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WHITE WHALE USE OF THE SOUTHEASTERN BEAUFORT SEA, JULY - SEPTEMBER 1984

by

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ABSTRACT

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This report presents data collected on white whales (Delphinapterus leucas) during six systematic aerial surveys of the southeastern Beaufort Sea during July, August and September, 1984. The first survey coincided with the period when white whales concentrated in the Mackenzie Estuary, yet 40.8 white whales/1 000 km^2 were observed offshore. White whale abundance in the offshore Beaufort generally increased from early July through to the third week of July (99.7/1 000 km^2), and then declined. Cow-neonate pairs were frequently recorded offshore. White whales may have started moving into Alaskan waters as early as mid-July, although the results suggest that most migrated from the region between late July and mid-September. The July 21-23 survey results were used to calculate a minimum estimate of 7 081 animals in the study area; this estimate does not include whales in Amundsen Gulf, and has not been corrected for unseen animals or for reduced detectability of white whales in outer portions of the transect strip. Calving and feeding may occur offshore.

Key words: aerial surveys; ice concentration; population size; oil and gas industry activities; distribution; abundance; detectability; calving; feeding; migrations; gross annual recruitment.

RESUME

Norton, P., and L.A. Harwood. 1985. White whale use of the southeastern Beaufort Sea, July-September 1984. Can. Tech. Rep. Fish. Aquat. Sci. 1401: v + 46 p.

Ce raport présente les données sur le béluga (Delphinapterus leucas) recueillies au cours de six relevés ariens consécutifs dans le sud-est de la mer de Beaufort aux mois de juillet, août et septembre 1984. La période du premier relevé coïncide avec celle où se produisit une concentration de bélugas dans l'estuaire du Mackenzie: par contre, 40,8 bélugas par 1 000 km^2 furent observés au large des côtes. L'abondance de bélugas au large de la mer de Beaufort a généralement augmenté du début juillet à la troisième semaine de juillet (99,7 bélugas/1 000 km^2), et a déclimé ensuite. Les observations de paires mère - nouveau-né furent fréquentes au large des côtes. Les bélugas peuvent avoir commencé à se déplacer vers les eaux de l'Alaska dès la mi-juillet, bien que les résultats semblent indiquer que la majorité quitta la région entre la fin juillet et la mi-septembre. Les résultats du relevé effectué les 21, 22 et 23 juillet furent utilisés pour établir à 7 081 (nombre estimatif minimum) le nombre de bélugas dans la région étudiée; ce chiffre estimatif ne comprend pas les bélugas dans le golfe Amundsen et n'a pas été corrigé en fonction des bélugas non observés ou de la détectabilité réduite des bélugas dans les parties périphériques de la bande transect. La mise bas et le nourrissement peuvent se produire au large des côtes.

Mots-clés: relevés aériens; concentration de la glace; grandeur de la population; activités de l'industrie petrolière et gazière; répartition; abondance; détectabilité; mise bas; nourrissement; migrations; recrutement annuel brut.

INTRODUCTION

Each spring the Beaufort stock of white whales, (Delphinapterus leucas), leaves its wintering areas in the Bering Sea, proceeds northward through the Chukchi Sea, and at Point Barrow, Alaska, proceeds eastward and enters the Beaufort Sea. It has been presumed that the stock follows the east-west offshore shear zone to the system of leads off the west coast of Banks Island and then to Amundsen Gulf. The earliest sighting in Amundsen Gulf was in late April (Braham et al. 1984). In the latter half of June, the white whales proceed southwestward, through the nearshore lead off the Tuktoyaktuk Peninsula, to the Mackenzie Estuary. Large numbers of white whales have been observed in specific locations, termed concentration areas, in the estuary through much of July (Norton Fraker 1983). However, there have been occasional reports of white whales moving away from the estuary or in the offshore area during this period (Slaney 1974; Fraker and Fraker 1979). The westward fall migration probably occurs in August and September; the specific route followed is not known (Fraker et al. 1978). While in the Beaufort Sea, the white whale stock is the subject of a subsistence harvest by local Inuit, and utilizes areas where oil and gas exploration activities are occurring. The effects of hunting and industry activities on the population can not be accurately assessed until white whale use of estuarine and offshore Beaufort Sea waters is more fully understood.

Previous systematic aerial surveys in the region have focussed on (1) white whale arrival to and distribution within the estuary, or (2) on bowhead whale distribution in offshore waters during late August - early September. This study was designed to examine the distribution, relative abundance and movements of white whales in the offshore waters of the Beaufort Sea during and immediately after the period of estuarine occupation. Four surveys at weekly intervals were planned, starting in early July. Limited coverage of nearshore waters was included in three of the surveys to allow comparison between nearshore and offshore areas. Two extensive surveys of the offshore area, one in late August and the other in early September, were sponsored by the Environmental Studies Revolving Funds (ESRF) and Indian and Northern Affairs Canada (INAC) under the Northern Oil and Gas Action Program (NOGAP) to monitor bowhead distribution. White whale data collected during these surveys have been included in this report, thus extending the time frame of systematic coverage of the offshore.

STUDY AREA

The study area was defined as the southeastern Beaufort Sea from the Alaska-Yukon border (141°W) east to Cape Bathurst (128°W), and from the mainland coast seaward to 9+/10 concentration of pack-ice (Fig. 1). Although the study area included primarily offshore waters, portions of nearshore areas such as Niakunak Bay and Kugmallit Bay were surveyed.

The study area is almost completely ice-covered during the winter. The pattern of ice break-up has been described by Marko and Fraker (1981). In spring, an east-west shear zone develops from Point Barrow, Alaska to the west coast of Banks Island. A north-south lead parallel to the west coast of Banks Island also develops early, usually by the first half of April. The lead that runs parallel to the Tuktoyaktuk Peninsula develops at the same time or somewhat later than this north-south lead. The formation of these leads results from the interaction of the

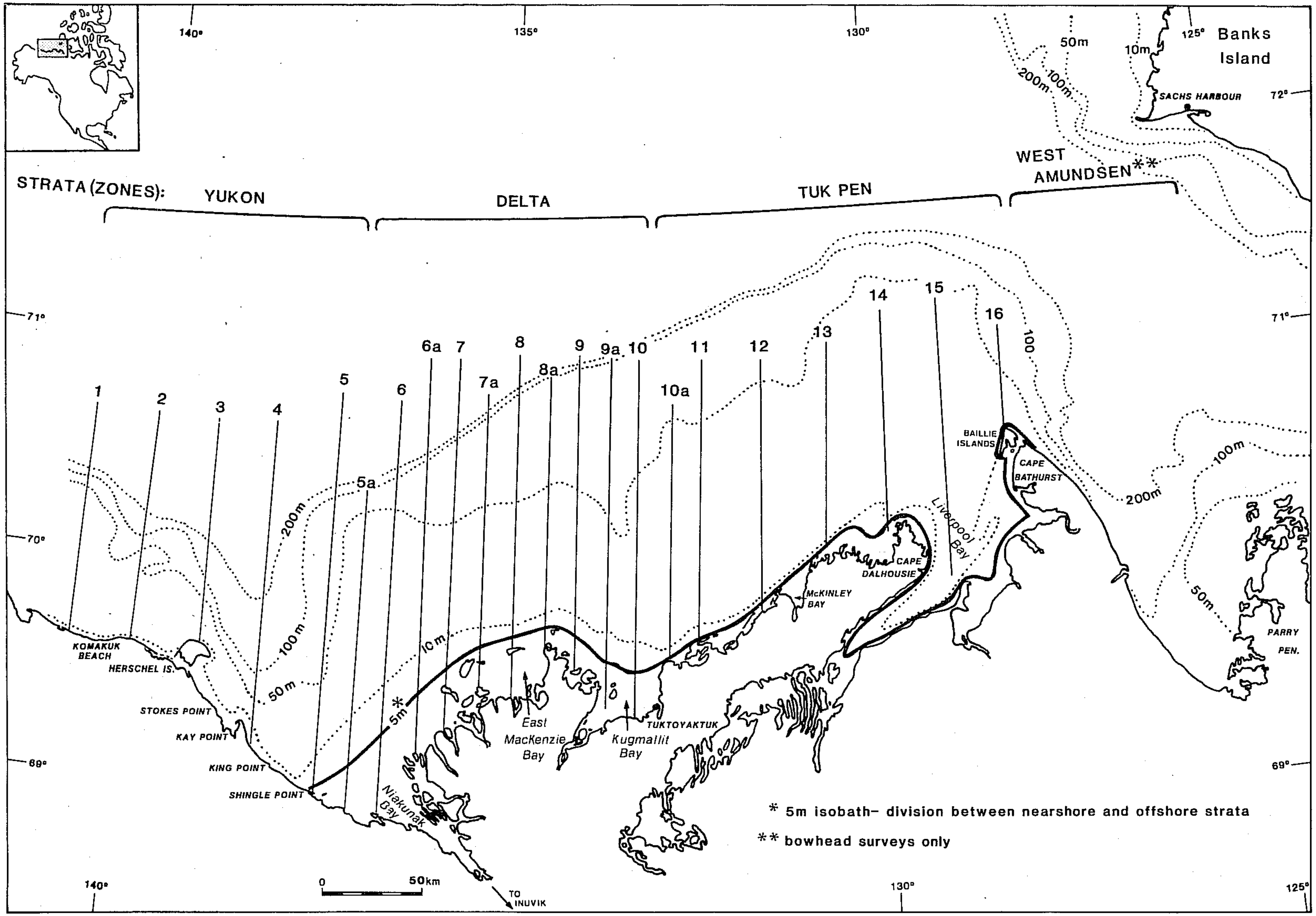


Fig. 1. Location of 1984 white whale systematic survey transects.

clockwise rotation of the gyral pack-ice and easterly spring winds. The landfast (first-year) ice shoreward of these leads usually begins to break up in June; the process is affected by the volume and current of the warm Mackenzie River discharge, heating from the sun and mechanical action of the wind and river currents (Dey 1980). As the ice breaks up, there is a gradual increase in the open water expanse; however, strong north or west winds may blow the ice floes back towards shore. Winds from the south and east push the floes towards the pack-ice. If the winds are variable, alternating zones of open water and open and close ice may develop. In fall, the temperatures drop, causing the leads in the close ice to freeze over. Freeze-up in coastal areas usually begins in late September or October.

The Mackenzie River discharge influences the nearshore areas throughout the open-water season and affects surface currents in much of the study area (McNeill and Garrett 1975). The location of the plume varies with the volume of discharge and wind direction and speed, and may extend well offshore, or be contained (e.g., Harwood and Borstad 1985).

METHODS

The data discussed in this report are from three sources: the present study, systematic aerial surveys for bowheads, and platform-of-opportunity programs involving industry personnel. Methods for this study are described in detail below; because of the similarities between the two systematic aerial survey programs, only differences between the two projects are given.

SYSTEMATIC AERIAL SURVEYS: JULY - EARLY AUGUST

Survey timing and location and stratification of the study area

Four systematic aerial surveys were conducted at approximately weekly intervals: July 5-9, July 13-18, July 21-23 and July 28-August 2. The extent of the study area covered varied among surveys due to variations in the position of the pack-ice edge, weather conditions and the location of a concurrent aerial survey program conducted by the Department of Fisheries and Oceans (second survey period only). North-south transect lines were established at 32 km intervals (Fig. 1). Given a transect width of 1.6 km, this resulted in approximately 5% coverage of the survey area. An additional six transect lines were flown during the July 5-9 survey, increasing coverage to approximately 10% in the area between Shingle Point and Warren Point. Coordinates for the start and endpoints of each survey transect line are provided in Appendix 1.

The study area was stratified to allow comparison of the results with those from past studies, and to provide areas with relatively homogeneous densities. Zone boundaries used were the same as those established in 1981 (Davis et al. 1982) and used since in bowhead surveys. The location of the Yukon, Delta and Tuk Pen zones is shown on Fig. 1. Each of these zones was further subdivided into nearshore and offshore strata. The 5 m isobath was selected as the boundary between nearshore and offshore areas on the basis of information from previous surveys of the estuary showing where white whales congregate (e.g., Norton Fraker 1983). The extent of the area sampled within each of the six strata during each survey is given in Appendix 2.

Shore was the southern end point for each transect line during each survey except the second one (see Survey No. 2). The northern endpoint for each transect line was designated as the edge of 9/10 pack-ice. Prior to each survey, the approximate location of this edge was determined using information provided by the Atmospheric Environment Service (AES) ice reconnaissance team based in Inuvik and the AES Beaufort Weather and Ice Office in Tuktoyaktuk. Weather and aircraft capabilities prevented reaching the 9/10 ice edge on many transects.

Survey platform

The aerial surveys were conducted from a Series 300 de Havilland Twin Otter aircraft based in Inuvik. A pilot, co-pilot, and the same two observers were present during all flights. The aircraft was equipped with either a Global Navigation System (GNS-500) or Collins LRN-70 navigation system.

Survey altitudes were checked and the desired altitude maintained using a radar altimeter. The planned survey altitude of 305 m (1 000 ft) was achieved for 97.9% of the total transect distance. Overcast conditions necessitated flying at 152 m for 1.4% of the total distance. The remaining portion was flown at an altitude of 457 m to avoid disturbance to waterfowl at the Kendall Island Bird Sanctuary. Surveying was not attempted if ceilings of <152 m existed, or if sea state exceeded 5 on the Beaufort Scale of Wind Force since detectability of marine mammals decreases with increasing sea state (e.g., McLaren and Davis 1985). Portions of transect lines where surveying was temporarily interrupted owing to weather are indicated by dashed lines on the distribution maps (see Fig. 2 and 5-9, Results).

The target ground speed was 200 km/h (108 knots) when flying transect lines, and 278 km/h (150 knots) when ferrying to the start of the next line. The calculated mean ground speed was 198 km/h (107 knots) during the transect surveys, but ranged from 170 to 235 km/h due to the effects of wind.

Survey methods

Bubble windows were used by both observers whenever surveying. With the exception of the July 5 flight, the two observers occupied the two window seats in the second row behind the cockpit. On July 5, both observers surveyed from the left side of the aircraft to obtain data on the number of whales not detected. A bubble window was installed behind the rear passenger door for that day. Communication between observers and pilots was maintained using an intercom system.

