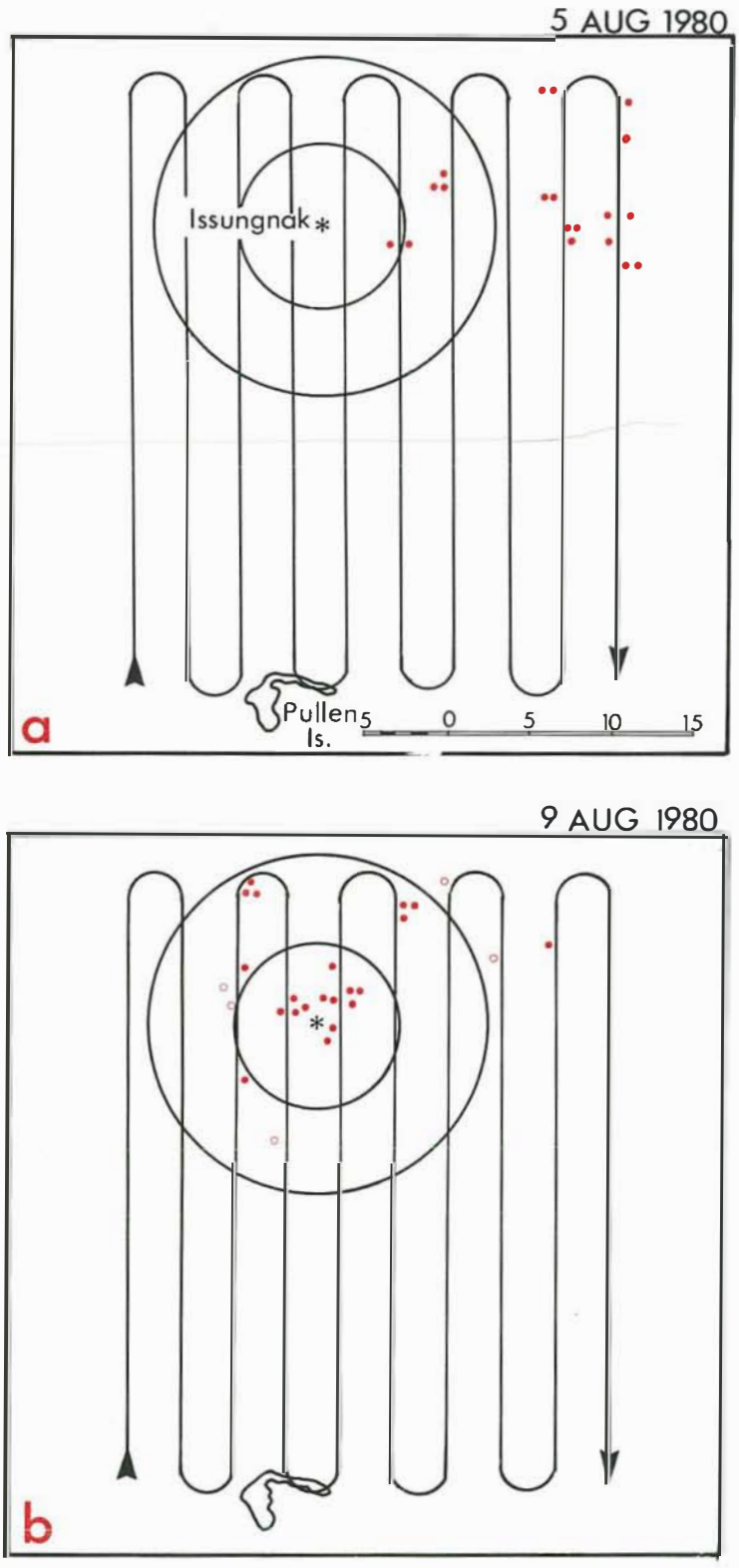
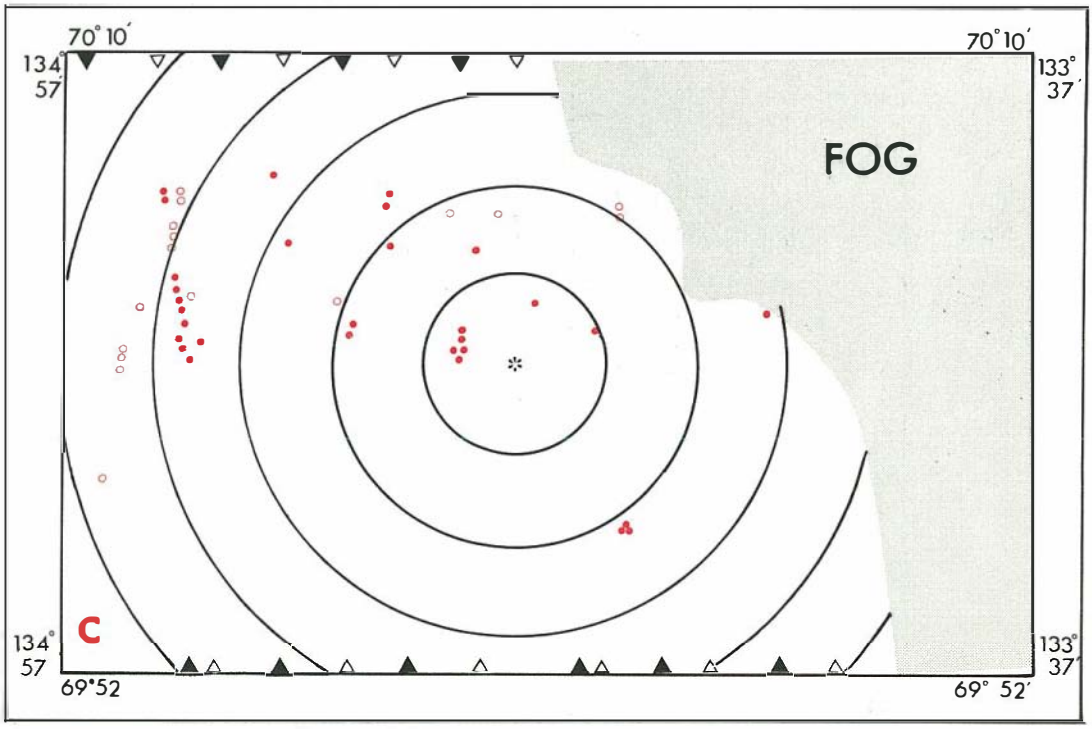


Figure 13. Observations of bowhead whales made during systematic surveys of the Issungnak area, August 1980.



