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# 057 Distribution, Abundance and Age Segregation of Bowhead Whales in the Southeast Beaufort Sea, August-September 1985

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# DISTRIBUTION, ABUNDANCE, AND AGE SEGREGATION OF BOWHEAD WHALES IN THE SOUTHEAST BEAUFORT SEA, AUGUST-SEPTEMBER 1985

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## SUMMARY

This study examines the spatial distribution, relative abundance, and age segregation of bowhead whales in relation to petroleum industry activities and oceanographic features in the southeast Beaufort Sea during the 1985 open-water season. Systematic aerial surveys were conducted during the periods of 18-24 August and 11-16 September. The study area extended from 141°W (Alaska-Yukon border) to 127°W (West Franklin Bay), and from the 2-m isobath seaward to a 9/10 concentration of pack-ice. Surface oceanographic conditions at the time of the surveys are described using satellite imagery analyses and in situ temperature and wind data from industry vessels. Aerial photographic surveys were undertaken from a second aircraft to provide information on the age/size class distribution and site tenacity of bowheads within the study area. Bowhead sightings recorded by other research teams working in the southeast Beaufort Sea during 1985 are also examined.

Pack-ice consolidated along the Tuktoyaktuk Peninsula by northerly winds during the latter half of June apparently prevented the westward movement of bowheads out of Amundsen Gulf until early August. By mid-August, large numbers of whales were present off the Yukon coast and the edge of the Mackenzie River plume. During the 18-24 August survey, 29 bowheads were observed on-transect, 11 bowheads were seen off-transect, and more than 40 were observed during ferrying flights. Whale sightings were concentrated along the shelf break east of Kay Point, just offshore of Shingle Point, within a band located 20-30 km offshore between Kay and Shingle Points, and at the edge of the Mackenzie plume. During the concurrent photogrammetry survey, most sightings were also concentrated close to the Yukon coast. During the 11-16 September field program, the portion of the study area east of 131°W could not be surveyed because of poor weather. A total of 23 whales was observed on-transect, 7 were seen off-transect, and 43 were observed during ferrying flights. The general distribution of whales during the September period was similar to that seen in the August survey. However, few whales were observed at the shelf break east of Kay Point, and an additional concentration was noted along the Yukon coast between Herschel Island and the Alaska-Yukon border. Whales were apparently abundant along the Yukon coast until mid-October.

The estimated abundance of bowheads in the study area was similar in the two surveys. During the August period, between 900 and 3800 whales were present in the study area, and between 800 and 3100 were estimated from the September survey. In both surveys, 65-80 per cent of these were found in the Yukon zone. The wide range of correction factors for whales present but submerged and thus not visible during the surveys is responsible for the lack of precision in estimates of actual abundance.

Examination of satellite imagery provides evidence that the distribution of bowheads during the survey period was related to oceanographic

features that may have resulted in concentration of prey organisms. Many bowheads were located in areas within Mackenzie Bay that were influenced by the Mackenzie River thermal and turbidity plume. High densities of zooplankton are known to occur at interfaces between warm fresh water and colder, saline water in offshore areas. The presence of cold, clear water along the Yukon coast suggests that upwelling was taking place in this area, which may also have resulted in localized concentrations of zooplankton. Whales were observed feeding both at the plume edge and in clear water near the Yukon coast.

A total of 47 bowheads was measured in the photogrammetric component of the study. The majority of these were photographed in Mackenzie Bay, particularly along the Yukon coast. Only five whales (11 per cent) could be considered to be adults (>12 m in length), indicating that predominantly subadult animals occurred in this portion of the study area. Similar observations in 1983 indicate that in at least some years the population is geographically segregated according to age. Thirty bowheads were individually identified from photographs of natural markings. These photographs have been included in the master bowhead catalogue archived at the National Marine Mammal Laboratory, Seattle, Washington. The lack of repeated sightings of identified individuals within the survey period precluded appraisal of site fidelity.

The surveys conducted in this study represent the sixth consecutive year of monitoring of the abundance and distribution of bowheads during late August and September in the southeast Beaufort Sea. Considerable variation has been observed in the distribution patterns of bowheads among previous years, and two hypotheses have been formulated to explain these variations. First, whales may be avoiding the industrial area as a behavioural response to industrial activity. Secondly, they may be responding to fluctuations in oceanographic features that affect food availability. In 1985, there was substantial overlap in the areas where bowheads were sighted and both the overall industry zone and specific sites of drilling and dredging programs. As observed in recent years, whales were concentrated in areas of probable high productivity of zooplankton, which provides additional support for the second hypothesis. It is suggested that the differential distribution of age classes of bowheads in their summer range is a result of either segregation during the spring migration or differences in preferred feeding habitats.

# RÉSUMÉ

Des recensements aériens systématiques ont été effectués au sud-est de la Mer de Beaufort, où il'n y avait aucun encombrement de glace, du 19 au 24 août et aussi entre le 11 et le 16 septembre 1985 en vue d'évaluer la répartition, le nombre et l'âge des baleines franches par rapport à l'activite industrielle déployée dans cette région de même que les traits océanographiques pertinents dans cette même région. Ces relevés devaient couvrir une superficie s'étendant de la frontière qui sépare l'Alaska du Yukon (à 141° de longitude ouest) jusqu'à l'tie ouest de la Baie de Franklin (à 127° de longitude ouest) et à partir de l'isobathe de 200 milles nautiques vers la mer jusqu'à une concentration de 9/10 de la banquise. Les conditions océanographiques de surface à cette époque y sont décrites d'après l'analyse des photos prises par satellite et les données de vent et de température _in situ_ provenant des navires industriels. On fait également état de relevés aérophotogrammétriques systématiques portant sur l'âge, la dimension et la tenacité de certains lieux d'habitat par les baleines franches dans la région étudieé. En outre, les trouvailles consignées par d'autres équipes de recherches sur ces cétacés au sud-est de la Mer de Beaufort en 1985 sont aussi examinées.

A la suite des vents du nordà la fin de juin, le champ de glace s'est raffermi tout au long de la Péninsule de Tuktoyaktuk, ce qui aurait pu empêcher le déplacement des baleines franches hors du Golfe d'Amundsen jusqu'au début d'août. A la mi-août, on pouvait compter de grands nombres de ces baleines au large de la côte du Yukon et près des contours du Mackenzie. Au cours des vols effectués entre le 18 et le 24 août, il a été possible d'observer 29 baleines franches le long des lignes d'observation, 11 autres se démarquant de cette zone et plus de 40 hors champ d'observation. Les cétacés observés formaient un troupeau qui se tenait de 20 à 30 km au large de Pointe Kay et de Pointe Shingle ainsi qu'au bord des contours du Mackenzie. De même, durant la photogrammétrie concurrente, la plupart des baleines observées étaient localisées près de la côte du Yukon. Entre le 11 et le 16 septembre, de mauvaises conditions atmosphériques ont rendu impossible l'analyse de la région qui se trouve à l'est de la longitude de 131° à l'ouest. On a pu compter seulement 23 baleines franches le long des lignes d'oberservation, 7 autres se démarquant de cette zone et 43 hors champ d'observation. La répartition des baleines était la même en septembre que celle du mois d'août. Cependant, peu de baleines ont été observées sur l'écueil à l'est de la Pointe Kay. Par contre, un rassemblement a été noté le long de la côte du Yukon, entre les îles Herschel et la frontière de l'Alaska et du Yukon. Un nombre important de baleines franches était présent le long de la côte du Yukon jusqu'à la mi-octobre.

On a estimé qu'il y a eu un nombre semblable de baleines franches dans les deux recensements de la même région. On a aperçu entre 900 et 3800 baleines dans la région pendant le mois d'août et on a estimé un nombre entre

800 et 3100 en septembre. En tenant compte des inexactitudes provenant du fait que certaines baleines se trouvaient submergées, donc invisible durant l'étude, on a donc estimé qu'entre 65% à 80% de ces cétacés se tenaient dans la zone du Yukon.

Les photo prises par satellite au cours de l'étude ont révelé que la population des baleines franches dépendait en fait des changements survenus dans les conditions océanographiques résultant en une concentration de proies dans cette région. Plusieurs cétacés étaient localisés dans certains endroits influencés par les eaux thermiques et bourbeuses du fleuve Mackenzie à l'intérieur de la Baie de Mackenzie. Des concentrations zooplanctoniques sont souvent attirées aux endroits où les eaux douces et chaudes rencontrent les eaux salées et plus froides le long de la côte. Du fait qu'il y avait des eaux claires et froides tout au long de la côte du Yukon suggère qu'il y avait une remonteé d'eau le long de cette côte expliquant ainsi la concentration zooplanctonique localisée. On a observé des baleines franches se nourrissant dans les eaux près du contour du Mackenzie ainsi que dans les eaux claires près de la côte du Yukon.

L'analyse photogrammétrique à révélé un total de 47 baleines franches au cours de l'étude. la plupart de ces cétacés ont été photographiés dans la Baie de Mackenzie mais surtout le long de la côte du Yukon. Seulement 5 de ces baleines franches (11%) ont été considérées comme étant adultes (>12 m de longueur) et par conséquent, une forte prépondérance de jeunes baleines se trouvaient dans cette partie de la région étudieé. Le fait qu'un nombre semblable de baleines ait été observé en 1983 prouve qu'une ségrégation géographique par rapport à l'âge des baleines franches se présente dans certaines années. On a pu identifier 30 baleines franches d'après les photographies qui mettaient en évidence leurs traits distinctifs. Ces photos reposent maintenant dans les archives du Laboratoire national des mammifères marins à Seattle, Washington. Le fait qu'il a été impossible d'observer dans ce même lieu, les baleines, déjà identifieés sur les photographies précédentes, a empêché une évaluation valable du site.

Les résultats de cette recherche représentent la sixième année consécutive de l'observation suivie de la répartition d'un grand nombre de baleines franches pendant la période de la fin août et septembre dans les eaux au sud-est de la Mer de Beaufort. Il n'en reste pas moins que la distribution de ces animaux a considérablement varié pendant les années précédentes. Deux hypothèses ont été émises pour tenter d'expliquer ces variations: En premier lieu, les baleines franches désiraient éviter les activités industrielles. En deuxième lieu, elles suivaient tout simplement les fluctuations océanographiques naturelles, physiques et biologiques dans la recherche de la nourriture. En 1985, un chevauchement considérable des baleines franches a eu lieu dans les régions où étaient déployées les activités industrielles et les activités des sites spécifiques de forage et de dragage. Comme on l'avait observé au cours des années passées, un nombre considérable de baleines franches s'était rassemblé dans les régions où la concentration

zooplanctonique était élevée. Les données fournies par l'étude semblent corroborer cette dernièr hypothèse. On propose que la répartition différentielle par rapport à l'âge des baleines franches dans leur vaste habitat estival provient soit de la ségrégation durant leur migration printanière, soit des différents habitats pourvoyant leur nourriture préférée.

# PART 1

## INTRODUCTION

The Western Arctic population of bowhead whales (Balaena mysticetus) winters in the Bering Sea (Brueggeman 1982) and is present in the Beaufort Sea and Amundsen Gulf region from May through to September or October. Prior to commercial exploitation, this stock probably contained between 14,000 and 26,000 bowheads (Breiwick et al. 1981) and certainly numbered no more than 40,000 (Bockstoce and Botkin 1983). The 1931 International Convention for the Regulation of Whaling prohibited commercial harvest of bowheads. The International Whaling Commission's most recent estimate of the current population size is 4417 ± 2613 animals (95 per cent confidence limits; IWC 1986). The bowhead whale is considered an endangered species by both the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and the International Whaling Commission (IWC).

This study examined the spatial distribution, relative abundance, and age segregation of bowhead whales in relation to petroleum industry activities and oceanographic features in the southeast Beaufort Sea during the latter half of August and first half of September 1985. During this period, bowheads are most likely to be found in areas where hydrocarbon exploration activities have been focused during the last few years. The project represents the sixth consecutive year of systematic aerial surveys for bowhead whales in the southeast Beaufort Sea. The emphasis in the study was on evaluation of the relationships between the relative distribution and abundance of whales and various physical and biological oceanographic parameters; an examination of the age/size class distribution of bowhead whales was also undertaken in selected portions of the study area.

Results of past surveys indicate that the late summer distribution of bowheads in the southeast Beaufort Sea varies among and within years (Renaud and Davis 1981; Davis et al. 1982; Harwood and Ford 1983; Harwood and Borstad 1985; McLaren and Davis 1985). In 1980, the first year in this series of systematic surveys, bowheads were frequently sighted in the area of petroleum industry operations. Although the location of the centre of the industrial zone has not changed substantially over the years, the number of bowheads observed in this zone during the 1981-1984 surveys was much lower than during the 1980 surveys. Two hypotheses have been formulated to explain the differences in bowhead whale distribution from 1980 to 1984 (Indian and Northern Affairs Canada and Environment Canada 1984, 1985). One hypothesis suggests that activities of the petroleum industry have caused, or contributed to, a progressive exclusion of bowheads from the development zone. The second hypothesis is that the distribution of bowheads is determined by physical and biological oceanographic factors, particularly those influencing the distribution and abundance of zooplankton.

Aerial photography of bowheads has provided data on the geographic distribution of size (and hence age) classes within the population (Davis et/al. 1983; Cubbage et al. 1984). The results of these studies suggest that the older component of the population (adult and near-adult) tends to be found outside the industrial development zone, whereas primarily young animals are found within this zone. Because there may be differential use of areas with and without industry activities by different age classes of animals (Indian and Northern Affairs Canada and Environment Canada 1985), the 1985 monitoring program included examination of the distribution of age classes of bowheads.

Evaluation of the second of the two hypotheses mentioned earlier is hampered by the very limited information available on zooplankton distribution and abundance in the southeast Beaufort Sea (Grainger 1975; Griffiths and Buchanan 1982). However, two other studies completed in the coastal waters of the Beaufort Sea in 1985 are expected to provide data on zooplankton densities near bowhead whale concentration areas (Bradstreet, M. and D. Fissel, LGL Limited and Arctic Sciences Ltd., in prep; Richardson, W.R. et al., LGL Limited, in prep.) Borstad (1985) and Harwood and Borstad (1985) recently reported that bowheads tend to congregate near areas where temperature and water colour gradients depicted in satellite imagery are greatest. Studies conducted in other areas have shown that zooplankton are commonly concentrated at surface fronts or gradients (Pingree et al. 1975; Mackas et al. 1980; Aiken 1981). These research results lend support to the hypothesis that variations in the relative abundance and distribution of bowheads in the Beaufort Sea are largely controlled by physical and biological factors which affect zooplankton distribution.

During the 1985 bowhead surveys, an attempt was made to fully integrate the systematic surveys, reconnaissance, and photogrammetric studies with near real-time data from satellite imagery. Extensive in situ investigation of oceanographic features in the study area from surface vessels was not undertaken as part of this project, although some relevant data collected during concurrent studies were used during preparation of this report (e.g., LGL Limited, Atmospheric Environment Service, Gulf Canada Resources Inc., and Department of Fisheries and Oceans [DFO]).

The methods and results of each component (systematic surveys, oceanography, and photogrammetry) of the 1985 monitoring program are discussed in separate sections of this report. The distribution of bowheads in relation to the location of the industrial development zone in the southeast Beaufort Sea is discussed in Part 2, and the relationships between the distribution of bowheads and oceanographic features are described in Part 3. The results of the photogrammetric study component are presented in Part 4, and include data on the size/age class distribution of bowheads and photo identification of whales. Part 5 provides an overview of the overall results of the 1985 bowhead whale monitoring program in relation to the two hypotheses identified earlier.

# PART 2

## SYSTEMATIC AERIAL SURVEY PROGRAMS AND BOWHEAD WHALES SIGHTED BY INDUSTRY PERSONNEL

P. Norton and L. Harwood

### METHODS

The relative distribution and abundance of bowhead whales were monitored during two systematic aerial surveys. The information obtained was supplemented with bowhead sightings made by industry personnel. The study area, survey timing, and survey procedures in 1985 were similar to those of previous programs.

#### Survey Timing and Location

The systematic surveys were completed during the periods 18-24 August and 11-16 September, 1985. The study area extended from 141°W to 127°W longitude, and from the 2-m isobath seaward. The planned northern boundary was 25 km beyond the 100-m isobath, except between 141°W and 138°W longitude where the boundary was to be 70°20'N latitude. However, the ice cover in 1985 was more extensive than in recent years and, therefore, the actual northern boundary of most of the transect lines was 16 km beyond the start of the 9+/10 ice cover. This change tended to increase the area surveyed in the western portion of the study area and decrease the area surveyed in the eastern portion, relative to the planned survey coverage.

A grid of 26 north-south transect lines spaced at 20-km intervals to produce 10 per cent survey coverage was established prior to the start of the surveys (Figure 1; Appendix A). Each survey was initiated on the westernmost transect line and proceeded eastward. To allow comparison of 1985 results with data from previous years, the study area was stratified into the Yukon, Delta, Tuktoyaktuk Peninsula (Tuk Pen), and West Amundsen zones (Figure 1), using boundaries established in 1981 (Davis et al. 1982). Ferrying flights each day to and from survey lines were flown over marine areas whenever possible.

#### Survey Procedures

Both surveys were conducted from a deHavilland DHC-6 (Twin Otter) aircraft chartered from Kenn Borek Air Ltd., Inuvik, N.W.T. Two observers and a pilot were present on each flight. The right observer occupied the co-pilot's seat and the left observer used the window seat in the second row of passenger seats. The left observation position was equipped with a bubble window. Communication between the observers and the pilot was maintained through the onboard intercom system during all surveys.

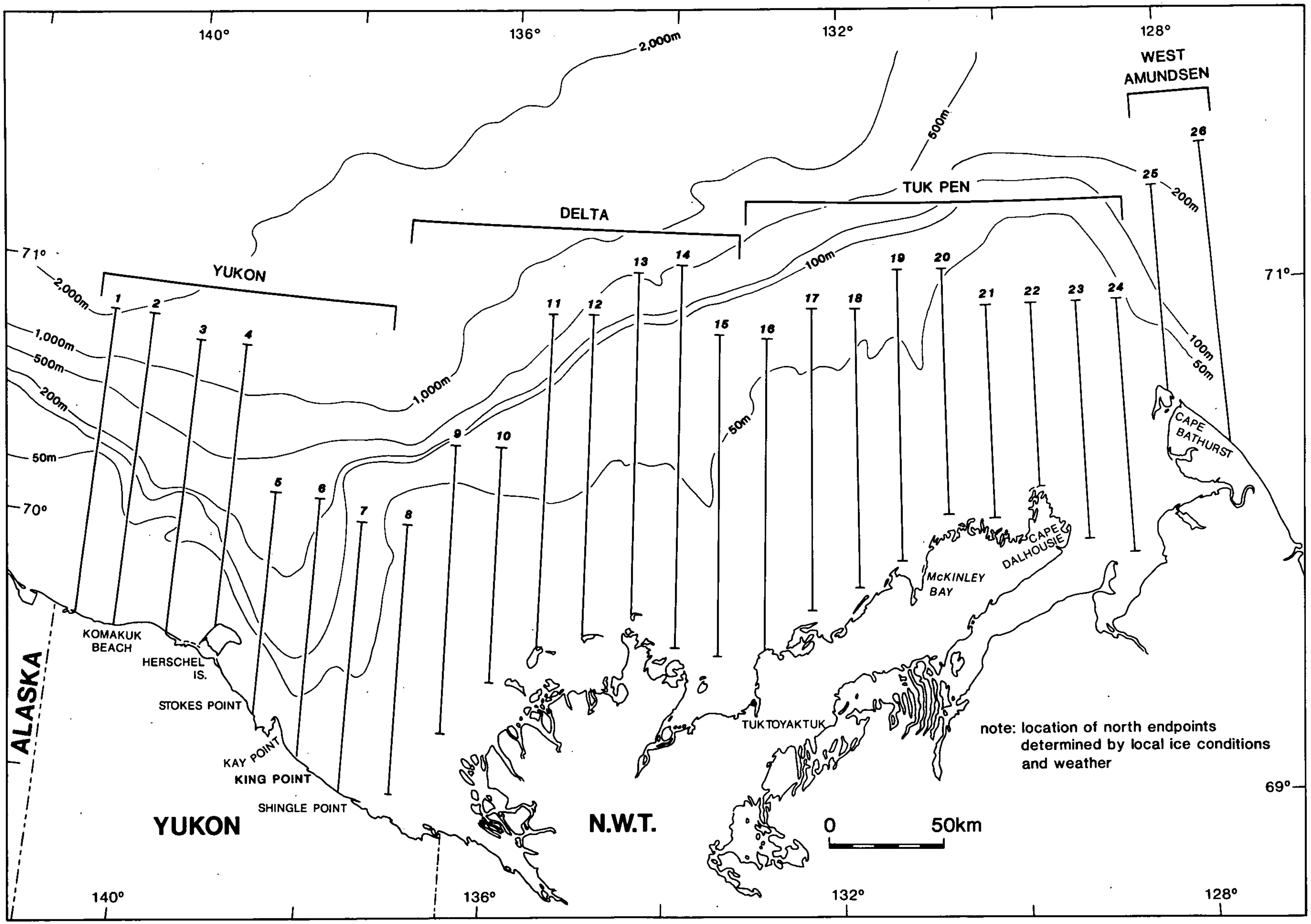


Figure 1. Transect lines and zone boundaries for the 1985 bowhead whale monitoring program.

A survey altitude of 305 m was planned for all flights. The altitude was determined with a radar altimeter and maintained at approximately 305 m for 93.7 per cent of the time spent surveying in August and 82.5 per cent in September. Low-lying cloud/fog necessitated a reduction in the survey altitude to 152 m for the remainder of the survey time. The planned ground speed was 200 km/h during the surveys and 278 km/h during ferrying flights. Mean ground speed during the surveys was 202.1 km/h in August and 205.6 km/h in September, but ranged from 166.3 to 249.6 km/h because of the effects of wind.

Information on whale, seal, and polar bear sightings, observation conditions, and survey locations were immediately recorded onto audio tapes and later transferred to data sheets. Tapes were not reused during the field program and have been retained by ESL Environmental Sciences Limited, Sidney, B.C. A copy of all data sheets has been archived by ESRF.

At the start and end of each transect line, time (±1 s), observation conditions (including sea state, wind and wave direction), radar altimeter reading, water colour, and ice type and percentage cover were recorded by one or both observers. Any changes in observation conditions, sea state, altitude, water colour, or ice type and cover along the transect line were also recorded. In addition, the locations of any visible oceanographic fronts or accumulations of debris, as well as mobile and stationary industry activities, were noted by the field crew. Sea state was rated in accordance with the Beaufort Scale of Wind Force. A water colour rating was determined using a standard six-point scale. Ice was classified as first-year or multi-year on the basis of colour, surface regularity, drainage pattern, and type and extent of ridging. Ice cover was classified using the following World Meteorological Organization (1970) categories: ice-free (0/10 cover), open water (<1/10 cover), very open pack-ice (1-3/10 cover), open pack-ice (4-6/10 cover), close pack-ice (7-8/10 cover), and very close pack-ice (9-9+/10 cover). Information on ice recorded during the surveys was supplemented with data obtained from the Atmospheric Environment Service (Environment Canada) offices in Inuvik and Tuktoyaktuk.

The field crew recorded information on all marine mammals sighted during the systematic surveys and associated ferrying flights. Information recorded for each whale sighting included:

- species
- number of individuals
- time of sighting and/or GNS display (see below)
- inclinometer reading or on/off-transect (see below)
- physical habitat associations (i.e., ice, sea state, water colour, visible fronts)
- relative age (calf or adult, based on apparent size )
- approximate distance between individuals and group organization

- behaviour (i.e., apparent activity)
- direction and rate of movement with respect to compass headings and geographical features
- presence of birds or mud trails which would provide evidence of feeding
- sighting cue (e.g., movement, surfacing animal)
- proximity to geographic features
- unusual markings.

The geographic position of each sighting along a transect was recorded as the number of nautical miles to the end of the line, as indicated by the navigation system (GNS or Collins LRN-70). The accuracy of the onboard navigation system was occasionally checked in the following manner. The elapsed time between the start of a transect line and the time of a sighting was compared with the time required to survey the complete line. This ratio was then multiplied by the total length of the transect line. However, because this calculation assumes that the ground speed of the aircraft was constant, which was seldom true, it is of only limited value as a check on navigational system accuracy.

The transect width during the systematic surveys was 2 km. At an altitude of 305 m, the inner edge of the visible strip was 50 m from the flight path on the left side of the aircraft (where the observer used a bubble window) and 150 m from the flight path on the right side (where there was no bubble window). To maintain equal viewing areas on both sides of the plane, the transect strip was 50-1050 m on the left and 150-1150 m on the right.

Lateral distance of most bowhead sightings from the flight line was measured with a Suunto PM-5/360 S inclinometer. The distance of the animal from the flight path was calculated by subtracting the angle of depression from 90 degrees and multiplying the tangent of that angle by the altitude. The angle of depression was measured when the animal was abeam the aircraft. For some sightings, the only information recorded on relative location throughout the transect width was whether the animal was on- or off-transect.

## Data Analysis

Bowhead densities were calculated by zone. Although a recent assessment of bowhead aerial survey techniques recommended using transect segments as sampling subunits (Oguss and Robertson 1985), this procedure was not followed for the present study. It was concluded that any differences in estimates of bowhead densities using the procedure recommended by these authors would be small in comparison to the much larger sources of error associated with differences in sea state (Davis et al. 1982) and particularly the proportion of time that bowheads spend at the surface (Wursig et al. 1985). Transect lengths used in the determination of zone densities were obtained from the navigation system, and fogged-out portions of the survey lines deducted. The uncorrected density of bowhead whales in each zone was calculated using the following formula:

$$\text{zone density} = \frac{\text{number of bowheads observed on-transect}}{\text{transect length x transect width (2 km)}}$$

The uncorrected zone density was multiplied by the area of the zone to obtain an uncorrected estimate of the number of bowheads therein. The size of each zone was determined from a 1:500,000 Mercator projection map; the east and west boundaries were located 10 km beyond the easternmost and westernmost transect lines in each zone and the southern boundary was the 2-m isobath. The northern boundary was obtained by extending the end of each transect line half-way (10 km) to the adjacent transect lines. Island and shallow water (<2 m) areas were then subtracted from the total. The size of each zone for the August and September surveys is indicated in Appendix B.

The uncorrected zone estimates were multiplied by 1.46 to correct for bowheads present at the surface but not observed during the surveys. This factor is an approximation based on data from Davis et al. (1982) which suggest that observers miss 31.5 per cent of the surfaced bowheads during systematic aerial surveys. Wursig et al. (1985) calculated the proportion of time that undisturbed bowheads spend at the surface. The yearly mean proportion of time that whales were on the surface ranged from 11 (1984) to 43 (1983) per cent. The zone estimates were, therefore, multiplied by 2.33 and 9.09 to correct for animals not seen because they were beneath the surface. Because of the lack of precision in the range of bowhead density estimates for each zone, they were further rounded to the nearest 100.

### Marine Mammal Sightings by Industry Personnel

Information on bowheads, seals, walruses, and polar bears sighted by industry and support personnel in the southeast Beaufort Sea was provided by Dome Petroleum Limited, Esso Resources Canada Limited, and Gulf Canada Resources Inc. Data from these sources were checked to eliminate multiple counts of the animal(s), and were then combined for discussion in this report. Only those whales identified to species were included in the present analysis.

Dome and Gulf had ice observers stationed on their drillships during 1985. Whenever possible, these observers undertook designated wildlife watches lasting 15 min once every 4 h. The ice observers recorded sightings during these watches as well as at other times. Incidental sightings of wildlife by other industry and support personnel on the drillships and support vessels were also recorded and represent the majority of the marine mammal observations. Esso did not follow a standardized wildlife reporting scheme in 1985. Nevertheless, some incidental sightings of marine mammals by personnel on Esso's facilities and vessels were reported to the company's Calgary office.

Bowheads were sighted and recorded by personnel on seven support vessels, one ice-breaker, and one helicopter in 1985 (see Appendix J for record of wildlife sightings by industry personnel).

## RESULTS

The bowhead sightings during the two 1985 systematic aerial surveys of the southeast Beaufort Sea are discussed below. Observations from the concurrent photogrammetric studies and sightings by industry personnel are also presented. Information obtained during these surveys and by industry personnel on white whales, seals, and polar bears is presented in Appendices C, D, and E, respectively.

### Bowhead Distribution, Movements, and Behaviour

The first survey began on 18 August and extended over a seven-day period (Appendix A). The survey was initiated in the westernmost portion of the study area and progressed from west to east as planned. A total of 29 bowheads (21 sightings) was observed on-transect and another 11 (7 sightings) were recorded off-transect (Figure 2; Appendix F). Over 40 bowheads were seen during ferrying flights, although these sightings may not represent 40 individuals because some animals may have been recorded during both ferrying flights and the systematic survey or counted on more than one ferrying flight.