Observers recorded information regarding all marine mammals sighted on and off transect, between survey transects, and on ferrying flights. The observations were recorded on audio cassette tapes, and later transcribed to data sheets. Whenever possible, information recorded for each sighting included:

- species
- number of individuals
- time and location of sighting
- inclinometer reading (to calculate lateral distance from center of transect)
- habitat
- age

- distance between individuals and group organization
- behaviour
- direction with respect to compass headings and geographic features and relative rate of movement, and
- presence of seabirds.

Synchronized digital watches were used to record the time of each sighting to the nearest second and the start and end times for each transect. This information, along with mean ground speed, was used to plot the location of sightings. Distance to the end of the transect line was read off the navigation system for sightings whenever possible, and served as a check on the mapping procedure.

Lateral distance of a sighting from the flight path was estimated using a Suunto PM-5/360 S inclinometer by recording the angle of depression from the horizontal to the animal(s) when it was abeam of the aircraft. Triangulation involving this angle and the survey altitude was then used to calculate the lateral distance. At an altitude of 305 m, each observer was able to scan waters directly over the flight path (transect center line). Therefore, the transect strip on each side of the aircraft was defined as the area extending from 0 to 800 m from the flight path. The selection of the 1 600 m transect width was made at the start of the field program, and therefore observers concentrated their efforts within that area.

For each white whale sighted, a relative age was determined. White animals were assumed to be adults. On the basis of previous experience and data given in Brodie (1971), immature white whales were classified as:

- neonates if less than one-half the length of the accompanying adult and light gray to slate gray;
- yearlings if more than one-half but less than two-thirds the length of an adult and gray;
- subadults if longer than two-thirds the length of an adult and light gray; or
- calves if there was insufficient information to classify individuals as one of the above.

A whale 'group' was defined as two or more animals within close physical proximity ($\leq$5 whale lengths), or two or more animals moving in the same direction and/or engaged in the same apparent activity within approximately 100 m. A 'sighting' could be a group or a solitary individual.

During surveys, both observers recorded information on weather (wind, fog, precipitation), amount of glare, wind/wave direction, the location of any visible fronts or debris slicks and sea state. One observer recorded information on coverage and type of ice. Ice cover was recorded according to classes established by the World Meteorological Organization (1970):

- open water, if less than 1/10 ice cover;
- very open pack-ice, if ice cover was 1/10 to 3/10;
- open pack-ice, if ice cover was 4/10 to 6/10;
- close pack-ice, if ice cover was 7/10 to 8/10; and
- very close pack-ice, if ice cover was 9/10 to 9+/10.

Very close pack ice was rarely encountered and was often not differentiated from close pack. Sampled areas for these two ice categories were combined when analyzing the data.

SYSTEMATIC AERIAL SURVEYS: LATE AUGUST - SEPTEMBER

This report presents white whale data obtained during the 1984 late August and September bowhead surveys. The methods and study approach of the bowhead program were the same as those for the white whale program, with the following exceptions:

- two Twin Otter aircraft were operated simultaneously;
- right side observers occupied the co-pilots' seats;
- the southern boundary of the study area was the 2 m isobath;
- most transect lines extended farther north;
- the eastern boundary extended into Amundsen Gulf, to 125°47'W (the West Amundsen offshore stratum added);
- transect lines were spaced at 20 km intervals;
- transect width was 2 km, 1 km on each side of the aircraft; and
- survey coverage was approximately 10%.

The same two observers conducted surveys during the white whale and bowhead programs, although an additional four observers were involved in the latter. For more information on the bowhead program refer to Harwood and Borstad (1985).

DATA ANALYSIS

The surveys utilized the strip transect method (Caughley 1977; Eberhardt et al. 1979) which limits the counting of individuals to a strip of prescribed width. This method assumes equal detectability of all surfaced animals throughout the strip width. In the white whale program, a transect width of 1.6 km (800 m on either side of the aircraft) was adopted, and white whale densities were calculated on the basis of the area surveyed. Densities were extrapolated to unsurveyed portions of the survey area for one survey (July 21-23) to provide an estimate of population size. A correction factor for sightable but not detected animals was calculated using results from the July 5 flight.

Since the landward boundary of the study area during the late August-September surveys was the 2 m isobath, systematic coverage in nearshore waters was not as extensive as that during the July - early August program. Calculation of white whale densities has not been attempted for the nearshore strata for the late August and September surveys because the area sampled was not comparable to that sampled in the white whale program, and was not considered a representative sample of all nearshore waters.

The relationship between white whale distribution and ice cover was examined, by survey, using a chi-square goodness-of-fit test. Observed values were the number of white whale sightings, by group type, observed in each ice cover class. The null hypothesis was accepted if the probability of obtaining the chi-square value was greater than 0.05.

White whale sightings were analyzed by group type to eliminate any bias due to segregation. The following categories were used:

- neonates and adults,
- yearlings and adults,
- subadults and adults,
- calves and adults,
- yearlings without adults,
- subadults without adults,
- calves without adults, and
- adults without immature animals.

Only group categories with more than 10 sightings during a survey were analyzed. Group types were first tested to determine if their distribution relative to ice cover was similar using a chi-square test for homogeneity; testing proceeded according to the order indicated above. Group types with statistically similar ($p>0.05$) distributions were pooled.

Expected numbers of whales seen in each ice cover class were calculated assuming (1) time spent at the surface in ice-covered waters was the same as in ice-free waters (i.e. no corrections made for areas obliterated by ice), and (2) the percent of animals which were visible just under the surface during the observation period was inconsequential. Expected number of whale sightings in each ice cover class was obtained by multiplying the percent of the total area surveyed in that class by the total number of whale sightings. To identify "preferred" (i.e. observed values greater than expected) and "non-preferred" (i.e. observed values less than expected) ice cover classes, an arbitrary cut-off of 7.81 for the contribution to the calculated chi-square was used; a chi-square value of 7.81 for a test with 3 degrees of freedom indicates a probability of 0.05.

WHITE WHALES SIGHTED BY INDUSTRY PERSONNEL

Details of white whale sightings reported by industry and industry support personnel in the southeastern Beaufort Sea region from June to October, 1984, were provided by Dome Petroleum Limited and Esso Resources Canada Limited. Reports by Gulf Canada Resources Inc. personnel were included with those from Esso. Data from these sources were cross-checked in an attempt to delete duplicate reports, and were then combined for discussion in this report.

Ice observers stationed on vessels operated by or on behalf of Dome recorded wildlife sightings during 10-minute observation periods scheduled once every 3 hours, if possible. Sightings made by ice observers incidental to and during the designated watch periods, as well as sightings made by other industry personnel at the sites are included.

Esso utilizes a different wildlife reporting scheme. At the beginning of each drilling season, sighting cards are distributed to the companies' employees and to subcontractors working in the region. Persons sighting (a) whale(s) are asked to fill out a card and then forward it to Esso's Calgary office. Sightings made by Gulf personnel were reported by sighting cards distributed by Esso.

RESULTS

Data on white whales collected during the 1984 systematic aerial surveys are described in the remainder of this report. Survey dates, size of survey area and coverage for each survey are summarized in Table 1.

Table 1. Synopsis of 1984 systematic offshore surveys.

Survey No.	Survey Period	Survey Area (km^2)	Approximate Coverage
1	July 5 - 9	47 562	8.2
2	July 13 - 18	42 462	4.9
3	July 21 - 23	63 121	5.2
4	July 28 - August 2	46 229	5.0
5	August 18 - 27*	106 634	10.0
6.	September 6 - 18*	96 449	10.0

* Shoreward boundary for this analysis was the 5 m isobath (see page 6).

Information on pinnipeds collected incidentally during the course of the white whale surveys is presented in Appendix 3. Data on the distribution and abundance of bowhead whales (Balaena mysticetus) collected during the 1984 systematic survey series in the southeastern Beaufort Sea are presented in Harwood and Borstad (1985).

ICE CONDITIONS

Ice conditions observed on each of the six surveys are illustrated in Fig. 2 and 5-9. Temperatures recorded by AES along the Canadian Beaufort Sea coast were near normal during the 1983/84 winter, slightly warmer during the following spring, and several degrees above normal during June and July. These warmer temperatures resulted in an early and extensive development of leads in the Beaufort Sea and in Amundsen Gulf. Break-up of the landfast ice barrier occurred on June 25 in Kugmallit Bay and on June 21 in Mackenzie Bay (AES, Tuktoyaktuk). By June 28, the lead offshore of the Tuktoyaktuk Peninsula was 55 to 110 km wide, and extended from Amundsen Gulf to west of the Alaska-Yukon border.

The pattern of an early break-up continued during the first part of July, and by mid-July, the main edge of the pack-ice was approximately 80 km offshore. Large floes produced from break-up in Amundsen Gulf drifted westward across the expanse of very open ice (1/10 to 3/10 coverage) and open ice (4/10 to 6/10 coverage). During the latter part of July and early August, onshore winds maintained the ice edge in a relatively static position.

During August, the combination of slightly below average temperatures and frequent periods of onshore winds reduced the width of the open water area offshore of the Tuktoyaktuk Peninsula to 30 to 70 km. Floes of first-year and multi-year ice continued to drift through the offshore areas. During the first half of September, temperatures were near normal. Frequent offshore winds resulted in an increase in the expanse of open water. The leading edge of the pack-ice receded to approximately 250 km from shore by the end of September. During the first half of October, new ice formed over much of the offshore area.

DISTRIBUTION, MOVEMENTS, RELATIVE ABUNDANCE AND BEHAVIOUR OF WHITE WHALES

The number and location of white whales sighted on-transect during the six systematic aerial surveys from July through September are shown in Fig. 2 and 5-9, along with the observed direction of whale movement and sites of stationary industry activity. In addition, the location of white whales observed off-transect and during ferrying flights are shown. For each survey in the series, the data on movements, including observations of no movement or random movement, were tallied and are presented in Fig. 3. White whale densities are given in Table 2 and illustrated on Fig. 4.

Table 2. Observed densities of white whales in the southeastern Beaufort Sea and west Amundsen Gulf, July-September 1984.

Nearshore Strata

Survey No.	Yukon	Delta	Tuk Pen	All
1	(0)	0.5690	(0.2637)	0.5548
2	NS	(2.6458)	(0)	(1.4643)
3	(0)	0.2879	(0.3708)	0.2919
4	(0)	(0.0228)	(0.8528)	0.2114
5	NA	NA	NA	-
6	NA	NA	NA	-

Offshore Strata

Survey No.	Yukon	Delta	Tuk Pen	W. Amund.	All
1	0.0664	0.0360	0.0431	NS	0.0408
2	0.0625	0.0806	0.0616	NS	0.0708
3	0.1499	0.0621	0.0929	NS	0.0997
4	0.0428	0.0180	0.0831	NS	0.0538
5	0.0083	0.0132	0.0239	0.0209	0.0164
6	0.0065	0.0079	0.0004	0.0018	0.0049

NS = not surveyed
NA = not analyzed because transects did not extend over waters < 2 m in depth.
( ) = density calculation based on < 100 km^2 sampled area.

Survey No. 1

The first systematic survey in the 1984 series was conducted on July 5, 6 and 9. Coverage was approximately 5%, except between Shingle Point and Warren Point, where coverage was approximately 10%. The survey was conducted in the planned west to east progression, and survey timing was not seriously disrupted by adverse weather. During this survey, all nearshore and offshore strata were sampled. The Mackenzie Estuary is included in the nearshore portion of the Delta zone. Only 1.78 km^2 and 18.96 km^2 were surveyed in the nearshore Yukon and Tuk Pen strata since water depths in these areas generally exceed 5 m.

The period of estuarine occupation usually begins when the landfast ice barrier north of the estuary fractures, allowing the whales access to Kugmallit and Niakunak bays (Norton Fraker 1983). The number of whales utilizing the estuary increases thereafter, and remains high for approximately three weeks. This first survey was timed to coincide with the period when large numbers were in the estuary. This represents the first time that offshore waters in the southeastern Beaufort Sea have been systematically surveyed at the same time that large numbers of white whales were known to be resident in the Mackenzie Estuary.

A total of 383 white whales (168 sightings) was recorded on-transect (Fig. 2). Of this total, 18 whales were neonates. An additional 51 white whales (24 sightings; no neonates) were recorded off-transect.

Within the estuary, white whales congregated in Kugmallit, East Mackenzie and Niakunak bays, although they were relatively common along portions of each transect line over estuarine waters. Overall, the distribution of white whales within the estuary was noticeably clumped (Fig. 2). The general pattern was of small (two-three animal) groups separated by approximately 200 to 500 m, for distances ranging from three to six kilometres along a given transect line. Observed white whale densities in nearshore portions of the Delta and Tuk Pen zones were 569.0 and 263.7/1 000 km^2, respectively (Table 2, Fig. 4). Although white whales in the estuary generally exhibited movement during the observation period, individuals within a group showed different orientations, thus no net directionality was apparent (Fig. 3).

White whales were widely distributed throughout offshore portions of the study area during the July 5-9 survey. Observed densities were similar in the offshore strata (Table 2), but were an order of magnitude lower than densities observed in the nearshore areas. As indicated on Fig. 2, the majority of whales observed offshore were moving during the observation period. Considering only the whales which showed marked directionality in their movements (47% of total sightings), 33% had a westerly component (SW, W, NW) and 33% had an easterly (SE, E, NE) component. No obvious north and south movement of whales, a result which could be indicative of movement of whales between estuarine and offshore waters, was apparent.

Whale activities observed in the nearshore strata included aerial displays (rolling, breaching, tail lobbing, flipper slapping, pair interaction), swimming, diving, resting (still at surface), and stirring up mud. The activities of white whales observed in offshore waters included swimming (at various rates; several synchronous formations observed), diving (deep, shallow and under ice dives), rolling, physical interaction of cow-neonate pairs, probable feeding, and resting (at or below surface). The activities of whales observed during subsequent surveys in the series were generally similar to those noted during this survey.