9 AUG

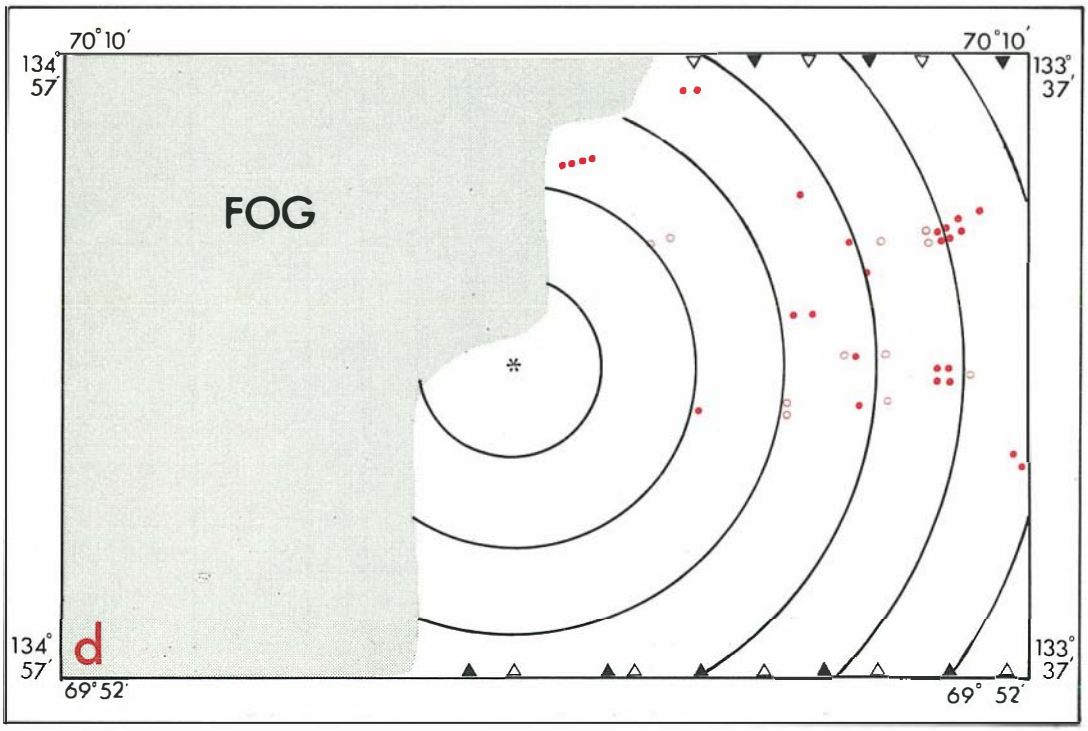


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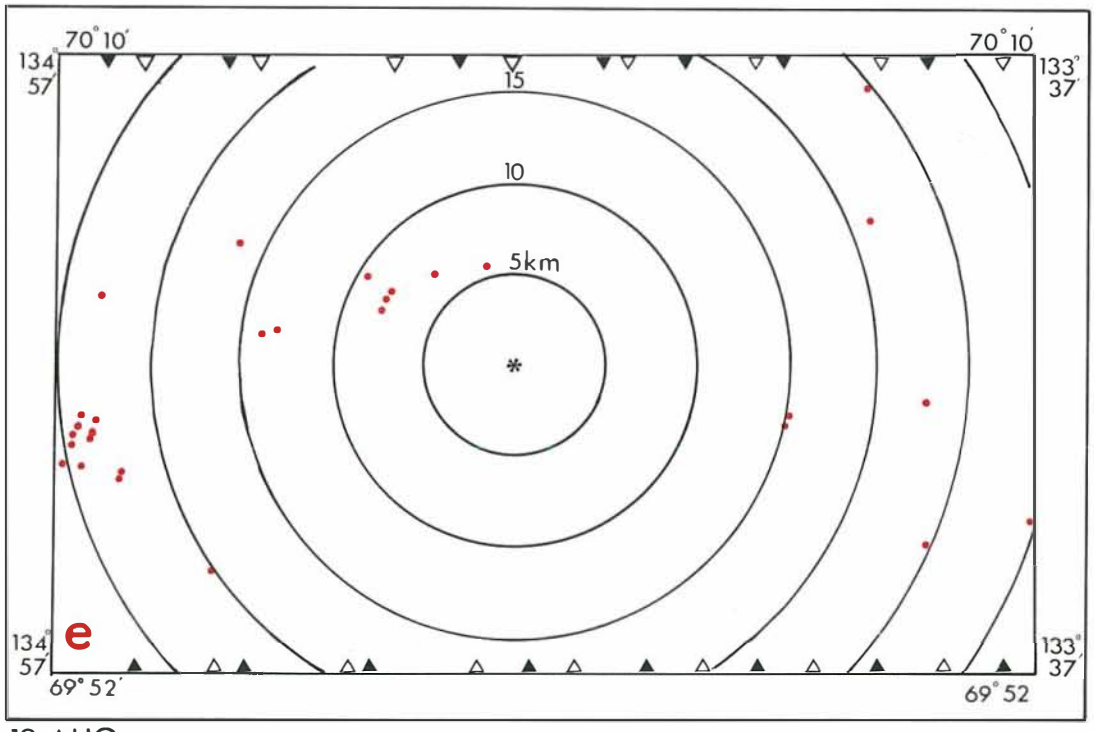
Figure 13. Continued



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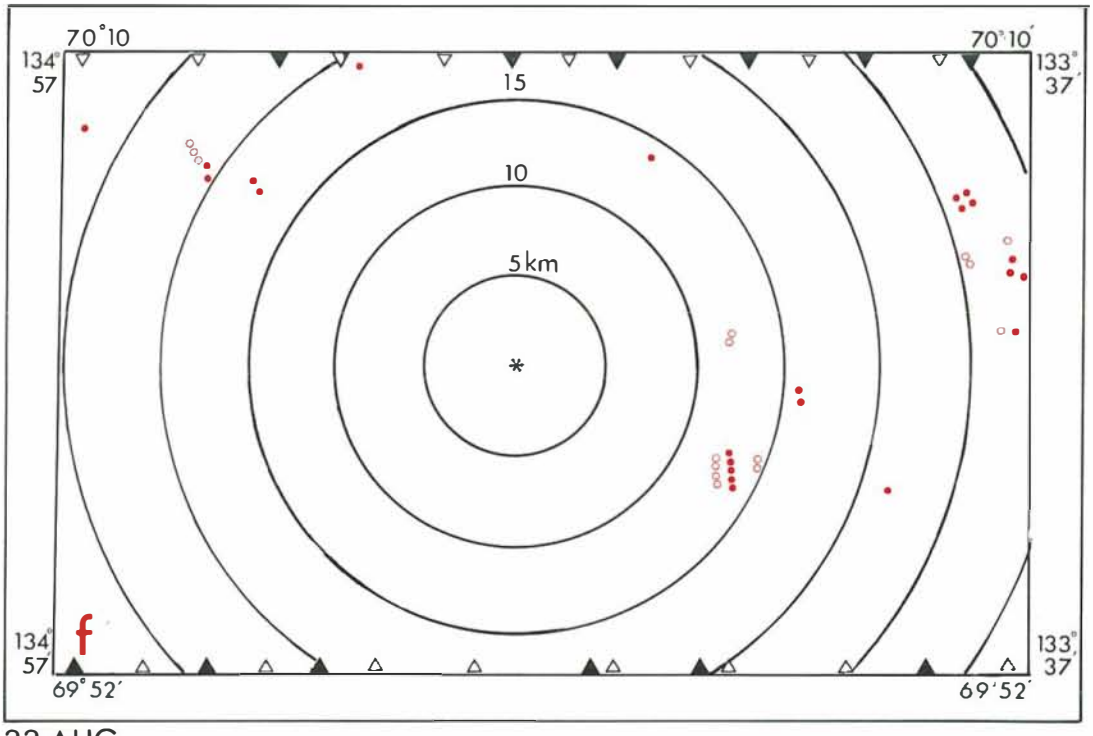

22 AUG

Figure 13. Continued

(1976-1978) sightings in the nearshore waters in and north of Kugmallit Bay to have an eastward component. Independent of the above data, Mr. Vince Steen (boat owner, Tuktoyaktuk, N.W.T., pers. comm.) told us that after bowheads appear in the Mackenzie estuary region, they move northeastward, parallel to the Tuktoyaktuk Peninsula. This nearshore eastward movement is also suggested by the timing and location of sightings on Figure 14. Note that the earliest sightings (first half of August) are near Issungnak, while most of the later sightings (latter half of August and first half of September) are farther east. Certainly the clustering of sightings around Issungnak reflects the high level of human activity (and therefore the potential to make observations) there, but the complete lack of sightings to the east in early August suggests that few whales were present in the nearshore area during that period. The surveys done by Renaud and Davis (1981) further substantiate this distribution pattern. During their surveys conducted between 6 and 7 August 1980, they reported seeing only six bowheads north of the Tuktoyaktuk Peninsula. More than 500 bowheads were observed in the same area between 21 and 24 August (Fig. 15). During the same period, there were still several bowheads around Issungnak (Fig. 13f). Neither Würsig et al. nor Renaud and Davis were able to find large numbers of bowheads in this region during early September.

Fraker and Bockstoce (1980) hypothesized that bowheads use the eastern Beaufort Sea as a feeding ground, and this was borne out by the 1980 observations of bowhead behaviour reported by Würsig et al. (1981). Although a variety of social behaviours were identified, feeding was the most common activity.