Most on-transect bowheads were observed from 10 to 45 km offshore of the Yukon coast; few were seen in the Delta or Tuk Pen zones, and no bowheads were recorded on-transect in the West Amundsen zone. The pattern of distribution of off-transect and ferrying sightings was similar to that of the on-transect sightings, except that bowheads were frequently observed within 1 or 2 km of the Yukon coast. During the concurrent August photogrammetry study, most sightings also occurred just offshore of the Yukon coast (Figure 3). However, some bowheads were observed 60-70 km offshore of the Yukon coast, north-northwest of McKinley Bay, and northeast of Cape Dalhousie, in areas where no bowheads were recorded during the systematic survey.

The second survey was initiated on 11 September and extended until 16 September, when a prolonged storm was forecast for the region and necessitated termination of the field program. As a result, only transect lines 1-20 were completed. As in August, the survey progression was from west to east. A total of 23 bowheads (18 sightings) was observed on-transect and seven individuals were recorded off-transect (Figure 4). Forty-three bowheads were sighted during the ferrying flights in September.

The pattern of whale distribution observed in September was similar to that documented in August. Most on-transect bowheads were observed in the southwest portion of the study area off the Yukon coast. However, 74 per cent

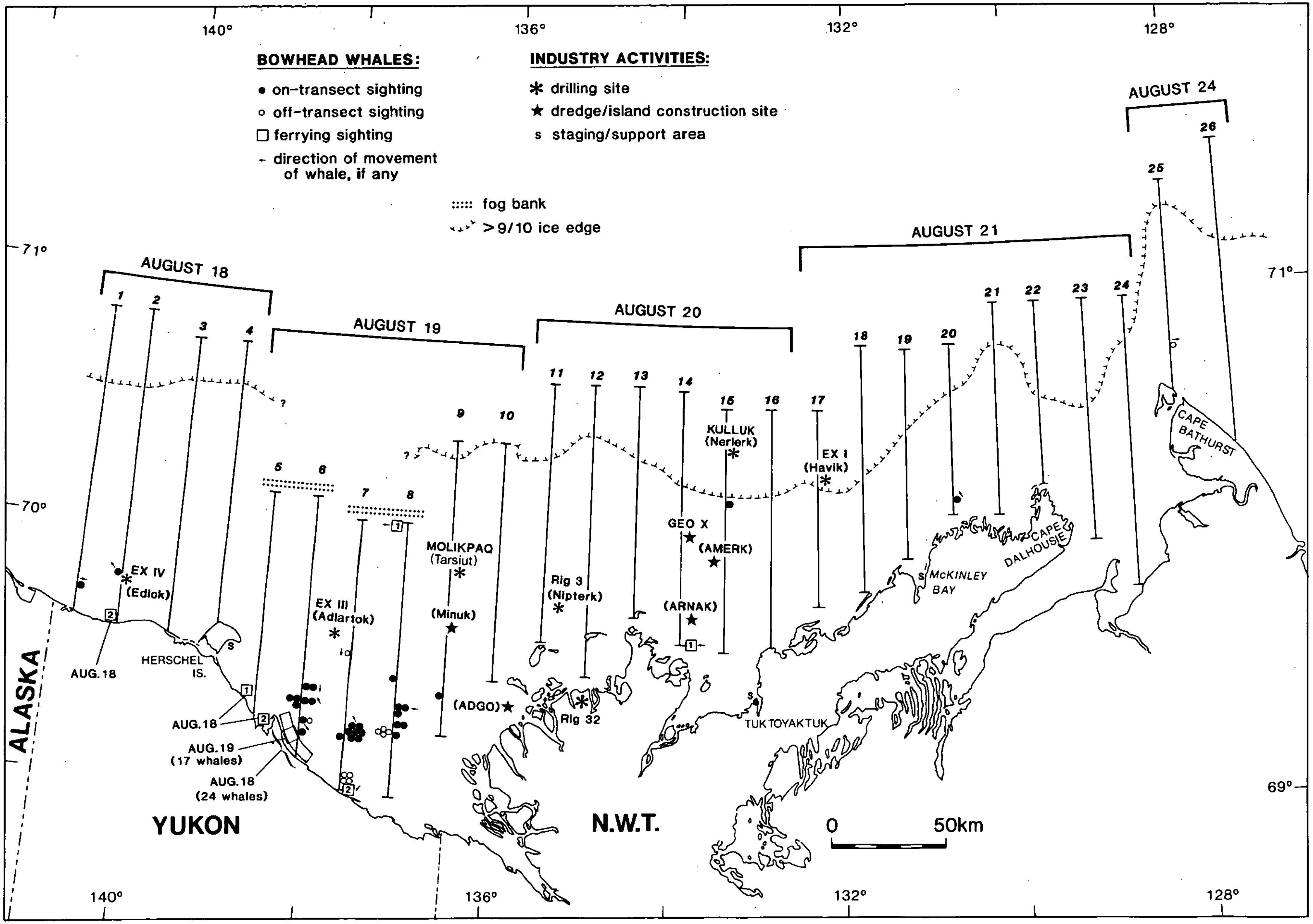


Figure 2. Location of bowhead whale sightings during systematic surveys conducted from 18 to 24 August, 1985.

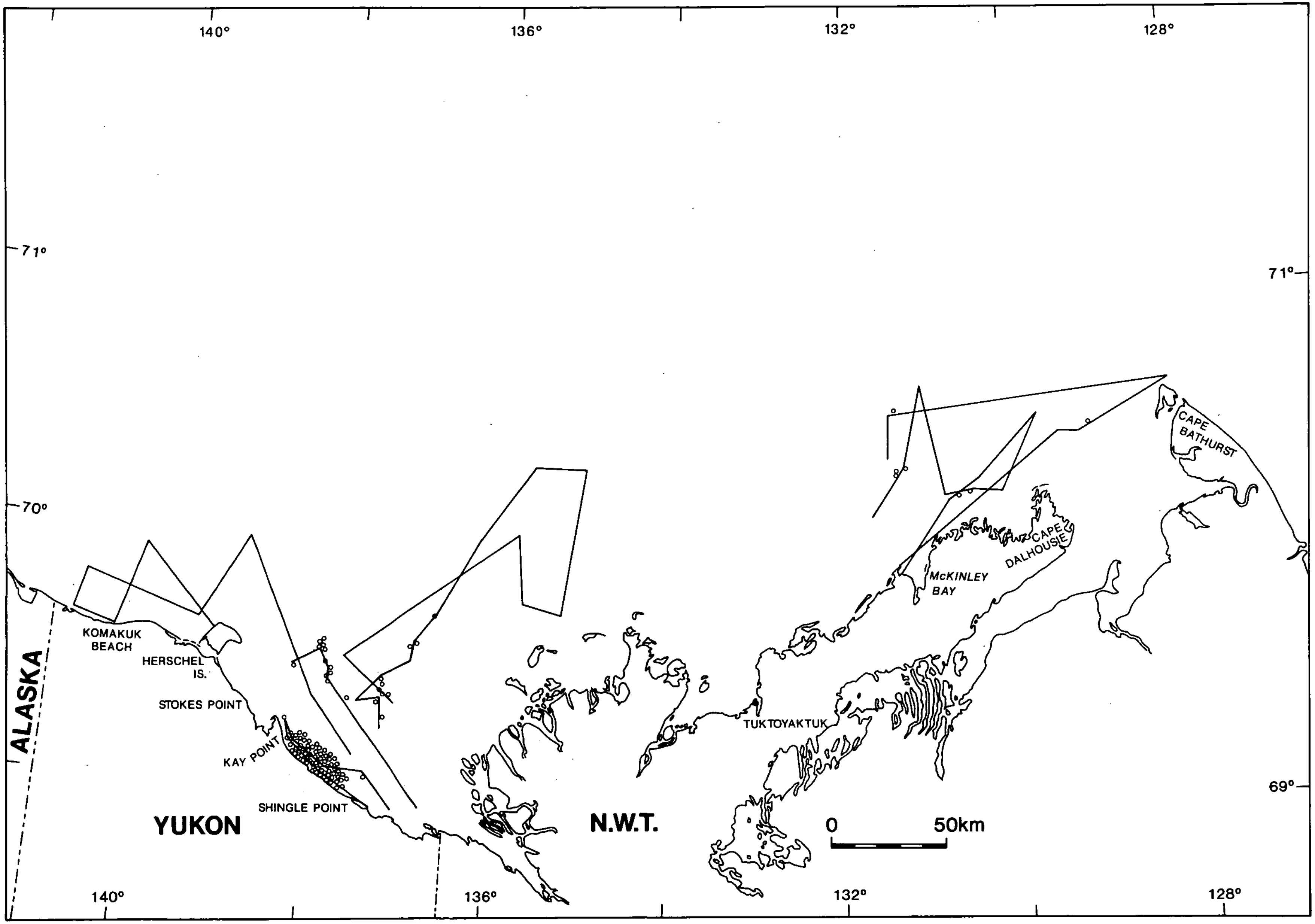


Figure 3. Location of bowhead whale sightings during the August 1985 photogrammetric surveys.

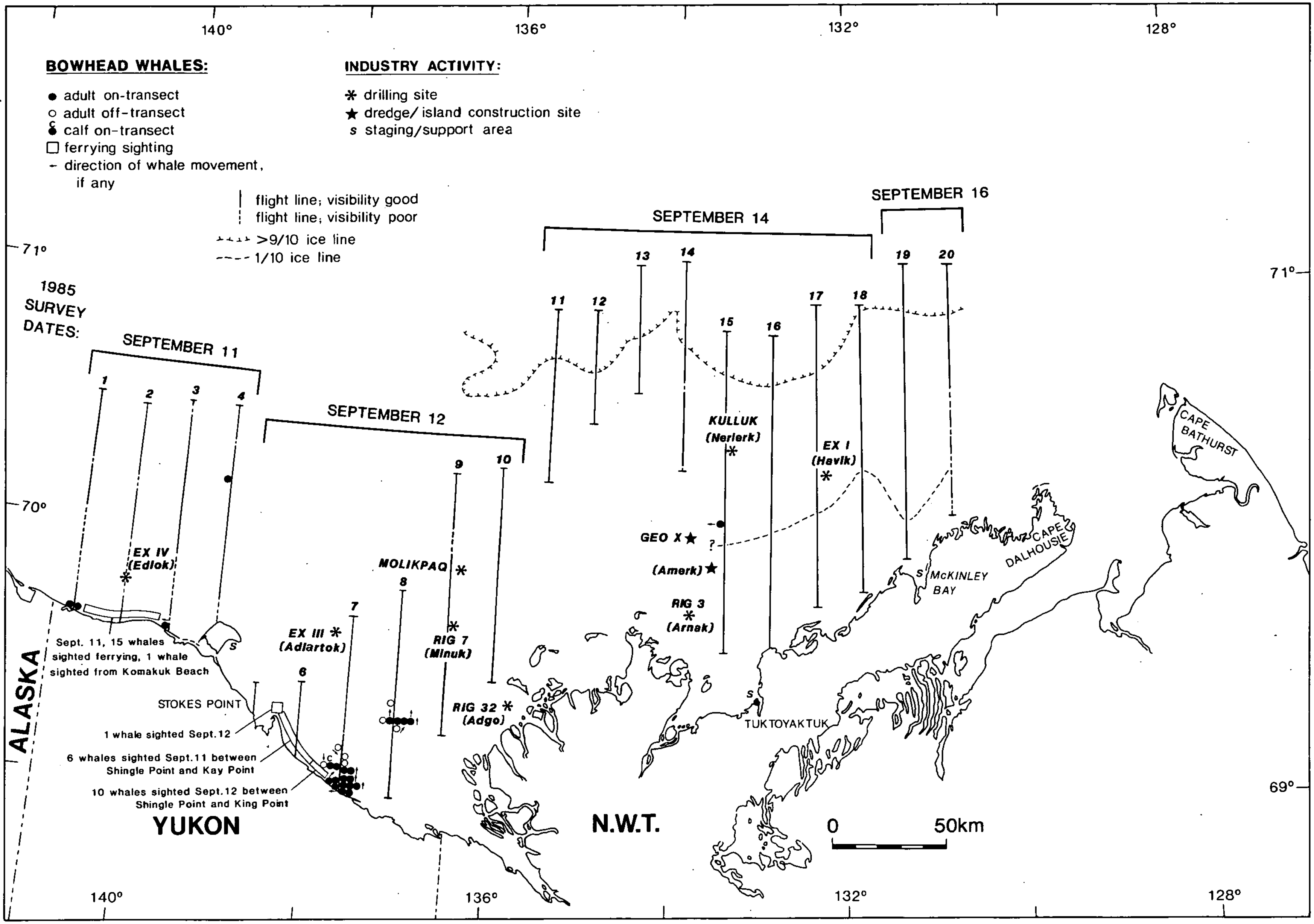


Figure 4. Location of bowhead whale sightings during systematic surveys conducted from 11 to 16 September, 1985.

of bowheads recorded on-transect during September were located within 10 km of the coast. In addition, more bowheads were present near Komakuk Beach in September than in August. A smaller number of whales (17 per cent of the total) was located approximately 40 km offshore. The distribution of ferrying and off-transect sightings was similar to the on-transect observations.

Most of the bowheads observed offshore of the Yukon coast during both surveys were swimming slowly on the surface, although a few remained motionless at the surface. Whales present among ice floes during both surveys showed no discernible movement. Breaching and "spy-hopping"[1] behaviours by bowheads along the Yukon coast were each observed on one occasion. Clear evidence of feeding behaviour was also documented during the photogrammetric study component in August; observations included whales with mud plumes trailing from their mouths or defecating, and a bowhead with its mouth open.

The direction of movement of some on-transect and off-transect bowheads was recorded during both systematic surveys. In the case of on-transect whales, the predominant direction of movement was to the northwest during August and either north or west in September (Figure 5). Off-transect bowheads were travelling south, southeast, east, or northeast (Figure 5). Because similar numbers of whales were observed in the same areas during both surveys and there was no consistent pattern of movement to the west, it is unlikely that fall migration had begun at the time that the 1985 systematic surveys were conducted. It is more likely that small-scale, local movements of bowheads were occurring throughout the period from mid-August to mid-September. Certainly, the facts that large numbers were present in the southeast Beaufort Sea and small numbers occurred off the Alaskan coast at that time suggest the migration was late in 1985.

As in past systematic surveys, group size was also recorded by observers during the 1985 bowhead whale monitoring program. On-transect sightings were of one or two bowheads during both systematic surveys, although one group of four whales was observed off-transect in August. During the photogrammetric study, a group of three bowheads was observed along the Yukon coast.

Abundance

The calculated zone densities ranged from 0 to 21.6 bowheads per 1000 $km^2$ (Table 1). The density of bowhead whales was consistently higher in the Yukon zone than in the other zones during both August and September. The

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1 a behaviour where the whale is positioned vertically in the water with its head above the water surface.

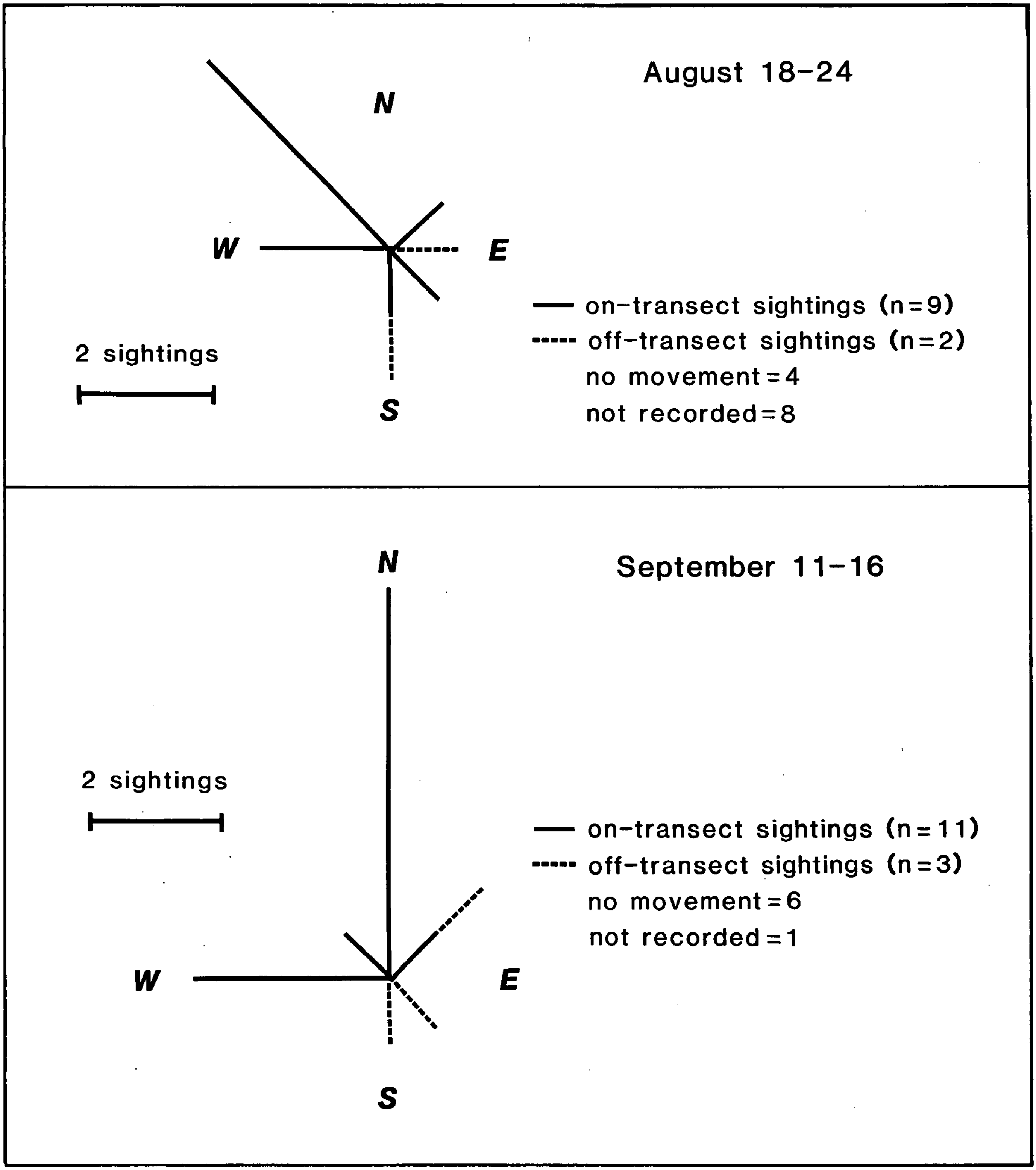



Figure 5.

Observed direction of bowhead whale movements, August-September 1985.

TABLE 1

Densities and estimated numbers of bowheads in the southeast Beaufort Sea, August-September 1985

| Time Period | Parameter | Zone | | | | |
|---|---|---|---|---|---|---|
| | | Yukon | Delta | Tuk Pen | West Amundsen | Total (PP)[a] |
| August 18-24 | number (km$^2$ surveyed) | 19 (1701) | 9 (1746) | 1 (1744) | 0 (433) | - |
| | density = no./1000 km$^2$ | 11.2 | 5.2 | 0.6 | 0 | |
| | uncorrected estimated no. of bowheads present | 190 | 94 | 11 | 0 | |
| | corrected estimated no. of bowheads present | 600-2500 | 300-1200 | 0-100 | 0 | 900-3800 (20-86)[b] |
| Sept. 11-16 | number (km$^2$ surveyed) | 18 (835) | 5 (1389) | 0 (1202) | NS[c] | |
| | density = no./100 km$^2$ | 21.6 | 3.6 | 0 | NS | |
| | uncorrected estimated no. of bowheads present | 179 | 50 | 0 | NS | |
| | corrected estimated no. of bowheads present | 600-2400 | 200-700 | 0 | NS | 800-3100 (18-70)[b] |

a PP = per cent of population; assumes population size is 4417 (IWC 1986), 31.5 per cent of bowhead whales at surface were missed by observers (Davis et al. 1982), and bowheads are visible 11-43 per cent of the time (Wursig et al. 1985).

b The lower value of the range of estimates is more realistic (see text).

c NS - not surveyed.

density in the Yukon zone was higher in September than in August, although this may be related to the fact that the area surveyed in September was smaller (Appendix B), and included the area where whales appeared to congregrate.

The estimated numbers of bowheads both within the Yukon zone and in the overall study area were similar in the two survey periods, although it is unknown if the same whales were present in the region surveyed in both August and September. One of the objectives of the study was to investigate site tenacity by bowheads during the August field program. However, the longest period between sighting and resighting an identifiable individual was only 78 min, and this prevented the evaluation of site tenacity. Given the accuracy of the navigation system (about 2 km), the individual in this instance was essentially in the same location during both sightings.

Because of the large range in the correction factor (2.33-9.09) used to account for whales not present at the surface during the surveys, there is a correspondingly wide variability in the proportion of the western Arctic population of bowhead whales estimated to be within the study area during both survey periods (Table 1). It is not possible to reduce these ranges without site-specific information on dive times and the proportion of time that bowheads spend at the surface. However, the research of Wursig et al. (1985) has indicated that the percentage of time that bowheads spend at the surface is correlated with water depth. Based on data presented by these authors, bowheads may be expected to spend 22 and 13 per cent of their time at the surface in water depths of 16-50 and 101-250 m, respectively. Because the areas where bowheads were most abundant in 1985 were relatively shallow (2-50 m), the lower correction factor (2.33) for submerged animals may be more applicable to the present data. If this is the case, then the lower of the range of estimates shown in Table 1 may be more realistic, particularly in view of the results of the photogrammetric studies (Part 4), which suggest that the majority of bowheads present in the study area were immature and could not be representative of the age structure of the entire population. Although improper size and placement of the transect can adversely affect the number of bowheads detected at the surface, the observed relationship between bowhead "sightability" and distance from the flight line (see Appendix G) suggests that the transect width is appropriate and, therefore, unlikely to bias the present results.

## Calf Sightings

One calf was observed during the systematic surveys. A cow-calf pair was sighted on-transect on 12 September just northwest of Shingle Point on the Yukon coast. This calf represents 4.3 per cent of the bowheads seen on-transect during the September survey. During the photogrammetric program, one calf was sighted during a non-systematic search. This sighting occurred on 21 August in an area north-northwest of McKinley Bay.

### Bowheads Sighted by Industry Personnel

Petroleum industry operations in the southeast Beaufort Sea during 1985 involved seven drilling units (Explorers I, III, and IV, Molikpaq, Kulluk, and Rigs 3 and 7) at 15 sites, 13 dredging/construction sites, and three staging/support areas (Pauline Cove, Tuktoyaktuk, and McKinley Bay). The boundaries of the main zone of industrial activities (Figure 6) were derived by joining adjacent sites of active industry activity in 1985. This procedure is similar to that followed by Richardson et al. (1985a) for previous years. More activities occurred off the Yukon coast than in past years.

Twenty bowhead whales (16 sightings) were observed by industry personnel involved in 1985 Beaufort operations in this region. The locations of August and September sightings are shown in Figure 6. The first sighting occurred on 29 June, north of McKinley Bay (not illustrated), whereas the last two sightings were located north of Toker Point and north of Pullen Island on 22 September.

## DISCUSSION

### General Trends - 1985

Late break-up in the Beaufort Sea in July may have delayed movement of bowheads from Amundsen Gulf to the region. Few whales were observed in the southeast Beaufort Sea before mid-August in 1985. For example, no bowheads were sighted during a DFO systematic aerial survey for seals in Amundsen Gulf in June (DFO, unpubl. data) or subsequent INAC systematic surveys for white whales in July (DFO, unpubl. data). Two bowheads were reported northwest of McKinley Bay on 29 June by industry personnel, and several bowheads were observed in Amundsen Gulf during July and early August (DFO, unpubl. data; W.R. Koski, LGL Limited, pers. comm.). There were several sightings of bowhead whales in the southeast Beaufort Sea on and after 7 August. Three sightings (four whales) occurred north and west of McKinley Bay on that date (W.R. Koski, pers. comm.), and there were five sightings of solitary bowheads on 7 and 8 August in an area 35-95 km offshore and just east of the Alaska-Yukon border (D. Ljungblad, Naval Ocean Systems Centre, pers. comm.). No whales were recorded in the latter area during reconnaissance flights on 2 and 6 August.

There was an influx of bowheads into the study area during mid-August. Relatively large numbers of whales were observed off the Yukon coast and the edge of the Mackenzie River plume on 14 August, whereas no whales had been reported in these areas on 10 August (W.R. Koski, pers. comm.). During the first survey period of the present study, concentrations of bowheads were recorded at the shelf break east of Kay Point, just offshore of Shingle Point, within a band located 20-30 km offshore between Kay and

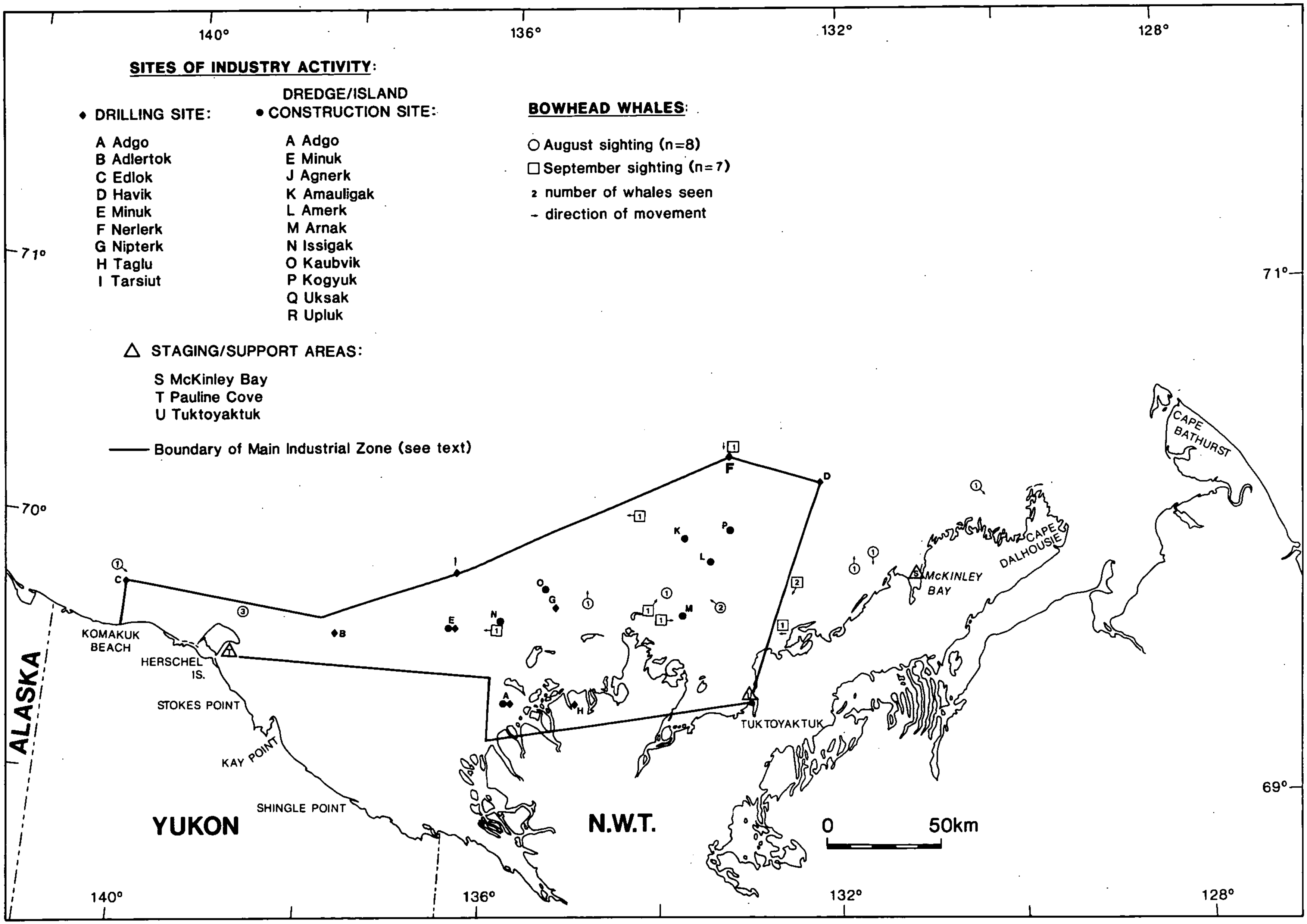



Figure 6. Sites of petroleum industry activity during August-September 1985 and locations of bowhead whale sightings by industry personnel.

Shingle points, and at the edge of the Mackenzie plume. Smaller numbers of whales (three sightings, four whales) occurred 0.1-25 km from the shoreline between Komakuk Beach and the Alaska-Yukon border. Ljungblad (pers. comm.) also recorded two sightings in this area during a reconnaissance flight on 17 August and another sighting on 29 August.

During the present investigation, there were scattered sightings of bowheads in some other areas of the study region. Most bowheads observed away from the concentration areas during this period were present among ice floes (two sightings in 1-3/10 ice cover and one sighting in 4-6/10 ice cover) and were lying relatively motionless at the water surface. An exception was a sighting in an area north of Cape Bathurst; a bowhead was seen moving slowly through an area where gulls were also observed.