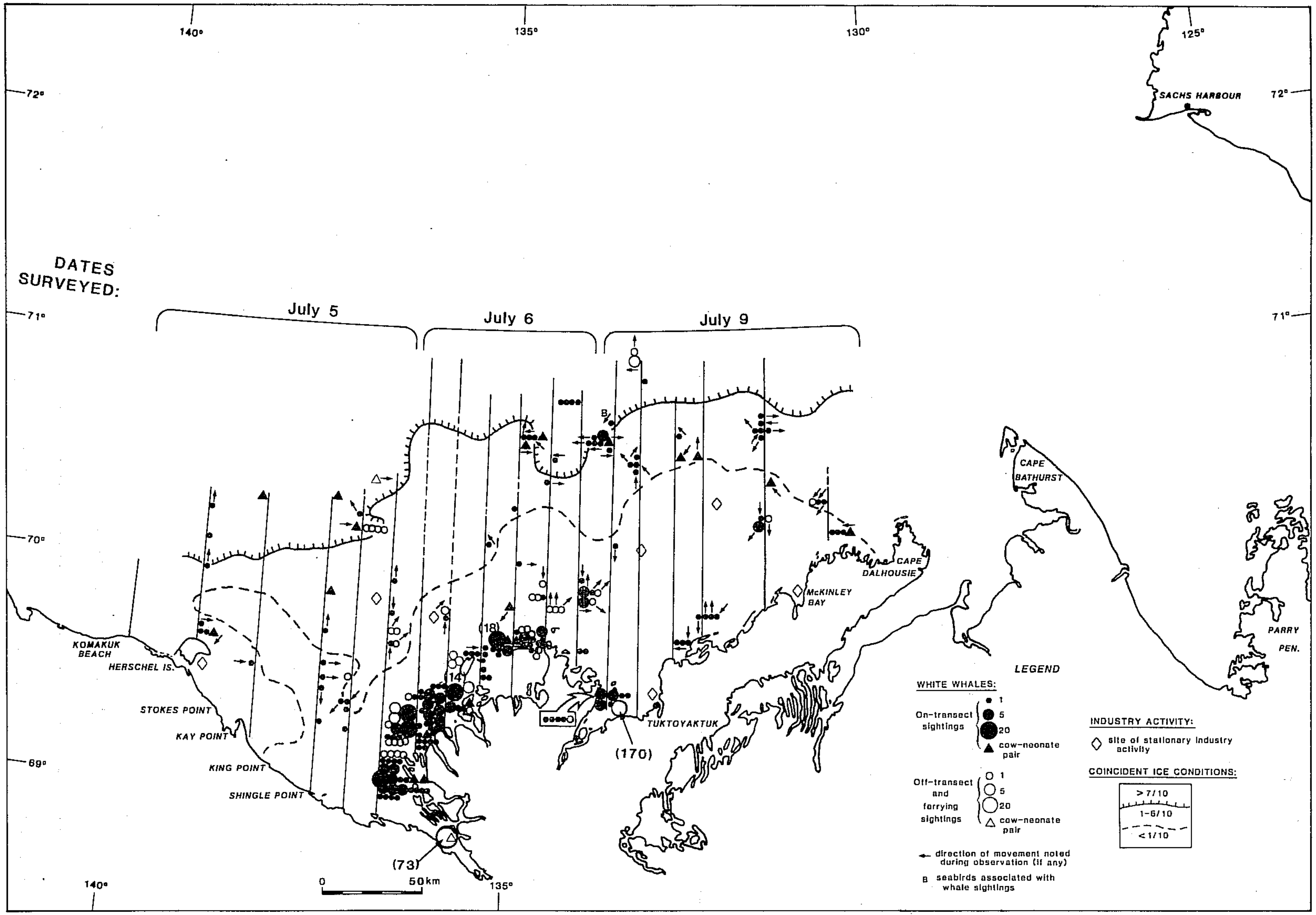


Fig.2. Distribution of white whales observed during first systematic aerial survey, 1984.

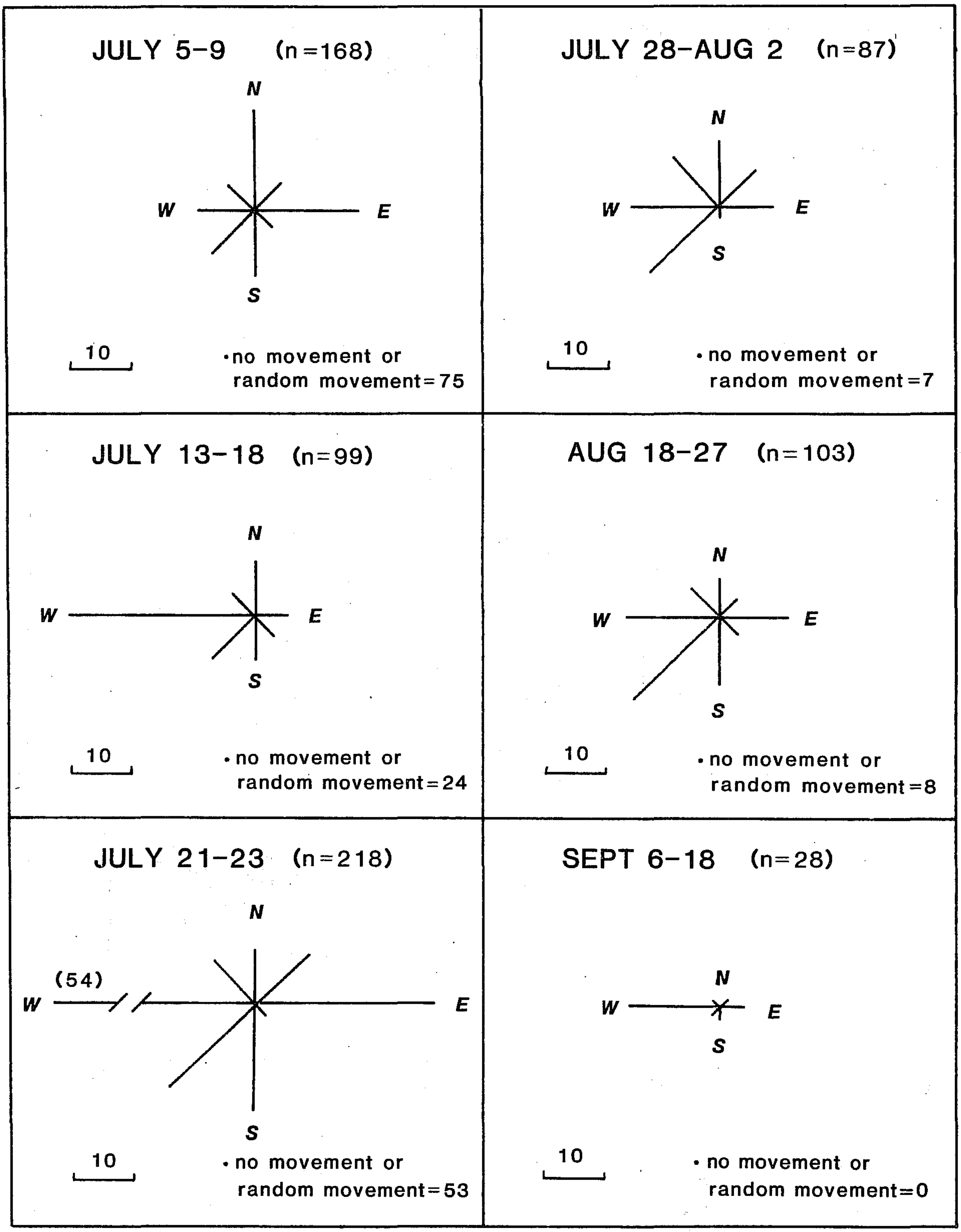


Fig. 3. Observed direction of movement of white whale groups on-transect, July–September 1984.

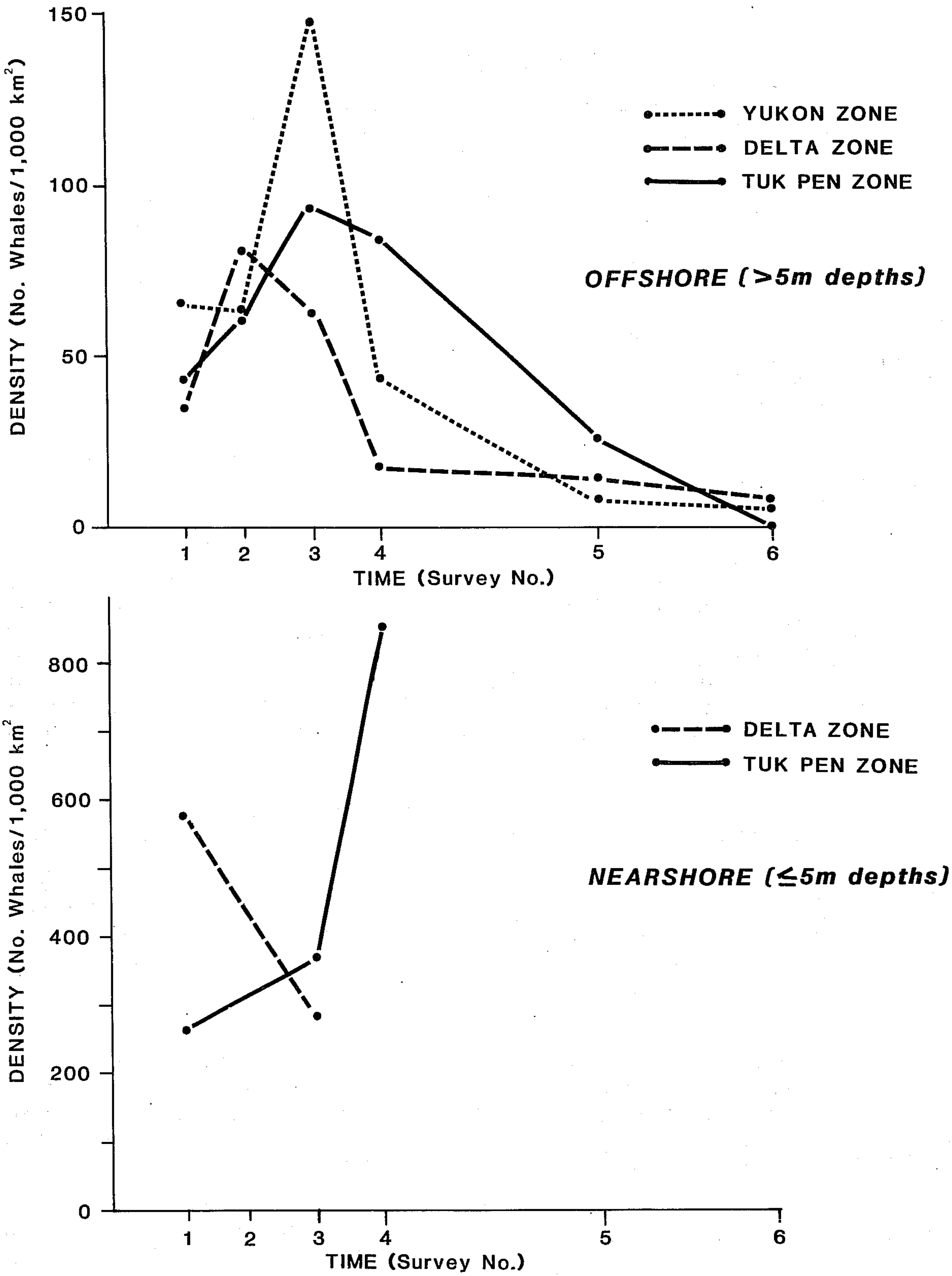


Fig. 4. Observed white whale densities in nearshore and offshore strata of the southeastern Beaufort Sea, July-September, 1984.

Survey No. 2

The second survey in the 1984 series was conducted on July 13, 17 and 18. Systematic coverage was approximately 5%, and the survey was completed in the planned west to east progression. Survey timing was not seriously disrupted by adverse weather. The survey was timed to coincide with the period when white whale abundance in the Mackenzie Estuary might start to decline.

In contrast to the other surveys during July and early August, the area sampled during the second survey did not include the nearshore Yukon zone; only 26 km^2 of the nearshore Delta zone (e.g., the Mackenzie Estuary) and 21 km^2 of the nearshore Tuk Pen zone were surveyed. The southern boundary was set at the same location as the northern boundary of a concurrent survey being conducted by the Department of Fisheries and Oceans so that the two study areas be complementary. However, adverse weather hampered surveys of the estuary, and results useful to this study were not obtained. Therefore, most of the discussion concerns the results of the offshore strata.

A total of 212 white whales (99 sightings) was recorded on-transect, and 26 of these were neonates (Fig. 5). An additional 13 white whales (6 sightings) were noted off-transect.

As in the previous survey, white whales were widely distributed throughout all strata in the offshore Beaufort during the July 13-18 period. Overall, the relative abundance of white whales in offshore waters increased between the first and second survey (Table 2). Densities in the Delta and Tuk Pen zones were higher than those observed during July 5 - 9, while the density of white whales in the Yukon zone was similar to that observed during the previous week. The location and movements of whales observed offshore do not clearly suggest whether the newly-arrived animals were from the Mackenzie Estuary, Amundsen Gulf, areas north of those surveyed, Alaskan waters, or a combination of two or more of these.

Most (73.4%) of the white whale sightings were of animals showing directional movement and, as indicated in Fig. 3, westward and southwestward movements were predominant. Congregations of white whales were observed seaward of the Mackenzie Estuary in West Mackenzie Bay, where few animals were observed during the previous week (Fig. 2). Without knowing the distribution and abundance of whales within the estuary, it is only possible to suggest that these large groups moved into West Mackenzie Bay from the estuary during the period between the two surveys.

Survey No. 3

This survey was started at 1440 on July 21 and completed within 48 hours. Due to favourable weather, it was completed on consecutive days and in the planned west to east progression. Systematic coverage was 5%, and the study area included all nearshore and offshore strata. This survey represents the second and last time in the 1984 series that > 100 km^2 were systematically surveyed in the nearshore Delta zone.

A total of 383 white whales (218 sightings) was observed on-transect, and 30 of these were neonates (Fig. 6). A total of 73 white whales (36 sightings, including one neonate) was observed off-transect.