Effects of Human Activities on Whales

Since offshore drilling in the Mackenzie estuary began in 1972, concern about possible effects on white whales and whale hunting has been expressed by both government officials and residents of the region who use the whales as a subsistence resource.

Recognizing these concerns, Esso Resources Canada Limited has supported studies of whales in the Mackenzie estuary for the past nine years. Throughout these studies, the basic objective has been to prevent significant adverse effects on white whales and on Inuit whale hunting.

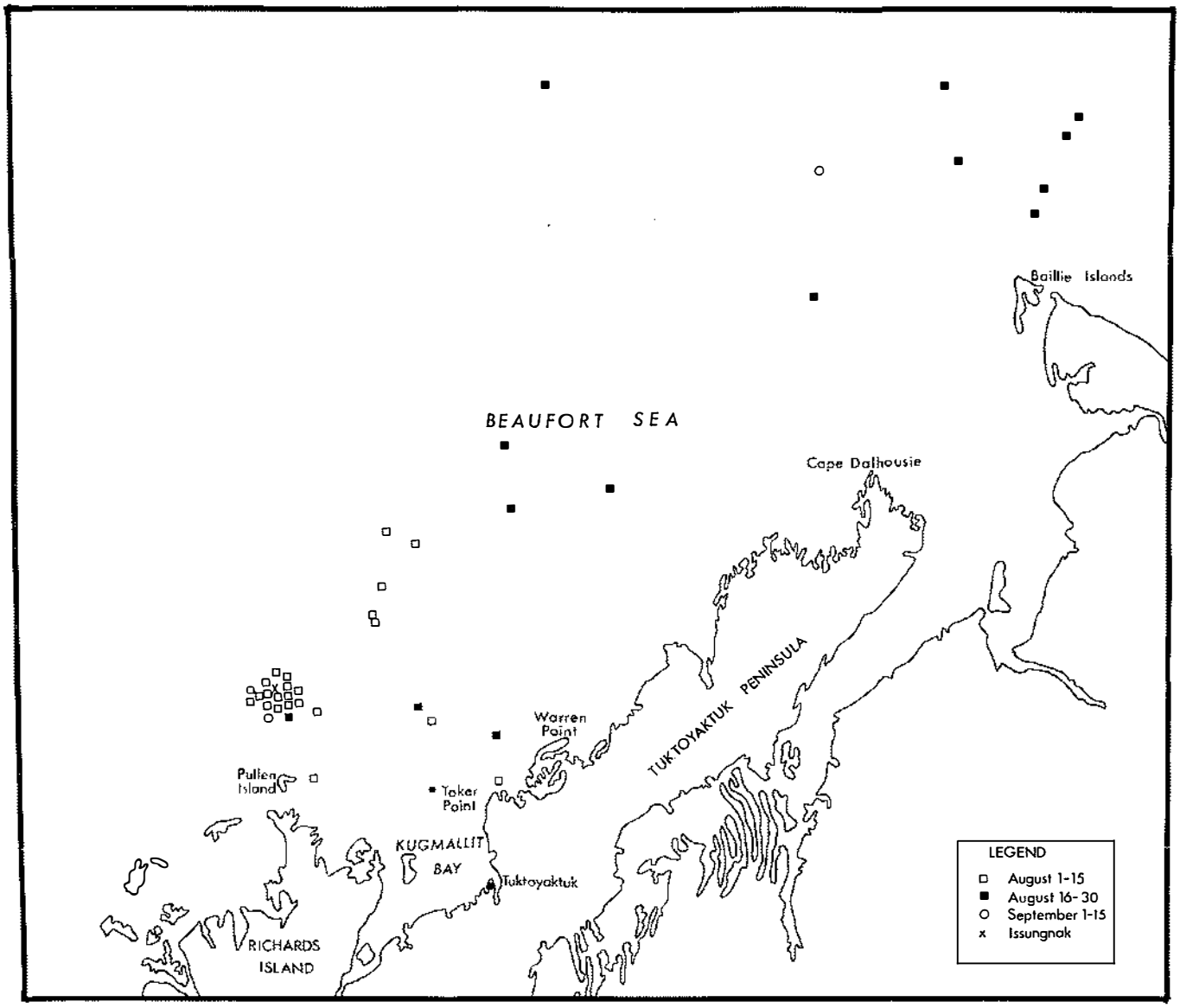

Figure 14. Locations of sightings of one or more bowhead whales, summer 1980. (From reports by industry and other personnel.)

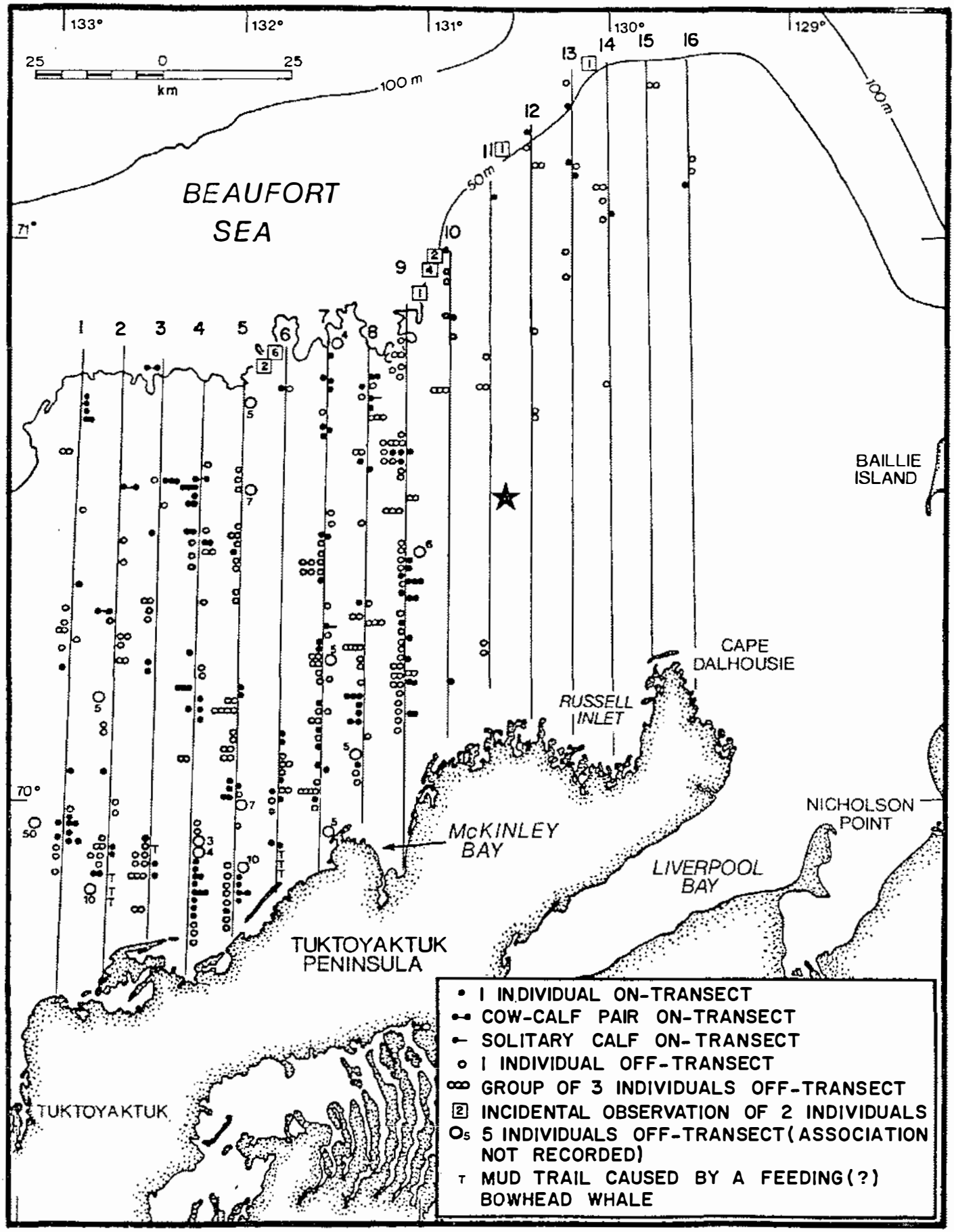

Figure 15. Distribution of bowhead sightings north of Tuktoyaktuk Peninsula, 21-24 August 1980. The star indicates the site of Kaglulik artificial island. (From Renaud and Davis 1981. Reproduced with permission of Dome Petroleum Limited.)