Bowhead densities along the Yukon coast and at the plume edge were also high during the September systematic survey. Between the two surveys, an estimated 600 whales were present at the edge of the Mackenzie River plume (W.R. Koski, pers. comm.). With the exception of the shelf break east of Kay Point, relatively large numbers of bowheads were observed in the same general areas as in August. The lack of sightings near Kay Point was likely related to the poor observation conditions in this area during the September survey. An additional bowhead whale congregation area was noted during the September field program; this area extended along the Yukon coast from Herschel Island to the Alaska-Yukon border. Personnel at the Komakuk Beach Distant Early Warning (DEW) Line site also reported seeing bowheads close to the shoreline after late August. Others found large numbers of bowheads along the Yukon coast until mid-October (C. Holdsworth, LGL Limited, pers. comm.).

As mentioned earlier, the fall bowhead migration probably did not begin until mid-to late September. For example, the first bowheads recorded north of Deadhorse (Alaska) were seen on 13 September, and they were observed in this area until 13 October (D. Ljungblad, pers. comm.). It is likely that the fall migration of bowhead whales out of the southeast Beaufort Sea in 1985 was similar to that recorded in 1979, when the migration proceeded in several small stages rather than two or three distinct and larger phases (D. Ljungblad, pers. comm.).

## 1985 Bowhead Distribution and Abundance Relative to Past Years

The relative distribution and abundance of bowheads in the southeast Beaufort Sea vary within an open-water season and from year to year. The late August distribution in 1985 was most similar to that observed in 1983 (Table 2). In 1981, 1982, and 1984, the largest numbers of bowheads were documented in the eastern portion of the study area, and fewer whales were found in this area in 1983 and 1985. The estimated number of bowheads present in the Yukon and Delta zones in 1985 was within the range observed in previous years (Table 3). However, fewer bowheads were estimated to occur in the Tuk Pen zone in

TABLE 2

Areas with concentrations of bowheads detected during systematic aerial surveys, 1981-1985[a]

| Time period | Relative location | 1985 | 1984 | 1983 | 1982 | 1981 |
|---|---|---|---|---|---|---|
| Late August | West | | Herschel Is. to Kay Point | | 35-65 km NNE of Kay Pt. | |
| | | 10-35 km N of King Pt. | | 0-10 km N of King Pt. | 125 km N of King Pt. | |
| | | 25-30 km N of Shingle Pt. | | | | |
| | | 30-45 km NNE of Shingle Pt. | | 5-15 km NNE of Shingle Pt. | | |
| | | | | | | 95-220 km N of eastern half of Yukon zone |
| | | | | | | 5-55 km N of Hooper Is. |
| | | | | | | 95-130 km N of eastern half of Tuk Pen |
| | | | 55 km NW of Cape Bathurst | | 120 km NW of Cape Bathurst | |
| | East | | 20 km N of Cape Bathurst | | | |
| Early September | West | | along coast N of Herschel Is. | | 25 km NW of Herschel Is. | |
| | | | 40 km N of King Pt. | | 100-130 km N of King Pt. | |
| | | | 2-12 km N of coast from King Pt. to Shingle Pt. | | | |
| | | 5-20 km NNW of Shingle Pt. | | | | |
| | | 35-40 km NNE of Shingle Pt. | | | | |
| | | | | | | 90 km NNE of Pullen Is. |
| | | | | | | 40-70 km N of Toker Pt. |
| | East | | | 40-125 km N of coast of Tuk Pen | | 40-70 km N of McKinley Bay |

[a] Only areas included in the 1985 surveys were compared with previous years. "Concentration" assumes >2 on-transect bowheads were observed. A maximum of three areas was selected for each survey. Data sources are: Davis et al. 1982; Harwood and Ford 1983; McLaren and Davis 1985; Harwood and Borstad 1985.

TABLE 3

Uncorrected estimates of bowheads in the southeast Beaufort Sea and Amundsen Gulf, late August - early September, 1980-1985[a]

| Time of Survey | Southeast Beaufort Sea Yukon Zone | Delta Zone | Tuk Pen | Total | West Amundsen Gulf |
|---|---|---|---|---|---|
| Late August | | | | | |
| 1980 | NS[b] | NS | 755 | 755 | NS |
| 1981 | 104 | 267 | 150 | 521 | NC[b] |
| 1982 | 319 | 67 | 120 | 506 | NS |
| 1983 | 50 | 21 | 118 | 189 | NS |
| 1984 | 30 | 36 | 71 | 137 | 21 |
| 1985 | 190 | 94 | 11 | 295 | 0 |
| Early September | | | | | |
| 1980 | NS | NS | 222 | 222 | NS |
| 1981 | 66 | 75 | 188 | 329 | 126 |
| 1982 | 290 | 42 | 30 | 363 | NS |
| 1983 | 10 | 110 | 193 | 313 | NS |
| 1984 | 260 | 18 | 39 | 317 | 84 |
| 1985 | 179 | 50 | 0 | 229 | NS |

a Estimates include extrapolations for areas between surveyed transects, but no corrections for submerged or undetected animals. Survey areas varied in size from year to year. Data sources are: Renaud and Davis 1981; Davis et al. 1982; Harwood and Ford 1983; McLaren and Davis 1985; and Harwood and Borstad 1985; present study.

b NC = not calculated.
NS = not surveyed.

August 1985 than in any previous year. The area of West Amundsen Gulf surveyed in the August 1985 survey period was too small to allow meaningful comparison of bowhead density estimates among years.

The early September distribution of bowhead whales in the Beaufort Sea has also varied. In 1985, bowheads were observed near the coast and offshore of Shingle Point. As is evident from Table 2, there was some overlap in bowhead concentration areas between 1984 and 1985. In contrast, there were no similarities between the September 1985 bowhead distribution and patterns observed in 1981, 1982, or 1983. As in late August, the number of bowheads estimated in the Yukon and Delta zones was within the range observed in previous years, but use of the Tuk Pen zone was unusually low during 1985 (Table 3).

The concentration of bowheads along the Yukon coast persisted for at least two months (mid-August to mid-October) in 1985 and at least five weeks in 1984. Previous concentrations of whales in this zone were recorded for much shorter periods (e.g., the 1983 concentration along the Yukon coast lasted for about two weeks). Three areas used by bowheads in previous years (around Herschel Island, offshore of the Tuktoyaktuk Peninsula, and north-northwest of Cape Bathurst) were not used by many whales in 1985. It is not known if the bowhead whales found in the above areas in previous years did not utilize the study area in 1985 or were located in other portions of the southeast Beaufort Sea.

## Distribution of Bowhead Whales in Relation to Industry Activity

In 1985, concentrations of bowheads were observed just within and just outside the boundary defined for the main industrial zone (Figure 6). Several bowhead sightings occurred off Komakuk Beach from mid-August through mid-September in an area located just inside this boundary (Figures 4 and 6). During the August photogrammetric program, at least eight sightings occurred east of Herschel Island within the industrial zone (Figures 3 and 6). Congregations of whales observed east of Kay Point and at the plume edge during the August systematic survey were within 20 km of the industrial zone boundary. Bowheads in all of the main concentration areas were located shoreward of the main industrial zone and, therefore, would have had to pass through the zone of industry activity to reach such areas.

Industry personnel reported 12 sightings (totalling 16 bowheads) within the development zone (Figure 6). Bowheads were observed 4 and 8 km from active drilling units and 4, 10, and 15 km from dredging operations. Similarly, bowheads were found within 4 km of an active drilling unit (Figure 2) and 13 km from an active dredge (Figure 4) during the systematic surveys.

The relationships between the distribution of bowhead whales and the location of oil and gas industry activities in the Beaufort region from 1976 to 1984 were recently summarized by Richardson et al. (1985a) as follows.

Limited data suggest that bowheads were relatively abundant in the main industrial zone during 1976 and 1977, but not in 1978 or 1979. In 1980, more complete information was available, and large numbers of bowheads were observed in the main industrial zone. There were fewer sightings of bowhead whales in the industrial zone during 1981 and 1982. In 1983, the number of sightings in the zone increased slightly over 1982 and, in 1984, even more sightings were documented. On the average, bowheads appeared to be as abundant in the main industrial zone during the present study as they were in 1984, although fewer animals were observed in the Tuk Pen zone.

# PART 3

# DISTRIBUTION OF BOWHEAD WHALES IN RELATION TO OCEANOGRAPHIC FEATURES

G.A. Borstad, J.C. Cherniawsky and R. Kerr

## BACKGROUND

The relationship between the distribution of whales and oceanographic phenomena, including factors affecting zooplankton distribution and abundance, was the subject of considerable research by Japanese scientists during the period from 1950 to 1970 (Uda and Nasu 1956; Nemoto 1962, 1963; Nasu 1966; Kawamura 1974; and others). In a summary of much of this work, Nasu (1966) indicated that baleen whale feeding grounds at high latitudes are associated with three types of oceanographic phenomena:

- fronts separating water masses
- eddying circulation resulting from instabilities along frontal boundaries or behind islands, capes, or promontories
- upwelling resulting from topographic effects or wind forcing.

In the Beaufort Sea, Griffiths and Buchanan (1982) first attempted to link oceanographic factors to the distribution of bowheads; these authors found that the zooplankton abundance in the vicinity of feeding bowheads was significantly greater than in nearby areas where whales were not feeding. Borstad (1984) introduced the use of satellite and aircraft remote sensing techniques to map oceanographic parameters that may influence the distribution of bowhead whales, and found that bowheads tended to be more abundant in the vicinity of thermal fronts or gradients. On the basis of satellite infra-red images, Borstad (1984) also noted that the Yukon coast and the area around Cape Bathurst frequently exhibited evidence of upwelling and strong thermal gradients which might be positively correlated with high zooplankton abundance.

Harwood and Borstad (1985) used satellite thermal and visible imagery to describe the surface oceanography of the southeastern Beaufort Sea during the 1984 bowhead monitoring program. Comparison of the observed bowhead distribution with available images suggested that bowheads may be associated with several types of oceanographic features. The most important of these were the estuarine front around Richards Island, upwelling fronts along the Yukon coast (under easterly winds), and eddying circulation in Franklin Bay and near Cape Bathurst. Although Harwood and Borstad (1985) were unable to statistically examine the relationships between whale distribution and oceanographic factors because of the small number of sightings, they concluded that their study results still provided evidence in support of the hypothesis that the distribution of bowheads is at least partly determined by food (zooplankton) availability, which is strongly influenced by oceanographic and meteorological phenomena in this region. In 1984, large numbers of whales were observed along the Yukon Coast in association with strong thermal gradients.

Thomson et al. (1986) examined the relationships between bowhead distribution and oceanographic and meteorological phenomena in the southeast Beaufort Sea through the use of historical in situ measurements in conjunction with satellite imagery. The historic data suggested that the abundance of zooplankton was greater in more saline, oceanic water than in areas where surface salinity was significantly reduced by freshwater input from the Mackenzie River. A comparison of the available bowhead distribution data with satellite imagery suggested that bowheads do not occur in the lowest salinity waters of the river plume. However, because bowheads were not consistently found in areas unaffected by the plume, their distribution may be affected by a complex set of factors related to seawater salinity, winds, and plume distribution.

## METHODS

### Airborne Water Colour Observation

Visual observations of water colour were recorded during the two systematic surveys using colour standards as a reference. These standards were prepared in 1984 using paint swatches chosen to reflect the range of colours observed from the air (blue-black, blue-green, dark green, light green, light green-brown, and light yellow-brown). If colour reference standards are used and observations are taken with care, airborne visual colour observations can be used to delineate water colour patterns under most conditions, including overcast periods (Borstad and Brown 1981; Harwood and Borstad 1985). The colour patterns observed from the air closely correspond to those shown in satellite imagery.

### Reception and Processing of Satellite Data

NOAA-9 AVHRR digital imagery was received at the Department of Oceanography, University of British Columbia (UBC). All imagery obtained after 15 August was examined immediately, and tapes containing usable cloud-free data were sent to G.A. Borstad Associates Ltd. in Sidney. Processing was completed at the Institute of Ocean Sciences (DFO) image processing laboratory.

Analytical procedures were essentially the same as those followed in 1984 (Harwood and Borstad 1985), and involved geometric rectification and preparation of descriptive graphics for the facsimile transmission. On most nights, two or more fax charts of sea surface temperature (derived from the thermal infra-red band 4, 10.3-11.3 μm) and turbidity patterns (from the broad band visible 0.55-0.90 μm channel 1) were transmitted to the field crew in Inuvik. A pair of portable facsimile machines was used to transmit documents over voice-grade telephone lines.

Usable (cloud-free) image data were obtained for 18, 19, 20, 21, 22, and 24 August (first survey) and for 12 and 13 September (second survey). Images received for 18-24 August were partly processed during the period when survey personnel were in the field, although calibration and more complete analyses were completed during November and December.

### Post-survey Processing Methods

After the field surveys, all five AVHRR bands were geometrically corrected to a greater level of precision than was considered practical for the "real-time" aspects of the monitoring program (1-2 km versus about 2-4 km). Graphics "masks" for the cloud, ice, and land in each image were then prepared. Masking is an image analysis procedure whereby certain areas on a digital image are assigned a uniform colour level for presentation. This visually sets off or excludes those areas from others in the image. In the resulting photographs of the image data (Plates 1 and 2), the cloud areas are white, ice is grey, and land is dark green.

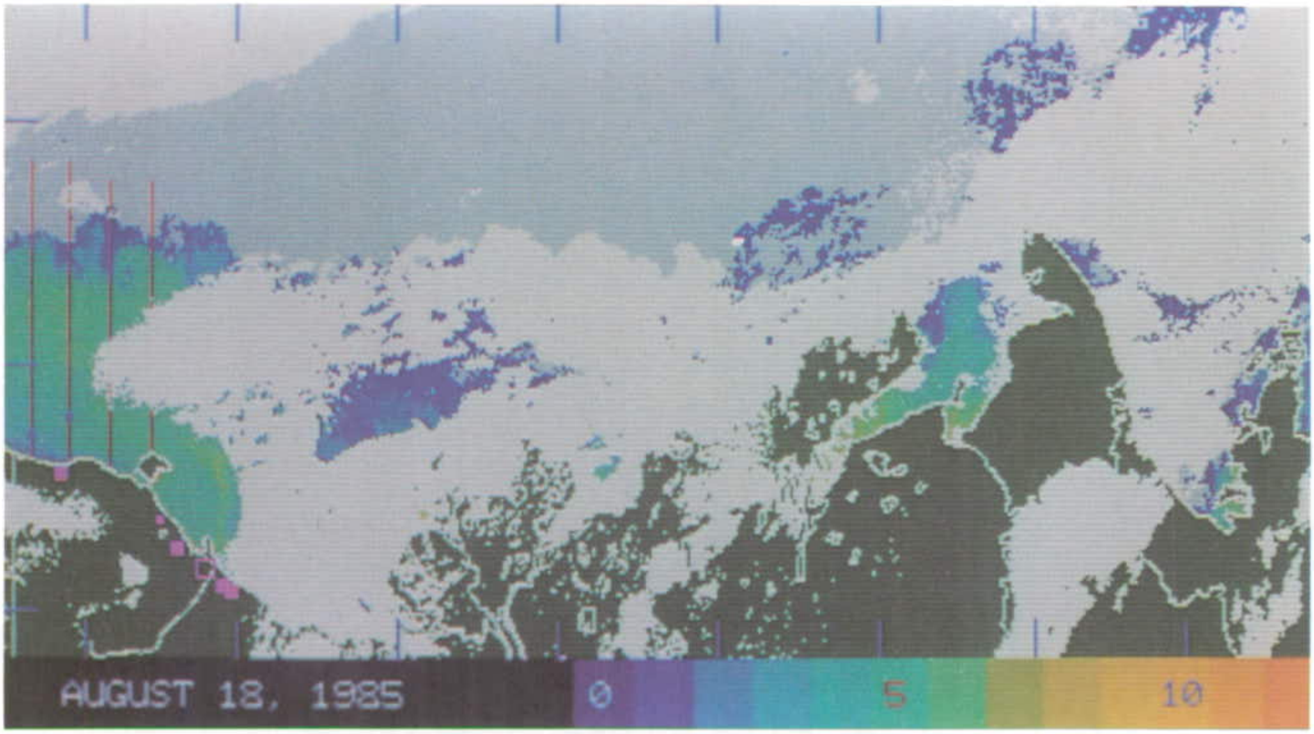
Plates 1 and 2. Sea surface temperature (°C) images of the southeast Beaufort Sea calculated from band 4 infra-red AVHRR data, which have been calibrated using <u>in situ</u> temperature data. Flight lines are indicated by vertical lines. Cloud is white and pack-ice is grey. Single on-transect bowhead sightings are shown as small blue squares, off-transect bowheads are orange, and sightings during ferrying flights are pink. Larger squares indicate sightings of 2-4 animals, and open squares mark the location of sightings of more than 5 bowheads. Sightings made along the coast are marked over the land areas so in-water features are not obscured.

1a. Sea surface temperature (°C) of the southeast Beaufort Sea on 18 August, 1985.

1b. Sea surface temperature (°C) of the southeast Beaufort Sea on 20 August, 1985.

2a. Sea surface temperature (°C) of the southeast Beaufort Sea on 21 August 1985.

2b. Sea surface temperature (°C) of the southeast Beaufort Sea on 13 September, 1985.


AUGUST 18, 1985
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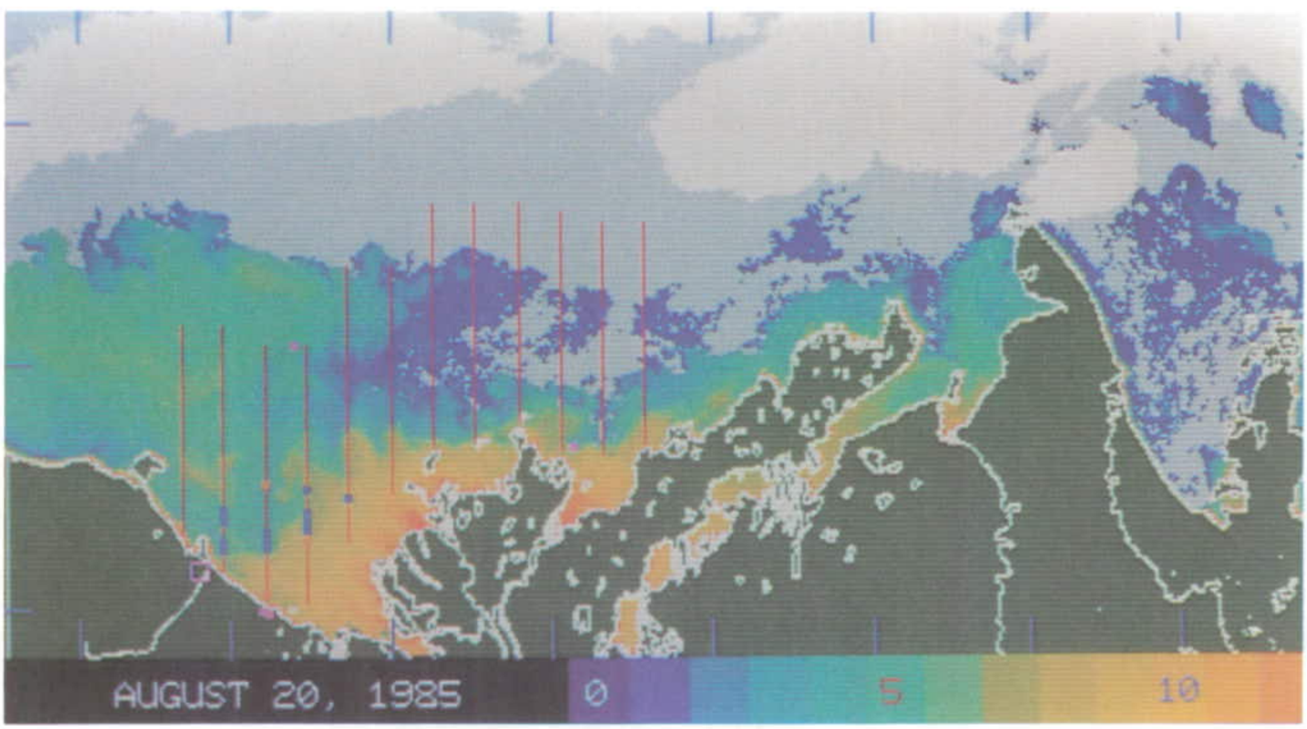
AUGUST 20, 1985
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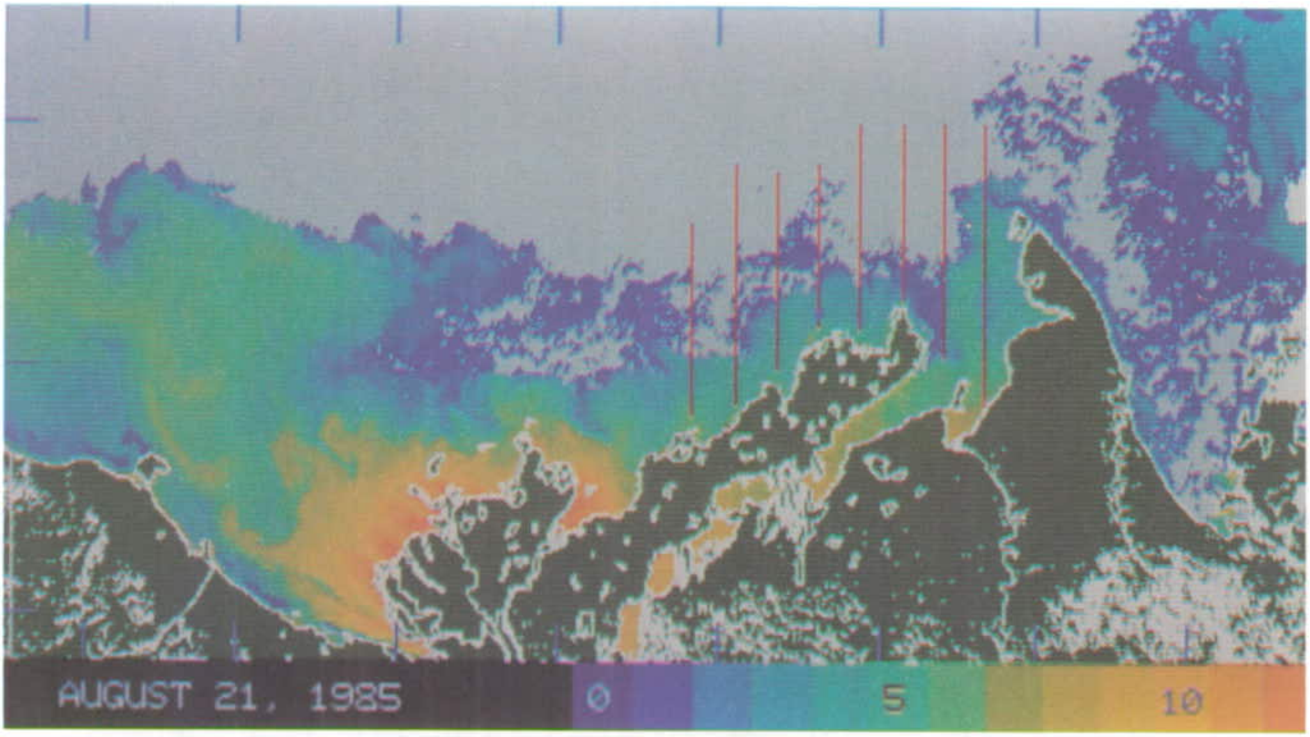
AUGUST 21, 1985
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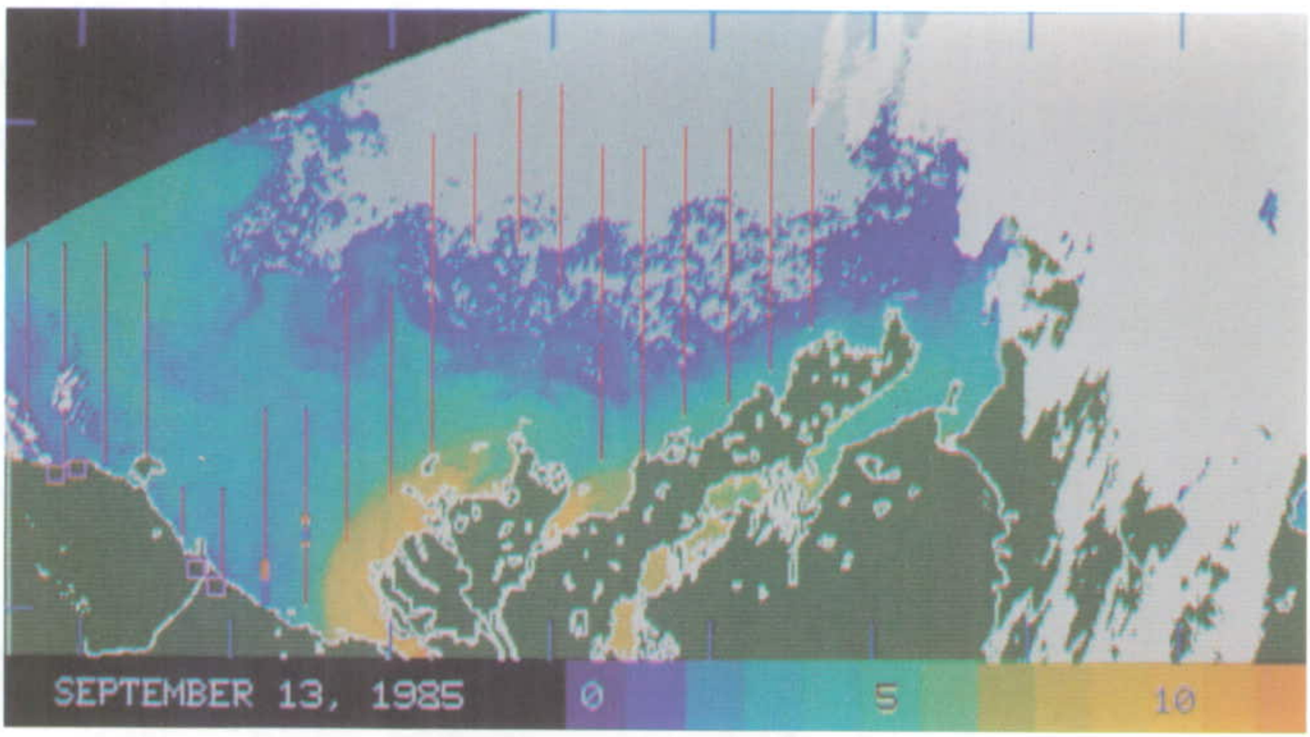
SEPTEMBER 13, 1985
0
5
10

Because a satellite-based calibration of sea surface temperature could not be completed for the data available this year, an approximate empirical calibration of the band 4 thermal image data was conducted using the small number of in situ temperature values that were available for the period of the surveys. This was simply a comparison of in situ temperatures against raw band 4 digital values as is presented in Tabata and Gower (1980), except that a very small number of points was available for comparison. Therefore, all the data were grouped and one calibration curve was used for all images (Figure 7). Because there may be a 1 to 2-km positioning error involved in the geometric correction of images, the range of digital levels within the 8 pixels surrounding the position of the vessel from which the in situ data were collected (about 1.5 km in diameter) was plotted as a horizontal error bar. The range of temperatures within ±3 h of the time of the image was plotted as vertical error bars. An approximate calibration line was drawn through these error bars, placing most reliance on points that had the smallest variability in space and time. The small number of data points did not allow a calibration more accurate than about ±1°C, although it is noteworthy that the curve is nearly identical to the one determined in 1984 (Harwood and Borstad 1985).

Comparison of Whale Distribution with Oceanographic Features Observed in Satellite Imagery

Sea surface temperature and turbidity patterns in open-water areas were determined from the analysis of the thermal and visible bands, respectively. The images in Plates 1 and 2 have been calibrated in terms of degrees Celsius.

To allow comparison of the distribution of bowheads with the magnitude of thermal gradients, the general equivalent of a first derivative was calculated for each image. A "gradient image" was created by an arithmetic operator which reassigned each pixel of a thermal image to the maximum difference between the original pixel and the eight pixels surrounding it. Areas containing cloud, ice, and land were ignored. Where possible, whale observations were compared with image data collected on the same day. However, the positions of bowheads sighted on days with cloud cover (19 August and 12 September) had to be compared with images available for the following days. The frequency distribution of the magnitude of the thermal gradient at the location of all observed whales was then plotted as histograms.

Because the number of whales observed this year was relatively low, statistical tests of distributional trends were not possible. The comparisons of water colour and temperature with distribution of bowhead whales involved the use of airborne water colour observations, geometrically corrected temperature images, or the derivatives of these images, and appear in Tables 4-7.