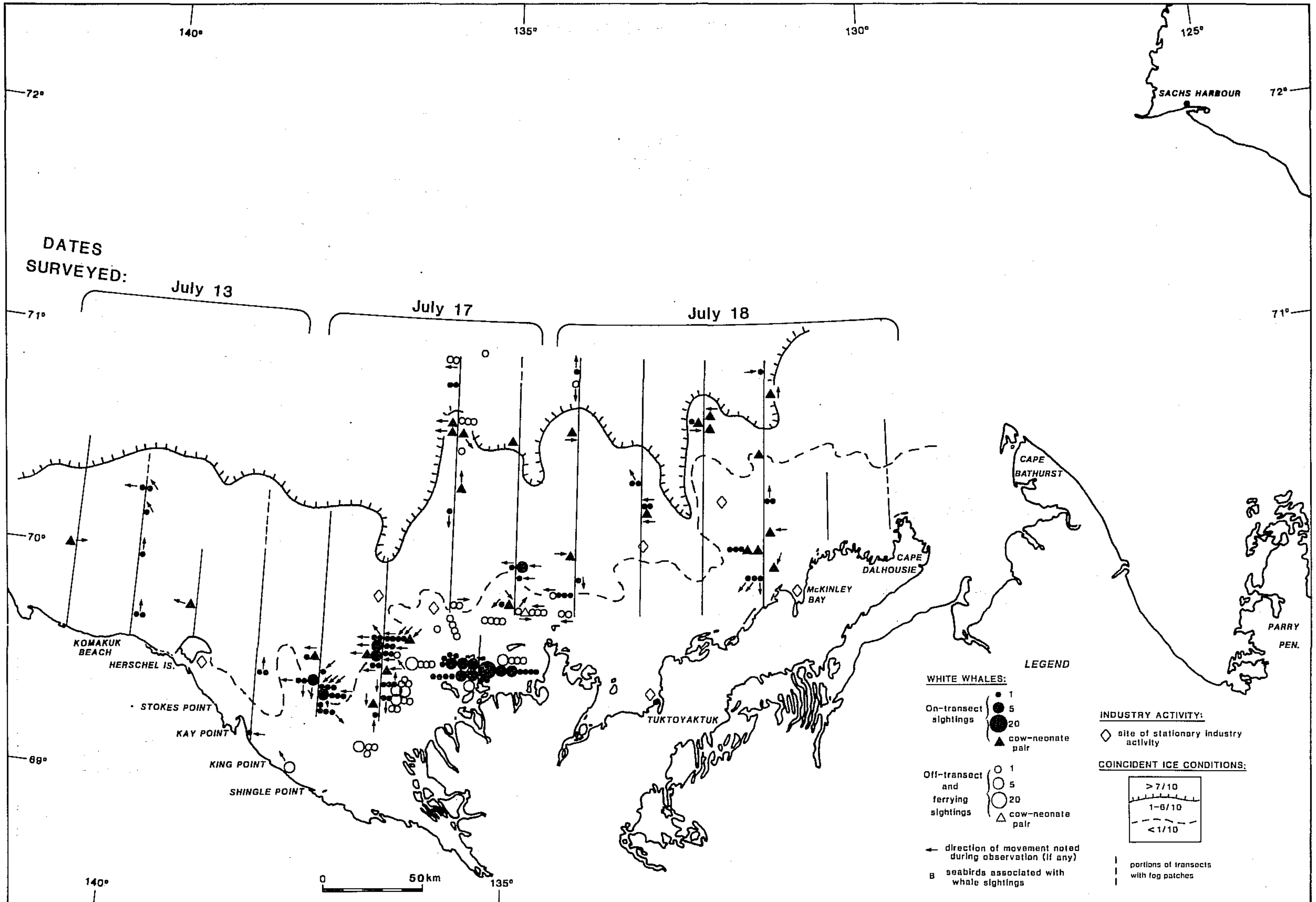


Fig.5. Distribution of white whales observed during second systematic aerial survey, 1984.

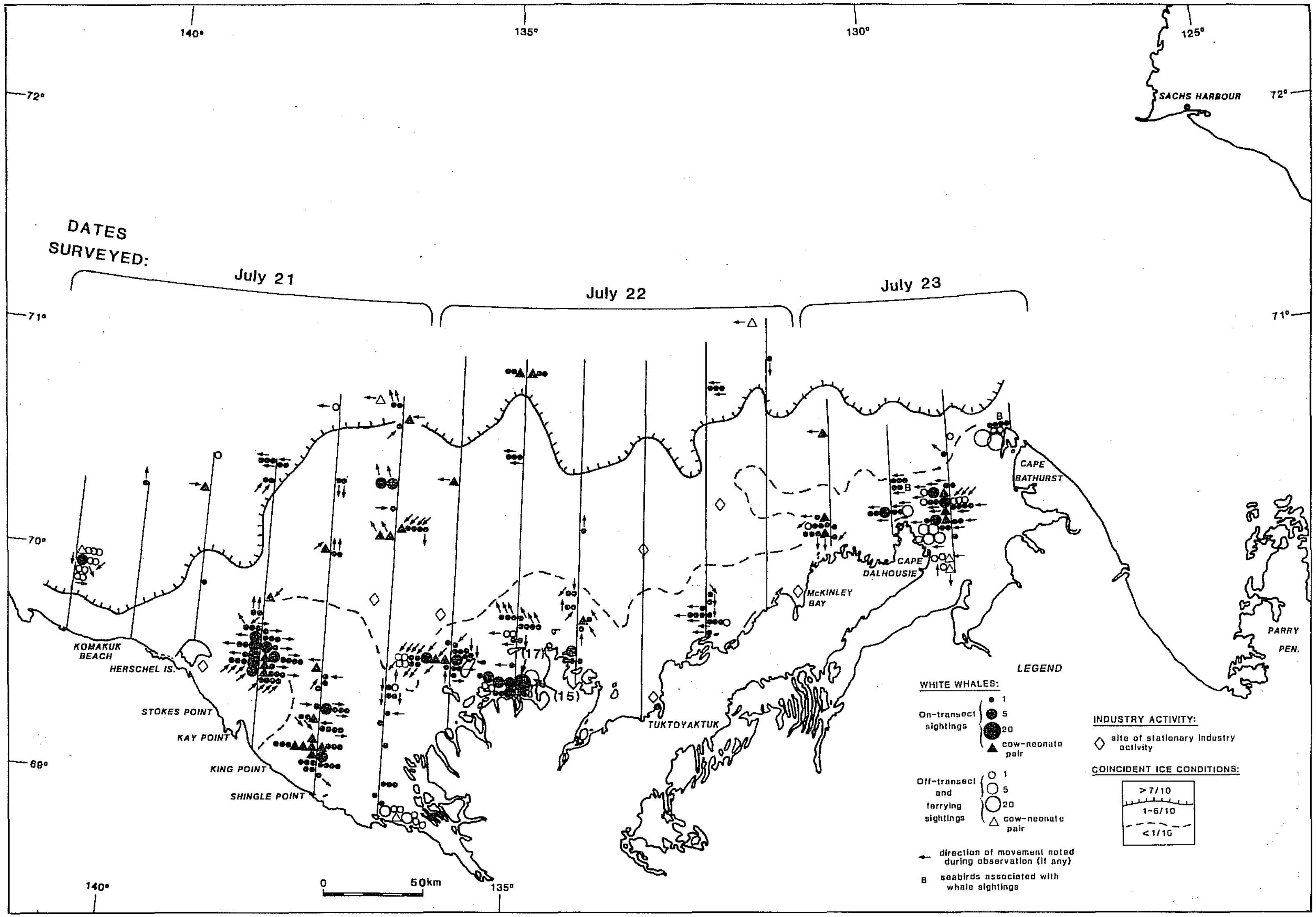


Fig.6. Distribution of white whales observed during third systematic aerial survey, 1984.

During this survey, white whales were widely distributed throughout the offshore strata and were concentrated in the nearshore Delta and Tuk Pen zones. However, the density in the nearshore Delta zone was approximately half that observed there during the first week of July, indicating that many whales had left the estuary between the first and third surveys. In contrast, the observed density in the nearshore Tuk Pen zone was considerably greater than that recorded in that area during July 5-9, suggesting a movement of whales into nearshore waters off the Tuktoyaktuk Peninsula had occurred. The apparent increase in the number of whales in this area and the fact that most were moving westward suggest that an influx from Amundsen Gulf occurred.

White whale densities in offshore strata of the study area were similar and all were lower than densities in the nearshore strata (Table 2). As during the previous week's survey, relatively large numbers of white whales were observed just seaward of the Mackenzie Estuary, near and in West Mackenzie Bay and offshore of the Yukon coast (Fig. 6).

Overall, most (70.5%) sightings were of whales showing directional movement; 38% of the sightings had a westerly component to their movements, while 44% had an easterly component (Fig. 3). Large groups moving along the Tuktoyaktuk Peninsula were headed predominantly westward, while those offshore of the Yukon coast were predominantly eastward. Consequently, no net overall directionality of movement was detected for the survey period.

Survey No. 4

The fourth survey in the series, the final one completed specifically to examine white whale use of the offshore Beaufort, was conducted on July 28, 30 and August 2, 1984. During this survey, coverage of the Delta zone was incomplete, and survey timing and progression were interrupted due to adverse weather (Fig. 7). Coverage in the nearshore Tuk Pen was similar to that in previous surveys. Coverage in offshore areas was approximately 5%.

In total, 144 white whales (87 sightings, including 13 neonates) were recorded on-transect (Fig. 7). Eleven whales (seven sightings, including one neonate) were observed off-transect.

The observed density of white whales in the nearshore Tuk Pen zone was noticeably higher than that recorded in this area during the previous week, suggesting that the influx of white whales into the area discussed for Survey 3 continued during the period separating Surveys 3 and 4 (Table 2). The predominantly westward movement of white whales in this area again suggests that they were arriving from east of the study area (e.g., Amundsen Gulf).

As during all previous surveys in this series, white whales were widely distributed throughout offshore portions of the study area. Densities were lower in each stratum than during the previous week (Fig. 4), and most (86.9%) sightings were of whales exhibiting directional movement during the observation period. Approximately 51% of the total whale sightings had a westerly component, while 16% had an easterly component (Fig. 3).

As discussed for Survey 1, the observed activities of white whales in the offshore strata were generally similar during all surveys. However, on July 30, a

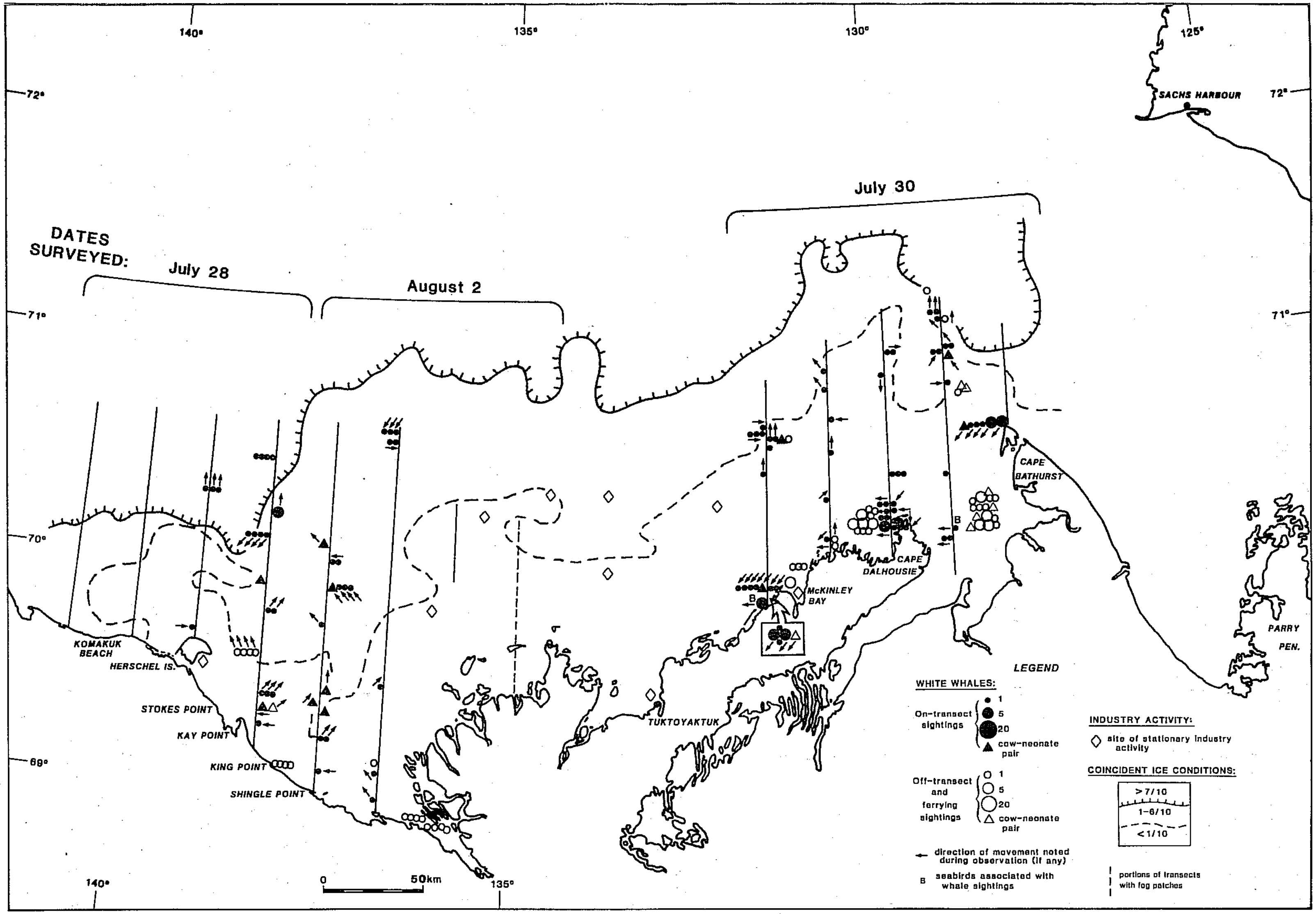


Fig.7. Distribution of white whales observed during fourth systematic aerial survey, 1984.

large (40+) group of white whales was observed near Baillie Islands. The movements, and behaviour of this group, along with the presence of seabirds, suggested that the group was actively feeding.

Survey No. 5

This survey, the first of two designed specifically to examine bowhead whale distribution in the southeastern Beaufort Sea, was conducted on August 18, 22, 23 and 27, 1984. With the exception of the six westernmost transects, survey timing and progression were not seriously disrupted by adverse weather. Survey coverage was approximately 10%.

A total of 174 white whales (103 sightings) was observed on-transect, and 11 of these were neonates (Fig. 8). Ten white whales (seven sightings) were observed off-transect. As during the previous two surveys, white whales were widely distributed throughout the offshore strata. Congregations of whales moving westward were again noted within 20 km of the Tuktoyaktuk Peninsula coast.

The trend of decreasing white whale abundance continued (Fig. 4); the observed densities in the offshore strata during this survey were lower than those recorded during the previous survey. Overall, the direction of whale movement noted during the observation period was predominantly westward (Fig. 3).