Esso has used the information gained from these studies to plan the locations and scheduling of specific logistic and exploration activities. In a number of instances, operational plans and schedules have been adjusted in a matter of hours or days to prevent or reduce possible adverse effects. Details of monitoring and mitigation operations in previous years can be found in Slaney (1973, 1974, 1975), Fraker (1976, 1977a, 1977b) and Fraker and Fraker (1979).

Since 1976, Esso has operated sufficiently far offshore to encounter bowhead whales. Because of the bowhead's rare-and-endangered status, studies since 1976 have included this species in addition to the white whales.

In 1980, Esso's offshore activities centered around Issungnak 0-61 (Fig. 16), 26 km north of Pullen Island, during the period (late June to early August) when white whales were present in substantial numbers. Activities around Issungnak involved dredging by the large suction dredge, *Beaver Mackenzie*, which operated adjacent to the island and discharged material onto the island through a floating pipeline, and various ancillary activities involving tugs, crew boats, and a barge camp. Supplies and personnel were transported to the Issungnak area by both boat and aircraft. Typically a Bell-212 helicopter operated between Tuktoyaktuk and the camp on the barge *Arctic Breaker*. Heavy, bulky supplies generally were transported by barge. The crew boat *Imperial Sarpik* frequently transported men and materials from Tuktoyaktuk to Issungnak. From 1976 to 1979 dredged material had been transported from Tuft Point to various island construction sites (Kugmallit H-59 and Arnak L-30 in 1976, Isserk H-47 in 1977, and Issungnak 0-61 in both 1978 and 1979); however, in 1980 no dredged material was transported to Issungnak. Therefore, in 1980 there was less Esso barge traffic than in previous years.

Logistics traffic operating out of Tuktoyaktuk consisted of shallow-draft and deeper draft vessels. Shallow-draft vessels moved out of Tuktoyaktuk up river to Inuvik and/or Bar C or out to Pullen Island (Fig. 16); deeper draft vessels necessarily moved between Tuktoyaktuk and the 'sea buoy', owing to their requirements for deeper water (Capt. J.W. Kavanagh, pers. comm.), then out to Issungnak or other locations. Esso used both

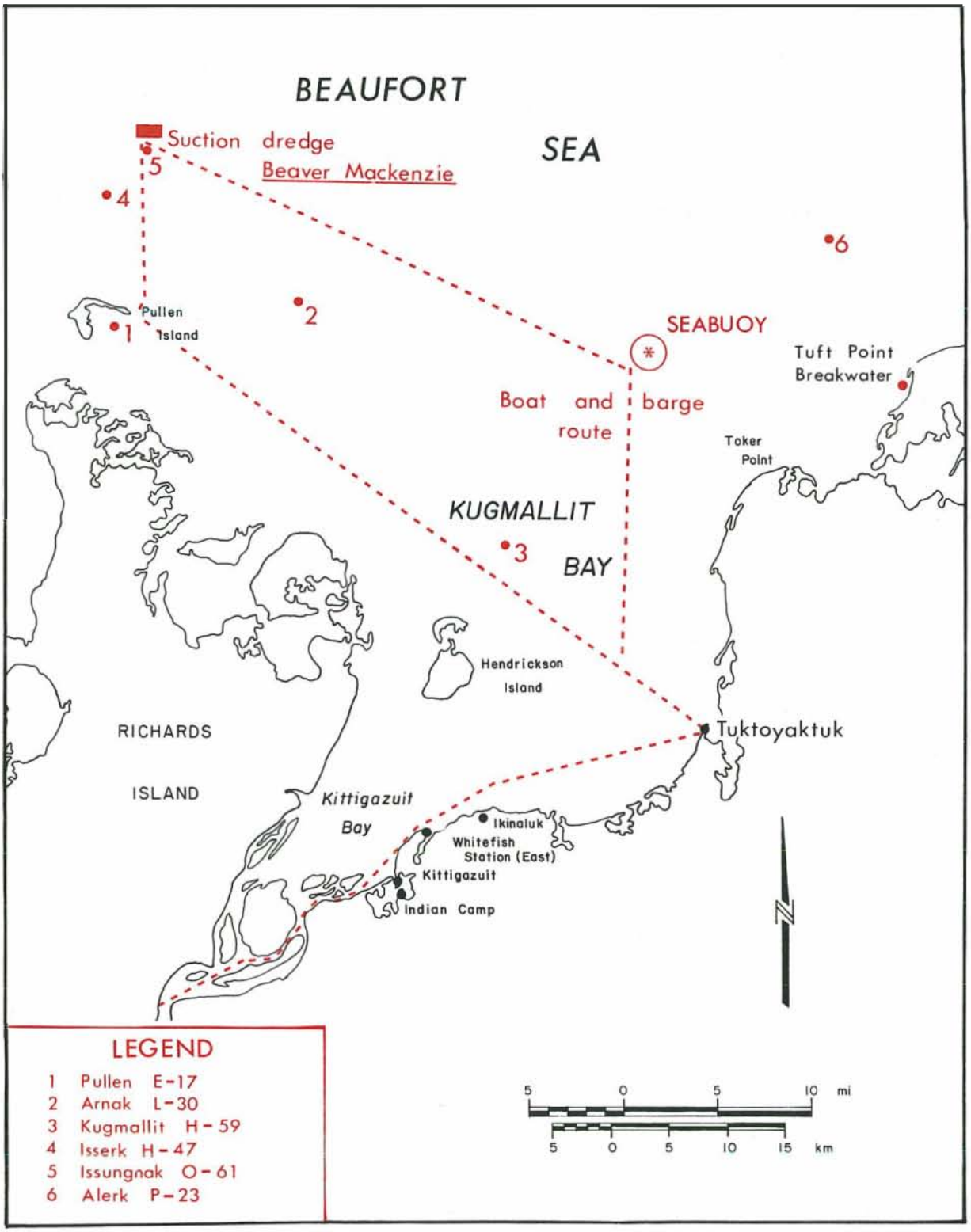

Figure 16. Locations of industrial activities in the Kugmallit Bay area, summer 1980.

shallow-draft and deeper draft vessels; other companies operating in the area, Northern Transportation Company Limited (NTCL) and Dome Petroleum Limited, mainly used vessels of the deeper-draft sort.

Human activities may have two types of visible effects: short-term avoidance reactions and long-term changes in distribution and/or abundance. These reactions are generally in response to moving vessels or to hunting; stationary operations (e.g., dredges) have less-noticeable or no effects on white whales. Information on the bowhead whale is as yet too fragmentary to assess the effects of human activities on this species.

Vessel Traffic and White Whales

Our previous studies have shown that moving vessels can have visible effects on white whales. We have noted short-term avoidance reactions by white whales in the Mackenzie estuary but of greater importance is the question of whether longer-term changes in distribution have occurred.

Short-term Effects

Under certain circumstances, vessel traffic has been demonstrated to affect white whales in the Mackenzie estuary (Fraker 1977a, b). These effects are of two types: (1) short-term changes in distribution resulting from the passage of a vessel through an area occupied by whales, and (2) the impeding of movement of whales along a travel route by frequent boat traffic.

An example of a short-term change in distribution occurred in Niakunak Bay on 11 July 1976, when a barge tow passed through a white whale concentration. Direct observations showed that whales at ranges up to 2400 m moved rapidly away from the barge; thus, the whales within a 4800 m-wide corridor were affected. The relatively long distance between the barge and the furthest whales that reacted strongly indicated that underwater sound was the main stimulus causing the response (Ford 1977; Fraker 1977a). Systematic surveys before, shortly after, and 30 h after the barge movement showed that effects persisted for at least 3 h. Whale distribution had returned to near normal by the time the last survey was done.