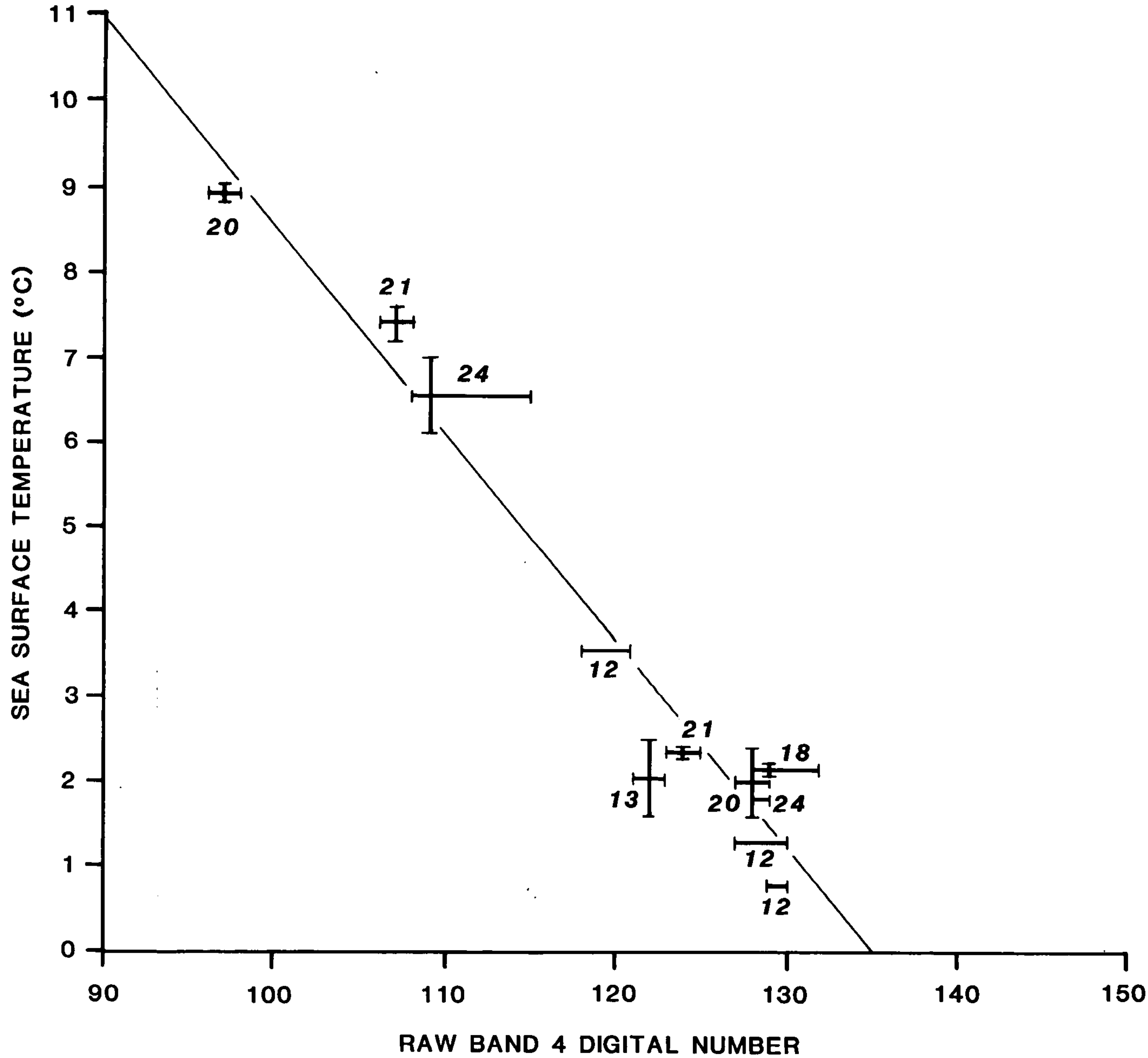


Figure 7. Comparison of AVHRR raw band 4 digital counts and in situ sea surface temperatures for 18 August to 13 September, 1985 (Bradstreet, M. and D.B. Fissel, LGL Limited and Arctic Sciences Ltd., in prep.). Vertical bars indicate the range of temperatures within a 6-h period centred on the time of the image. Horizontal error bards indicate the range of digital numbers in the 8 pixels (about a 1.5-km radius) surrounding the location of the measurement.

TABLE 4

Distribution of bowhead sightings in relation to water depth

| Parameter | Water depth[a] <10 m | 10-50 m | 50-100 m | >100 m | Totals |
|---|---|---|---|---|---|
| | | 18-24 August 1985 | | | |
| km on-transect | 848 (15) | 2261 (40) | 1243 (22) | 1300 (23) | 5652 |
| no. sightings | 7 (25) | 19 (68) | 2 (7) | 0 (0) | 28 |
| | | 11-16 September 1985 | | | |
| km on-transect | 556 (16) | 1660 (48) | 755 (22) | 456 (23) | 3427 |
| no. sightings | 13 (52) | 11 (44) | 0 (0) | 1 (4) | 25 |

[a] Percentage of totals in parentheses

TABLE 5

Distribution of bowhead sightings in relation to bottom slope[a]

| Parameter | Bottom slope (depth range in 10-km radius) <10 m | 10-50 m | 50-100 m | >100 m | Totals |
|---|---|---|---|---|---|
| | | 18-24 August, 1985 | | | |
| no. sightings | 10 (36) | 18 (64) | 0 (0) | 0 (0) | 28 |
| | | 11-16 September, 1985 | | | |
| no. sightings | 11 (44) | 15 (60) | 0 (0) | 0 (0) | 25 |

[a] Percentage of totals in parentheses

TABLE 6

Distribution of bowhead sightings in relation to ice coverage[a]

| Parameter | Percent Ice Coverage <10 | 10-30 | 40-60 | 70-90+ | Totals |
|---|---|---|---|---|---|
| | | | 18-24 August, 1985 | | |
| km on-transect | 2995 (53) | 904 (16) | 622 (11) | 1130 (22) | 5652 |
| no. sightings | 18 (86) | 2 (9) | 1 (5) | 0 (0) | 21 |
| | | | 11-16 September, 1985 | | |
| km on-transect | 1988 (58) | 514 (15) | 207 (6) | 720 (21) | 3427 |
| no. sightings | 16 (89) | 2 (11) | 0 (0) | 0 (0) | 18 |

[a] Percentage of totals in parentheses

TABLE 7

Distribution of bowhead sightings with respect to airborne visual observations of water colour[a]

| Parameter | Water colour | | | |
|---|---|---|---|---|
| | Brown | Green | Blue-Black | Totals |
| | | 18-24 August, 1985 | | |
| km on-transect | 170 (3) | 3052 (54) | 2430 (43) | 5652 |
| no. sightings | 2 (9) | 18 (86) | 1 (5) | 21 |
| | | 11-16 September, 1985 | | |
| km on-transect | 137 (4) | 788 (23) | 2501 (73) | 3427 |
| no. sightings | 0 (0) | 17 (94) | 1 (6) | 18 |

[a] Percentage of totals in paranetheses

## RELATIONSHIP BETWEEN THE DISTRIBUTION OF BOWHEAD WHALES AND ENVIRONMENTAL FEATURES IN THE SOUTHEAST BEAUFORT SEA

### Water Depth/bottom Topography/Ice

Because of the extensive ice cover in 1985, the systematic surveys for bowheads did not continue as far offshore as in 1984. The survey transects extended only past the 100-m isobath in the western portion of the study area (transects 1 through 7). As a result, the survey results may be biased to whales present in relatively shallow water.

Most of the bowheads sighted in August were north and east of Kay Point in the Mackenzie Bay area. Tables 4-6 summarize the distribution of bowhead sightings in relation to water depth, the approximate bottom slope (expressed as the depth range within a 10-km radius of the sighting), and percentage ice coverage.

### Water Colour

Although visual observations of water colour are difficult to analyse quantitatively, they do provide a simple index of water clarity and can be used to delineate the location of the Mackenzie River plume and the extent of influence of the river. Harwood and Borstad (1985) reported that maps of water colour produced from this type of information closely corresponded to the patterns depicted in satellite imagery.

Most bowheads sighted in 1985 were in ice-free areas, in green-coloured water from 20 to 50 m deep and in regions of slowly varying bottom slope. Whales were observed less frequently in clear blue-black, ice-covered waters such as on the Tuktoyaktuk Shelf or in deep water near the Shelf break. The statistical significance of these relationships is unknown, however, because of the small number of whales sighted during each survey.

### Distribution of Bowheads in Relation to Sea Surface Temperature Patterns

<u>18-25 August, 1985</u>. Plates 1 and 2 illustrate the spatial variability in surface water temperatures throughout the study area, and the relationships between observed bowhead distribution and these temperature patterns. Transects and whale sightings are plotted on images for the same days, except for the observations on two cloudy days (19 August and 12 September), which are plotted on the image for the following day.

The August images show a plume of warm water extending toward the north and west from the vicinity of Richards Island. Surface temperatures were near 13°C at the mouths of the river channels and between 9 and 13°C in the main body of the plume; the latter were largely restricted to an area less than 20 m deep surrounding Richards Island. This part of the plume was separated from colder surface waters over deeper areas further offshore by a thermal gradient which, in some places, reached 4°C in 2 km. It is evident from these photographs and from visual airborne observations that the bowheads observed on transects north and east of Kay Point during August were located in close association with the plume edge. A group of eight whales observed north of Kay Point on 19 August was within a narrow tongue of warm water that extended north past Kay Point from Mackenzie Bay. Observers during the systematic surveys noted pronounced changes in water colour within 2-3 km of all of these groups of whales. Two individual bowheads sighted west of Herschel Island were in an area of less distinct thermal gradients near the southern edge of the warm plume. Cold water present near the coast and the cold (0-1°C) water wake west of Herschel Island (apparent in the 21 August image) suggest that upwelling and turbulence may be important convergence mechanisms in this part of the southeast Beaufort Sea.

Whales were sighted along the Yukon coast during ferrying flights on 18 and 19 August, although comparison with thermal patterns in this area is not possible because cloud cover prevented receipt of satellite data. However, it is noteworthy that during the short (35-h) period of southeasterly winds on 20 and 21 August, the warm water moved away from the coast and was replaced by approximately 0°C water from a depth of about 5-6 m. Surveys for bowheads did not occur at this time and location, but large numbers of bowheads were documented along this part of the Yukon coast on 22 August during the photogrammetric study component.

Figure 8 illustrates the distribution of bowheads in relation to visual water colour observations recorded during a short repeat survey of the Yukon coast on 22 August. No satellite image was obtained on this day because of overcast conditions and local fog. However, airborne colour observations are generally consistent with the patterns depicted in images available for 21 and 24 August. A 10 to 20-km wide tongue of turbid water from the Mackenzie River extended almost to Herschel Island, whereas clearer, green water was present near the coast. The number and distribution of bowheads observed at the southern ends of the systematic survey transects were similar to those documented three days (19 August) earlier, although whales were no longer sighted to the north of the turbid tongue of the Mackenzie plume. This may have been attributable to the very poor survey conditions on 22 August (low ceilings, winds, and fog), or a slightly more northerly distribution of bowheads on 19 August.

<u>13 September, 1985. The relationship between the bowhead distribution observed during the</u> September surveys and water temperature patterns depicted in the 13 September satellite imagery is illustrated in Plate 2b. Most sightings occurred in Mackenzie Bay on 12 September when cloud cover was present in this area.

Bowheads were found in approximately the same locations as in August (i.e., along the western edge of the Mackenzie Bay thermal and turbidity plume

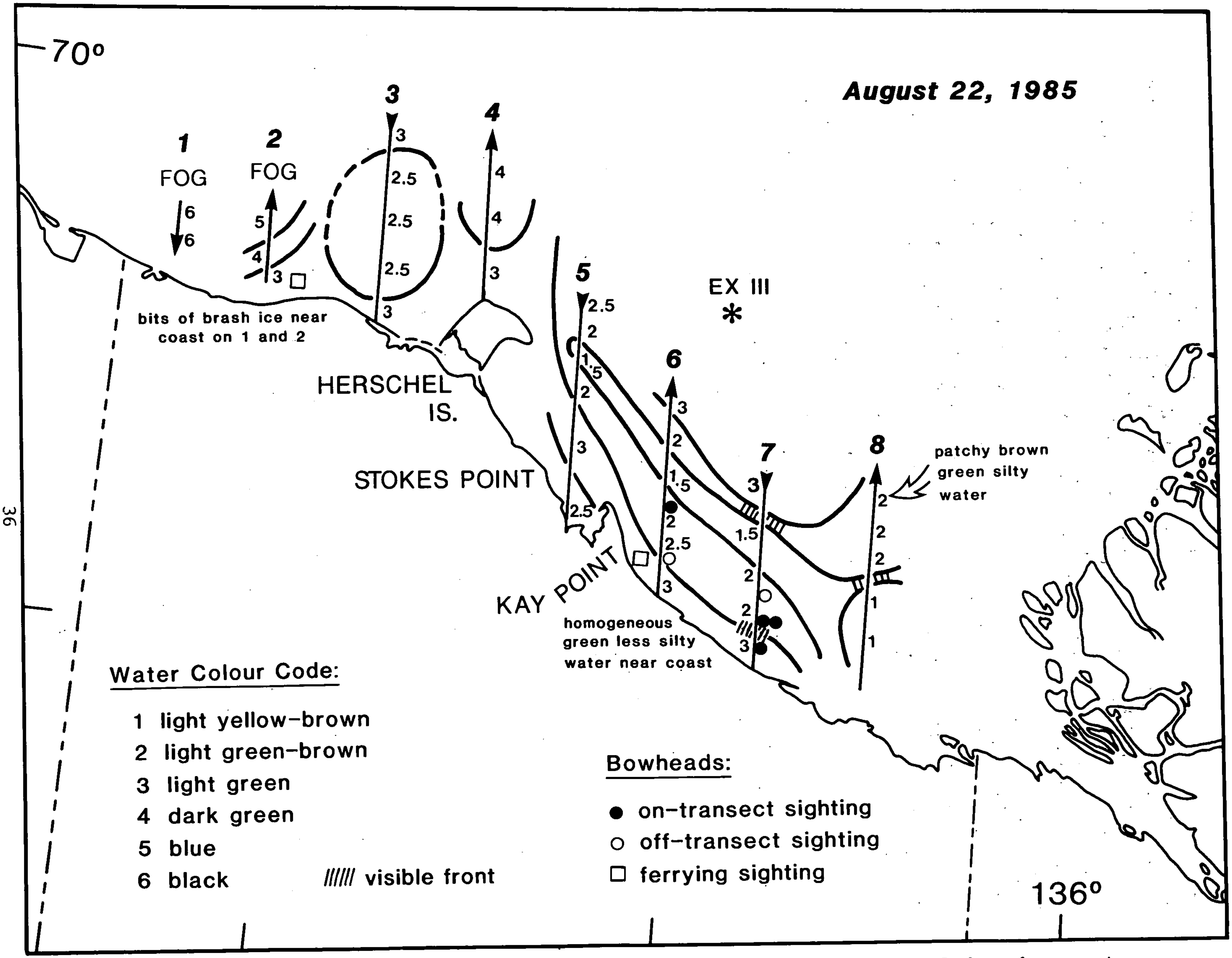


Figure 8. Visual water colour observations recorded during a repeat survey of the Yukon coast

and along the Yukon coast), but thermal contrast in the 13 September image was much less than observed in the August images. There is not a well-defined relationship between whale distribution and thermal patterns depicted in the one image available for September. An enhanced image for 13 September shows that the bowheads north of Shingle Point were located along the edge of the plume, but about 5-10 km west of the sharpest thermal gradients. The large congregations of animals along the coast off Komakuk Beach and at Kay, King, and Shingle Points were in water that was only slightly cooler than that further offshore. The single bowhead located 80 km north of Herschel Island on transect 4 was also present in an area of weak thermal contrast, but near the edge of the warm remnant plume in that region.

Thermal Gradients

As in 1984, the relationship between the distribution of bowhead whales and thermal gradients in areas influenced by the outflow of the Mackenzie River was evaluated during the present investigation. This involved the preparation of frequency distributions of the number of whales observed on- and off-transect and during ferrying flights, and the number of kilometres under the flight path (i.e., the available habitat searched), both as a function of the thermal gradients within about a 1.5-km radius of each bowhead sighting. The results of these analyses for the August and September surveys are shown in Figures 9 and 10, respectively. The frequency distribution for the kilometres under the flight path was the sum of those areas which were both cloud- and ice-free on the day of a given survey, except for 19 August which was cloudy and, therefore, gradients were calculated from the image available for the following day. Because the position of whales observed during ferrying flights was not precisely determined, these observations are presented separately from on- and off-transect whales in the two histograms.

During the August systematic surveys, the frequency distribution data indicate that on- and off-transect bowheads were more likely to occur in habitats characterized by higher thermal gradients than would be expected on the basis of spatial extent of the available habitat surveyed with a given temperature gradient (Figure 9; Chi-square goodness of fit: $p<0.01$, df = 2, n = 44). At the same time, most whales documented during the ferrying flights were located in areas along the Yukon coast with relatively high thermal gradients.

In contrast to the situation observed in August, there was little evidence to suggest that bowheads were preferentially located in areas with relatively large thermal gradients during September (Figure 10; Chi-square $p>0.25$, df = 1, n = 25). The reason for the apparent difference in relationship between bowhead distribution and the location of thermal fronts is unclear, but may be related to a combination of factors. These include a change in the behaviour of bowheads prior to westward migration, a change in the temperature-salinity structure of the upper water column leading to a decrease in thermal contrast, or a lack of time for bowheads to respond to a change in position of the Mackenzie River plume.

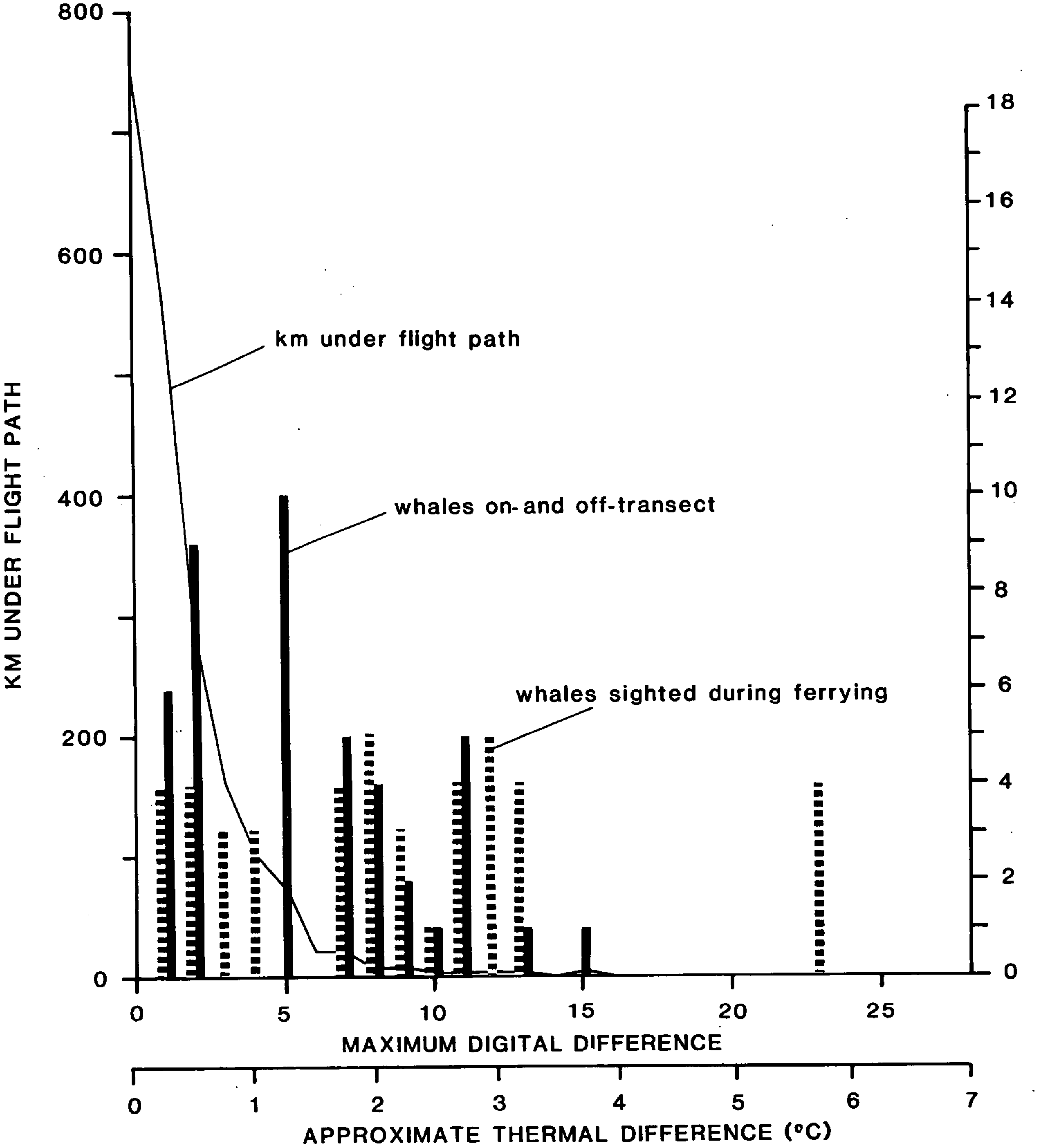


Figure 9. Comparison of the frequency histograms for bowheads observed from 18 to 22 August and transect kilometres (the available habitat searched) versus thermal gradients calculated from the 18, 20, and 21 August images. Gradients were measured from the satellite images as the maximum difference between the pixel at the location of the whale and the surrounding 8 pixels (approximately a 1.5-km radius).

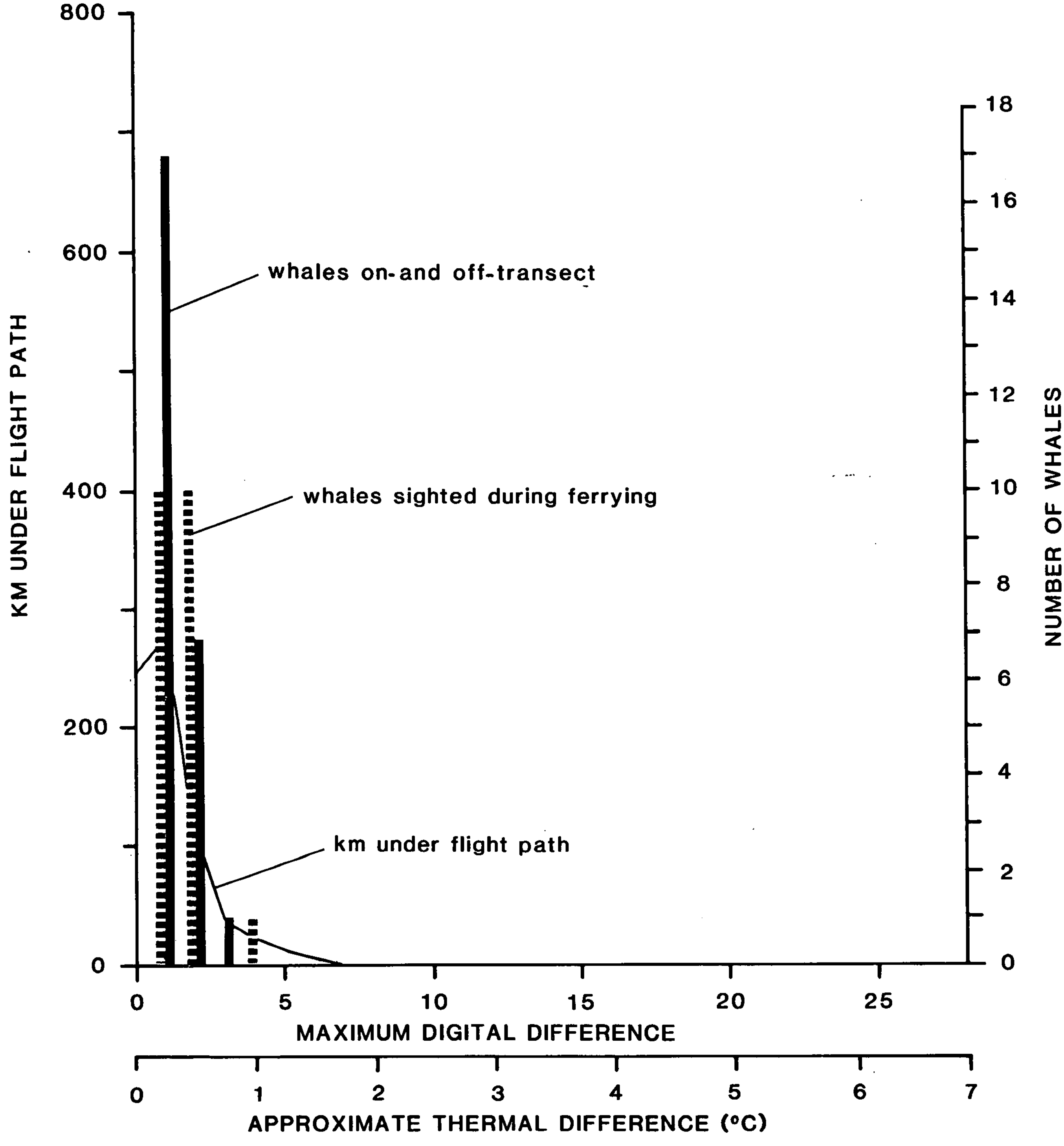


Figure 10. Comparison of the frequency histogram for the 12 and 13 September bowhead observations and transect - kilometres (the available habitat searched) versus thermal gradients calculated from the 13 September image.

RELATIONSHIP BETWEEN BOWHEAD WHALE DISTRIBUTION AND OCEANOGRAPHIC FEATURES IN THE BEAUFORT SEA

As indicated earlier, there is a hypothesis that the spatial and temporal variability in the distribution of bowheads on their summer range is at least partly associated with differences in the availability of their prey (zooplankton), which, in turn, is influenced by a number of oceanographic and meteorological processes. The Department of Fisheries and Oceans (Western Region) has been examining the distribution of zooplankton in the southeast Beaufort Sea since 1984. Its studies have shown that extremely large numbers of copepods are often found at the interfaces between warm fresh water and more saline waters in offshore areas (M. Lawrence, DFO, pers. comm.). Zooplankton have apparently been most abundant just below the less dense surface freshwater layer. Although this research has not been completed, the results of preliminary data analyses lend support to the suggestions of Borstad (1984) and Harwood and Borstad (1985) that higher zooplankton abundance at certain types of oceanographic fronts may lead to preferential feeding of bowheads in such areas. However, the types of fronts that may be characterized by relatively high densities of zooplankton in the Beaufort Sea remain unknown.

Most of the bowhead whales observed during both the August and September surveys were located in areas within Mackenzie Bay that were influenced by the Mackenzie River thermal and turbidity plume. Whales (transect line 8) appeared to be feeding along the edge of the main portion of the plume, and were observed in the same general area over a period of several days. At the time of both surveys, relatively large numbers of bowheads were seen near the Yukon coast off Shingle, King, and Kay Points. Although no in situ data are available to confirm the presence of high zooplankton densities in these areas, previous authors have suggested that upwelling along the Yukon coast may be responsible for the concentration of plankton organisms (Borstad 1984; Harwood and Borstad 1985). Evidence of a short-duration upwelling event associated with westward movement of surface waters is apparent in satellite imagery available for 20 and 21 August. On the other hand, no marked thermal gradients in the Kay Point area were evident in the 13 September image, despite the fact that many bowheads were present in this area. It is possible that some physical or biological factor not detectable in thermal images may have been responsible for the congregation of bowheads at this time, although this cannot be confirmed or refuted on the basis of available information.

It is also possible that bowheads tend to return to areas that were characterized by relatively high food availability in previous years, and may remain in such areas until reduced prey abundance or a migratory urge results in their movement to another area. There is a clear adaptive advantage for animals to return to areas within their summer range that have historically provided an abundant food supply. The region of Mackenzie Bay west of Richards Island has historically been an important bowhead summering (and presumably feeding) area. There is also increasing evidence that zooplankton are congregated below and at the edge of the Mackenzie River plume (Griffiths and Buchanan 1982; Erickson et al. 1983; M. Lawrence, pers. comm.). Consequently, the presence of bowheads in this part of the study area may be largely related to the presence of the Mackenzie plume and possible high densities of prey organisms at the plume edge and in areas along the Yukon coast where shallow upwelling from below the plume can concentrate zooplankton. Nevertheless, local and seasonal conditions such as the location of the pack-ice edge would also be expected to have a significant influence on the distribution of bowheads in the region in any given year.

## COMPARISON OF BOWHEAD WHALE DISTRIBUTIONS AMONG YEARS

The distribution of bowheads in 1985 was similar to that observed in August 1983 and 1984 and September 1985. In August 1984, surface winds were predominantly onshore, with strong northwesterlies occurring on some days (Atmospheric Environment Service 1985). As a result, the distribution of the Mackenzie plume near the end of the month was spatially limited, with its western edge situated approximately north of Shingle Point (Harwood and Borstad 1985). As was the case this year, large numbers of bowheads were repeatedly observed feeding in the vicinity of this plume edge during the last half of August 1984 (Harwood and Borstad 1985; Richardson et al. 1985a).

In late August 1983 and early September 1984, periods of easterly winds resulted in westerly surface water movements. Thermal images available for these periods indicate the presence of a warm plume that extended well beyond Herschel Island, with colder upwelled water occurring along the Yukon coast. A similar situation existed in 1985, when strong easterly winds resulted in the westward flow of warm water from the Mackenzie River. The presence of cold water along the Yukon coast also suggested that upwelling was occurring inshore of the plume. Although the frequency and duration of these events in each of these years remain unknown, the fact that large numbers of bowheads were documented in this region in three consecutive years provides circumstantial evidence that the distribution of at least some part of the bowhead population is correlated with oceanographic phenomena that may concentrate their predominant prey.