Survey No. 6

The final survey in the series was completed on September 6, 11, 12, 13, 17 and 18, 1984. Of all the 1984 systematic surveys, this one was the most hampered by adverse weather. Both survey timing and progression were interrupted (Fig. 9). Systematic coverage was approximately 10%.

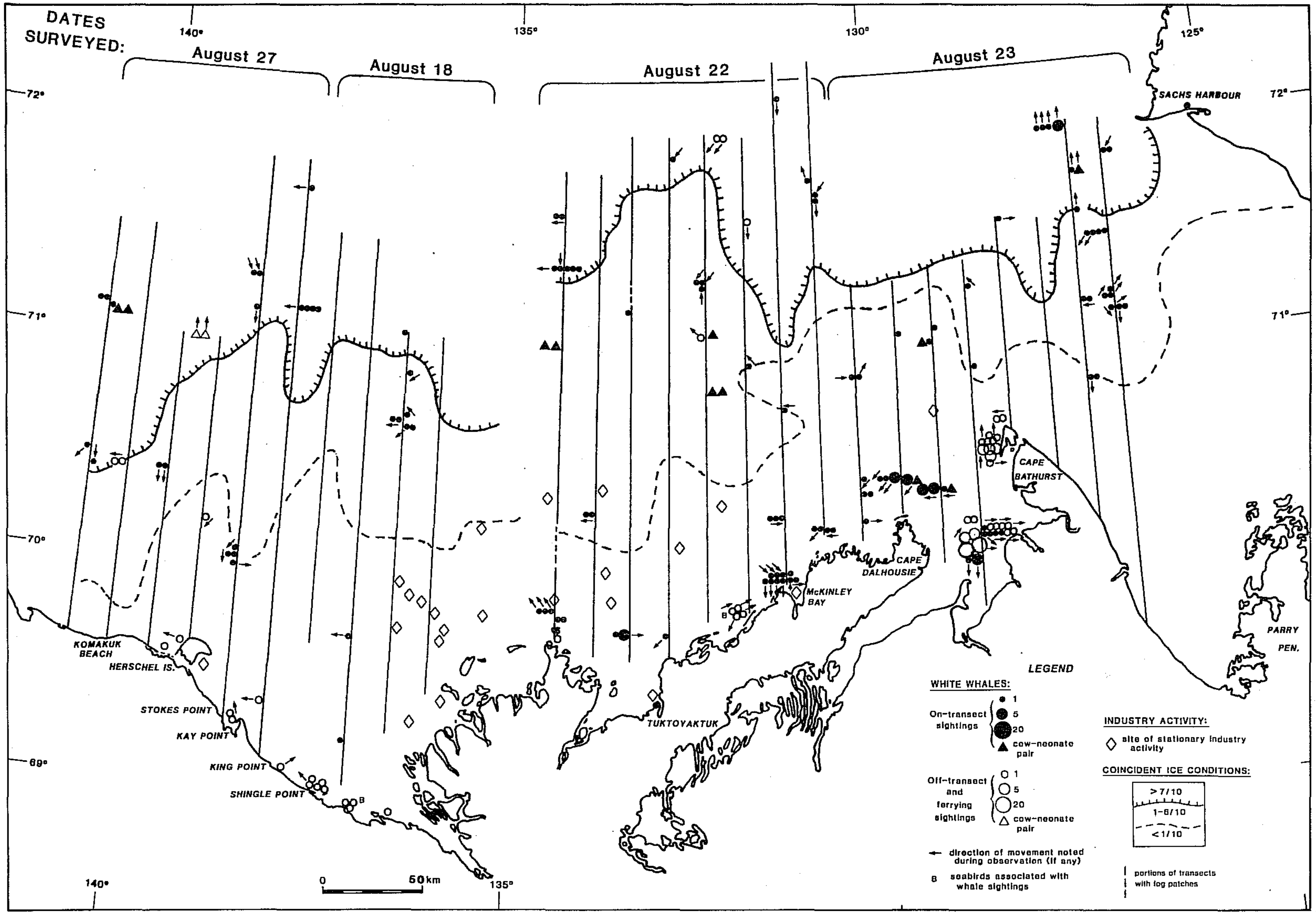
A total of 47 white whales (28 sightings, including two neonates) was recorded on-transect (Fig. 9). None were recorded off-transect.

The distribution of white whales noted during this survey was different from those noted during previous surveys. Small numbers were distributed throughout the Yukon zone and western half of the Delta zone, primarily in offshore waters. No whales were sighted offshore of the Tuktoyaktuk Peninsula or near Baillie Islands and only three whales were observed in the eastern half of the study area. Densities in every stratum were considerably lower than those in the previous survey (Table 2), and overall direction of whale movement was predominantly westward (Fig. 3).

Sightings by industry personnel

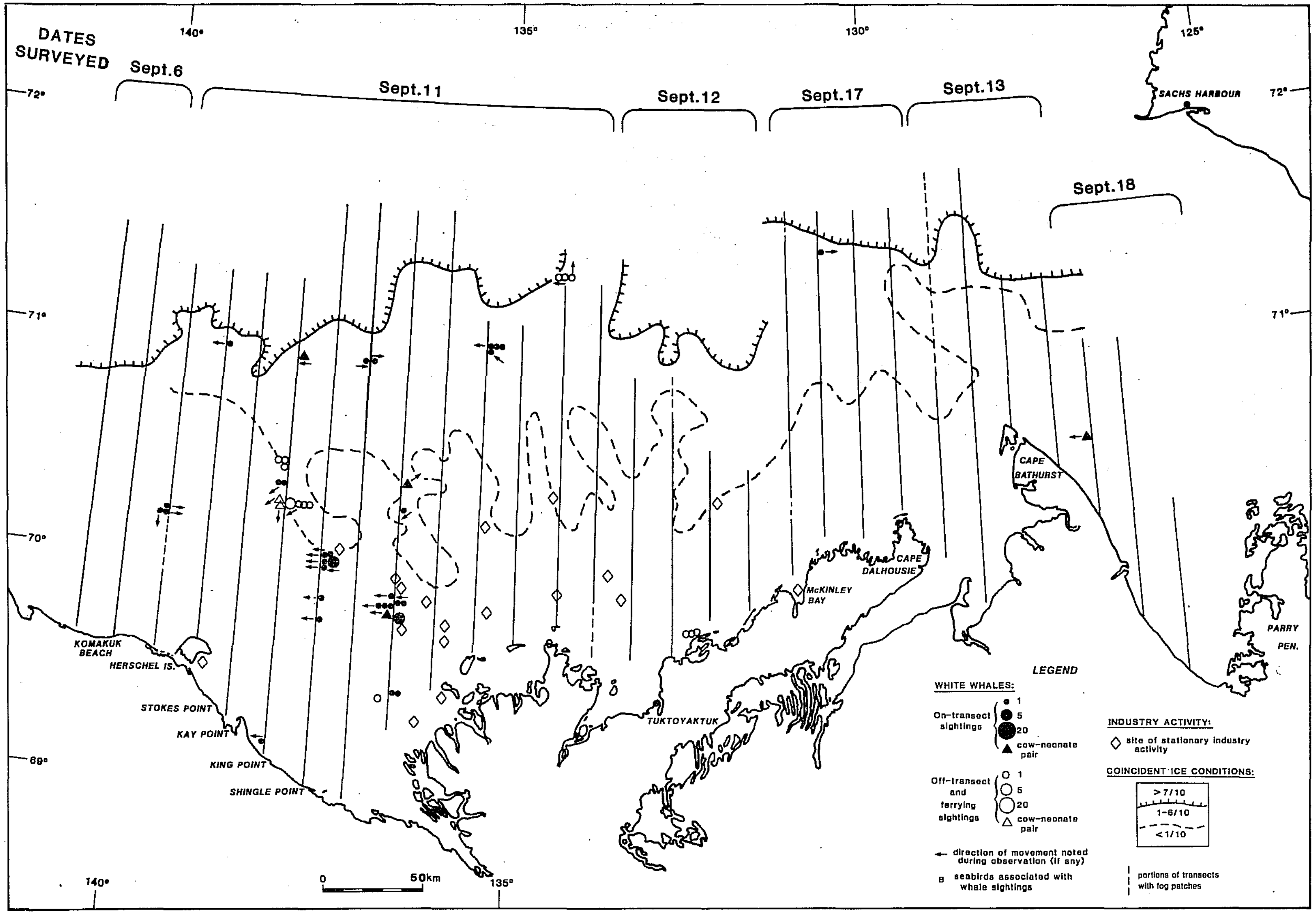
A total of 346 white whales (51 sightings) was observed and reported by industry personnel in the southeastern Beaufort Sea during the open-water period, July-October 1984. Only sightings identified with respect to species were included.

The locations of these white whale sightings are indicated on Fig. 10 and 11. Approximately 80% of the sightings were recorded during July, while 8% and 12% were recorded during August and September, respectively. The majority (78%) of the 1984 white whale sightings reported by industry were made during helicopter flights over the Mackenzie Estuary.



*data collected incidentally during ESRF/NOGAP surveys for bowhead whales

Fig.8. Distribution of white whales observed during fifth systematic aerial survey, 1984.*



*data collected incidentally during ESRF/NOGAP surveys for bowhead whales

Fig.9. Distribution of white whales observed during sixth systematic aerial survey, 1984.*

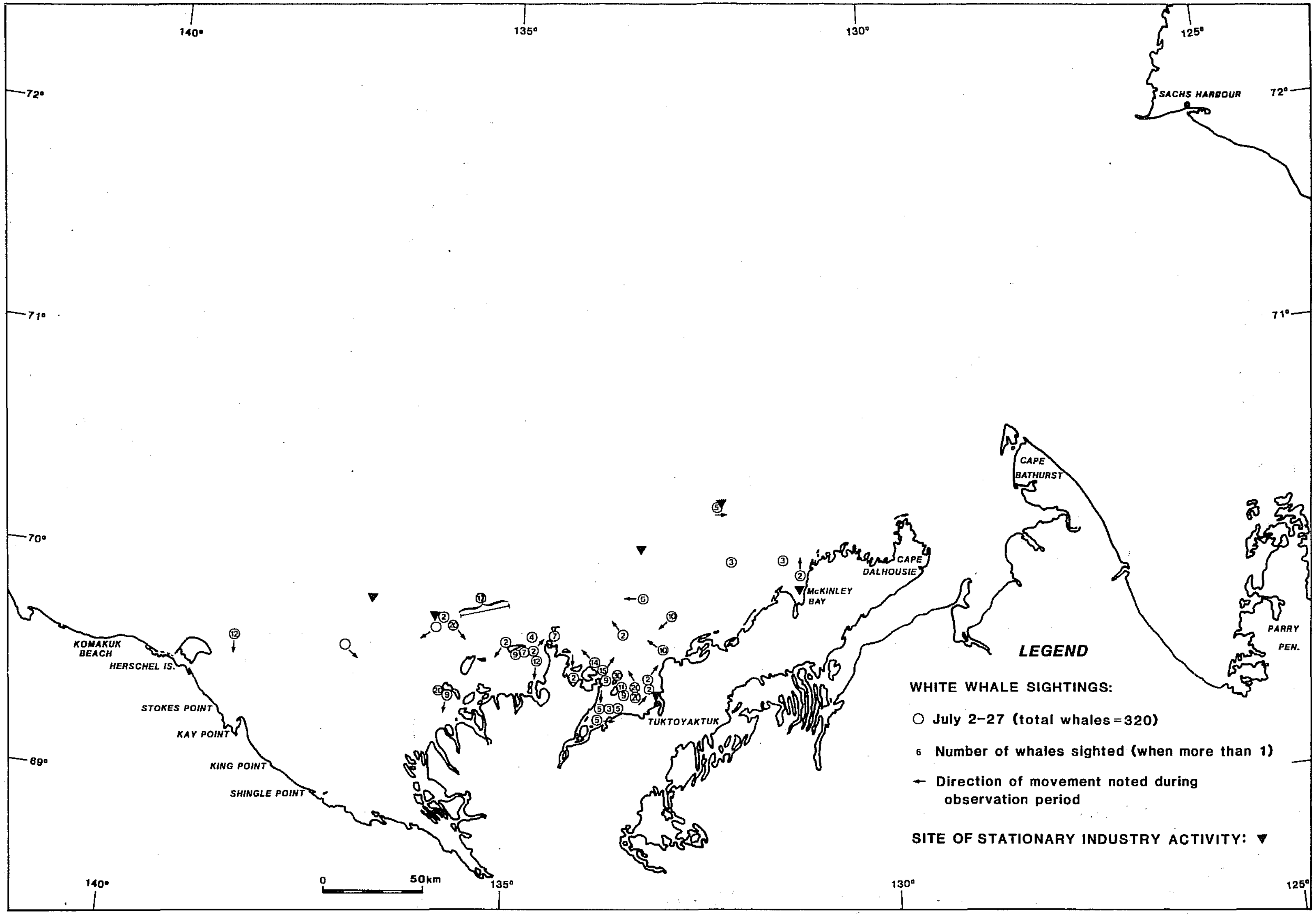


Fig.10. Location of white whales sighted by industry personnel in the southeastern Beaufort Sea, July 2-27, 1984.