Interruption of whale movement along a travel route was observed near Tuft Point along the Tuktoyaktuk Peninsula, also in 1976. In late July

and August whales move along the coast of the Tuktoyaktuk Peninsula, apparently returning to the estuary. During much of the open-water period in 1976, barges transported material from a borrow area adjacent to Tuft Point to the artificial island site at Kugmallit H-59 (Fig. 16). During a period of about two weeks, when barge movements to and from Tuft Point numbered about 25 per day, approximately 150 white whales remained northeast of Tuft Point. It is unusual for whales to remain in this area for such an extended period. That their presence was related to activities in the Tuft Point area was indicated by three things: (1) their appearance followed by only three days the start of barging from Tuft Point, (2) the whales remained in the area during the period when there were consistently about 25 barge movements per day, but left when barge movements temporarily ceased; subsequently the number of barge movements was smaller and no whales remained in the area, and (3) we made three direct observations of groups of white whales that were apparently trying to move past the Tuft Point area, but that seemed to have been turned back by the operations there -- particularly barge traffic (Fraker 1977a). The Tuft Point location was used again in 1978 and 1979, but the number of barge movements was much smaller, typically six per day or less, and no significant interference with whale movements occurred (Fraker 1978; Fraker and Fraker 1979). Underwater sound from the barge traffic did not offer a sufficient explanation for the failure of the whales to cross the barge route, and Fraker (1977b) hypothesized that the whales might have been 'blocked' by a sonar-reflecting 'barrier' of air micro-bubbles that would have been detected by the whales' echolocation system as a solid obstacle. Such an effect has been reported for other toothed cetaceans (Norris et al. 1978).

Long-term Effects

The most important question is whether the short-term effects of vessel disturbance has had any long-term implications for the white whale population.

If vessel traffic in the Mackenzie estuary was producing long-term effects on the distribution and/or numbers of white whales, these effects should be manifested by a decline in the number of whales using the area with the most traffic, i.e., Kugmallit Bay. This bay has been used by

large numbers of white whales in three of the nine years studies have been done - 1973, 1976, and 1977; low numbers were recorded there during at least four of the other six years - 1972, 1978, 1979, and 1980. (Data from 1974 and 1975 are insufficient to calculate peak estimates.)

Possible explanations for the low number of white whales using Kugmallit Bay, particularly during the past three years, include the following:

1. Over-harvesting by Inuk hunters.
2. Disturbance caused by hunting activities
3. Disturbance from industrial activities, primarily vessel traffic.
4. Spring ice conditions which deny the whales access to Kugmallit Bay during the spring migration period.

It should be emphasized that these factors, discussed below, could act independently or in concert to cause a reduction in the level of use by whales.

Overharvesting--If Inuk hunters were overharvesting the whales that use Kugmallit Bay, then a decline in use of the bay would occur because fewer animals remained. This presupposes, however, that the whales using Kugmallit Bay effectively form a sub-population that has limited mixing with the rest of the Mackenzie estuary population. There is no evidence which addresses this question directly, but observations of whales moving between different parts of the estuary indicate that it is extremely unlikely that sub-populations exist within the Mackenzie population.

The peak estimated numbers of white whales in Kugmallit Bay has declined from 2448 in 1976 to just 120 in 1980 (Table 20). However, only an estimated 591 whales were killed (394 landed + 197 estimated killed-and-lost) during this five-year period. Clearly, over-harvesting could not be solely responsible for the decline in the numbers of white whales using Kugmallit Bay, assuming moderate natural mortality, even if there were no reproduction during the period.

Table 20. The total estimated kill of white whales in Kugmallit Bay and the percentage in relation to peak estimated numbers, 1976-1980. The killed-and-lost rate, 33.3% of the total kill, is from Fraker (1977a, 1980).

Year	Whales landed	Estimated whales killed-and-lost	Estimated total kill	Estimated peak numbers	Total kill as percentage of peak numbers
1976	110	55	165	2448	6.7
1977	86	43	129	1932	6.7
1978	81	40.5	121.5	780	15.4
1979	80	40	120	496	24.2
1980	37	18.5	55.5	120	46.3
Totals	394	197	591	5776	-

Hunting-induced Disturbance--In the course of whale monitoring studies, there have been several observations that indicate that white whales are disturbed by hunting activities (Slaney 1973, 1974; Fraker 1978; Fraker and Fraker 1979; Fraker et al. 1979). When hunters chase whales in the concentration areas, short-term, local changes in distribution result. But there also appear to be longer-term effects, i.e., whales may vacate a concentration area earlier than ususal in a given year.

We have seen movements of relatively large numbers of whales, up to several hundred, away from hunting areas, apparently in response to disturbance from hunting activities. Many hunters also recognize that this happens. One particularly well-documented instance occurred on 22 July 1978 when we observed a mass movement of several hundred white whales from the concentration area near Hendrickson Island, apparently in response to the hunting activities of at least five, and probably more, parties of hunters.

We identified three reasons why disturbance from hunting activities in Kugmallit Bay has been a concern in recent years:

1. Typically, 120-150 whales, which is about 75% of the total kill within the estuary, have been killed within Kugmallit Bay.

2. This mortality, plus associated hunting disturbance in Kugmallit Bay, has had to be absorbed by the relatively small number of whales in this area in 1978-1980. Of the peak estimated numbers in Kugmallit Bay, we estimate that 15.4% were killed in 1978, 24.2% in 1979, and 46.3% in 1980 (Table 20). Clearly, the mortality plus hunting disturbance must have greatly affected the small number of whales that were present.

3. Because the Hendrickson Island concentration area in Kugmallit Bay is so small and so well sheltered from rough water, all parts of that area are accessible to hunting. This is not the case in either the Niakunak or Kendall Island areas. Especially in the Niakunak area, which is very large, the whales can escape to undisturbed parts of the concentration area.

We suspect that when a small number of whales, such as have used Kugmallit Bay in the past three years, are subjected to intensive hunting disturbance, the same individuals are repeatedly affected, become sensitized to the presence of the hunting activities, and may vacate the concentration area earlier than they would have otherwise. Figure 5 shows that the number of whales in Kugmallit Bay in 1978 declined sharply at the end of July, which was a week or more earlier than in 1976 or 1977. In 1979, when peak numbers were lower than in 1978, the number of whales declined sharply in mid-July. In 1980, the number of whales remained low throughout the summer. Our interpretation of the above information is that when about 2000 or more whales are present in Kugmallit Bay, as in 1973, 1976, and 1977, there may be enough animals to sustain the effects of the kill plus hunting disturbance without resulting in a noticeable or early decline in numbers. How-

ever, when few animals are present, there may be (1) an early decline in numbers, and (2) possibly a reduced peak estimate. The former may result after the whales have been chased repeatedly. In western Alaska, for example, in areas where white whales are herded during hunts, the whales become progressively more difficult to herd after the first hunt in each season (J.J. Burns, Alaska Dept. Fish and Game, pers. comm.).

However, disturbance is a necessary concomitant of hunting, although this could be reduced in the Mackenzie estuary through the use of certain improved equipment and techniques (Fraker 1980). We hasten to point out that in both 1978 and 1980, hunting did not begin until the middle of July (because of poor weather), and therefore, could have had no effect on early numbers.

Vessel-induced Disturbance--If vessel traffic were to have a major long-term effect on white whales, one would expect the most obvious changes when the level of activity was greatest. Although the data on the amount of vessel traffic are incomplete for 1976 and 1977, traffic in Kugmallit Bay was more frequent than in 1980. In 1976, in particular, there were often up to 25 barge movements per day plus additional crew boat movements between Tuft Point and Kugmallit H-59, and Tuft Point and Arnak L-30. During the period when whales were present, most of this traffic was to or from the artificial island, Kugmallit H-59, which is relatively near the Hendrickson Island whale concentration area (Fig. 16). Dome Petroleum also began offshore drilling operations in 1976, and these continued on a larger scale in 1977. If marine traffic were to seriously affect the whales in Kugmallit Bay, one would have expected a significant effect in 1976, when the traffic was most frequent, or possibly in 1977, if there were a delayed effect. But in both of those years, the peak number of whales in Kugmallit Bay was about 2000 or more and the numbers remained high (500 or greater) for two weeks or more (Fig. 5). The whale harvest was also good in both years -- 110 in 1976 and 86 in 1977.