As in past studies of bowhead whales involving a satellite imagery component (Harwood and Borstad 1985; Thomson et al. 1986), strong thermal and turbidity gradients were observed during the present investigation in several areas where whales were not simultaneously documented. There are a number of possible explanations for the lack of bowheads in areas where they might be expected on the basis of oceanographic features depicted in satellite imagery.

a) Many of the physical and biological oceanographic factors that could influence the distribution of bowhead whales cannot be recognized in infra-red and visible satellite imagery. For example, the surface thermal imagery does not completely provide an indication of the near-surface density structure of the water column, particularly away from the sources of warm river water. As a result, this subsurface structure must be inferred from data for the surface only, usually in the absence of supporting _in situ_ observations.

b) Not all types of thermal gradients or oceanographic fronts are likely to be locations of relatively high densities of zooplankton. This is expected to be dependent on a range of meteorological, hydrological, and oceanographic factors, as well as the history of water masses and their associated planktonic communities.

c) Despite the suggestion that bowheads must feed almost continuously during their period of residence in the southeast Beaufort Sea to meet their annual energy requirements (Indian and Northern Affairs Canada and Environment Canada 1984), it is possible that other behaviours (e.g., social interaction) may also be important during this period and occur in the same general time frame as feeding behaviour.

## PART 4

## PHOTOGRAPHIC STUDIES OF BOWHEAD WHALES IN THE SOUTHEAST BEAUFORT SEA DURING AUGUST 1985

James Cubbage and John Calambokidis

### INTRODUCTION

This component of the 1985 Beaufort Sea bowhead whale monitoring program was completed during the same period as the August systematic surveys described in Part 2, and involved the use of a second survey aircraft and field crew. This component had the following two primary objectives:

- to determine the length frequency distribution of bowhead whales in various parts of the study area for evaluation of possible age segregation of the stock during its period of summer residence in the southeast Beaufort Sea; and
- to photograph individually recognizable whales to provide a basis for evaluation of site tenacity and movement patterns of bowheads on their summer range.

### FIELD METHODS

#### Survey Design

Aerial surveys were conducted for a total of 29 h (including ferrying and calibration time) to photograph whales previously sighted by the crew completing the systematic surveys. In all but one instance, the crew on the photographic plane was able to locate bowheads in the same areas where the systematic survey team found whales. On days when whales were not observed from the first plane, non-systematic lines were flown with the photographic plane to search for whales in other parts of the study area.

#### Field Equipment

Photographic surveys were conducted from a DHC-6-300 (Twin Otter) equipped with spare wingtip fuel tanks, bubble windows, an open camera hatch, and a portable microcomputer-based data acquisition system. Photographs of whales were taken with two cameras. For photogrammetric measurements of whale lengths, a Pentax 6x7 cm format camera with a 105-mm lens and Ektachrome ISO

200 film was used. Photos for individual identification of whales were taken with either a Nikon FE (35-mm format) equipped with motordrive and low dispersion f2.8 180-mm ED lens loaded with Ektachrome ISO 200 film, or a Nikon FM2 with the same type of motordrive and lens, but loaded with Tri-X black and white film rated at 1600 ISO.

Custom-designed equipment was used in conjunction with the camera gear described above. The photogrammetric camera (Pentax) was maintained in a vertical position with respect to the sea surface with an electronic levelling system. The system consisted of a series of mercury switches mounted on the back of the camera; tones were produced when the camera was within 4 degrees of vertical in relation to the ground. A portable computer (Compaq) was interfaced with the aircraft navigation system (GNS) and radar altimeter, and was used to record all flight data. Through a connection with the strobe output on the Pentax, a signal was sent to the computer at the instant a photograph was taken with the photogrammetric camera to record the exact altitude, time, and location. Custom software developed by Cascadia was used to operate the data acquisition system. For each photograph, both the computer-accessed flight data and information directly entered to the keyboard by an observer were saved as a disk file and printed to provide a hard-copy back-up.

### Photographic Procedure

Each day, the photographic surveys were initiated 2-3 h after the systematic survey crew and aircraft left Inuvik, as observations of the latter crew generally provided the direction to the photographic component of the study. The photographic surveys were conducted from an altitude of 225 m (750 ft) and air speed of 185-205 km/h (100-110 kts). Observers occupied the co-pilot's seat and cabin seats adjacent to bubble windows on each side of the aircraft. Throughout the surveys, communication among the observers and the pilot was maintained through the use of the onboard intercom system. The manual entry of data into the microcomputer was completed by the observer occupying the co-pilot's seat.

When bowheads were sighted, the two observers in the main cabin moved to the camera hatch (approximately 45 x 60 cm) located in the floor at the aft end of the aircraft. For safety reasons, both observers were attached to harnesses. The photogrammetric cameraman faced aft and the photo ID cameraman faced forward on the aft side of the hatch. After the pilot oriented the aircraft over the whale at an altitude of 145 m and speed of 165 km/h (475 ft and 90 kts), the ID cameraman panned and shot two to five photos as the whale came into view slightly forward of the aircraft. The photogrammetric camera was fired once as the whale passed directly beneath the aircraft. Data on the camera level and frame numbers from the ID camera were then relayed to the observer in the co-pilot's seat and recorded on the computer. All photographs were taken at a minimum shutter speed of 1/1000 s. The focus on the photogrammetric camera was fixed at 150 m (500 ft).

## Calibration and Verification Procedures

To calibrate the altimeter and the focal length of the photogrammetric camera, repeated flights were made over a target of known length. The target consisted of two strips of sailcloth 15 m long with white bands sewn every 5 m. The strips were arranged in a cross with one axis along the flight path and the other perpendicular to it. The strips were staked down and measured before and after the calibration flights.

The calibration target array was photographed at Shingle Point on 18 August as the first flight of the study. Additional photos were taken on 25 August. Ten vertical photos taken at a shutter speed of 1/1000 s during these two flights form the basis of the calibration of the system.

To verify the calibration, photographs of additional targets distinct from the calibration target were taken. The verification targets were between 12.5 and 13.5 m long and were placed near refuelling areas or the calibration target. Photographically derived measurements of the verification targets provided a good estimate of system precision and accuracy.

## LABORATORY PROCEDURES

Once the crew returned from the field, all photographic film was processed and the computer disks were copied as part of a normal back-up procedure. Photo catalogues were then produced on the basis of the computer data base record of the survey. The images of whales on photographs were measured with a binocular dissecting microscope at 25x magnification. An ocular reticle with 100 marks per 4.08 mm of stage distance was calibrated with a stage micrometer to the nearest 0.01 mm. Images were measured to the nearest 0.04-0.02 mm, depending on the image quality. Images were graded according to apparent flex of the whale in the vertical axis, and measurements were taken from the end of the rostrum (snout) to the notch in the flukes. The resolution of the images at these measurement points was also graded. Both types of grades used a five-point scale shown in Table 8. All images with views of the snout and fluke notch were examined and measured three times by a single observer. The average of these measurements was then used for subsequent analyses. Grades for both flex and resolution were also averaged.

## Calibration Targets

As indicated above, a total of 10 vertical photographs of the calibration targets was obtained during the field program. For each photo, six lengths (5, 10, and 15 m along and across the flight path) were subsequently measured in the laboratory. Photo scales derived from measurements of the targets (SM) were compared with scales derived from the

TABLE 8

Grades of photo images observed and noted during image measurement.[a]

| Grade | Description |
|---|---|
| Overall whale orientation | |
| 1 | Whale is straight, without apparent flex or arch. |
| 2 | Whale is slightly arched or flexed. |
| 3 | Whale is definitely arched or flexed. |
| 4 | Whale is severely arched and a measurement will certainly underestimate length of animal. |
| 5 | Unacceptable. |
| Rostrum tip and fluke notch resolution | |
| 1 | Good resolution; measurement point is clear and unequivocal. |
| 2 | Fair resolution; point is apparent, but somewhat indistinct. |
| 3 | Poor resolution; point is barely visible and indistinct. |
| 4 | Estimate; point is obscured, but nearby clues (jaws, fluke tips, caudal peduncle) allow a reasonable estimate. |
| 5 | Unacceptable. |

[a] Each whale was given three grades: one on individual orientation, and one each on fluke notch and rostrum tip resolution.

altimeter reading and nominal focal length of the camera lens (SA). The relationship is described by the following equation:

$$SM = 6.71 + 1.01(SA)$$

As is evident in Figure 11, the relationship between the true scale and the altimeter/focal length-derived scale was highly linear ($r^2 = 0.996$, $n = 10$) and therefore used to calibrate all measurements. It should be noted that this equation simultaneously calibrates the nominal focal length of the lens as well as the nominal altitude reported by the aircraft's altimeter. Thus, the equation used to measure all whales and verification targets was:

$$\text{object size} = \text{image size}\ [6.71 + 1.0195\ (\text{altitude/focal length})]$$

Verification targets

To determine the accuracy of the above calibration, measurements based on the photogrammetric system were compared with the true measurements of three verification targets. Two verification photos taken on 21 August, one taken on 24 August, and six taken on 25 August were measured to evaluate the accuracy of the calibrated measurement system. The first three photos were taken at McKinley Bay and the last six at Shingle Point. The photogrammetric measurements are compared with true measurements in Table 9.

A relatively high level of precision and accuracy in the measurement system is evident from this comparison. The variance is significantly lower than that reported by both Davis et al. (1983)[1] and Cubbage et al. (1984) for their photogrammetric procedures ($p<0.01$, two-tailed variance ratio test; Zar 1984). It is also emphasized that the above results are based on measurements of targets that were independent of those used for calibration and involved photography of targets at different locations and times. The low variance achieved during this program is attributed to the electronic camera level system and the instant unequivocal altitude record provided by the computer data acquisition system. These devices were not used in the Davis et al. (1983) study and their application was not perfected at the time of the Cubbage et al. (1984) investigation.

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[1] Davis et al. (1983) reported variances for mean measurements of 9.55 and 14.31 m. The estimated variance for a 12.79-m (SD = 0.14 m) measurement was interpolated linearly from their variance data on 9.55 m and 14.31 m, and then compared with the variance determined for the present study.

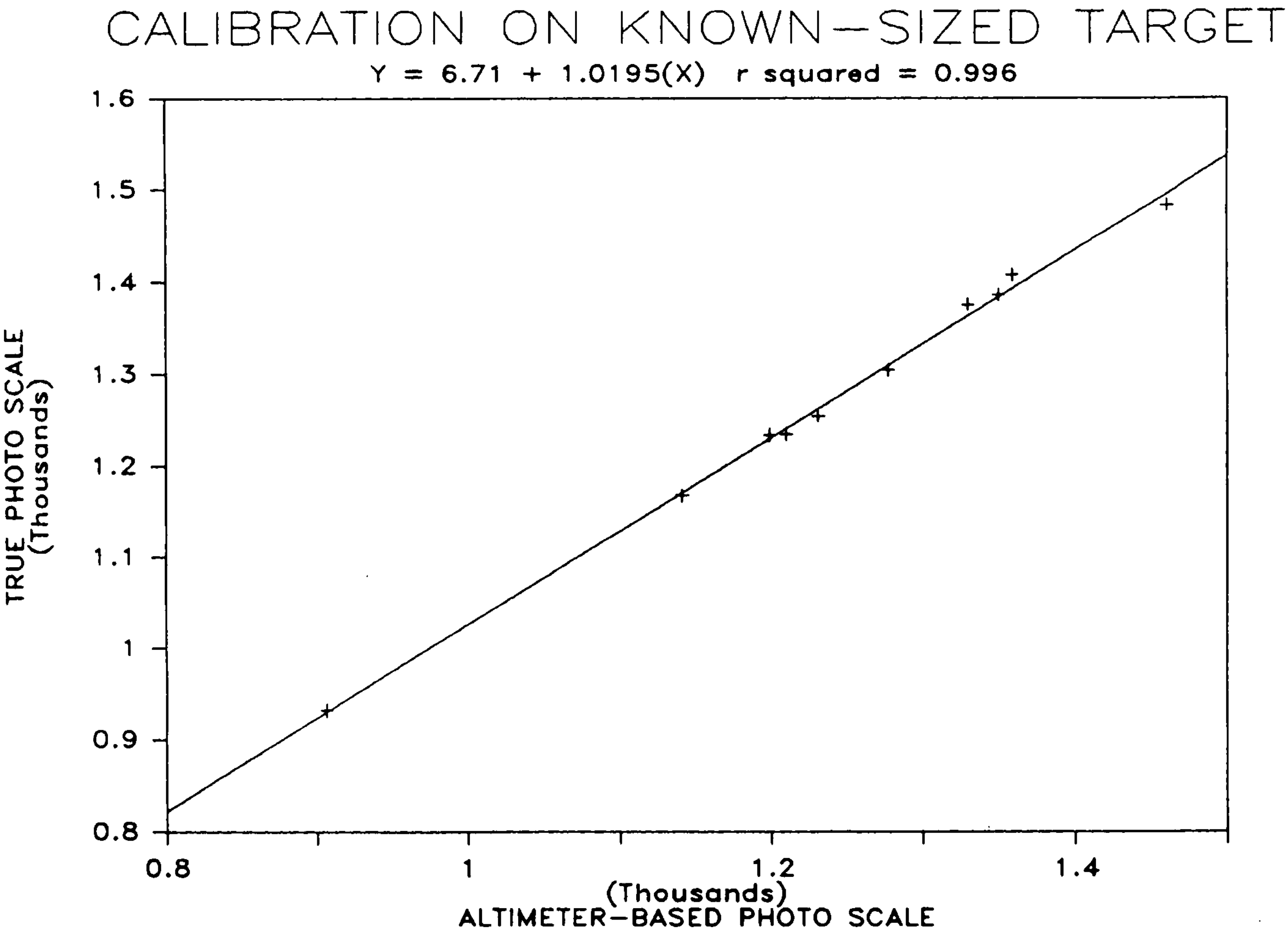


Figure 11. True photo scale (true length/photo image length) regressed on altimeter-based scale (altitude/focal length)

TABLE 9

Lengths of verification targets measured through photogrammetry

| Photo No. | Flight altitude (m) | True length (m) | Measured length (m) | Error (m) | Per cent Error |
|---|---|---|---|---|---|
| 45 | 110 | 13.104 | 13.26 | 0.156 | 1.18 |
| 46 | 131 | 13.104 | 13.18 | 0.076 | 0.58 |
| 52 | 139 | 13.50 | 13.62 | 0.12 | 0.86 |
| 106 | 88 | 12.50 | 12.51 | 0.01 | 0.06 |
| 108 | 120 | 12.50 | 12.45 | -0.05 | -0.38 |
| 110 | 130 | 12.50 | 12.59 | 0.09 | 0.75 |
| 112 | 135 | 12.50 | 12.56 | 0.06 | 0.47 |
| 115 | 127 | 12.50 | 12.51 | 0.01 | 0.07 |
| 116 | 169 | 12.50 | 12.41 | -0.09 | -0.73 |
| Mean | | 12.75 | 12.79 | 0.042 m<br>SD = 0.080 m | 0.32 |

Coefficient of variation = 0.6 per cent of the measured mean

## Systematic Errors

Errors associated with radial lens distortion, film flatness, and affine distortion caused by aircraft motion and focal plane shutter movement all contributed to the variance in the measurement system shown in Table 9. It is expected that the magnitude of these errors did not vary throughout the survey and thereby contribute additional unmeasured systematic error. A detailed discussion of possible sources of error in whale photogrammetry is provided in Cubbage et al. (1984).

## Individual Identification

All slides and negatives were examined to determine the occurrence of recognizable individual whales in more than one photograph. Prints were made when specific animals had clear markings that may allow them to be reidentified in photos taken in a subsequent year. These prints were also examined for intra-year matches.

## Repeat Measurements

Repeat measurements were conducted on bowheads that could be identified by scars to examine variance in the whale measurement system and contrast it with that found for the verification targets. Davis et al. (1983) reported that the chance of reidentifying a bowhead increased with its size (and presumably age) because the larger animals have more prominent scarring. The majority of the bowheads photographed during this study were small, and, as a result, there were few opportunities for repeat measurements of reidentified animals. Table 10 shows the repeat length measurements of the three whales that were reidentified from photographs taken on 25 August.

There was a greater degree of variance in the whale length measurements than detected with the verification targets discussed above. The average variation in the lengths of individual whales was 1.5 per cent of the average measured length of each whale. The comparable figure for the verification targets was 0.6 per cent. The primary reasons for the increase in variability during actual measurements of bowheads are expected to be whale flex and arch and the reduced resolution in photographs taken through turbid water. Differences in whale orientation with respect to the surface and light refraction also contribute to measurement variance, but to a lesser extent than the factors mentioned above.

TABLE 10

Lengths of measurable reidentified whales[a]

| ID No. | Photo No. | Date | Mean grades[b] Flex | Snout reso | Fluke reso | Length (m) |
|---|---|---|---|---|---|---|
| 85-01 | 54 | 25 Aug. | 3.0 | 1.0 | 1.3 | 12.35 |
| 85-01 | 55 | 25 Aug. | 2.0 | 1.0 | 1.0 | 11.93 |
| 85-01 | 56 | 25 Aug. | 1.0 | 1.0 | 1.0 | 12.44 |
| 85-29 | 149 | 25 Aug. | 2.7 | 2.0 | 2.0 | 10.72 |
| 85-29 | 150 | 25 Aug. | 2.7 | 3.7 | 4.0 | 10.57 |
| 85-30 | 149 | 25 Aug. | 3.7 | 2.0 | 1.0 | 11.57 |
| 85-30 | 150 | 25 Aug. | 1.7 | 1.7 | 1.7 | 12.07 |

a Photos with resolution or flex grades worse than 3 on more than half the replicate observations are not included.
b reso = resolution grade

## RESULTS AND DISCUSSION PHOTOGRAMMETRY

### Length Frequency

Whales were present in 77 of the photographs taken with the photogrammetric camera during the 1985 bowhead whale monitoring program. Images that had both resolution and flex grades worse than 3 in more than half the replicate observations were culled and not considered further in this study. Four images of duplicate whales that were identified as a result of obvious scarring were also removed in determination of the length frequency distribution of the component of the bowhead population photographed this year. After this screening, 47 images of a quality suitable for further analysis and discussion remained. A histogram of the whale length determined in 1985 is presented in Figure 12; the location and length of each measured animal are indicated in Appendix H.

Adult bowhead whales are clearly underrepresented in the sample obtained in the present photogrammetric study. Adult bowheads are probably not less than 12.5 m in length (Cubbage et al. 1984; Nerini et al. 1984). Information on the length of adults has been obtained from landed whales and examination of ovaries, as well as from three-dimensional (3-D) aerial photography. The 3-D photography results in measured lengths that are consistently about 3 per cent greater than those derived from measurements of 2-D images. Therefore, for the purpose of this investigation, 12 m is considered the lower length limit for an adult female bowhead; this figure is consistent with data presented in Davis et al. (1983). Using this 12-m size limit, only 11 per cent of the bowheads photographed in 1985 (5 of 47 measured animals) can be considered adults.

Based on an upper limit of 7.5 m for a bowhead calf (Cubbage et al. 1984; data adjusted for present 2-D photogrammetry), 8.5 per cent (4 animals) of the measured whales were considered calves. It is noteworthy that the largest bowhead observed in 1985 was accompanied by the smallest, and were obviously a cow-calf pair.

### Length by Location

As is evident from Figure 13, the majority of bowhead whales photographed during this study component (44 of 47 animals) occurred in the Mackenzie Bay area. Despite two days of survey effort to the east of Tuktoyaktuk, only three usable whale lengths were obtained in this region. Nevertheless, the largest and smallest bowheads were documented off Atkinson Point in this part of the study area. Three other possible adult bowheads (12-12.5 m) were photographed in the Mackenzie Bay area, and three whales that were likely calves (7-7.15 m) were also observed in the same general region.

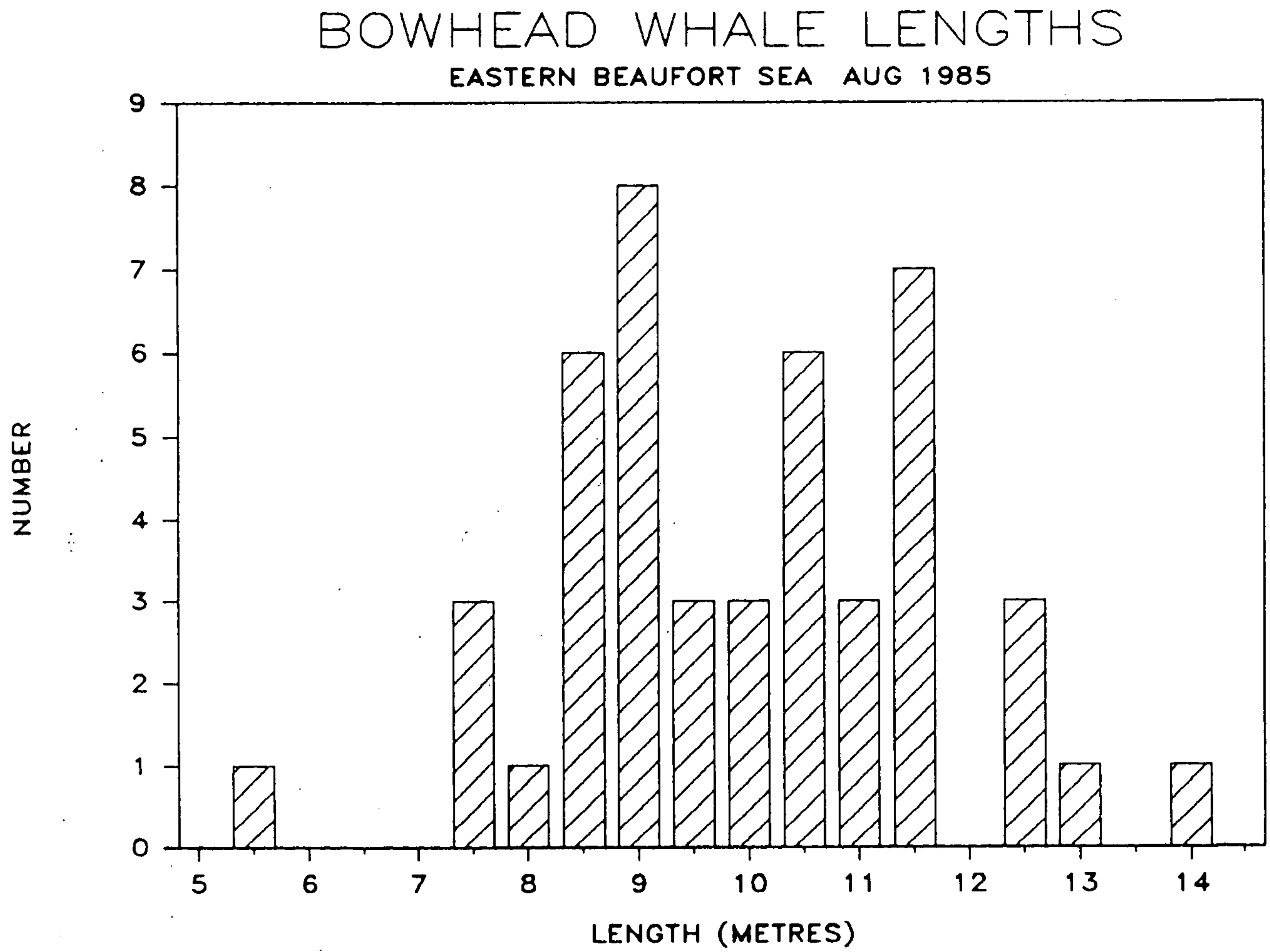


Figure 12. Frequency distribution of the lengths of the 47 bowhead whales measured in 1985 from photos of acceptable quality (see text)

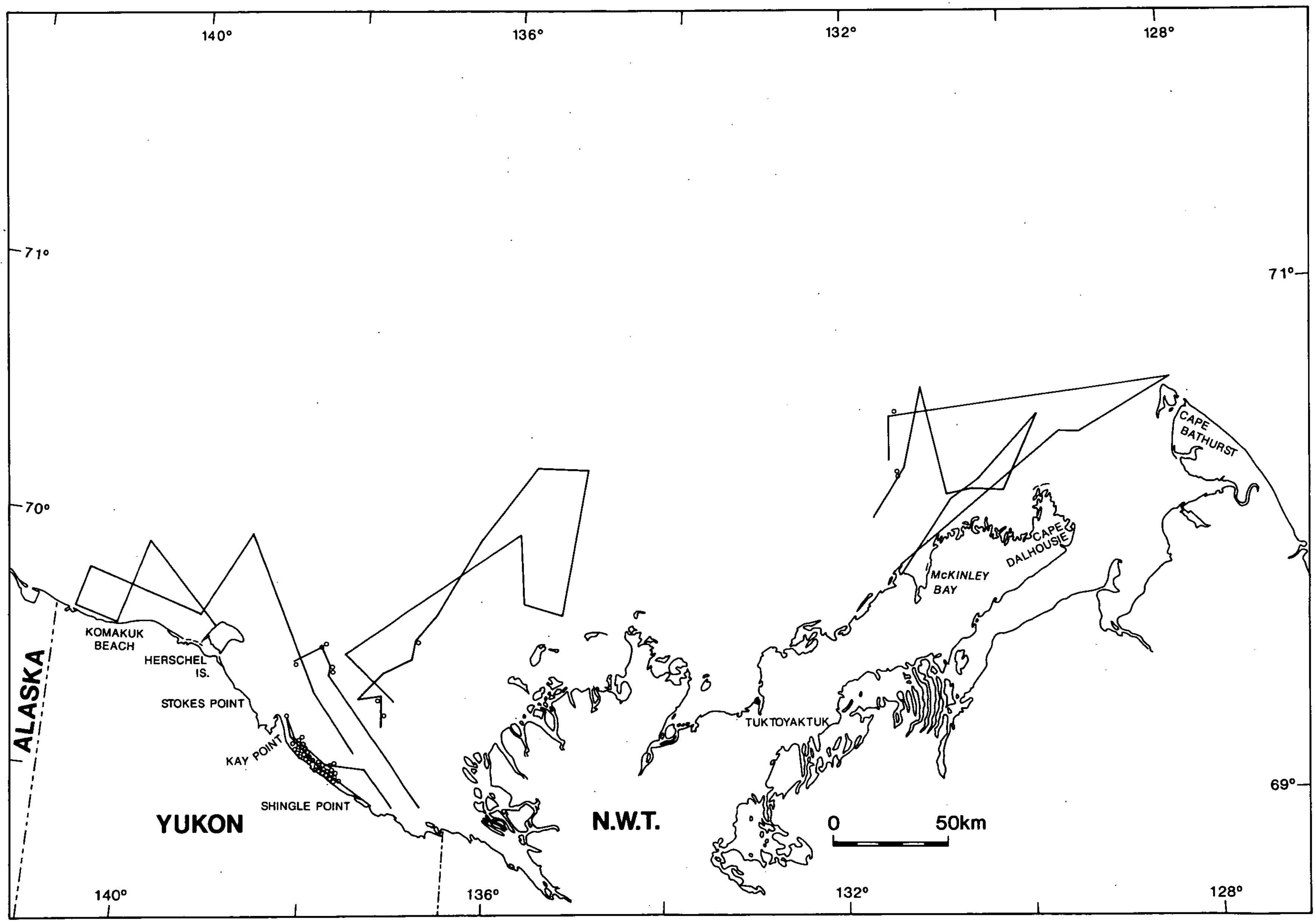


Figure 13. Locations of bowhead whales measured for length in the photogrammetric study component (n = 47).

The region where most bowheads were photographed was characterized by the presence of relatively turbid water associated with the Mackenzie River plume. This hampered the simultaneous resolution of a whale's fluke notch and snout in the same photograph and, therefore, limited the number of usable images compared with the success of photogrammetric measurements when whales occur in clear water. However, an apparent upwelling event resulted in relatively clear water near the coast on the last day of the survey, making it possible to photograph bowheads near the area of their highest observed densities. Useful measurements could still not be obtained from whales that were vertically flexed in the water because the measurement points were not discernible below a water depth of approximately 1 m.

## Comparison of Bowhead Lengths Determined in Various Studies

There are significant differences in the length frequency of bowhead whales determined during this study and those documented in 1982 (Davis et al. 1983) and 1983 (Cubbage et al. 1984). Both previous studies also involved measurement of bowhead lengths in the eastern Beaufort Sea using photogrammetric techniques. Although the 1982 and 1983 studies had a larger geographic scope, they did encompass the region surveyed during the present investigation. Photogrammetric studies were also completed in 1981 and 1984. The results of the former investigation (Davis et al. 1982) are not compared with the present data because of their preliminary nature. The results of 1984 studies (Davis et al., in prep.) have not yet been published.

The results of 1982, 1983, and 1985 photogrammetric measurements of bowhead whales in the southeast Beaufort Sea are compared in Table 11. For the purpose of this comparison, bowhead lengths were divided into four classes: <8 m, 8-10 m, 10-12 m, and >12 m. Bowhead whale lengths in 1985 were significantly smaller than those measured in both 1982 and 1983 (t-test, $p<0.001$), and there were also significant differences in the proportion of whales in the four size classes (chi-square test, $p<0.001$ for both cases). The primary difference between the 1985 measurements and those from 1982-1983 is the low proportion of whales longer than 12 m found in 1985; the percentages of measured whales in this size category in 1982, 1983, and 1985 were 45, 48, and 11 per cent, respectively. The proportion of whales in the 8 to 10-m length category was substantially greater in 1985 than in the two earlier investigations. The small bias (about 3 per cent) caused by comparison of animal lengths measured with 2-D (1982 and 1985) and 3-D (1983) photogrammetry is expected to be insignificant in relation to the large yearly differences in the size class distribution of photographed whales.