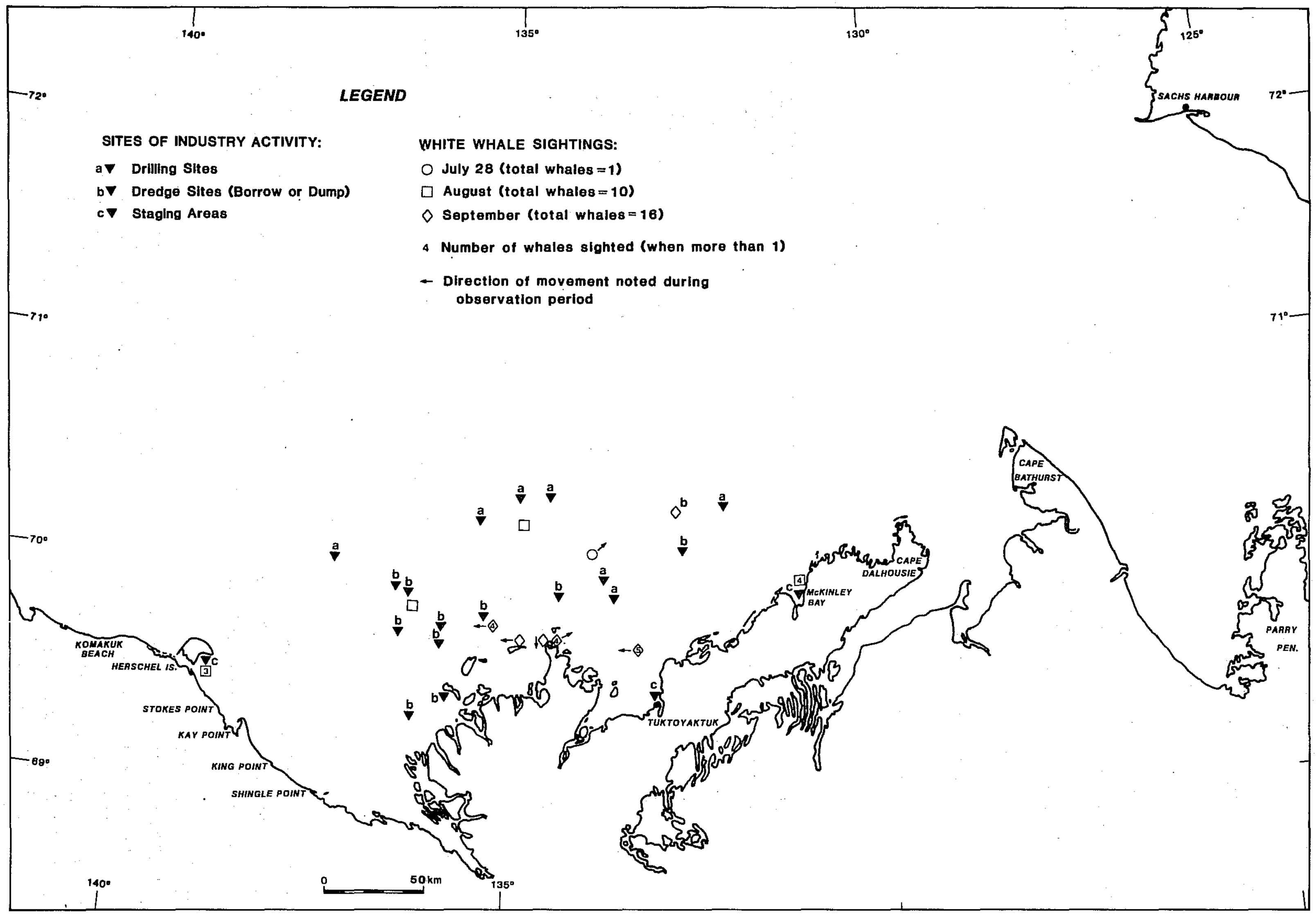


Fig. 11. Location of white whales sighted by industry personnel in the southeastern Beaufort Sea, July 28– September 9, 1984.

GROUP SIZE

The mean number of whales per sighting was determined for white whales sighted on-transect in relatively clear offshore waters. This analysis was not completed for white whales observed in muddy estuarine waters, since they are visible only within a few centimeters of the surface and appear/disappear from view within 1-2 seconds.

Sightings were categorized as one of the following three types for analysis: adults and immature animals (neonates, yearlings, subadults and calves), immature animals only and adults only. The number of whales per sighting was small (<3.0) for all types for all surveys (Table 3), and no trend of increasing or decreasing group size was evident during the course of the survey series.

Table 3. Mean number of white whales per sighting.

		Mean number of white whales/sighting (% of total on-transect sightings)			
Survey No.	Total On-transect Sightings	Adults and Immatures	Immatures Only	Adults Only	All Group Types
1	100	2.39 (23)	1.17 (6)	1.62 (71)	1.77
2	80	2.19 (40)	1.17 (8)	1.33 (52)	1.66
3	173	2.30 (27)	1.00 (2)	1.46 (71)	1.67
4	79	2.29 (22)	1.25 (5)	1.50 (73)	1.66
5	97	2.75 (16)	1.00 (1)	1.44 (82)	1.65
6	28	2.56 (32)	1.33 (11)	1.25 (57)	1.68
All surveys combined	557	2.36 (26)	1.17 (4)	1.47 (70)	1.68

ESTIMATES OF NEONATES IN POPULATION, 1984

In muddy estuarine waters, white whale calves are particularly difficult to identify and classify according to age. Consequently, the percentage of neonates in the population has been calculated using only data from the offshore strata.

If an immature animal's length relative to the length of the adult could not be determined, the immature was identified as a "calf". A proportion of the "calves" observed were probably neonates, although it was not possible to estimate what this unknown and probably varying proportion was. Consequently, a range of the percentage of neonates in the sample has been calculated. The lower limit assumes that no immature animals that were not aged were neonates, while the upper limit assumes that all immature animals that were not aged were neonates. The actual percentage of neonates in the population is probably within the range calculated.

The range of percentage of neonates observed is given in Fig. 12, and was noted to vary from survey to survey. The increase in the percentage of neonates between the first and second survey (8.6 to 15.5% for the first survey, 18.2 to 23.8% for the second) may indicate that calving occurred between the surveys, that cow-neonate pairs moved into the study area from other areas, or that the non-cow-neonate segment of the population moved out of the study area. This apparent increase could also be a sampling artifact. The decline in number and the percentage of neonates observed during the late August and early September surveys may indicate that the fall migration of cow-neonate pairs had begun.

RELATIONSHIP BETWEEN OBSERVED WHITE WHALE DISTRIBUTION AND ICE COVER

Frequent periods of onshore winds through July and August caused the pack-ice edge to be scattered and extensive, although the leading edge was within 100 km of the coast in most areas. The permanent polar pack remained in the vicinity of 73°N latitude. Because the pack-ice edge was unconsolidated and the range of the aircraft limited, most northbound survey transects in July and August were terminated after a 7/10 or 8/10 pack-ice cover was reached. During September, refreezing of leads was noted at the north end of transects and ice covers of 9/10 and 9+/10 were encountered. Changes in the distribution of ice and the extent of fog which frequently formed over the pack-ice resulted in variations among surveys in the extent of sampling of the different ice cover classes (Table 4).

Table 4. Percent ice cover classes surveyed.

Survey No.	Survey Period	Surveyed Area (km^2)	Percent of Total Area Surveyed by Ice Cover Class			
			<1/10	1-3/10	4-6/10	7-9+/10
1	July 5 - 9	3 387*	50.2	15.7	14.1	19.9
2	July 13 - 18	2 068*	23.9	32.6	24.5	19.0
3	July 21 - 23	3 253*	28.9	26.0	19.9	25.3
4	July 28 - Aug 2	2 331*	67.8	10.6	7.4	14.2
5	Aug 18 - 27	10 603 +	44.0	22.3	10.8	22.9
6	Sept 6 - 18	9 645 +	67.2	17.0	2.2	13.6

* based on transect width of 1.6 km
\+ based on transect width of 2.0 km

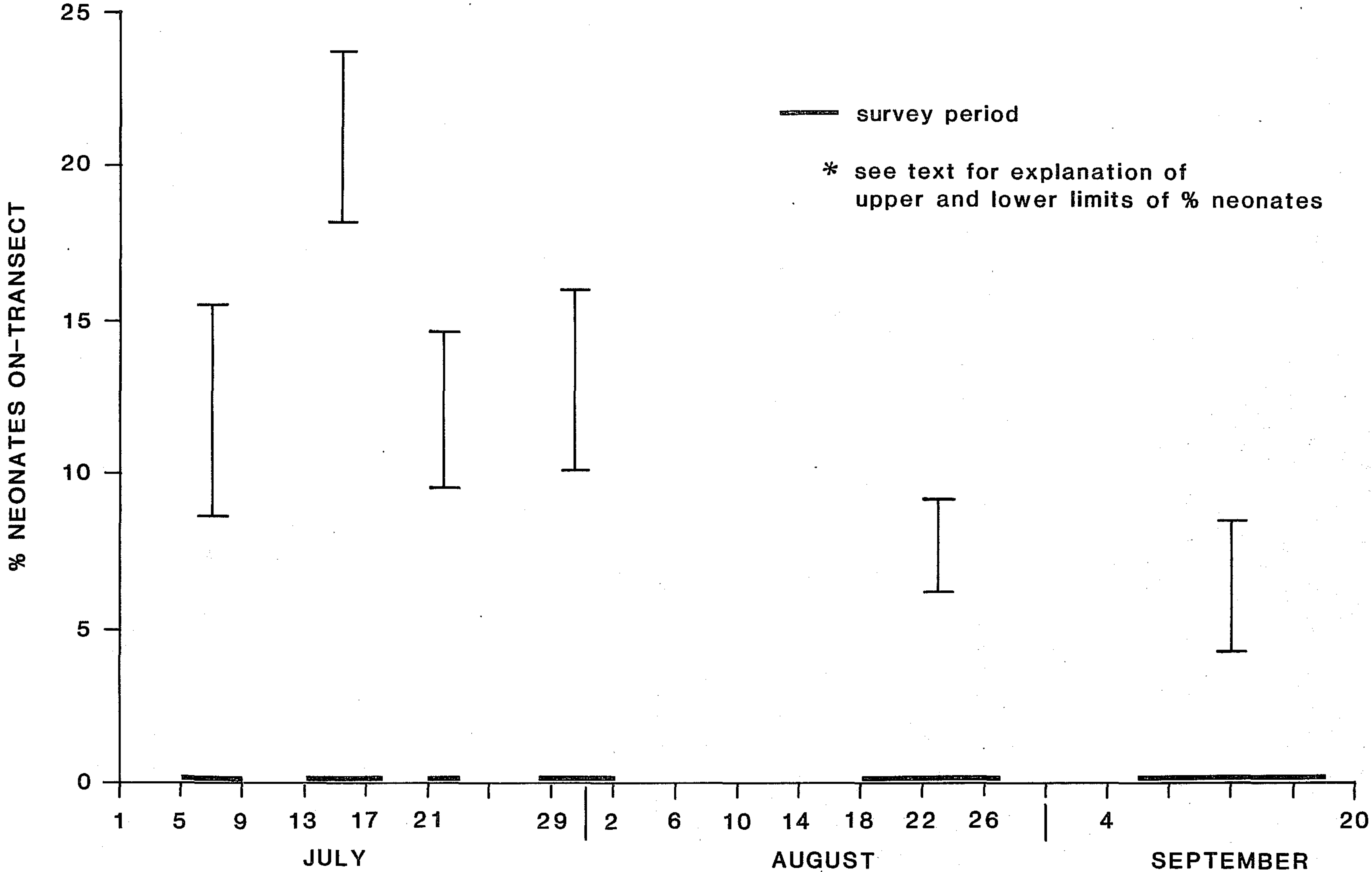


Fig. 12. Percentage of neonates observed on-transect, July-September, 1984.

Cow-neonate, cow-calf and adults only were the only group types for which ten or more sightings during any one survey were made, although which of these group types had enough sightings to be analyzed varied among surveys (Table 5). For Surveys 5 and 6, only one group type (adults only) could be examined. Cow-neonate and cow-calf groups showed similar ice cover preferences (Table 5). Adults only showed similar ice cover preferences as cow-neonate and/or cow-calf groups during Surveys 1 and 4, but not during Surveys 2 and 3 (Table 5).

If there was a preference for one ice cover class, <1/10 ice cover (open water) was preferred during every survey except in September, during which 1-3/10 ice cover was preferred (Table 6). The 7-9+/10 ice cover class was the most frequently "non-preferred" ice cover class.

Table 5. Group types showing ice cover preferences.

Survey No.	Group Types with >10 Sightings	Probability of group type having same ice cover preferences as previous group type*
1	cow-neonate	-
	cow-calf	✓ 0.45
	adults only	✓ 0.21
2	cow-neonate	-
	adults only	< 0.005
3	cow-neonate	-
	cow-calf	✓ 0.50
	adults only	✓ 0.007
4	cow-neonate	-
	adults only	✓ 0.65
5	adults only	-
6	adults only	-

* according to chi-square test for homogeneity (df = 3); previous group types pooled if no significant difference was found.

Table 6. Ice cover preferences by group type.

Survey No.	Groups Examined	"Preferred" Ice Cover*	"Non-preferred" Ice Cover*
1	cow-neonate/calf & adults only	<1/10	1-3; 4-6; 7-9+/10
2	cow-neonate	none	none
	adults only	<1/10	none
3	cow-neonate/calf	<1/10	none
	adults only	<1/10	1-3; 4-6; 7-9+/10
4	cow-neonate & adults only	none	7-9+/10
5	adults only	none	none
6	adults only	1-3/10	none

* Contribution to chi-square > 7.81

ESTIMATE OF POPULATION SIZE

A rough estimate of stock size has been attempted using the results from the third (July 21-23) survey. The survey was completed within 48 h, and observation conditions were generally excellent, although fog did limit coverage north of Cape Bathurst. Survey timing and progression were not interrupted, reducing the potential for bias caused by double-counting or missing individuals. No extrapolation for whales in areas north, east or west of the survey area has been attempted.

Since the calculation of a population estimate was not among program objectives, a detailed examination of survey biases was not undertaken. However, some data were collected to allow a preliminary examination of effective transect width and the proportion of sightable animals missed by observers.

White whale detectability

Distance from the flight line was estimated for 317 of the total 648 transect sightings (48.9%, Table 7); the remainder of the sightings were noted as on or off the 1 600 m transect strip. Detectability of both individuals and groups generally decreased with distance from flight path, although this trend was more pronounced for individuals (Fig. 13). A marked decline in detectability was noted at 300 m for groups and for individuals, and then again at 500 m for groups, and 600 m for individuals. Similar trends in white whale detectability were noted during 1981 surveys (Davis and Evans 1982).