Because of the location of the whale concentration area in Kugmallit Bay and the general characteristics of the waters there, it is quite isolated from disturbance from industrial activities. It is generally agreed that underwater sound is probably the main feature of marine traffic

that can affect marine mammals such as white whales. Therefore, it is of value in evaluating the potential for disturbance of whales in Kugmallit Bay to consider the distance over which sounds may travel before decreasing (owing to spreading, absorption, and attenuation losses) to quiet ambient levels. Working in waters of about 3 m depth* in the Mackenzie estuary, Ford (1977) measured underwater sounds produced by vessels and other offshore industrial activities. By comparing these sounds with the known hearing sensitivity of the bottlenosed dolphin (*Tursiops truncatus*), which was presumed to be similar to that of white whales, Ford computed that a whale might be expected to hear sounds from the loudest recorded vessel (a tug pushing a loaded barge) at a distance up to 3.3 km under quiet water conditions. Under rough conditions, water noise would greatly reduce the distance over which the sounds would be audible. Fraker (1977a) made observations of whales responding to a barge tow passing through Niakunak Bay. The tugs (one of which was one of the loudest measured by Ford) were pushing a loaded barge tow through a concentration of whales. Direct observations showed that the whales responded at distances up to 2.4 km. These results suggest that the whales can tolerate a certain level of disturbance without responding or that sound propagation conditions were less favourable in Niakunak Bay, where the observations were made, than in Kugmallit Bay, where Ford made his sound recordings. From this discussion it appears that under ideal (i.e., quiet) conditions, a white whale in the shallow waters of the Mackenzie estuary might be expected to detect a loud vessel at a distance of up to 3.3 km. Thus, except at the southernmost part, whales in the Hendrickson Island concentration area are not likely to be able to hear sounds from marine traffic. They are most likely to be affected by traffic when they are outside of the concentration area and when they are relatively close to any traffic.

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* The deeper the water, the better that sound will travel. Most of the parts of the Mackenzie estuary that are used by whales are 2 m or less in depth. Thus, measurements made in water that was 3 m deep would yield propagation loss figures that are somewhat low, and therefore, conservative for our purposes.

The other mechanism by which white whales might be affected by vessel traffic -- the introduction of a sonar-reflecting 'barrier' of air micro-bubbles -- appears to require a relatively high frequency of vessel movements (to maintain dissolved air in the water), such as occurred in 1976 near Tuft Point when there were up to 25 movements per day. There was no such high frequency of movements along a particular route in 1980 (Fig. 17).

On the basis of our current knowledge of effects of vessels on white whales, we conclude that the levels of marine traffic observed in 1980 were insufficient and were in the wrong place to have had more than a minor effect on whales in Kugmallit Bay, and that cumulative effects on whales from one year to the next are not likely. The conclusion that there were no serious effects in 1980 is contrary to the reports of J. Avik and H. Chicksi (DFO 1980) who concluded that vessel traffic between Tuktoyaktuk and Pullen Island interfered with the movements of whales to the Hendrickson area. The movements along this route were not very frequent (Fig. 17), and we suspect that the attribution of an effect to these movements reflects the frustration that the hunters were having with their lack of success in hunting.

Mackenzie Estuary Ice Conditions--The landfast ice barrier across the Mackenzie estuary must be breached before the whales can enter. The timing of break-up appears to have a large potential for influencing the distribution of white whales within the estuary. Although the timing of ice break-up is not related to human activities, we are discussing it here because of its importance in considering possible long-term changes in the number of white whales using Kugmallit Bay. In each of the past three years most white whales have apparently migrated past Kugmallit Bay before ice conditions there have allowed the whales access. In 1980, surveys along the edge of the landfast ice east of the Mackenzie estuary demonstrated the presence of large numbers of white whales moving toward the estuary during the latter half of June. The ice broke in West Mackenzie Bay on 27 June, and large numbers of whales immediately entered and travelled to Niakunak Bay. The ice barrier in Kugmallit Bay fractured on 30 June, but surveys along the

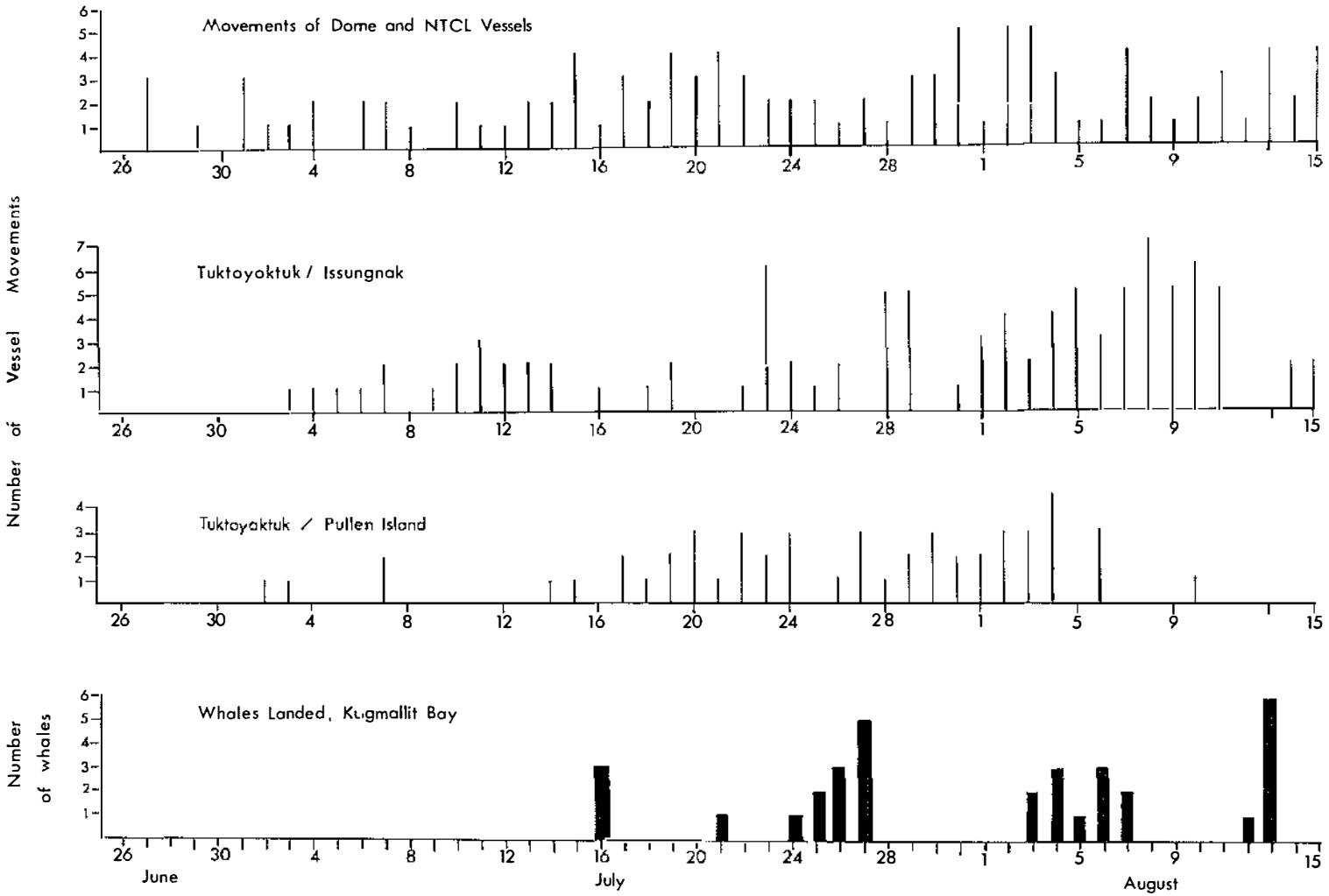

Figure 17. Frequency of vessel movements and known dates of white whale kills in Kugmallit Bay area, summer 1980. Vessel movement information from Esso Resources Canada Limited and from summaries provided by other companies to Mr. Richard Barnes (Dept. of Fisheries and Oceans, Inuvik, N.W.T.).

ice edge on that date and on 6 July failed to locate any whales migrating to the estuary. This indicates that most of the migration had taken place before 30 June. On the basis of this information, we predicted in early July 1980 that numbers of white whales in Kugmallit Bay would remain low, and that the harvest would, therefore, be smaller than normal.