Significant differences in the lengths of bowhead whales on various parts of their summer range have been documented by Cubbage et al. (1984), and may partially explain the differences in the length distribution of bowheads among the years compared in this report. Because of the potential for geographic segregation of different size classes of bowheads in the southeast Beaufort Sea and Amundsen Gulf region and the effect this would have on

TABLE 11

Bowhead whale lengths separated into four size classes for comparison of 1985 results with those for 1982 and 1983[a]

| Year | n | Size classes in (m) <8 | 8-10 | 10-12 | >12 | Mean | SD |
|---|---|---|---|---|---|---|---|
| All areas | | | | | | | |
| 1982 | 361 | 43 (12) | 53 (15) | 99 (27) | 166 (46) | 11.7 | 2.7 |
| 1983 | 197 | 20 (10) | 34 (17) | 49 (25) | 94 (48) | 11.9 | 2.8 |
| 1985 | 47 | 6 (13) | 20 (43) | 16 (34) | 5 (11) | 9.8 | 1.7 |
| Mackenzie Bay area only | | | | | | | |
| 1982 | 250 | 24 (10) | 36 (14) | 76 (30) | 114 (46) | NA[b] | NA |
| 1983 | 91 | 11 (12) | 26 (29) | 39 (43) | 15 (16) | 10.5 | 2.3 |
| 1985 | 44 | 5 (11) | 20 (45) | 16 (36) | 3 ( 7) | 9.7 | 1.5 |
| 1983 Mackenzie Bay lengths separated into N and S groups[c] | | | | | | | |
| 1983 | 57 | 10 (18) | 10 (18) | 27 (47) | 10 (18) | 10.6 | 2.6 |
| 1983 | 34 | 1 ( 3) | 16 (47) | 12 (35) | 5 (15) | 10.4 | 1.8 |

a Percentage of whales in each size class is shown in parentheses. Data for 1982 are from Davis et al. (1983) and for 1983 from Cubbage et al. (1984). Lengths for 1983 are from data base C (see Cubbage et al. 1984).

b Not available from Davis et al. 1983.

c Dividing line for North and South groups was 69°40'N.

comparisons of data from different years, further inter-year analyses were completed for only those bowheads present in the Mackenzie Bay area, where most whales were observed and photographed in 1985. Cubbage et al. (1984) provided data on bowhead lengths for four regions, and one of these (Region No. 2) includes the Mackenzie Bay area and waters north to 70°30'N latitude. Similarly, Davis et al. (1983) included data on the lengths of bowheads in different areas, and one of these (Herschel Core) is located to the north of, but most closely corresponds to, the Mackenzie Bay area. When 1983 and 1985 data were compared for Mackenzie Bay, there was no significant difference (chi-square, $p>0.05$) in the proportion of bowheads within each of the four size classes described above. However, this was not the case when the 1982 data for Herschel Core were compared with the 1985 data for Mackenzie Bay. The reason for the significant differences in the size class distribution of bowheads between 1982 and 1985 is unknown, although the more northerly location of most whale sightings in the former year may reduce the comparability of the results of the two studies.

Examination of inter-year differences in bowhead length frequency distributions is further complicated by the differences in lengths of whales that occur even between adjacent areas in a given year. Differences in the lengths of bowhead whales found in the northern and southern portions of Mackenzie Bay in 1983 (boundary is 69°45'N) are also shown in Table 11. There was a significant difference in the lengths of whales located in these two areas (chi-square, $p<0.05$), primarily due to the greater proportion of 8 to 10-m animals in the southern part of Mackenzie Bay.

It is possible that the higher proportion of 8 to 12-m bowheads found in Mackenzie Bay during 1983 and 1985 may reflect a recent change in the distribution of the population on its summer range, with primarily young animals occurring in the Bay and along the Yukon coast. It is equally plausible that the distribution observed in 1982 was atypical of an otherwise consistent spatial distribution pattern. Nevertheless, the predominance of smaller bowheads in this part of the southeast Beaufort Sea suggests that some factor, or group of factors acting in concert, is "attracting" young animals or "repelling" older ones in this area, and/or there is some (as yet) unknown but inherent behavioural pattern responsible for the presence of younger bowheads in the Mackenzie Bay - Yukon coast area. For example, there is increasing circumstantial evidence that bowheads in this part of the Beaufort Sea are frequently found close to oceanographic features that may either lead to concentration of their prey (e.g., convergence areas associated with upwelling phenomena) or have relatively high densities of prey organisms at certain times (e.g., edge of the Mackenzie River plume).

Because the majority of the bowheads present in the study area were not adults and younger animals cannot be readily identified through patterns of scars, it is likely that some duplicate animals were present in the sample analysed for length frequency distribution. Several analytical procedures were considered to reduce the potential number of duplicate measurements. For example, an algorithm based on whale location and potential swimming speeds was described by Cubbage et al. (1984) to cull the data set for all possible duplicates. However, when this method was applied to the present data, it severely reduced the number of closely congregated whales near Shingle Point (i.e., all but six animals). If length is considered in the algorithm so that adjacent animals greater than 1.0 m apart in length are not removed, the length categories with higher frequencies are culled proportionately more often than samples at the outlying frequencies. It is possible to replace observations that were removed by the location algorithm if they appear different on the basis of scars, although this then skews the data toward older, more easily identified animals. In view of these analytical biases, the algorithm described by Cubbage et al. (1984) was not applied to the present data. Although some unidentified bowheads may have been measured more than once, the fact that at least 50 and perhaps up to 180 bowheads were in the area (see Part 2) minimizes the risk of repetitive sampling.

## Integration of Photogrammetric and Systematic Survey Results

The location of bowheads observed and photographed during this component of the 1985 monitoring program reflected the relative distribution and abundance noted in the systematic aerial surveys. Of the 40 bowhead whales observed during the systematic surveys, 35 (87.5 per cent) were located in the Mackenzie Bay region. In the photogrammetric study component, 94 per cent (44 of 47 animals) of the bowheads were photographed in this area. Therefore, the study team assigned to the photogrammetric component of the investigation "sampled" whales in rough proportion to their distribution and abundance in the study area.

Given the range of correction factors applied to the systematic survey data to arrive at population densities (particularly related to the time that whales are present at the surface), it is possible that up to 98 per cent of the Western Arctic population of bowhead whales was present in the study area during August 1985. However, for reasons outlined below, it was concluded that a sizeable fraction of the population did not occur within the areas surveyed. If it is assumed that an unbiased sample of animals in the study area was obtained during the photogrammetric investigations (i.e., the measurable images were obtained in rough proportion to the regional abundance of bowheads), the resulting inferred age structure would be inconsistent with the basic biology of the bowhead whale. Data presented in Breiwick et al. (1984) provide evidence that immature individuals comprise no more than 40 per cent of the population, whereas 89 per cent of the bowheads measured through photogrammetry in the present study would be considered immature. If it is assumed that the entire immature component of the population was present in the study area, and an additional 12 per cent of those animals in the area were mature (i.e., 5 mature animals/42 immature animals = 0.12), then no more than 1979 bowheads were present in the region based on the IWC (1986) estimate of current population size (1.12 x [0.4 x 4417]). Thus, absolutely no more than 45 per cent of the current estimate of the size of the bowhead population occurred in the study area. It is also concluded that the age structure of bowhead whales in the study area during August 1985 was highly skewed toward yearlings and subadults.

# RESULTS AND DISCUSSIONS - INDIVIDUAL IDENTIFICATION

## Technique Evaluation

Images of 30 whales photographed in 1985 were of sufficient resolution to warrant inclusion of prints in the master catalogue of bowhead whale photographs archived by the National Marine Mammal Laboratory in Seattle, Washington. These prints were not selected only because of their high resolution and clear definition, but also because each animal had distinct markings that could allow future reidentification. Four of these bowheads were photographed more than once during the present investigation, although the majority of the whales photographed were small and few had sufficient scarring to allow reidentification through matching of photos from future bowhead research or monitoring programs.

The use of a second camera that was dedicated to photographic identification of whales appeared to be an improvement over techniques used in earlier studies, as the additional cameraman was able to pan off vertical to search for whales as they passed under the survey aircraft. The use of a motordrive on this camera also allowed several photos to be taken of an individual whale, and subsequently provide a greater number of images to allow distinction of whale markings from seawash and glare. However, the most significant improvement in photographic procedure was the increased resolution associated with the use of a 180-mm lens (70 per cent greater focal length) on the photo ID camera compared with the 105-mm lens mounted on the camera employed for photogrammetric measurements. The Nikon 180 ED lens is also specifically constructed to produce very high resolution images with low chromatic aberration.

## Other Observations from the Photographic Study Component

One bowhead (Photo No. 85-20) was reidentified just over 1 h after it was initially sighted, and moved less than 0.18 km in the 78 min between observations. Because analysis of navigational data associated with other resightings within less than 5 min and the photography of calibration targets indicate that the accuracy of the navigational system is unreliable within distances of 1.8 km, it is concluded that this individual bowhead remained in essentially the same location (or moved no more than 1.8 km) for a period of 1 h or more.

Review of photographs obtained during the present monitoring program also provides evidence that bowheads were actively feeding near the Mackenzie Delta. The photographic record clearly shows mud trails streaming from the mouths of whales, a bowhead swimming on its side with its mouth open, and faces behind several animals. The close proximity of whales in some groups was also evident in some photographs, as up to three bowheads were documented in a single frame (an area of about 80 x 90 m).

# PART 5

## EVIDENCE RELATED TO EXISTING HYPOTHESES ON FACTORS AFFECTING BOWHEAD WHALE DISTRIBUTION IN THE SOUTHEAST BEAUFORT SEA

Wayne S. Duval

Two hypotheses have been formulated as part of the Beaufort Environmental Monitoring Project (BEMP) to explain the annual variability in the distribution of bowhead whales observed in the southeast Beaufort Sea since systematic aerial surveys were initiated in 1980 (Indian and Northern Affairs Canada and Environment Canada 1984, 1985). One hypothesis suggests that activities of the oil and gas industry have caused, or contributed to, the exclusion of bowheads from the development zone (the "exclusion hypothesis"). The second hypothesis suggests that the distribution of bowheads is determined by physical and biological oceanographic factors, particularly those influencing the distribution and abundance of zooplankton (the "food hypothesis").

During the most recent BEMP workshop addressing the bowhead whale (Indian and Northern Affairs Canada and Environment Canada, in prep.), it was concluded that testing of these hypotheses is unlikely to be possible within a sound statistical framework and, therefore, must rely on the "weight-of-evidence" from past and future research and monitoring efforts directed at this species. This concluding section of the report summarizes the results of the 1985 bowhead whale monitoring program in relation to these two hypotheses, and offers additional ideas on factors that may be affecting the distribution of bowheads in the study area. It is emphasized that both hypotheses may be valid to a greater or lesser extent, despite the increasing evidence that distributional patterns may be related to natural oceanographic phenomena. This section also discusses possible differences in the bioenergetic requirements and feeding preferences of various age classes in the bowhead population.

### THE EXCLUSION HYPOTHESIS

The relationships between the distribution of bowhead whales and the location of petroleum industry activities in the Beaufort Sea between 1976 and 1984 were recently examined and summarized by Richardson et al. (1985a). The primary impetus to the exclusion hypothesis appears to be the comparison of the results of the first systematic surveys conducted in 1980 with those from subsequent years. In that year, large numbers of bowheads were found in the portion of the Beaufort Sea where most industry operations were focused (Renaud and Davis 1981). Fewer animals have been sighted in the zone of industry activity since 1980, although it is apparent that substantial inter-annual variability exists in the distribution of this population within the region (Davis et al. 1982; Harwood and Ford 1983; Harwood and Borstad 1985; McLaren and Davis 1985; present study).

The evidence in support of the exclusion hypothesis has been examined during the workshops conducted as part of the Beaufort Environmental Monitoring Project (Indian and Northern Affairs and Environment Canada 1984, 1985). For example, marine vessel movements through or near areas where bowheads are congregated have caused avoidance reactions, although affected individuals reoccupy ship tracks and resume normal behaviour within 1 or 2 h (Richardson et al. 1983a, b, both cited in Indian and Northern Affairs Canada and Environment Canada 1984). Concern has been expressed that if bowheads are prevented from feeding during the summer period, this loss could be significant in terms of the energetics of individual whales. BEMP participants concluded that a serious loss of habitat and feeding opportunities could occur if some combination of industrial activities (i.e., offshore structures and ship traffic) creates a large zone of total exclusion, which included a significant portion of available feeding habitat, and bowheads began to avoid the relatively large zone of overall industrial activity rather than simply reacting to or avoiding specific activities within the industrial zone (Indian and Northern Affairs Canada and Environment Canada 1984).

The locations of petroleum industry facilities and operations and the boundaries of the main industry zone in 1985 were described in Part 2 of this report. As in past years, bowheads were sighted within a few kilometres of operating drilling units and dredges, and the observed congregations of whales off the Yukon coast were, depending on interpretation of the boundary, either within or just outside the primary zone of industry activity (Figures 2-4 and 6). In addition, whales present in concentration areas within Mackenzie Bay would have had to migrate through the main industry zone to reach such areas by mid-August to mid-September (see Part 2). These observations provide evidence that exclusion of at least some portion or age classes in the bowhead population did not occur during 1985.

The large numbers of whales observed along the Yukon coast and within the western portion of Mackenzie Bay for the third consecutive year, in conjunction with the spatial distribution patterns documented over the period 1981-1985, suggest that the high proportion of the bowhead population observed in the development zone during 1980 may have been an atypical situation. This is further supported by the few years of non-systematic surveys of whales conducted prior to 1980 (Fraker 1977, 1978; Fraker and Fraker 1979), when bowheads were not observed concentrated in the industrial zone. One possible explanation for the distribution observed during 1980 may be the delay in migration of bowheads through Bering Strait by almost a full month due to unusually severe ice conditions (Ljungblad et al. 1980). Blockage of bowhead movements by ice at this point in their spring migration corridor is apparently an irregular occurrence, but may have had subsequent implications for the distribution of whales on their summer range. It is possible that because of this delay in migration and the oceanographic conditions in 1980 (see Thomson et al. 1986 for review), bowheads did not travel as far as normal into the eastern Beaufort Sea - Amundsen Gulf region. If this was the case, larger numbers of whales would be expected to occur in the Delta and Tuk Pen zones. Consequently, the spatial distribution pattern in that year may have been atypical rather than the norm. This would weaken the "exclusion hypothesis".

It could be argued that because the majority of the bowheads observed within or adjacent to the main zone of industry activity in recent years have been immature individuals (Part 4), exclusion of the adult portion of the population is still occurring. This is conceivable if the responses of bowheads to disturbances associated with industry operations vary with the age of affected individuals, and adults have learned to avoid areas of industrial activities whereas immature animals have not. Alternatively, the low proportion of adults in the development zone may be attributable to other biological factors. First, the migration timing of different age groups of bowheads into the eastern Beaufort Sea - Amundsen Gulf region (Braham et al. 1980) may naturally influence their subsequent spatial distribution within the region, with the majority of the immature animals occurring within the Mackenzie Bay area and the adults elsewhere in the region (i.e., beyond the industrial development zone). Secondly, geographic segregation of bowheads on their summer range may occur as a result of differences in the preferred feeding habitats and bioenergetic requirements of different age classes. The latter possible cause of observed spatial distribution trends is discussed below in relation to the "food hypothesis".

## THE FOOD HYPOTHESIS

Over the past few years, there has been increasing evidence that temporal and spatial variability in the distribution of bowheads on their summer range is at least partly related to differences in the availability of their prey (primarily zooplankton), which is influenced by a number of oceanographic and meteorological factors (e.g., Borstad 1984; Harwood and Borstad 1985). The present study provides further evidence in support of the "food hypothesis".

Most of the bowheads observed during both the August and September surveys were located in areas within Mackenzie Bay that were influenced by the Mackenzie River plume. Whales were also sighted in an area of anticipated upwelling along the Yukon coast (Part 3). The link between bowhead feeding and zooplankton concentrations associated with the plume edge was also strengthened this year by the preliminary results of studies conducted by DFO (Western Region). This research demonstrated the presence of large numbers of copepods at the interface between the warm freshwater surface layer of the Mackenzie plume and underlying saline water (M. Lawrence, pers. comm.). These observations are consistent with the results of studies conducted in other major estuaries, such as the Fraser River estuary, where an order of magnitude increase in the abundance of small calanoid copepods has been documented just beyond the plume edge (T. Parsons, UBC, pers. comm.). At the same time, bowheads were observed feeding near areas where relatively high densities of zooplankton may have occurred. For example, one group of whales appeared to be feeding along the edge of the main plume during the systematic surveys (Part 2). Photographs taken during the photogrammetric study component (Part 4) also provide a clear record of feeding activity in bowhead concentration areas within Mackenzie Bay.

The following discussion is an attempt to examine further the food hypothesis to help explain, on a theoretical basis, the congregation of generally immature bowheads within the Mackenzie Bay - Yukon coast area and the low number of adults observed in this part of the southeast Beaufort Sea. Although only speculation at the present time, the ideas are offered as a plausible explanation for the spatial distribution patterns observed in the bowhead population during at least the last three years. It is emphasized that a wide range of physical and biological factors may affect the movements and distribution of bowheads during their summer residence in the Beaufort Sea in any given year. Nevertheless, as it is also clear that bowheads are not distributed randomly within the region and there is ample evidence of congregation of individuals during certain periods, it is possible that observed trends have implications for the survival and/or energy balance of the population.

It is probable that immature bowheads have greater energy requirements per unit biomass than do adults. One of the fundamental principles of vertebrate physiology is the higher energy requirements of animals during periods of active growth compared with maintenance energy requirements of adults or the seasonal energy demands associated with reproduction. Therefore, it may be essential that immature bowheads obtain sufficient energy reserves through active feeding during their period of summer residence in the Beaufort Sea. It is conceivable that these energy requirements are met through feeding in areas that support relatively high standing stocks of zooplankton. Lowry and Frost (1984) calculated that, based on a feeding season of 105 days in the Canadian Beaufort Sea and 25 days in the Alaskan Beaufort Sea, or 3120 h total, bowheads can obtain their annual food requirements if they feed somewhat over half the time they are on the feeding grounds and concentrate their efforts in areas where prey are relatively abundant. Such areas may include the estuarine frontal systems associated with the discharge of the Mackenzie River or areas of occasional shallow upwelling along the Yukon coast. As indicated earlier and in several other reports, zooplankton may become concentrated in both of these types of areas due to either convergence of water masses or the presence of density gradients associated with fresh water - sea water interfaces. The congregation of immature bowheads in this area for feeding may be particularly important as it has been shown that copepods in September have a caloric value almost 50 per cent higher than those sampled in late July and early August (Lowry and Frost 1984). At present, there is insufficient information to determine if immature bowheads traditionally return to such areas because of an inherent behavioural (migratory) response, or if shorter-term responses to local changes in food availability during the summer of any given year result in movements to areas supporting high densities of zooplankton. Either or both mechanisms are plausible and would have an associated adaptive advantage.

It is also possible that immature bowheads have a higher feeding efficiency in coastal and estuarine waters where the predominant members of the zooplankton community are small copepods. A Minerals Management Service study of age-specific differences in the morphology of bowhead baleen has been initiated and may provide information relevant to evaluation of possible differences in the feeding efficiency of various age classes of bowheads. It is expected that major differences in the size of baleen fibres will not exist between immature and adult bowheads (M. Nerini, National Marine Fisheries Service (NMFS), National Oceanographic and Atmospheric Administration (NOAA), pers. comm.), although small differences in the diameter of baleen fringes of other young and adult baleen whales have been measured (Nemoto 1959, cited in Kawamura 1980). Very large differences in filtering and feeding efficiencies could be associated with relatively small differences in the structure or arrangement of baleen fibres. A difference of only 50-100 µm in the average distance between fibres in a filtration apparatus can make an enormous difference in the size and amount of prey retained by this apparatus. If smaller whales have a finer baleen structure or more regular arrangement of fibres than do adults, they may more efficiently retain the small copepods that are expected to dominate the zooplankton community in the Mackenzie River estuary during August and September. Although currently unsubstantiated, feeding efficiency in terms of the biomass of plankton ingested per unit volume of water filtered may be maximized when immature bowheads feed in such coastal-estuarine areas.

The foregoing energetic and feeding efficiency arguments have been applied to immature bowheads in the Mackenzie Bay region, but it is reasonable to expect that a similar bioenergetic and food-related basis for seasonal and spatial distributional trends could exist for adults. If the concept outlined earlier regarding the structure and/or arrangement of the baleen is valid, it is possible that adults would be unable to obtain sufficient prey or at least have lower feeding efficiencies in areas where small copepods comprise the majority of the zooplankton community. The preferred feeding habitats of adults may be away from the Mackenzie River Estuary and in deeper offshore waters where a greater proportion of the planktonic community is composed of larger zooplankters such as euphausiids. Although there is limited information available on spatial differences in the structure of the zooplankton community in the Beaufort Sea, data available for other areas indicate that these larger planktonic forms are generally found in deeper waters away from estuaries (T. Parsons, pers. comm.). If this were also true for the Beaufort Sea, then higher numbers of adult bowheads may be expected in Amundsen Gulf, Franklin Bay, and other deeper areas within the region, where historical whaling records show that many bowheads were taken. This would also help explain the limited numbers of adults observed within the main industry zone, as most of this zone is influenced by the turbid freshwater plume from the Mackenzie River at various times during the open-water season (e.g., Thomson et al. 1986) and much of it can be characterized as being relatively shallow. The recent observations of Wursig et al. (1985) provide some support to this hypothesis as these authors reported that the proportion of time that bowheads spend at the surface is substantially less in areas where the water depth is greater than 100 m. Longer dive times may be a reflection of a feeding behaviour involving deeper dives (perhaps to the deep scattering layer) to obtain prey such as euphausiids which are distributed over a much greater depth range in the water column than are small estuarine-type copepods, and are also located well below the surface at various times of the day because of their extensive diel vertical migrations and avoidance of high light intensities. These new concepts and the existing hypotheses need further evaluation, as they are a plausible explanation for observed trends in the distribution of bowheads in the southeastern Beaufort Sea - Amundsen Gulf region.

It is concluded that the range of factors that influences the distribution of various age classes of bowheads in the region is likely complex, and probably varies to a large degree from year to year and within a given summer. Nevertheless, availability of suitable quantities and types of prey may be an overriding factor given the expected importance of this region as a feeding habitat (Indian and Northern Affairs Canada and Environment Canada 1984). The results of this and other recent research programs lend further support to the hypothesis that the temporal and spatial distribution patterns of bowheads on their summer range are correlated with food availability and, therefore, likely influenced to a large extent by the oceanographic and meteorological phenomena that affect the distribution of their prey.

# APPENDIX A

## TRANSECT LOCATION AND SURVEY DATES

August 1985

| Zone | Transect Number | Survey Date | Longitude (°W) | Latitude (°N) South End | Latitude (°N) North End | Transect Length (km)* |
|---|---|---|---|---|---|---|
| Yukon | 1 | 18 | 140°42.9' | 69°37.2' | 70°50.0' | 134.8 |
| | 2 | 18 | 140°11.9' | 69°36.2' | 70°50.0' | 136.7 |
| | 3 | 18 | 139°39.8' | 69°35.1' | 70°45.0' | 129.5 |
| | 4 | 18 | 139°07.7' | 69°38.0' | 70°45.0' | 124.1 |
| | 5 | 19 | 138°37.0' | 69°18.6' | 70°10.0' | 95.2 |
| | 6 | 19 | 138°06.5' | 69°08.5' | 70°10.0' | 113.9 |
| | 7 | 19 | 137°34.7' | 69°02.2' | 70°05.0' | 116.3 |
| Delta | 8 | 19 | 137°02.8' | 60°02.2' | 70°05.0' | 116.3 |
| | 9 | 19 | 136°31.1' | 69°17.1' | 70°26.0' | 127.6 |
| | 10 | 19 | 136°00.0' | 69°29.1' | 70°25.0' | 88.7 |
| | 11 | 20 | 135°28.7' | 69°39.6' | 70°40.0' | 111.9 |
| | 12 | 20 | 134°57.2' | 69°41.7' | 70°40.0' | 108.0 |
| | 13 | 20 | 134°24.5' | 69°44.2' | 70°40.0' | 103.3 |
| | 14 | 20 | 133°53.9' | 69°39.5' | 70°40.0' | 112.0 |
| | 15 | 20 | 133°23.2' | 69°38.1' | 70°35.0' | 105.4 |
| Tuk Pen | 16 | 20 | 132°50.8' | 69°39.5' | 70°35.0' | 102.8 |
| | 17 | 21 | 132°19.9' | 69°48.8' | 70°35.0' | 85.6 |
| | 18 | 21 | 131°47.9' | 69°51.5' | 70°50.0' | 108.2 |
| | 19 | 21 | 131°17.2' | 70°00.6' | 70°50.0' | 92.6 |
| | 20 | 21 | 130°46.1' | 70°10.0' | 70°50.0' | 72.4 |
| | 21 | 21 | 130°14.9' | 70°10.9' | 71°00.0' | 92.2 |
| | 22 | 21 | 129°42.1' | 70°16.2' | 71°00.0' | 79.8 |
| | 23 | 21 | 129°09.8' | 70°00.9' | 71°00.0' | 111.1 |
| | 24 | 21 | 128°39.9' | 69°51.2' | 71°00.0' | 127.4 |
| West | 25 | 24 | 128°08.8' | 70°36.3' | 71°27.0' | 93.9 |
| Amundsen | 26 | 24 | 127°34.2' | 70°26.1' | 71°32.3' | 122.6 |
| Yukon | 3A+ | 22 | 139°39.8' | 69°35.1' | 69°55.1' | 33.3 |
| | 4A | 22 | 139°07.7' | 69°38.0' | 69°55.5' | 32.4 |
| | 5A | 22 | 138°37.0' | 69°18.6' | 69°38.6' | 37.0 |
| | 6A | 22 | 138°06.5' | 69°08.5' | 69°28.5' | 37.0 |
| | 7A | 22 | 137°34.7' | 69°02.2' | 69°22.2' | 37.0 |

APPENDIX A (continued)

September 1985

| Zone | Transect Number | Survey Date | Longitude (°W) | Latitude (°N) South End | Latitude (°N) North End | Transect Length (km)* |
|---|---|---|---|---|---|---|
| Delta | 8A | 22 | 137°02.8' | 69°02.2' | 69°22.2' | 37.0 |
| Yukon | 1 | 11 | 140°42.9' | 69°37.2' | 70°30.0' | 67.8 |
| | 2 | 11 | 140°11.9' | 69°36.2' | 70°28.0' | 64.4 |
| | 3 | 11 | 139°39.8' | 69°35.1' | 70°30.0' | 76.5 |
| | 4 | 11 | 139°07.7' | 69°38.0' | 70°30.0' | 86.9 |
| | 5 | 12 | 138°37.0' | 69°18.6' | 69°25.6' | 13.0 |
| | 6 | 12 | 138°06.5' | 69°08.5' | 69°26.6 | 33.5 |
| | 7 | 12 | 137°34.7' | 69°02.2' | 69°43.0' | 75.6 |
| Delta | 8 | 12 | 137°02.8' | 69°02.2' | 69°50.0' | 88.5 |
| | 9 | 12 | 136°31.1' | 69°17.1' | 70°18.5' | 102.4 |
| | 10 | 12 | 136°00.0' | 69°29.1' | 70°20.0' | 94.3 |
| | 11 | 14 | 135°28.7' | 70°17.0' | 70°58.0' | 75.9 |
| | 12 | 14 | 134°57.2' | 70°31.0' | 70°58.0' | 50.0 |
| | 13 | 14 | 134°24.5' | 70°38.4' | 71°08.7' | 56.1 |
| | 14 | 14 | 133°53.9' | 70°20.7' | 71°10.5' | 87.6 |
| | 15 | 14 | 133°23.2' | 69°38.1' | 70°53.6' | 139.8 |
| Tuk Pen | 16 | 14 | 132°50.8' | 69°39.5' | 70°52.7' | 135.8 |
| | 17 | 14 | 132°19.9' | 69°48.8' | 70°00.0' | 131.9 |
| | 18 | 14 | 131°47.9' | 69°51.5' | 70°00.0' | 126.7 |
| | 19 | 16 | 131°17.2' | 70°00.0' | 70°09.3' | 128.3 |
| | 20 | 16 | 130°46.1' | 70°10.9' | 70°09.3' | 78.7 |

*Portions of transect lines where minimum survey conditions were not met have been subtracted.

+"A" designated a transect flown during the oceanographic systematic survey (see Part 2).