The effective transect width was not adjusted (narrowed) to reflect the decreased detectability of white whales along outer portions of the transect strip

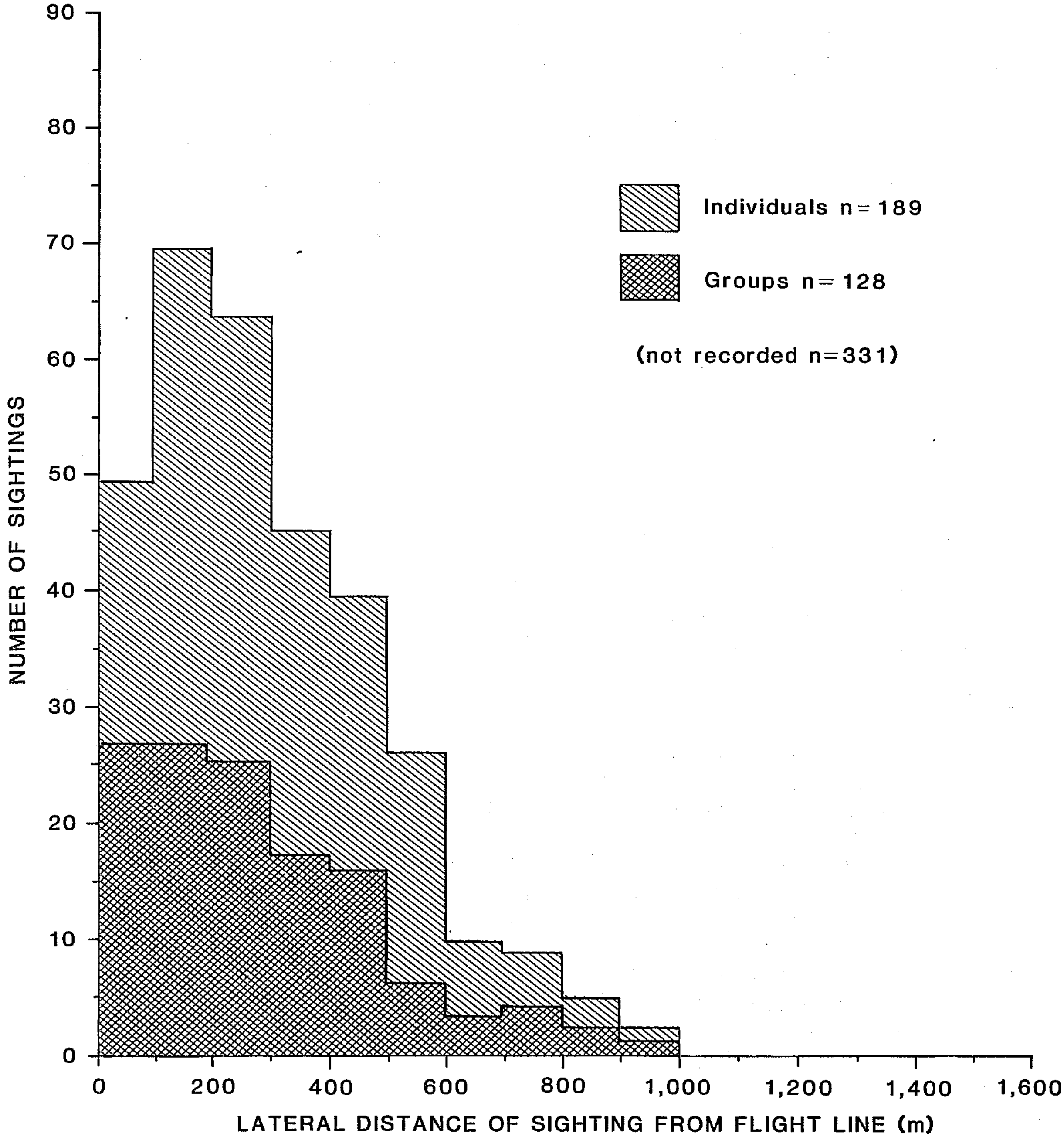


Fig. 13. Frequency distribution of lateral distance from flight line of individuals and groups of white whales, July– early August 1984.

because distance measurements were not available for half of the sightings. As a result, the number of whales on-transect was probably underestimated, and densities calculated on the basis of the 1 600 m transect strip, conservative.

Table 7. Number of white whale sightings for which lateral distance from flight line was recorded.

Survey No.	Total No. of Sightings	No. (%) with Inclinometer Readings	
1	189	67	(35.4)
2	107	60	(56.1)
3	258	130	(50.4)
4	94	60	(63.8)
	648	317	(48.9)

Correction factors for undetected animals

A preliminary assessment of the number of white whales missed by observers was undertaken. White whales missed by observers would include animals that were at the surface and not seen by the observer as well as animals that were at the surface when the field was viewed by one observer but beneath the surface and therefore not detectable when the field was viewed by the second observer. On July 5, 1984, both observers surveyed through bubble windows on the left side of the aircraft. Of the 30 sightings made in offshore waters on that day, six were recorded by both observers (duplicates) on the basis of time of sighting and number of animals in group. Therefore, 24 distinct sightings were made during surveys of the offshore on July 5. It was not possible to positively identify duplicate sightings in the Mackenzie Estuary because more than 70 whales were sighted within 4 minutes in this area and few details of behaviour and group size could be detected.

If six of the 24 offshore sightings were duplicates, then 25% of the sightings were recorded by both observers and 75% were recorded by only one. If p represents the proportion seen by one observer, then p^2 is the proportion seen by both observers, $(1-p)^2$ is the proportion missed by both observers, and $2p(1-p)$ is the proportion seen by only one observer. Solving for p using the proportions observed during the July 5 flight gives:

$$\frac{p^2}{2p(1-p)} = \frac{0.25}{0.75}$$

$$\frac{p}{2(1-p)} = \frac{0.25}{0.75}$$

$$0.75\,p = 0.5 - 0.5\,p$$

$$1.25\,p = 0.5$$

$$p = 0.4$$

This indicates that the counts obtained during the July surveys should be multiplied by a factor of 2.5 (1/0.4) to get an estimate of the number of sightable whales. This correction factor has been used to calculate a possible upper limit of the population estimate for the July 21-23 survey.

Comparable estimates of the proportion of white whales missed by observers is not available for previous studies, so the applicability of this correction factor cannot be examined. However, the factor is considered preliminary (probably high) for two reasons. Firstly, on July 5, neither observer had recently conducted an aerial survey and recent survey experience is known to be an important factor in observer performance (M.C.S. Kingsley, Freshwater Institute, Winnipeg, pers. comm.). Secondly, of all the on-transect sightings made during the program, only 5.3% were used to calculate this correction factor.

Estimate of 1984 white whale population size

Extrapolation of the observed white whale densities to unsurveyed portions of the study area for the third survey produced a population estimate of 7 081 ± s.e. 1 584 white whales. This uncorrected estimate has 7.5 degrees of freedom associated with it, so the approximate 95% confidence limits are 7 081 ± 2.365(1 584) = 3 335 - 10 827 (2.365 is student's t-statistic for df = 7).

The 7 081 estimate is undoubtedly conservative because (1) no factor to account for missed (submerged or surfaced) animals has been applied, (2) the size of the effectively surveyed area was lower than that used in the calculations (effective transect width narrower than the 1 600 width assumed) and (3) not all of the area used by the population (e.g., Amundsen Gulf) was surveyed. Applying the correction factor calculated in this study, the estimate becomes 17 702 white whales, but this figure may be high.

WHITE WHALE SIGHTINGS NEAR OIL AND GAS INDUSTRY ACTIVITIES

Sites of industry activities during the 1984 surveys, indicated on Fig. 2 and 5-9, included the locations of seven drilling units (Explorers I-IV, SSDC, Kulluk, Rig 7), six dump or borrow sites and three staging/support areas (Tuktoyaktuk, McKinley Bay and Pauline Cove). Most of these activities were located within the offshore Delta zone. However, there was a single drill site and a borrow site in the offshore Tuk Pen zone, a staging area in the nearshore Tuk Pen Zone, a staging area in the nearshore Yukon zone and a drilling site in the offshore Yukon zone.

During the systematic surveys, 27 white whales were recorded within 20 km of active industry sites (Fig. 2, 5, 6, 9). In addition, industry personnel reported 49 sightings of 347 white whales in the oil and gas exploration area (see Sightings by industry personnel).

In addition to the above sightings, on July 30, five white whales were observed approximately 2 km west of the McKinley Bay artificial island during a ferrying flight. During the July 6 survey 13 white whales were observed within 100-200 m of the leeward shore of an abandoned sacrificial beach island (Issungnak). In general, the type of movements of the 13 whales and the presence of seabirds indicated that the whales may have been feeding.

DISCUSSION

GENERAL TRENDS: 1984 AND PAST YEARS

The six 1984 systematic aerial surveys are the longest time series examining white whale distribution in the region and the first time offshore areas have been examined in early July. As in past years, in 1984 large numbers of white whales occupied the Mackenzie Estuary during the first half of July. At the same time, however, relatively large numbers were widely distributed throughout offshore waters of the southeastern Beaufort Sea. These results clearly indicate that either (1) the entire Beaufort stock did not utilize the estuary in 1984, or (2) that if all the stock did utilize the estuary, they did not do so simultaneously. Davis and Evans (1982) have also suggested that not all the Beaufort stock occupies the estuary based on their survey data.

The distribution of white whales within the Mackenzie Estuary has been monitored annually since 1972. However, these surveys had different objectives and a different study approach from the present program. Systematic coverage during most years was 33-50%, and surveys were conducted at frequent intervals during the period when white whales were concentrated in the estuary. The results of these studies indicate that white whale distribution and abundance varied markedly from day to day among specific areas in the estuary. For example, in 1977, the number of whales estimated to be in Niakunak Bay changed from 2 424 on July 18, to 1 190 on July 19, to 2 612 on July 21, and the specific locations where white whales were observed also varied from day to day (Fraker et al. 1979). Given that these short-term changes in the distribution and abundance of white whales within the estuary are known to occur, and that coverage in 1984 was limited to 10% on one day during the period of white whale concentration in the estuary, we did not attempt to compare our results for nearshore areas to results from previous years.

Group size and observed activities of white whales did not vary markedly throughout the 1984 open-water period. However, distribution, relative abundance and movements of the stock did change during the survey series. For example, the number of white whales occupying the Mackenzie Estuary declined between the first and third weeks of July. This decline coincided with an increase in white whale densities throughout the offshore Beaufort, and in nearshore waters off the Tuktoyaktuk Peninsula. These results suggest that whales which had left the estuary may have moved offshore and/or eastward.

After the apparent increase in white whale abundance throughout the offshore Beaufort during the third week of July, white whale numbers decreased steadily in all areas through the remainder of the 1984 open-water period. The distribution and relative abundance of white whales in each offshore stratum were similar during any given survey, suggesting no detectable preference for a particular offshore geographic area. White whale densities in strata with differing levels of industry activities were generally similar; however, industry activities occupy only a small proportion of the area within any stratum, and comparison of densities within strata are not a suitable means by which to assess potential industry-related effects. As described earlier, there were several reports of white whales in the vicinity of industry activities during the 1984 open-water period.

Distribution of white whales did appear to be related to ice cover. A decided preference for areas of open water (<1/10 ice cover) was noted for some group types during all but the last survey; in September adults preferred very open pack-ice. During the second and fourth surveys, cow-neonate groups did not show any statistically detectable preference for a particular ice cover class. Adults not accompanied by immature animals did not show any statistically detectable preference for a particular ice cover class during the fourth and fifth surveys.

The 1984 surveys had a study approach similar to systematic aerial surveys conducted since 1980 in the southeastern Beaufort Sea to examine bowhead whale distribution. White whales sighted incidentally during these surveys have been described (Renaud and Davis 1981; Davis and Evans 1982; Harwood and Ford 1983; McLaren and Davis 1985). The 1981 program involved a series of surveys which extended from late July to mid September, while the other surveys focussed on the late August-September period. The offshore distribution of white whales in late July 1984 was similar to that observed in late July 1981 (Davis and Evans 1982). For example, in both years, small groups of white whales were widely distributed throughout the offshore Beaufort, and larger numbers and groups were recorded seaward of the Mackenzie Estuary. The results from the late August-September surveys from 1980-84 indicate that the distribution of white whales in the offshore Beaufort varied among years. While the relative abundance generally decreased as the survey periods progressed in each year, the specific locations where white whales were recorded generally varied. In most years, however, few white whales were recorded in nearshore waters off the Yukon coast during late August and September.

Two objectives of the present program were to (1) examine timing of the white whale fall migration, and (2) to determine if white whales move between Mackenzie Estuary, offshore Beaufort Sea and Amundsen Gulf waters during the open-water period. The relative abundance of white whales among zones and surveys provides some evidence regarding the timing and location of possible shifts in the distribution of the population. In addition, the direction of whale movement noted during observation periods is a useful parameter for examination of population movements. Although observers can not consistently distinguish local movements and migratory movements, sample size was large and it is believed that a large net directional movement indicates migration.

The frequent observation of relatively large numbers of white whales moving westward offshore of Baillie Islands, at the entrance to Liverpool Bay, and in nearshore waters off of the Tuktoyaktuk Peninsula suggest that an influx of white whales from Amundsen Gulf occurred during the period from late July through late August. While a comparable movement was not detected during the 1981 surveys, there have been numerous reports of white whales moving predominantly southwestward along the Tuktoyaktuk Peninsula starting in mid July in other years (e.g., Norton Fraker and Fraker 1982; Norton Fraker 1983). Although it has been speculated that white whales move between the estuary and nearshore Tuktoyaktuk Peninsula waters following the estuarine concentration period, the conspicuous absence of whales moving eastward in this area during 1984 and past years strongly suggest that the southwestward-moving animals had probably arrived from points east (e.g., Amundsen Gulf).

Relatively large numbers of white whales were observed seaward of the Mackenzie Estuary during mid to late July coincident with a decrease in abundance in the estuary. Surveys conducted in late July 1981 also reported that large numbers were present seaward of the estuary (Davis and Evans 1982).

The aforementioned population shifts within the region complicate determination of the timing of the fall migration. During the first survey, whale movements showed no net directionality. By mid July, however, white whale movements were predominantly westward or had a westward component. This finding, along with the fact that white whales were present in the offshore Alaskan Beaufort during the latter half of July (D. Ljungblad, Naval Ocean Systems Center, San Diego, pers. comm.), suggest that it is possible that a few white whales may have started their 1984 fall migration as early as mid July. However, the animals sighted in Alaskan waters may not have entered Canadian waters in 1984. During late July, white whale movements showed no marked directionality; and offshore densities were greater than those observed the previous week. This may have been partly the result of white whales moving into the southeastern Beaufort Sea from Amundsen Gulf or these animals may have come from north of the survey area. From late July through mid September, white whale movements were predominately westward and densities steadily decreased. These results suggest that the fall migration was underway by late August; the fall migration was nearly complete by mid-September.