Two types of evidence lead us to conclude that the late break-up of the landfast ice in Kugmallit Bay (in relation to the timing of the whales' migration to the estuary) was mainly responsible for the low numbers in this area in 1980. First, direct evidence comes from surveys along the edge of the landfast ice which showed that large numbers of whales were migrating before the ice broke in Kugmallit Bay, but not after. Second, indirect evidence comes from the general pattern of change in abundance seen over the past several years of study. It appears that the number of whales entering Kugmallit and Niakunak Bays increases rapidly after the first whales arrive if there are to be large numbers present. When high numbers occur in Kugmallit Bay, they tend to do so early in the season, although perhaps not as early as in Niakunak Bay (Fig. 5). The number of whales present in Kugmallit Bay were low early on in 1980, as they were also in 1978 and 1979. However, numbers were high early in 1973, 1976, and 1977, when large numbers were present in Kugmallit Bay. It is significant that in 1978 and 1979, very large numbers of whales were found in Niakunak Bay (Fig. 5), strongly indicating that whales that might otherwise have been in Kugmallit Bay had gone to Niakunak Bay. We suspect that a similar number of whales were in Niakunak Bay in 1980, also, but poor weather interfered with surveys during the early period when peak numbers would be expected.

Overall Conclusion

The continued presence of large numbers of white whales in the Mackenzie estuary indicates that there has been no serious or long-term effect on white whales from either industrial operations or whale hunting. Esso's willingness to reduce potential effects by avoiding certain sensitive areas (e.g., Niakunak Bay), and by reducing the level of activity (e.g., by consolidating barge moves), has, in our opinion, significantly reduced the potential for adverse impacts.

In considering the potential for repeated disturbance to cause whales to avoid a particular area, such as Kugmallit Bay, it may be instructive to consider the example of hunting disturbance. Despite the great increase in industrial activities in the Mackenzie estuary region, hunting undoubtedly is still the main source of disturbance to white whales. In contrast to industrial disturbance, hunters pursue the whales in the areas where they gather in the greatest densities. Yet the whales have returned to the same areas, even though they have been chased there repeatedly year after year.

Bowheads and Offshore Exploration

Relatively large numbers of bowheads were observed by industry personnel and by us in and north of Kugmallit Bay during 1976, 1977, and 1978, but few were seen in 1979.* The decline in the number of sightings, particularly in 1979 but also in 1978, caused us to suggest that the reasons for the variation be investigated (Fraker and Fraker 1979). A much greater amount of information about the occurrence of bowheads in the Issungnak area was gathered in 1980 than in any other year so far - a consequence of the complementary studies funded by Esso and by the U.S. Bureau of Land Management. During much of the time that the studies were underway, there was considerable activity at the Issungnak site. The large suction dredge *Beaver Mackenzie* was working to rebuild the island, and there were various ancillary activities involving tugs, crew boats, and a barge camp.

No bowheads were seen during our first systematic survey of the Issungnak area on 24 July, although substantial numbers were seen during surveys on 5, 9, 11, 12, and 22 August (Table 18; Fig. 13). Industry personnel reported the first bowhead sighting near Issungnak on 2 August and the last on 11 September (Table 17). Sightings were made most frequently in the first half of August; similarly, highest densities observed during the the systematic surveys and reconnaissance surveys were found during this same period.

* In 1976 there were 16 sightings of 47 bowheads, in 1977 there were 28 sightings of at least 101 whales, and in 1978 there were 8 sightings of 63 whales. But in 1979 there were only 2 sightings of a total of 7 individuals.

Several of the bowheads seen during aerial surveys were quite near the construction activities, the closest being within 800 m (Table 18). During the six surveys in August, a total of 20 bowheads was seen within 5 km of the Issungnak Island: 12 bowheads during one survey on 9 August. A total of 64 bowheads was seen within 10 km of Issungnak -- 23 during the 9 August Esso survey. Because the distribution of bowheads was obviously variable from day to day and uneven within the surveyed areas, it is not possible to determine statistically whether there was any avoidance of the immediate vicinity of the activity site, although visual inspection of the data does not suggest avoidance (Fig. 13, Table 18).

A total of 18 sightings of one or more whales was reported by personnel working on vessels in the Issungnak area. Several sightings were reported to have been within 0.5 km of the vessel from which the observation was made. On 3 or 4 August, a group of three whales was reported to have stayed near the *Arctic Breaker* for about 12 h, with one individual approaching to within about 16 m.

The sightings reported by industry personnel, plus the results of our systematic surveys for Esso (this study) and BLM (Fraker et al. 1981), indicate that the bowheads in the Issungnak area were not apparently disturbed by the construction activities there. It should be recognized that we do not know in detail what the industrial sound environment was during the periods when these observations were made; however, at least some whales obviously show some degree of tolerance for both (1) the physical presence of the artificial island, boats, dredges, etc. and (2) the sounds that are produced - the operation never is quiet, even when the dredge is not working.

The fact that considerable numbers of bowheads were present near Issungnak in August 1980 raises the question as to why there had been so few in some other years, particularly 1979. The number of animals detected is obviously affected by the amount and timing of observation effort. However, the observation effort from vessels was at least as great and possibly greater before 1980 than in that year. Also, the numbers of sightings made by industrial personnel on boats and by aerial surveyors show a parallel trend, i.e., high in 1980, low in 1979, and moderate in 1978. The simplest explanation is that the whales have shown a different distribution from one year to another, independent of industrial activities.

Effects of Industry Activities on Whale Hunting

Possible effects of offshore activities on whale hunting has been a major concern from the outset of island construction in 1972. Two types of effects are possible: (1) direct interference with hunting activities, and (2) effects on the distribution and/or abundance of whales within the hunting areas. To date, there has been a small amount of direct interference with the hunting, owing primarily to vessel traffic. However, Esso has taken active measures in certain instances to reduce or eliminate disturbance to hunters by altering the location, timing, and amount of activity in certain areas (Slaney 1975; Fraker 1977a, b, 1978; Fraker and Fraker 1979). We detected no interference with hunting in 1980, nor was there any obvious relationship between the number of whales landed and vessel traffic in Kugmallit Bay, particularly vessels travelling between Tuktoyaktuk and Pullen Island (Fig. 17).

PART 4

SUMMARY

1. The first white whales arrived in the estuary on 27 June in 1980, between 1500 and 2000 h, through a break in the landfast ice that occurred in West Mackenzie Bay, about 25 km north of Shingle Point. Although a break in the ice in Kugmallit Bay occurred on 30 June, no whales were seen there until 4 July.

2. Initially, more than 95% of the white whales were present in Niakunak Bay, while less than 5% were in Kugmallit Bay. This difference appears to have been a consequence of the timing of the break-up of the landfast ice in relation to the migration. Surveys of the edge of the landfast ice indicated that by the time the ice had broken in Kugmallit Bay, nearly all of the whales had moved into Niakunak Bay.

3. The maximum estimated number of white whales in the Niakunak Bay concentration area in 1980 was 4234; however, based on the pattern of change in abundance in other years it is probable that a higher peak number was reached during a period of poor weather when surveys were not possible. The maximum estimated number in Kugmallit Bay was only 120 in 1980. We believe that the total number of white whales using the Mackenzie estuary is in the order of 7000.

4. The geographical extent of the Niakunak Bay concentration area used in 1980 was within the boundaries observed in previous years. Too few whales were seen in Kugmallit Bay to determine a concentration area.