## APPENDIX B

### SIZE OF STUDY AREA AND PERCENT SURVEY COVERAGE BY STRATUM

| 1985 Survey Period | Size of Stratum $km^2$ (percent survey coverage) | | | |
|---|---|---|---|---|
| | Yukon | Delta | Tuk Pen | West Amundsen |
| 18-24 August | 17,000<br>(10.0) | 18,100<br>(9.6) | 17,820<br>(9.8) | 4,370<br>(9.9) |
| 11-16 September | 8,300<br>(10.1) | 13,990<br>(9.9) | 12,160<br>(9.9) | NS |

## APPENDIX C

## WHITE WHALE SIGHTINGS RECORDED DURING BOWHEAD SURVEYS AND BY INDUSTRY PERSONNEL

### C.1 Aerial Survey Results

White whales were systematically recorded during the 1985 bowhead whale monitoring program. A total of 134 animals was observed during the August surveys. Of these, 83 (74 adults, 6 neonates, 3 subadults) were sighted on-transect, 5 (all adults) off-transect, and 46 (40 adults, 4 neonates, 2 subadults) during ferrying flights and the oceanographic survey (Figure C-1). Nine adult white whales were seen during the September survey, and all of these were recorded on ferrying flights (Figure C-1).

Inclinometer readings taken for 32 of the 61 on-transect sightings indicated that white whale detectability was not uniform across the width of the transect. Twenty-three sightings (71.9 percent) were within the inner half (500 m) of the transect, while only nine (28.1 percent) were within the outer half (501-1000 m).

The relationship between white whale distribution and ice cover was examined during analysis of data collected in 1985. The expected number of sightings in each ice cover category was calculated by multiplying the total number of on-transect sightings by the percent of the total kilometers surveyed that were in each ice cover category. Only the August survey results were used in this analysis, as there were no on-transect sightings during the September survey. White whales were not randomly distributed with respect to ice cover (chi-square test, $p<0.005$). There were more sightings than expected in areas with 1-3/10 ice cover and fewer sightings than expected in areas with <1/10 ice cover.

Mean group size was 1.43 and 4.5 white whales for all sightings in August and September, respectively, although only two groups were observed during the September surveys. The largest group recorded in August comprised six whales (5 adults and one neonate). In August, white whales were sighted in association with seabirds on two occasions (Figure C-1). One sighting occurred southeast of Kay Point on 19 August and the other west of Cape Dalhousie on 21 August.

Although a reproductive rate could be calculated on the basis of the August sightings, too few whales and no neonates were observed during the September surveys. Neonates accounted for 7.2 percent of the whales sighted on-transect and 7.5 percent of all the white whales recorded in the August systematic surveys.

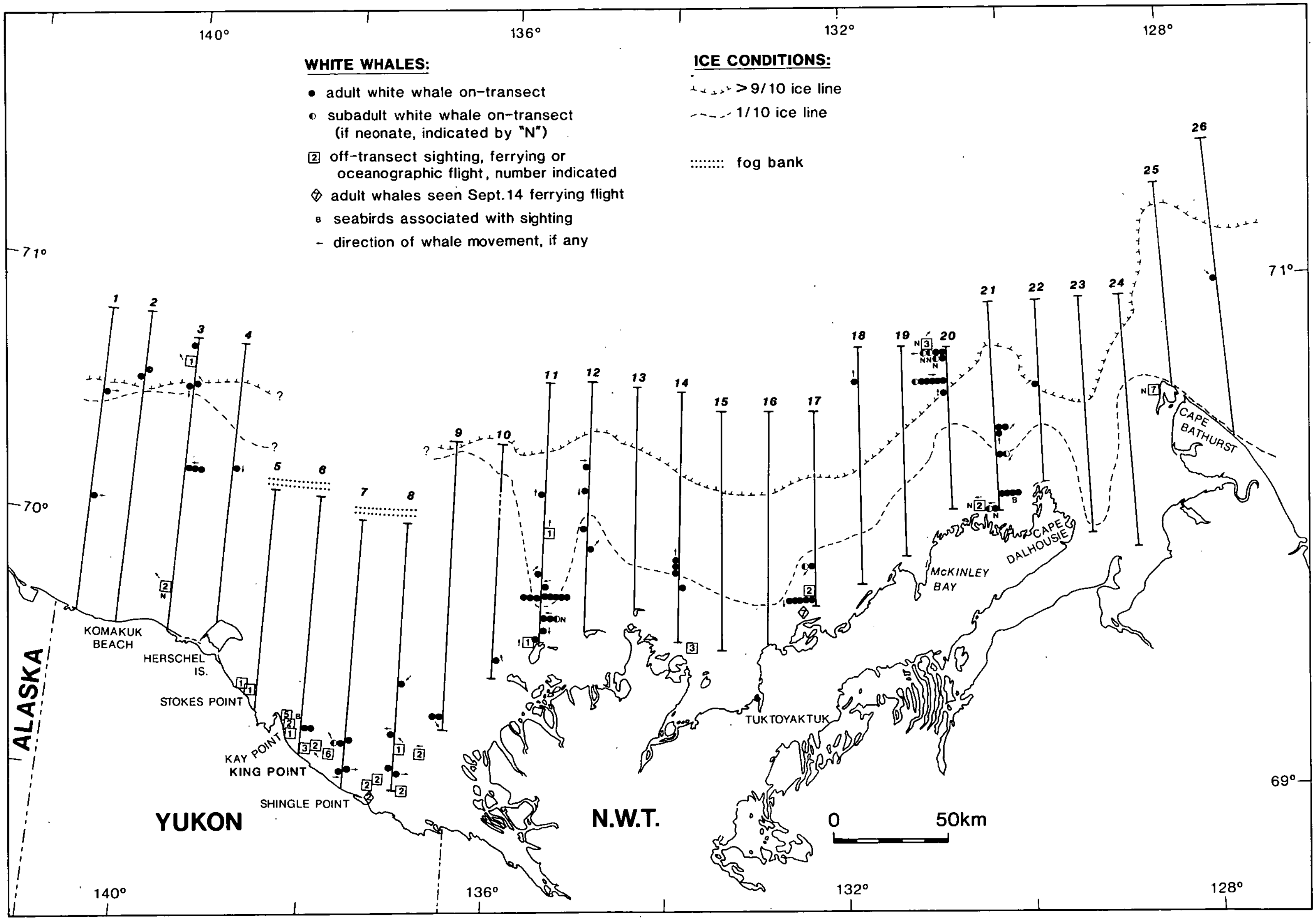


Figure C-1. Locations of white whales sighted during August and September 1985 systematic surveys for bowhead whales.

## C.2 Sighting by Industry Personnel

Industry personnel reported a total of 17 sightings (84 white whales) between 20 June and 4 September 1985. Six of the sightings (in June, July, and early August) were around Herschel Island, including one group of four whales that remained near Pauline Cove for a period of two weeks starting in late July. Four of the white whale sightings in August were in McKinley Bay, where three whales were apparently observed feeding on 13 August in association with seabirds. The remaining seven sightings were of animals in offshore areas. A map showing the white whale sightings by industry personnel during 1985 is provided in Norton and Harwood (1985a).

## C.3 General Comments

The information on white whales obtained during the 1985 bowhead surveys and from reports by industry personnel is consistent with the pattern of distribution and abundance described by Norton and Harwood (1985b). These authors suggest that white whales leave the Mackenzie Estuary concentration areas in mid-July and move into offshore waters. However, small groups of whales may move into nearshore areas to feed. All three sightings of white whales in conjunction with feeding seabirds in 1985 were in nearshore areas during August. Norton and Harwood (1985b) found that white whale densities in offshore areas decreased steadily from late July through September, suggesting that the fall migration had started by the end of July and was nearly complete by mid-September. The migration pattern in 1985 was consistent with this trend since the total number of white whales recorded during the September survey was only 6.7 percent of the number observed in August.

# APPENDIX D

## SEALS SIGHTED INCIDENTALLY DURING BOWHEAD SURVEYS AND BY INDUSTRY PERSONNEL

### D.1 Aerial Survey Results

Ringed and bearded seals are the only common pinnipeds in the southeast Beaufort Sea, and both species were observed incidentally during the 1985 bowhead whale monitoring program. No walruses were observed during the surveys conducted this year.

A total of 80 ringed seals was seen on-transect during the 18-24 August survey, and ten individuals were observed on-transect during the 11-16 September survey. Sixteen ringed seals were recorded incidentally to the systematic surveys during either oceanographic or ferrying flights. The locations of these sightings are shown on Figures D-1 (August) and D-2 (September), along with coincident ice conditions. Sites where seabirds were seen in association with seals are also indicated on the figures.

The detectability of ringed and bearded seals is affected by survey conditions and observer seat position to an even greater extent than detectability of bowheads. Seals are most easily detected in areas with calm seas (e.g., Beaufort Scale 0-2) and where there is no glare from the water surface. Furthermore, even in areas where survey conditions are excellent, seals are not equally detectable throughout the 2-km wide transect strip. Seal detectability generally decreases at a distance of 200 to 400 m from the flight path, depending on sea state and the seal group size. Consequently, seal numbers recorded during bowhead surveys are undoubtedly gross underestimates of their actual abundance in open water areas.

During late August, most of the study area was examined under excellent survey conditions, thus maximizing the opportunities for detection of seals. Ringed seals were observed throughout the study area, occasionally in association with seabirds or bowhead whales. Bearded seals were only seen in the eastern portion of the study area, and were not as abundant as ringed seals. Only a few ringed seals were sighted during the September survey, although this may have been a result of the lower dectability of seals because of less favourable survey conditions during this period. There is also a possibility that a portion of the ringed seal population moved out of the study area between the August and September surveys.

Large congregations of ringed seals were observed in the southeast Beaufort Sea during bowhead surveys conducted from 1980 to 1984 (Renaud and Davis 1981; Davis et al. 1983; Harwood and Ford 1983; Harwood and Borstad 1985; McLaren and Davis 1985). The congregations are believed to consist of

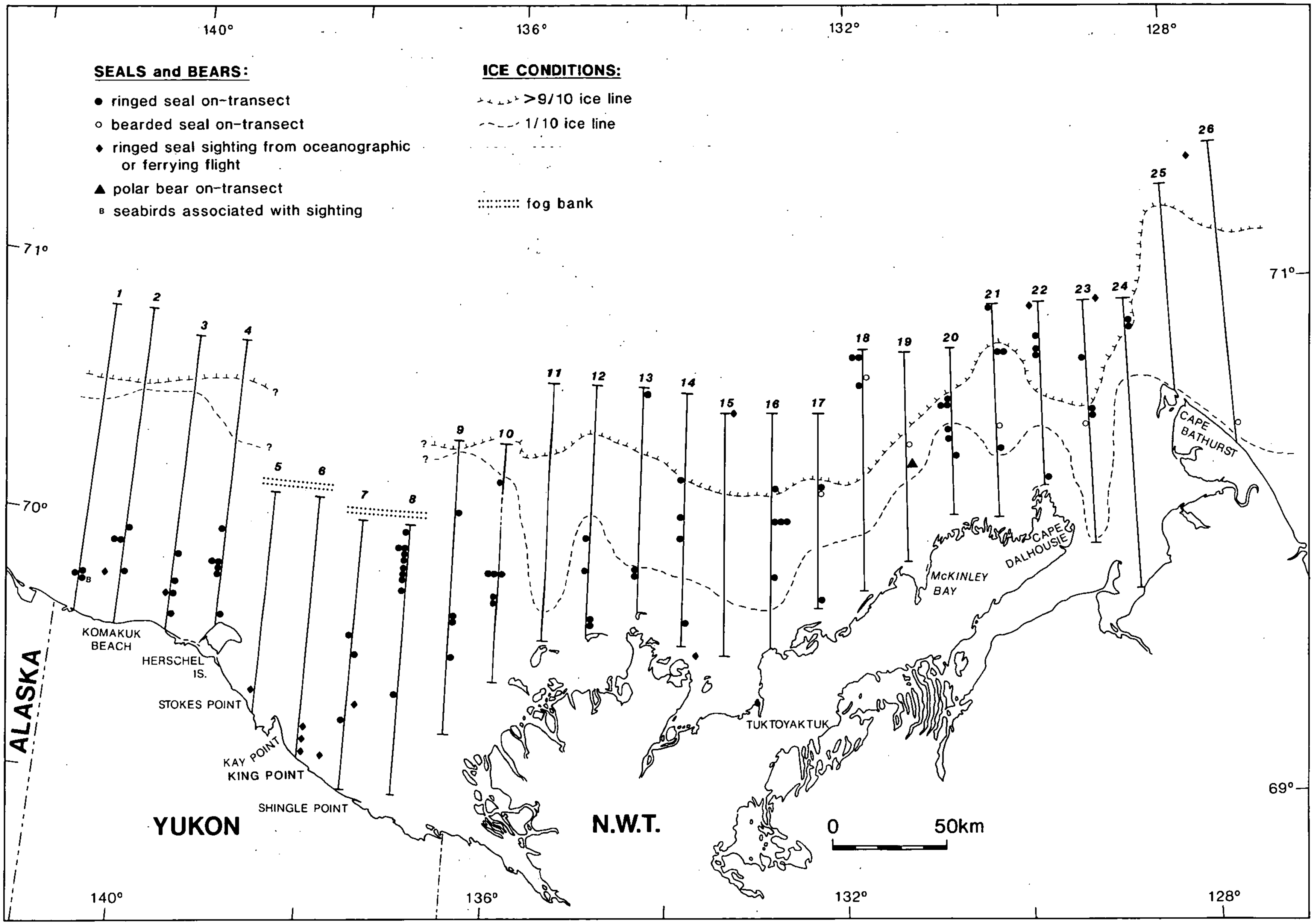


Figure D-1. Locations of sightings of seals and polar bears during 18-24 August 1985 surveys for bowhead whales.

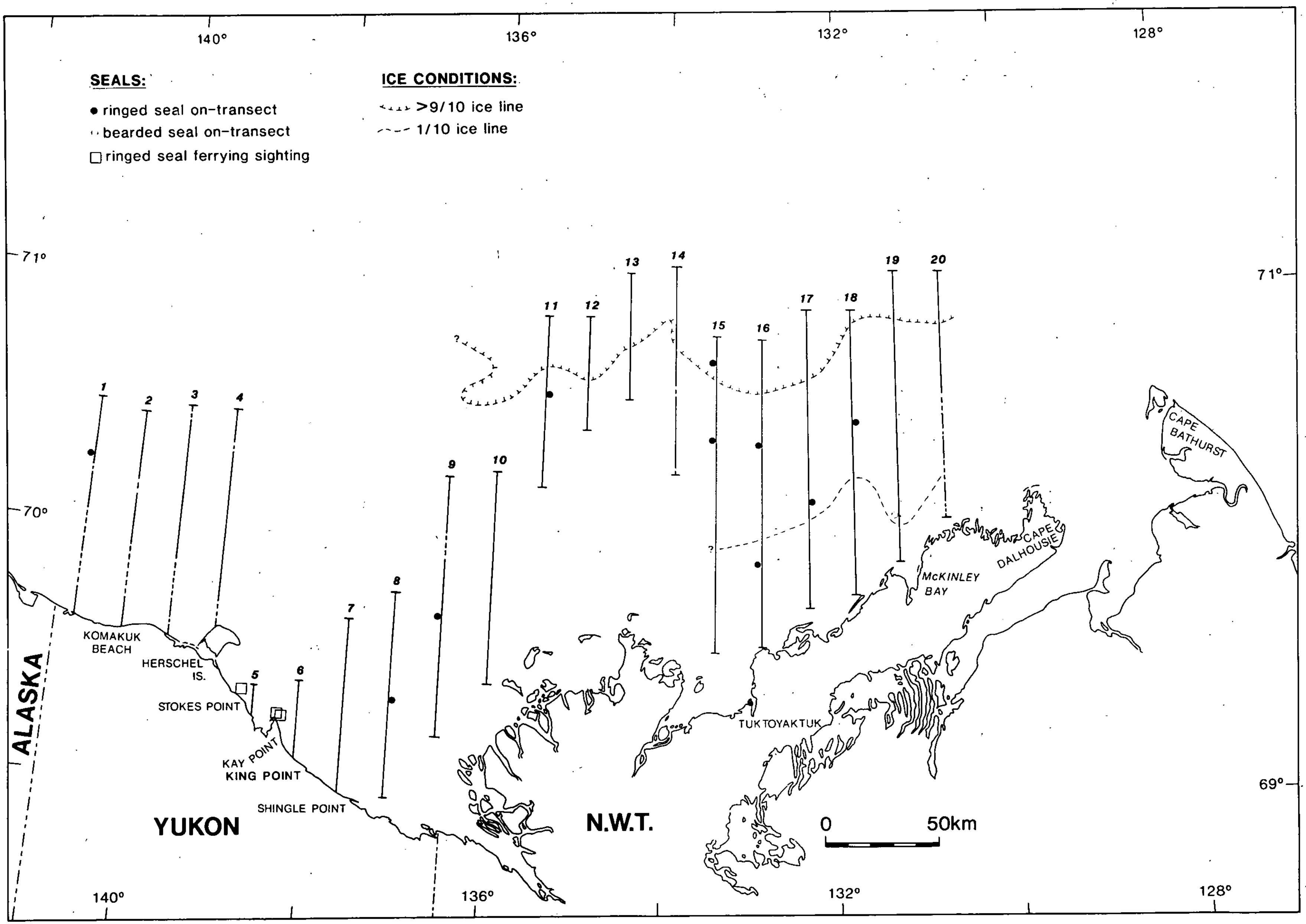


Figure D-2. Locations of sightings of seals during 11-16 September 1985 surveys for bowhead whales.

thousands of seals which may be exploiting an abundant supply of prey organisms (probably zooplankton). Although survey conditions during late August 1985 were considered adequate to allow detection of such seal congregations, none were documented. This may have been related to the effects of severe ice conditions in 1985 on seal prey distribution and abundance, but cannot be confirmed on the basis of available information.

## D.2 Observations by Industry Personnel

Seal sightings by ice observers and industry personnel on support vessels and facilities operated by or on behalf of Dome Petroleum Ltd. and Gulf Canada Resources Inc. were reviewed as part of this study. The value of these data is somewhat limited due to differences in weather conditions at the time information was recorded and the variable levels of experience of observers. Nevertheless, they do provide a useful supplement to the data collected during the systematic surveys. In many instances, the seal(s) was not identified by species or was incorrectly identified (e.g., reports of grey seals, harp seals). Sightings may also have been duplicated over consecutive watch periods by observers on stationary support vessels or facilities. Because of these uncertainties all observations by industry personnel have been combined and reported here as "seals".

At least 377 seals were sighted by industry personnel during the 1985 drilling season. The sightings, grouped according to the vessel type from which the report originated, are summarized in Table D-1. Half the records originated from four drillships operating at or moving between the following sites: Edlok, Akpak, Nerlerk, Agnerk, Arluk, Adlartok, and Havik. The remainder of the reports were from personnel on mobile vessels operating between these sites, shorebases (McKinley Bay, Tuktoyaktuk), and staging areas (Herschel Island). No walruses were sighted by industry personnel in 1985.

TABLE D-1

Seal sightings reported by industry personnel in 1985

| Vessel type | No. of vessels with reports | Total no. of seals sighted | Sighting dates (first and last) | Percent of total seals sighted |
|---|---|---|---|---|
| Drillship | 4 | 188 | 10 June-8 Nov | 50 |
| Supply | 5 | 72 | 27 June-23 Sept | 19 |
| Icebreaker | 1 | 50 | 18 June-11 Sept | 13 |
| Support | 5 | 67 | 29 June-26 Sept | 18 |
| | | 377 | | |

The number of seals recorded by industry personnel in 1985 (377) is comparable to the number observed in 1982 (385). Many more seals were reported in 1983 (1500) and 1984 (2200). Although these figures may reflect actual changes in the relative abundance of seals in the main industrial zone, this cannot be concluded with certainty because of variable levels of survey effort and observer experience, as well as differences in observation conditions throughout the drilling season.

# APPENDIX E

## POLAR BEARS SIGHTED INCIDENTALLY DURING BOWHEAD SURVEYS AND BY INDUSTRY PERSONNEL

### E.1 Aerial Survey Results

One polar bear was recorded during the systematic survey on 21 August 1985. The location of the sighting is shown in Figure A-1. The animal was a solitary adult, and was observed swimming between floes of 4-6/10 ice concentration.

### E.2 Sightings by Industry Personnel

During the period 11 June to 8 November 1985, industry personnel on vessels or facilities operated by Dome and Gulf reported sighting a total of 64 polar bears (44 groups). This total included six bears identified as subadults and four young-of-the-year cubs. Information on these sightings is summarized in Table E-1. Some sightings may have been repeat observations of the same bear(s), although repeat observations have been culled where they are obvious.

The number of bears sighted by industry personnel in the southeast Beaufort Sea during 1985 was lower than in 1984 (106), but higher than in 1982 (3) or 1983 (37). Opportunities for observing bears increase when the pack-ice occurs in the vicinity of drilling activities, as was the case in 1984. Most industry sites in 1985 (observation posts) were located landward of the ice edge, despite the fact that the ice edge was closer to shore than in 1984. In contrast, the study area was virtually ice-free in 1982 and 1983.

TABLE E-1

Polar bear sightings reported by industry personnel, 1985

| Vessel type | No. of vessels with reports | Total no. bears sighted (no. of cubs or subadults) | Total No. of groups | Approximate sighting locations |
|---|---|---|---|---|
| Drillship | 3 | 29 (6) | 16 | Havik, Agnerk, Akpak, 70°10'N-70°21'N, 132° W - 134° W |
| Icebreaker | 2 | 19 (3) | 13 | 69°45'N-70°30'N, 131°11'W-138°17'W |
| Supply | 4 | 8 (0) | 8 | Havik, Arluk, 69°45'N-70°23'N, 132°W-135°35'W |
| Support | 3 | 8 (1) | 7 | 69°33'N-70°23'N, 129°37'W-138°25'W |
| Total | | 64 (10) | 44 | |

## APPENDIX F

LOCATIONS OF ON-TRANSECT SIGHTINGS OF BOWHEAD WHALES

| Date | Line No. | No. of Whales | Latitude (°N) | Longitude (°W) |
|---|---|---|---|---|
| 18 Aug | 1 | 1 | 69°43.0' | 140°42.9' |
| 18 Aug | 2 | 1 | 69°48.0' | 140°11.9' |
| 19 Aug | 6 | 2 | 69°22.0' | 138°06.5' |
| 19 Aug | 6 | 1 | 69°21.9' | 138°06.5' |
| 19 Aug | 6 | 2 | 69°24.4' | 138°06.5' |
| 19 Aug | 6 | 2 | 69°23.5' | 138°07.1' |
| 19 Aug | 6 | 1 | 69°16.7' | 138°06.5' |
| 19 Aug | 6 | 1 | 69°14.5' | 138°06.5' |
| 19 Aug | 7 | 2 | 69°04.2' | 137°34.7' |
| 19 Aug | 7 | 1 | 69°04.2' | 137°34.7' |
| 19 Aug | 7 | 1 | 69°04.2' | 137°34.7' |
| 19 Aug | 7 | 1 | 69°16.6' | 137°34.7' |
| 19 Aug | 7 | 2 | 69°18.6' | 137°34.7' |
| 19 Aug | 7 | 2 | 69°18.6' | 137°34.7' |
| 19 Aug | 7 | 2 | 69°18.9' | 137°34.7' |
| 19 Aug | 7 | 1 | 69°15.5' | 137°34.7' |
| 19 Aug | 7 | 1 | 69°30.6' | 137°34.7' |
| 19 Aug | 8 | 1 | 69°29.6' | 137°02.8' |
| 19 Aug | 8 | 4 | 69°17.4' | 137°02.8' |
| 19 Aug | 8 | 2 | 69°23.9' | 137°02.8' |
| 19 Aug | 8 | 1 | 69°21.8' | 137°02.8' |
| 19 Aug | 8 | 2 | 69°20.9' | 137°02.8' |
| 19 Aug | 8 | 1 | 69°19.7' | 137°02.8' |
| 19 Aug | 9 | 1 | 69°27.1' | 136°31.1' |
| 20 Aug | 15 | 1 | 70°13.0' | 133°23.2' |
| 21 Aug | 20 | 1 | 70°13.6' | 130°46.1' |
| 22 Aug | 7A* | 1 | 69°09.7' | 137°34.7' |
| 22 Aug | 7A | 2 | 69°06.9' | 137°34.7' |
| 22 Aug | 7A | 1 | 69°05.2' | 137°34.7' |
| 22 Aug | 6A | 1 | 69°17.4' | 137°06.5' |
| 22 Aug | 6A | 1 | 69°12.5' | 138°06.5' |
| 24 Aug | 25 | 1 | 70°46.3' | 128°08.8' |
| 11 Sept | 1 | 1 | 69°38.4' | 140°42.9' |
| 11 Sept | 1 | 1 | 69°37.8' | 140°42.9' |
| 11 Sept | 3 | 1 | 69°35.5' | 139°39.8' |
| 11 Sept | 4 | 1 | 70°22.9' | 139°07.7' |
| 12 Sept | 7 | 2 | 69°02.2' | 137°34.7' |
| 12 Sept | 7 | 2 | 69°02.2' | 137°34.7' |

APPENDIX F (continued)

| Date | Line No. | No. of Whales | Latitude (°N) | Longitude (°W) |
|---|---|---|---|---|
| 12 Sept | 7 | 1 | 69°02.3' | 137°34.7' |
| 12 Sept | 7 | 1 | 69°04.1' | 137°34.7' |
| 12 Sept | 7 | 1 | 69°04.4' | 137°34.7' |
| 12 Sept | 7 | 2 | 69°06.5' | 137°34.7' |
| 12 Sept | 7 | 1 | 69°08.2' | 137°34.7' |
| 12 Sept | 7 | 1 | 69°09.6' | 137°34.7' |
| 12 Sept | 7 | 1 | 69°02.2' | 137°34.7' |
| 12 Sept | 7 | 2 | 69°02.6' | 137°34.7' |
| 12 Sept | 7 | 2 | 69°07.3' | 137°34.7' |
| 12 Sept | 7 | 1 | 69°07.3' | 137°34.7' |
| 12 Sept | 7 | 1 | 69°11.9' | 137°34.7' |
| 12 Sept | 8 | 1 | 69°23.1' | 137°02.8' |
| 12 Sept | 8 | 1 | 69°19.3' | 137°02.8' |
| 12 Sept | 8 | 1 | 69°18.9' | 137°02.8' |
| 12 Sept | 8 | 1 | 69°19.3' | 137°02.8' |
| 12 Sept | 8 | 1 | 69°19.3' | 137°02.8' |
| 12 Sept | 8 | 1 | 69°19.3' | 137°02.8' |
| 12 Sept | 8 | 1 | 69°17.5' | 137°02.8' |
| 14 Sept | 15 | 1 | 70°08.2' | 133°23.2' |

*"A" designates a transect flown during the oceanographic systematic survey.

## APPENDIX G

### EFFECTIVE TRANSECT WIDTH

The strip transect method of estimating whale numbers assumes equal detectability of animals across the transect strip. During the 1985 surveys, inclinometer readings were taken for 47 of 58 on-transect bowhead sightings. The distance from the flight line was calculated for each sighting by multiplying the tangent of the angle between the flight path and the sighting by the altitude. These distances were then plotted at 100 m intervals.

The planned transect width extended 1000 m on each side of the flight line (2 km total), and as indicated in Figure G-1, the distribution of sightings across this 1000 m distance was not uniform. There was a large peak in the number of sightings within the 1-100 m interval, very few sightings from 101-400 m, and a second, smaller peak from 401-500 m away from the flight line. The number of bowhead sightings then gradually declined with distance.

The frequency distribution of sightings along the transect width observed in 1985 is different from the bi-modal distribution documented in 1984 (Harwood and Borstad 1985). However, in both years, there were approximately equal numbers of sightings in the inner (1-500 m) and outer (501-1000 m) halves of the transect strip (24 vs. 29 in 1984, 18 vs. 15 in 1985). Because of the small number of sightings in any one year, differences in distribution across the transect width are likely due to chance. If the 1984 and 1985 sightings are combined (because the survey techniques used were the same and several of the observers participated in both programs), the resulting pattern is more similar to a uniform distribution than either the 1984 or 1985 distributions. Davis et al. (1982), using the same techniques, found a relatively uniform distribution of sightings from 1-1000 m from the flight line. Thus, the assumption of equal detectability of bowheads across a 2000 m transect width is unlikely to have biased the population estimates calculated during the present investigation.