POPULATION SIZE

The size of the Beaufort white whale stock estimated in past studies has increased as survey techniques have been standardized, and as the geographic scope of the surveys has been expanded. Prior to 1976, the population was estimated to contain 200-3 500 animals, based on coastal surveys in the Mackenzie Estuary (Sergeant and Hoek 1974). In 1976, a survey format including 50% coverage of the white whale concentration areas in the Mackenzie Estuary was standardized, and the maximum number estimated thereafter has varied from 3 500 in 1981 (Norton Fraker and Fraker 1982) to 7 500 (Robertson and Millar 1984). The variability in the estimated size of the population using the estuary may be due to variable survey conditions and timing of survey coverage (Norton Fraker and Fraker 1982) or may be a correct assessment of the numbers using the estuary in different years.

The 1981 bowhead survey series covered much of the Beaufort Sea and Amundsen Gulf, and resulted in a minimum population estimate of 11 500 white whales (Davis and Evans 1982). This estimate is believed to be low because coverage in the Yukon zone was limited, the effective transect width was less than the 1 600 m width used in the calculations, no correction factor for unseen animals was applied, and survey lines did not extend farther south than the 5 m isobath.

The July 21-23, 1984 survey results led to the calculation of a minimum population estimate of 7 081 animals. The estimate is undoubtedly low because 1) Amundsen Gulf was not surveyed (1 750 animals were estimated there during a comparable time period in 1981), 2) the effective transect width was narrower than the 1 600 m width used in the calculations, and 3) no correction was applied to account for unseen animals. Applying the correction factor calculated in this study (2.5) gives a population estimate of approximately 17 702 animals. However, the correction factor is preliminary as it is based on only 24 sightings, and the population estimate of 17 702 white whales is probably high.

Beaufort white whales winter in the Bering Sea, probably in association with white whales that summer in the Bering and Chukchi seas. Whether these whales constitute more than one stock has not yet been determined. Finley et al. (1983) consider the Beaufort animals a separate stock because these animals would probably be separated from the other groups, on their spring migration to summering grounds, during the April-May breeding season. Braham et al. (1984) mention the possibility that white whales from Soviet waters may join with those from the Bering Sea in summering in Canadian waters.

GROSS ANNUAL RECRUITMENT

The percentage of whales sighted in the offshore area that were classified as neonates during the first, third and fourth surveys is comparable to gross annual recruitment rates reported for white whales by other researchers (Table 8). The rates do not include any immature animals for which a relative age could not be determined. The percentage of neonates calculated for the July 13-18 survey (18.2% neonates, 23.8% if all immature animals of unknown age are considered to be neonates) is higher than rates reported by others or calculated for the other July 1984 surveys. Such a rate could only be possible if it is assumed that the white whale population (1) consisted of only mature animals, (2) had an equal sex ratio, (3) had females that reproduced once every two or three years (as suggested by Sergeant 1973; Brodie 1971), and (4) had no neonate mortality. At least the first and probably the fourth of the above assumptions do not apply to the Beaufort white whale stock, suggesting the percentage of neonates calculated for the second survey is not representative of the gross annual recruitment of the stock.

The high gross annual recruitment rate noted during the July 13-18 survey may have resulted for one or more of the following reasons. Firstly, if cow-neonate pairs were segregated from other group types, then the percentage of neonates observed in the offshore would not be representative of the entire population. Secondly, females may have moved offshore to calve during the third week of July, returning to the estuary with the newborns by late July. Finally, the high percentage of neonates observed may have been a sampling artifact. For example, cow-neonate pairs may have spent a greater proportion of their time at the surface than other group types during this survey and this would result in their being sighted proportionately more frequently. Furthermore, cow-neonates may have been over-represented in the sample due to chance.

Table 8. Reproductive rate of white whale populations in different regions.

Area	Year	Method	Percentage Neonates in Population	Reference
Cumberland Sound, Baffin Island	1966-69	Field examination	9.0	Brodie 1971
Seal River	1956	Aerial survey	11.4	Sergeant 1973
Hudson Bay	1967	Field examination	11.7	Sergeant 1973
Cunningham Inlet, Somerset Island	1973	Aerial photographs	12.1, 17.9*	Heyland 1974
Alaskan Beaufort Sea	1974	Aerial photographs	13.6	Ray and Wartzok 1980
Creswell Bay, Somerset Island	1975	Aerial survey	12.6	Finley 1976
Yukon, Delta & Tuk Pen zones Beaufort Sea	1981	Aerial survey	15.2+, 17.00+	Davis and Evans 1982
Yukon, Delta & Tuk Pen zones	1984	Aerial survey	8.6, 9.5, 10.1, 18.2	this study

* different scales of photographs used.
\+ calculated from information given in report

WHITE WHALE USES OF OFFSHORE WATERS

The results of this study clearly indicate that the Beaufort stock of white whales uses offshore areas throughout the summer. Even during the period when white whales were concentrated in the Mackenzie Estuary, an overall density of 40.8 white whales/1 000 km^2 was observed in the offshore area. Although it is clear that offshore areas are important to this stock, the reasons why they occupy the offshore in large numbers are not known.

Calving may occur in offshore waters of the Beaufort Sea, although this has never been observed. In the present study, more neonates were sighted offshore during the July 13-18 survey than during the July 5-9 survey (26 vs 10 neonates), even though survey coverage decreased from 8.2% to 4.9%, which suggests that calving may have occurred in the area between the two surveys. Finley (1976) suggested that calves just born remain at the surface and make no attempt to move or to dive; several neonates observed offshore in 1984 exhibited this behaviour.

Despite many years of intensive surveys of the Mackenzie Estuary, calving has never been observed there, and only a few neonates have been recorded. These results suggest that calving does not occur in the Mackenzie Estuary; however, the calves are dark and therefore difficult to detect in the turbid, estuarine waters. In the eastern Arctic (where turbidity does not limit neonate detectability to the same extent as in the Mackenzie Estuary), calving has not been observed during intensive surveys of the estuaries, and it has been hypothesized that calving occurs offshore (Finley 1976). Females with full-term foetuses have been harvested in the Mackenzie Estuary, suggesting that the calving period coincides with the period of estuarine occupation and therefore when large numbers also occur offshore.

Offshore waters may also serve as feeding areas for white whales. Activities indicative of feeding have seldom been observed in the estuarine concentration areas, and few whales landed in the Mackenzie Estuary contain recently ingested food. Several observations of small groups of whales diving and in association with seabirds have been made in nearshore areas (e.g., Shingle Point, Toker Point, Warren Point, Atkinson Point), but the numbers of animals involved are small compared with the estimated size of the population. These findings suggest that if a large proportion of the population feeds in the region, as is likely, feeding may occur in the offshore. This is supported by the fact that several examined whale stomachs have contained squid beaks and the few beaks that have been identified were Gonatus fabricii, a typical offshore species (Fraker et al. 1978). In 1984, apparent white whale feeding was observed on at least three occasions - near the abandoned artificial island at Issungnak, at the entrance to Liverpool Bay, and near Baillie Islands. Two of these sightings were in the offshore area (water depth > 5m). White whales have been seen feeding beneath fast ice in a bay in the eastern Arctic (Finley and Johnston 1977) and several authors have suggested that white whales may leave estuarine areas to feed beneath ice offshore (Hay and McClung 1976; Finley 1976).

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Appendix 1. Transect location and survey dates.

SURVEY 1 - July 5-9, 1984

Transect no.	Zone	Survey date (July 84)	Longitude (°W)	Latitude (°N)		Transect length (km)
				South	North	
2	Yukon	5	139°57.1'	69°37.1'	69°57.1'	36.9
3		5	139°06.7'	69°38.8'	70°20.0'	76.3
4		5	138°16.4'	69°12.9'	70°20.0'	124.0
5		5	137°26.0'	69°00.0'	70°20.0'	148.0
5a	Delta	5	137°00.8'	68°56.0'	70°21.3'	158.0
6		5	136°35.6'	68°55.0'	70°26.5'	170.0
6a		6	136°10.3'	68°52.1'	71°00.0'	237.0
7		6	135°45.1'	69°19.6'	71°00.0'	185.9
7a		6	135°20.0'	69°31.0'	70°51.4'	149.0
8		6	134°54.8'	69°28.8'	70°51.4'	134.0
8a		6	134°29.6'	69°44.0'	70°56.2'	133.0
9		6	134°04.5'	69°34.0'	70°56.2'	152.2
9a		9	133°39.4'	69°22.5'	71°00.0'	180.6
10		9	133°14.1'	69°23.6'	71°00.0'	178.5
10a	Tuk.	9	132°48.8'	69°39.0'	70°50.0'	131.5
11	Pen.	9	132°23.5'	69°45.9'	71°00.0'	137.2
12		9	131°33.1'	69°52.7'	71°00.0'	124.6
13		9	130°42.7'	70°11.0'	70°30.0'	35.2

Appendix I (cont'd). Transect location and survey dates.

SURVEY 2 - July 13-18, 1984

Transect no.	Zone	Survey date (July 84)	Longitude (°W)	Latitude (°N)		Transect length (km)
				South	North	
1	Yukon	13	140°47.4'	69°37.5'	70°30.0'	97.2
2		13	139°57.1'	69°36.8'	70°30.0'	98.5
3		13	139°06.7'	69°38.5'	70°02.2'	43.8
4		13	138°16.4'	69°12.9'	70°20.0'	124.3
5		17	137°26.0'	69°20.0'	70°10.0'	92.6
6	Delta	17	136°35.6'	69°20.0'	70°02.4'	78.5
7		18	135°45.1'	69°50.0'	71°00.0'	129.6
7a		17	135°20.0'	69°31.1'	69°42.7'	21.5
8		18	134°54.8'	69°50.0'	71°00.0'	129.6
9		18	134°04.5'	69°50.0'	71°00.0'	129.6
10		18	133°14.1'	69°50.0'	71°00.0'	129.6
11	Tuk.	18	132°23.5'	69°50.0'	71°00.0'	129.6
12	Pen.	18	131°33.1'	69°52.7'	71°00.0'	124.6
13		18	130°42.7'	70°11.0'	70°26.0'	27.8
14		18	129°52.3'	70°13.0'	70°26.4'	24.8

Appendix 1 (cont'd). Transect location and survey dates.

SURVEY 3 - July 21-23, 1984

Transect no.	Zone	Survey date (July 84)	Longitude (°W)	Latitude (°N) South	Latitude (°N) North	Transect length (km)
1	Yukon	21	140°47.4'	69°37.5'	70°20.0'	78.7
2		21	139°57.1'	69°36.8'	70°30.0'	98.5
3		21	139°06.7'	69°38.5'	70°30.0'	95.4
4		21	138°12.9'	69°12.9'	70°30.0'	142.8
5		21	137°26.0'	69°00.0'	70°50.0'	204.0
6	Delta	21	136°35.6'	68°55.2'	70°50.0'	212.6
7		22	135°45.1'	69°20.0'	71°00.0'	185.2
8		22	134°54.8'	69°29.0'	71°00.0'	168.5
9		22	134°04.5'	69°32.7'	71°00.0'	161.7
10		22	133°14.1'	69°23.8'	71°00.0'	178.2
11	Tuk.	22	132°23.8'	69°45.0'	71°05.0'	148.0
12	Pen.	22	131°33.1'	69°52.7'	71°10.0'	143.1
13		23	130°42.7'	70°11.0'	70°50.0'	72.2
14		23	129°52.3'	70°11.0'	70°41.6'	56.7
15		23	129°01.9'	70°00.0'	70°50.0'	92.6
16		23	128°11.8'	70°37.3'	70°44.7'	13.7

Appendix 1 (cont'd). Transect location and survey dates.

SURVEY 4 - July 28 - Aug. 02, 1984

Transect no.	Zone	Survey date (July/Aug 84)	Longitude (°W)	Latitude (°N)		Transect length (km)
				South	North	
1	Yukon	28	140°47.4'	69°37.5'	70°40.0'	115.7
2		28	139°57.1'	69°36.8'	70°40.0'	117.9
3		28	139°06.7'	69°38.5'	70°40.0'	113.9
4		28	138°16.4'	69°15.2'	70°40.0'	157.0
5		02	137°26.0'	69°00.0'	70°40.0'	185.0
6	Delta	02	136°35.6'	68°55.2'	70°40.0'	194.0
7		02	135°45.1'	69°58.8'	70°20.0'	39.3
8		02	134°54.8'	69°29.0'	70°16.0'	87.0
12	Tuk.	30	131°33.1'	69°52.7'	71°30.0'	116.6
13	Pen.	30	130°42.7'	70°11.0'	71°03.6'	97.4
14		30	129°52.3'	70°11.0'	71°30.0'	113.7
15		30	129°01.9'	70°00.0'	71°15.0'	138.9
16		30	128°11.8'	70°37.3'	71°06.5'	54.6

Appendix 2. Extent of area sampled within each stratum by survey, July-September 1984.

	Area Sampled (km^2)						
	Yukon		Delta		Tuk Pen		West Amundsen
	Nearshore	Offshore	Nearshore	Offshore	Nearshore	Offshore	Offshore
July 5-9	1.78	300.91	460.48	1890.82	18.96	648.94	NS*
July 13-18	NS	624.05	26.08	942.30	21.04	454.55	NS
July 21-23	3.56	987.04	274.39	1175.50	26.97	785.84	NS
July 28 - Aug 2	3.56	1073.27	87.71	332.77	26.97	806.29	NS
Aug 18-27	NC+	3019.00	NC	2639.10	NC	3619.30	1386.00
Sept 6-18	NC	3068.80	NC	3048.80	NC	2442.00	1085.30

* NS = not surveyed
\+ NC = not calculated

Appendix 3. Seal sightings recorded during white whale surveys, July-August 1984.

Ringed seals (Phoca hispida) and bearded seals (Erignathus barbatus) are the only pinnipeds commonly observed in the southeastern Beaufort Sea. During the white whale surveys, 90 ringed seals and 13 bearded seals were observed on-transect. An additional 23 ringed seals but no bearded seals were observed while ferrying to and from the transect lines. Sightings of both species were made during each survey as shown below:

	Ringed Seals		Bearded Seals
	On Transect	Ferrying	On Transect
Survey 1	12	11	4
Survey 2	10	1	4
Survey 3	48	10	2
Survey 4	20	1	3

Most of the sightings were of solitary individuals. However, small groups were seen during all but the second survey, as shown below:

	Group Size of Ringed Seals On-transect			
	1	2	3	>3
Survey 1	10	1	0	0
Survey 2	10	0	0	0
Survey 3	37	4	1	0
Survey 4	14	3	0	0