5. Hunting camps were established in all parts of the estuary during the last week in June. Hunting was finished by about mid-July in Niakunak Bay, but continued to mid-August in both Kugmallit Bay and the Kendall Island area. The 1980 white whale harvest of 90 was 46 less than the 1972-1979 average; hunters from Tuktoyaktuk and Kugmallit Bay camps landed

substantially fewer whales than normal. The reduced harvest in Kugmallit Bay was mainly a result of the scarcity of whales, but poor weather was also a contributing factor.

6. The sex ratio of the landed catch of white whales was 0.95 males : 1 female. This is statistically different from the ratio of 3.42 males : 1 female in the 1974-1978 catch. The change in sex ratio probably is the result of decreased selectivity by hunters. Decreased selectivity presumably was forced by the reduced number of whales present in certain areas and by the limited hunting opportunities resulting from poor weather. The changed sex ratio probably does not reflect a fundamental change in the structure of the population at large. There was no change in the mean lengths of landed males or females.

7. Large numbers of bowheads were present in the Issungnak area from early August to mid-September in 1980. As many as 23 individuals were observed within 10 km of the island site and dredging operation during a single survey; this, of course, does not include animals that may have been beneath the surface. The main activity of bowheads in the Issungnak area, as well as elsewhere in the southeastern Beaufort Sea region, appears to be feeding.

8. Vessel traffic, the main industrial activity in Kugmallit Bay in 1980, does not appear to have had a significant effect on the use of Kugmallit Bay by white whales or on the success of whale hunters.

9. Although few bowheads had been present near the Issungnak artificial island construction site in 1979, large numbers were present in 1980. Significant numbers of bowheads were also observed near offshore operations from 1976-1978. This suggests that the bowheads were absent from near industrial operations in 1979 for natural reasons, such as food availability, rather than as a response to island-building operations.

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Appendix 1. Number of whales counted during aerial surveys in the Mackenzie estuary, by survey line and area, 1980. NS means that line was not surveyed on that date.

	Kugmallit Bay Survey Lines															
Dates	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	Totals
5 July	0	0	11	0	0	0	0	NS	NS	NS	NS	NS	NS	NS	NS	11
10 July	0	0	0	0	0	0	0	0	5	0	NS	NS	NS	NS	NS	5
12 July	NS	NS	0	0	0	0	0	0	NS	NS	NS	NS	NS	NS	NS	0
16 July	NS	0	0	0	0	0	0	0	0	0	NS	NS	NS	NS	NS	0
22 July	0	0	0	0	0	0	0	0	0	0	NS	NS	NS	NS	NS	0
24 July	0	0	0	0	0	0	0	15	0	NS	NS	NS	NS	NS	NS	15
28 July	0	0	0	0	1	4	1	0	0	3	NS	NS	NS	NS	NS	9
3 August	0	0	0	0	0	0	0	0	6	14	NS	NS	NS	NS	NS	20
12 August	0	0	0	0	0	0	9	3	0	0	0	2	1	NS	NS	15
Totals	0	0	11	0	1	4	10	18	11	17	-	2	1	-	-	75

Appendix 1. (Continued)

Dates	Niakunak Bay Survey Lines												Totals
	N-B	N-A	N-1	N-2	N-3	N-4	N-5	N-6	N-7	N-8	N-9	N-10	
28 June	0	0	0	0	0	26	39	30	5	27	NS	NS	127
30 June	0	0	0	0	29	35	13	0	0	0	NS	NS	77
1 July	0	0	0	115	164	182	178	190	93	107	11	NS	1040
3 July	0	0	0	0	55	168	120	128	46	39	36	NS	592
10 July	0	0	0	9	92	206	206	157	103	82	134	47	1036
15 July	0	0	0	0	7	109	146	165	156	55	57	NS	695
25 July	0	0	0	0	0	2	0	6	4	6	1	NS	19
Totals	0	0	0	124	347	728	702	676	407	316	239	47	3586

Appendix 1. (Continued)

Dates	West Mackenzie Bay Survey Lines						Totals
	WM-1	WM-2	WM-3	WM-4	WM-5	WM-6	
29 June	0	9	9	21	13	0	51
2 July	5	4	0	6	0	0	15
5 July	0	0	5	0	0	56	61
8 July	0	2	0	NS	NS	NS	2
9 July	0	0	21	3	6	0	30
11 July	0	3	3	1	2	3	12
14 July	0	0	3	44	0	4	51
19 July	0	0	0	15	3	1	19
21 July	0	0	0	0	0	0	0
7 August	0	0	64	37	33	16	150
Totals	5	17	105	127	57	80	391

Appendix 1. (Continued)

Dates	EM-A	EM-1	EM-2	EM-3	EM-4	EM-5	EM-6	EM-7	EM-8	EM-9	EM-10	Totals
5 July	0	0	0	0	0	0	0	NS	NS	NS	NS	0
9 July	0	8	0	1	1	0	0	0	0	0	0	10
11 July	0	1	0	0	0	NS	0	2	NS	NS	NS	3
19 July	0	1	0	3	0	2	0	0	0	0	0	6
5 August	3	34	10	23	5	3	0	0	1	0	0	79
Totals	3	44	10	27	6	5	0	2	1	0	0	98

Appendix 2. Observations of white whales made by industry personnel and others, 1980.

Date Time	Location	Number of whales	Direction of movement	Observations	Observer Company
23 June	48 km W of Cape Parry	~50			B. Mackenzie
25 June 1055	48 km NNW of Baillie Islands	7			M. McKerral
24 July	between Pullen Island and Issungnak 0-61	3			
	S and E of Pullen Island	3			
	Pullen Island to Immerk B-48	6			M. Psutka ERCL
	around Pelly Island	3			
	west of Pelly Island	6			
	6-18 km NE of Garry Island	50-60		two groups of 8 or 9, one group of 15; they were probably gamming	
25 July 1300	Hutchison Bay	1	none	no reported reaction to helicopter 46 m above; water depth = ~2 m	L. Pelletier DFO
5 August 1610	17 km N of Hendrickson Island	25	W	no reported reaction to helicopter 610 m above; water depth = 9 m	P. Thurgar Dome

Appendix 2. (Continued)

Date Time	Location	Number of whales	Direction of movement	Observations	Observer Company
6 August 0800	4 km E of Garry Island	15		no reported reaction to helicopter 460 m above	B.G. Cox ERCL
6 August 0800	9 km S of Hooper Island	20		no reported reaction to helicopter 460 m above	B.G. Cox ERCO
6 August 1730		34+	W	many calves; no reported reaction to Bell 206 helicopter 15 m above; water depth = 3 m	G. McKinnon DFO
9 August 1440	34 km NW of Tuft Point	70±20 in groups of 6-10	SW	no reported reaction to Pressure Ridge 100 m away	L. Hobbs U.S.NMFS
10 August 1620	103 km N of Baillie Islands	1	WSW	no reported reaction to Bell 206 helicopter 460 m above	B. MacDonald Kenting Helicopters
14 August 2100	NE of Pullen Island	100+	W	no reported reaction to Bell 212 helicopter 152 m above	A. MacDougald Associated Helicopters
16 August 1630	Eskimo Lakes	2 groups of 8 each	SSE	No reported reaction to Bell 206 helicopter 61 m above	B. MacDonald Kenting Helicopters
18 August 1207	Boat harbour at Tuft Point	4+		no reported reaction to Pressure Ridge 75 m away	L. Hobbs U.S.NMFS

Appendix 2. (Continued)

Date Time	Location	Number of whales	Direction of movement	Observations	Observer Company
24 August 2015	10 km NNE of Toker Point	10	WSW	no reported reaction to S/V Ungaluk 150 m away	L. Hobbs U.S.NMFS
3 September 1045	51 km N of Atkinson Point	2	S	no reported reaction to GSI Mariner 3.2 km away	D. Weston GSI
10 September	3 km SE of Hooper	6	none	whales were possibly feeding; gulls flying overhead and sitting on water; smelt and juvenile arctic and least cisco abundant in area; no reported reaction to helicopter 61-91 m above	M. Lawrence FMS