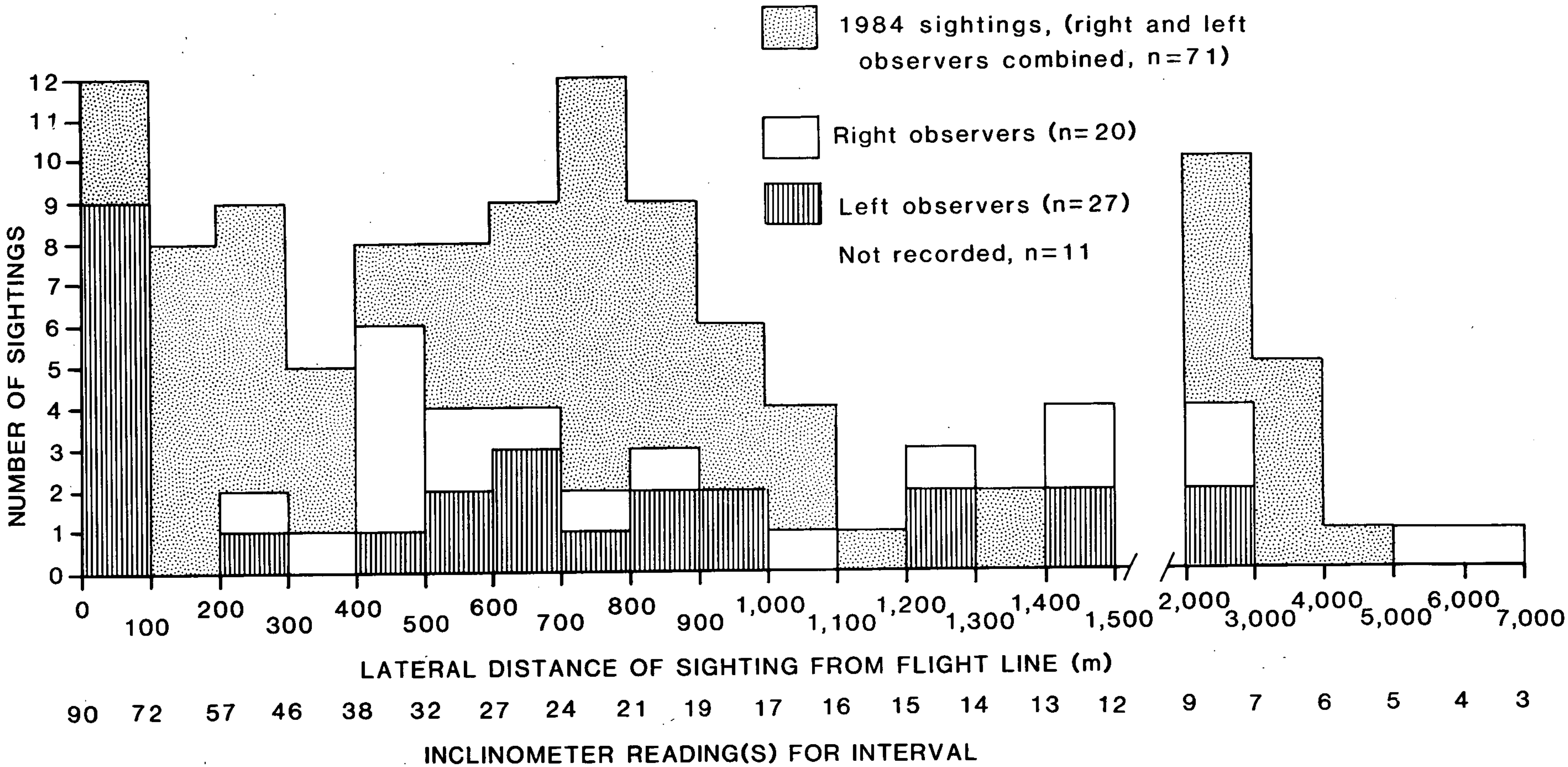


Figure G-1. Comparative distribution of on-transect bowhead sightings across the transect width in 1984 and 1985.

## APPENDIX H

LENGTHS AND LOCATIONS OF WHALES PHOTOGRAPHED IN AUGUST 1985. ANIMALS WITH RESOLUTION AND FLEX GRADES WORSE THAN 3 OR MORE THAN HALF OF THE OBSERVATIONS ARE NOT INCLUDED (SEE METHODS)

| Photo No. | Date | Time (MDT) | Latitude (°N) | Longitude (°W) | Length |
|---|---|---|---|---|---|
| 26 0 | 8/19/85 | 15:02:27 | 69°30.0' | 137°40.0' | 8.31 |
| 26 1 | 8/19/85 | 15:02:27 | 69°30.0' | 137°40.0' | 9.18 |
| 32 0 | 8/19/85 | 15:28:32 | 69°36.0' | 137°55.5' | 8.92 |
| 34 0 | 8/19/85 | 15:29: 6 | 69°36.2' | 137°54.4' | 9.36 |
| 36 0 | 8/19/85 | 15:51:36 | 69°30.8' | 138°12.2' | 8.71 |
| 40 0 | 8/20/85 | 15:25:55 | 69°25.6' | 137°13.3' | 9.65 |
| 42 0 | 8/20/85 | 17:28:12 | 69°38.2' | 136°52.2' | 11.41 |
| 44 1 | 8/20/85 | 18:05:42 | 69°23.6' | 137°14.4' | 9.83 |
| 49 0 | 8/21/85 | 18:30:38 | 70°20.8' | 131°24.4' | 5.50 |
| 49 1 | 8/21/85 | 18:30:38 | 70°20.8' | 131°24.4' | 13.90 |
| 56 0 | 8/24/85 | 17:10:43 | 70°35.3' | 131°25.5' | 12.44 |
| 70 0 | 8/25/85 | 13:01:33 | 69°06.8' | 137°46.6' | 10.23 |
| 70 1 | 8/25/85 | 13:01:33 | 69°06.8' | 137°46.6' | 8.79 |
| 77 1 | 8/25/85 | 13:32:27 | 69°10.1' | 138°08.8' | 11.95 |
| 80 0 | 8/25/85 | 13:40:41 | 69°12.1' | 138°10.0' | 10.27 |
| 82 0 | 8/25/85 | 13:55:23 | 69°13.3' | 138°06.6' | 10.14 |
| 85 0 | 8/25/85 | 14:14:11 | 69°11.4' | 138°06.6' | 11.26 |
| 86 0 | 8/25/85 | 14:22:54 | 69°09.6' | 138°00.0' | 9.32 |
| 87 0 | 8/25/85 | 14:24:16 | 69°09.4' | 138°03.3' | 7.23 |
| 88 0 | 8/25/85 | 14:37:55 | 69°18.4' | 138°16.6' | 10.08 |
| 89 0 | 8/25/85 | 14:44:47 | 69°09.9' | 138°03.3' | 10.13 |
| 91 0 | 8/25/85 | 14:45:44 | 69°09.0' | 138°02.2' | 11.09 |
| 93 0 | 8/25/85 | 14:46:39 | 69°09.3' | 138°02.2' | 7.32 |
| 94 0 | 8/25/85 | 14:50:24 | 69°10.2' | 138°04.4' | 8.37 |
| 96 0 | 8/25/85 | 14:59:38 | 69°06.2' | 137°49.9' | 9.92 |
| 97 0 | 8/25/85 | 15:00:38 | 69°06.4' | 137°47.7' | 7.85 |
| 97 1 | 8/25/85 | 15:00:38 | 69°06.4' | 137°47.7' | 8.76 |
| 103 0 | 8/25/85 | 15:22:16 | 69°04.9' | 137°43.3' | 11.36 |
| 121 0 | 8/25/85 | 17:38:23 | 69°04.4' | 137°44.4' | 10.30 |
| 121 2 | 8/25/85 | 17:38:23 | 69°04.4' | 137°44.4' | 10.95 |
| 122 0 | 8/25/85 | 17:39:27 | 69°04.0' | 137°45.5' | 8.75 |
| 123 0 | 8/25/85 | 17:40:40 | 69°02.8' | 137°42.2' | 8.98 |
| 124 0 | 8/25/85 | 17:48:14 | 69°09.8' | 138°05.5' | 12.38 |

APPENDIX H (continued)

| Photo No. | Date | Time (MDT) | Latitude (°N) | Longitude (°W) | Length |
|---|---|---|---|---|---|
| 125 0 | 8/25/85 | 17:49:48 | 69°20.1' | 138°06.6' | 11.42 |
| 127 0 | 8/25/85 | 18: 1:16 | 69°11.4' | 138°12.2' | 8.16 |
| 129 0 | 8/25/85 | 18: 8:45 | 69°08.0' | 138°05.5' | 8.26 |
| 131 0 | 8/25/85 | 18:10:42 | 69°07.9' | 138°04.4' | 11.35 |
| 132 0 | 8/25/85 | 18:12:16 | 69°08.4' | 138°02.2' | 8.13 |
| 138 0 | 8/25/85 | 18:27:27 | 69°05.4' | 137°52.2' | 11.23 |
| 139 0 | 8/25/85 | 18:27:38 | 69°05.4' | 137°53.3' | 8.67 |
| 141 0 | 8/25/85 | 18:33:40 | 69°04.7' | 137°51.1' | 12.97 |
| 142 0 | 8/25/85 | 18:34:30 | 69°05.7' | 137°53.3' | 10.72 |
| 144 0 | 8/25/85 | 18:36:44 | 69°05.2' | 137°55.5' | 7.35 |
| 145 0 | 8/25/85 | 18:38: 9 | 69°06.2' | 137°56.6' | 8.62 |
| 148 0 | 8/25/85 | 18:49:57 | 69°04.3' | 137°47.7' | 8.30 |
| 149 0 | 8/25/85 | 18:51:52 | 69°04.1' | 137°47.7' | 10.72 |
| 150 0 | 8/25/85 | 18:52:35 | 69°04.5' | 137°46.6' | 12.07 |

## APPENDIX I

## SUPPLEMENTARY OCEANOGRAPHIC INFORMATION

### PHYSICAL OCEANOGRAPHY OF THE STUDY AREA

In the Beaufort Sea, convergence phenomena, upwelling, and the location of the Mackenzie River plume and the pack-ice edge are all affected in a fairly complex manner by a number of physical and meteorologial factors. These include the shape of the coastline and bathymetry, large (regional) and small (local) scale winds, river discharge, seasonal extent of sea ice, and the resulting water circulation and stratification (Herlinveaux and de Lange Boom 1975; MacNeil and Garret 1975; Borstad 1984; Harwood and Borstad 1985; Thomson et al. 1986). During persistent westerly and northwesterly winds, the net surface flow in the southern Beaufort Sea is generally eastwards and toward the coast. The pack-ice moves south, the extent of the open water decreases and the warm, turbid river plume is pushed eastward around Richards Island and is tranported along the Tuktoyaktuk Peninsula. During southeasterly, easterly, and northeasterly winds, the net surface flow is toward the west and offshore. Under this wind regime, the ice retreats and expands the area of open water, and the river plume also expands and branches into two tongues. The eastern tongue of the plume extends north of Kugmallit Bay, while the western tongue is transported to the northwest along the Yukon coast.

During "good" ice years, the ice edge lies beyond the shelf break at about 72°N latitude in August, while it can be as close as 30 km from the coast in "bad" ice years. The severity of ice conditions depends in large part on the persistence of westerlies and northwesterlies in any given year.

Water stratification contributes to circulation patterns by establishing horizontal density and pressure gradients, which in turn lead to gradient (geostrophic) currents. It also inhibits upwelling and transfer between water layers. Stratification in the Mackenzie Bay area and over the Tuktoyaktuk Shelf is effectively controlled by the Mackenzie River discharge, the motion of the plume, and the location of the ice edge. The depth of the summer thermocline (and halocline and pnycocline) in the area is usually less than 10 m and often 5 m or less.

Fronts and areas of upwelling are important as sites of relatively high biological productivity (Simpson et al. 1978; Floodgate et al. 1981; Richardson 1985). Upwelling brings nutrients from the lower layers of the water column into the photic zone and can stimulate phytoplankton production during the summer. However, the importance of summer upwelling to bowheads would depend on zooplankton production and subsequent biomass, which have been shown to be closely linked to phytoplankton production (e.g., Richardson 1985). Upwelling that occurs after August may not result in significantly increased primary production because of rapidly decreasing illumination at this time of year. It is unlikely that late season upwelling could be translated into sufficient zooplankton biomass to be significant to the feeding of bowheads. On the other hand, fronts are areas of convergence of water masses and may be of substantially greater significance to feeding bowheads because they can lead to locally high concentrations of planktonic organisms.

## ENVIRONMENTAL CONDITIONS IN THE SOUTHEAST BEAUFORT SEA

## DURING AUGUST-SEPTEMBER, 1985

### Surface Winds

The surface wind regime in the study area during August 1985 is summarized in Figure I-1 as 6-hourly wind vectors, and is based on data collected from Beaudril's mobile arctic caisson (Molikpaq), which was stationed at Tarsiut in Mackenzie Bay. Only synoptic meteorological charts were available for September and are not presented here. Data obtained from industry vessels at other locations indicate that the wind regime at Tarsiut was fairly representative of conditions in the western portion of the study area.

Prevailing winds before and during the August systematic survey were from the southeast and northeast, except for a brief period of northerly and northwesterly winds on 16 August. AES synoptic charts show that winds at all reporting stations from 1 to 3 September were easterlies, but after several days of variable winds, they became northerly and northeasterly at 5 to 10 m/sec (10 to 20 knots) on 9 September at locations east of Richards Island. Winds remained easterly or were calm along the Yukon and Alaskan coasts between 9 and 11 September. On 12 and 13 September, winds were from the south and southwest at 5 to 12 m/sec (10 to 25 knots).

### Ice Conditions

The ice cover began to disappear from Amundsen Gulf and Franklin Bay in mid May. By late May, Amundsen Gulf was ice-free and the land-fast ice along the Tuktoyaktuk Peninsula started to break up and separate from the coast. In early July, eastern Mackenzie Bay and the southern part of the Tuktoyaktuk Shelf were clear of ice, but heavy pack-ice was still present along the Peninsula. During July, the area of open water in Mackenzie Bay expanded westward to near Herschel Island and northward to about 70°N

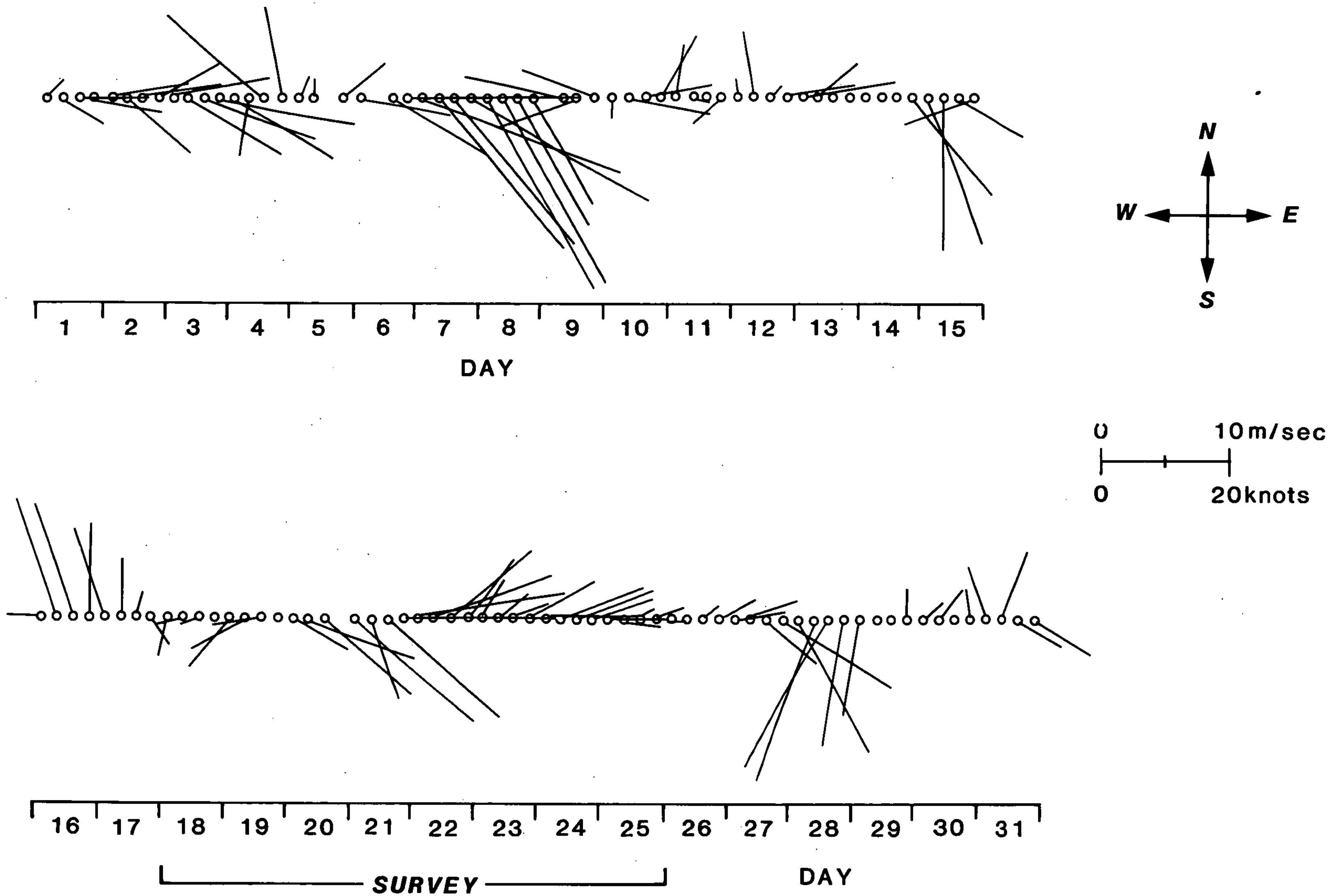


Figure I-1 Wind speed and direction measured from the drillship Molikpaq at Tarsiut in Mackenzie Bay during August 1985. Wind velocity is indicated by the length of the arros, while orientation of the arrows indicates the wind direction (tails of the arrows are upwind).

latitude, although most of the Shelf remained covered by 6+/10 pack-ice. This trend continued during the last half of August and first half of September, with the open water area enlarging to reach a point near Deadhorse in Alaska and north to about 71°N latitude. At this time, a 20-km wide band of open water was present along the Tuktoyaktuk Peninsula, with open pack-ice further to the north. East of Kugmallit Bay, the transition to 7/10 pack-ice was about 100 km offshore and parallel to the coast.

There is substantial annual variability in the location of the summer ice edge in the southeast Beaufort Sea. The difference in the position of this edge between "good" and "bad" ice years can be as large as 300 km (Milne and Herlinveaux, undated). In relation to historic conditions, 1985 may be considered a bad ice year. The ice edge was close to the shelf break over most of the region and, in some places, such as in the Cape Bathurst and Cape Dalhousie area, the ice was located over the shelf itself. This limited the northern extent of some transects during the aerial surveys. Figure I-2 shows the approximate location of the ice edge in late August 1985 in relation to its median position in late August during the period 1961-1972.

## The Pattern of Sea Surface Temperature

The thermal images presented in Plates 1 and 2 show the evolution of the warm water plume extending from Mackenzie Bay during the 18-24 August survey, as well as the upwelling areas along the Yukon coast and cold fronts near the ice edge. The winds in August were primarily from the east and, therefore, the plume was transported a considerable distance to the west.

Cloud over Mackenzie Bay obscured the main part of the turbidity plume on 18 August, but two narrow tongues of warm water were present to the north of Kay Point and Herschel Island. These features are not clearly visible in Plate 1a because of low thermal contrast. On 19 August, cloud obscured all but the warmest part of the plume in Shallow Bay, but a clear image was obtained on 20 August (Plate 1b). The August images provide evidence of a plume of warm water that extended toward the north and west from the vicinity of Richards Island. Surface temperatures were near 13°C at the mouths of the river channels and between 9° and 13°C in the main body of the plume. This part of the plume was separated from colder surface waters located further offshore by a thermal gradient which, in some places, was characterized by a 4°C temperature change in 2 km. This thermal gradient was situated near the 20 m isobath surrounding Richards Island. The presence of several lobes along the northern boundary of the main part of the plume and comparison of the 20 and 21 August images suggest that the plume was being transported to the west.

In enhanced images, a less pronounced thermal tongue can be traced westward from Mackenzie Bay, leaving the coast at Kay Point and continuing north to the ice-edge, where it widens and bends back upon itself in a series of small eddies. This feature is also visible in the calibrated temperature

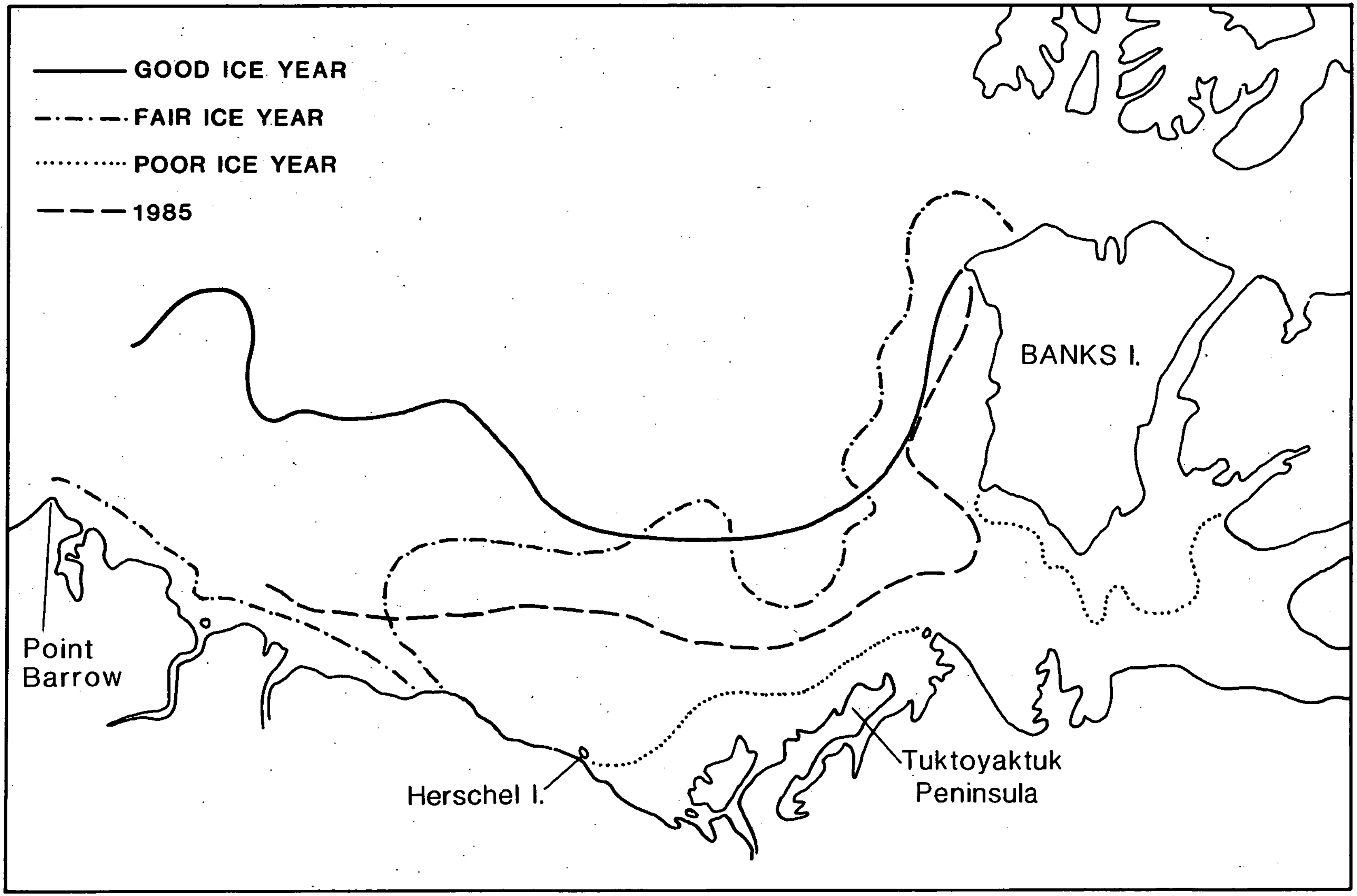


Figure I-2 Comparison of the approximate position of the ice edge in late August with its position in 'good', 'moderate' and 'poor' ice-years (adapted from Milne and Herlinveaux, undated).

images, but much of its structure north of Herschel Island is not discernable. Cold (0-1°C) surface water was located west of Herschel Island on the Yukon coast, as well as in a cold water wake off the northwest corner of this island. The spatial extent of this cold water area increased between 20 and 21 August, suggesting that upwelling or offshore movement of the surface waters was occurring.

In the eastern part of the study area, cold (0-1°C) surface water was also present in the vicinity of a large mass of open pack-ice (4-6/10 cover) extending westward from an area north of Kugmallit Bay. Warm (10-11°C) water from Kugmallit Bay itself was pushed against the western shore of the bay and around Richards Island to the west.

On 21 August, the overall thermal pattern was much the same as on the preceding day, except that cold water was present along the Yukon coast east of Kay Point. The latter is expected to be the result of southeasterly winds on 20 August, which would have pushed the warm, fresh, and less dense surface plume away from the coast. Colder, more saline and dense waters would then be transported to the surface. The temperature of this upwelled water suggests that it probably originated just below the brackish water layer at a depth of 5 or 6 m. Due to the very strong pyncocline and the resulting decrease in friction between the upper and lower water layers, relatively little wind forcing is required to move the plume (in this case, a 5 to 10 m/sec southeasterly wind for about 24 h).

No images were obtained on 22 and 23 August, but some of the western part of the study area was cloud-free on 24 August (image not included here). The lobes along the northern edge of the Mackenzie Bay plume had folded over to the west under the influence of easterly winds, and the mass of open pack-ice north of the Tuktoyaktuk Peninsula had moved further to the west.

Early September was cloudy and only one clear image was obtained during the period of this survey. The 13 September thermal image (Plate 2b) shows a different pattern than was evident in August. In Mackenzie Bay, the plume from the main western channel of the river was cooler and narrower than in August (8-10°C in September versus 9-13°C in August). The warm water plume was located against Richards Island with its outer edge near the 5-6 m isobath; in contrast to the situation in August, no lobes were present along its northern boundary. Some remnants of the warm water patterns found in August were still present north and west of Herschel Island, but surface temperatures were cooler than in August and the thermal contrast was much less pronounced. Enhanced imagery for this day shows that the eddy structure north of Herschel Island was separated from the main body of the plume by an area of nearly uniform water temperature. This may have been caused by a weak divergence in the wind field between 9 and 11 September (easterly winds along the Yukon and Alaska coasts and northerlies from Mackenzie Bay to the east), followed by strong southwesterly winds on 12 and 13 September. Because the surface water layer is relatively thin, unequal wind forcing over the entire area and any prolonged eastward movement of the main plume could have resulted in a separation of the warm waters in the northwest limit of the plume near Herschel Island.

## Frontal Phenomena

Thermal fronts or gradients are visible in Plate 1 near the ice edge, along the edge of the Mackenzie River plume, and in areas of upwelling. The strongest gradients were located just north of Richards Island, and separated relatively warm river water from an area of extensive pack-ice just a few kilometers to the north. In fact, the plumes of warm water leaving the channels of the Mackenzie River could be traced to the vicinity of the pack-ice throughout much of the study area. This may have caused a combination of an ice-edge upwelling (divergence) and a plume edge downwelling (convergence), although it it not possible to confirm the existence of these phenomena due to lack of in situ STD measurement near the ice edge.

The only fronts that appear to be associated with upwelling were located east and west of Herschel Island on the Yukon coast. In these areas, evidence of cold water near the coast was apparent in satellite imagery, while warm and (by inference) fresh, less dense water was observed offshore. These fronts were most pronounced on 21 August, when southeasterly winds paralleled the coast and caused an offshore movement of surface waters and upwelling of colder waters from below the plume.

During 1985, the ice cover extended over most of the shelf-break, except in the area of Herschel Canyon, and there were no visible fronts associated with the shelf-break.

## APPENDIX J

## WILDLIFE OBSERVATION RECORDS FOR THE 1985 DRILLING SEASON

(Asterisk next to time indicates that the sighting was made during a watch)

### EXPLORER I

| DATE | TIME | NUMBER / SPECIES | LOCATION | COMMENTS |
|---|---|---|---|---|
| **Whales** | | | | |
| Aug. 13 | 1645 | 3 beluga | McKinley Bay | at entrance to bay near turning basin; appeared to be feeding -- followed by gulls. |
| 18 | 0800 | 2 beluga | McKinley Bay | feeding in bay |
| **Seals** | | | | |
| Aug. 11 | 0650 | 1 ringed seal | 70°12';131°43' | swimming past port side of ship |
| 11 | 0930 | 1 ringed seal | 70°12';131°43' | swimming past starboard side of ship |
| 18 | 0700* | 1 ringed seal | McKinley Bay | feeding in bay |
| 18 | 1500* | 1 seal | McKinley Bay | on port side of ship |
| 19 | 1500 | 1 seal | McKinley Bay | swimming by ship |
| 22 | 1815 | 1 seal | Havik B-41 | |
| 25 | 1800* | 1 seal | Havik B-41 | |
| 25 | 2300* | 1 seal | Havik B-41 | |
| 26 | - | 2 seals | Havik B-41 | by #7 anchor wire |
| 27 | - | 1 ringed seal | Havik B-41 | by #8 anchor wire |
| 27 | 2300* | 1 seal | Havik B-41 | swimming by port bow |
| 28 | - | 2 seals | Havik B-41 | swimming |
| 28 | 1900* | 1 seal | Havik B-41 | feeding off starboard quarter |
| 31 | - | 1 seal | Havik B-41 | swimming between #7 and #8 anchor wire |
| Sep. 01 | 1050 | 1 seal | Havik B-41 | swimming on port side |
| 01 | 1530 | 1 seal | Havik B-41 | swimming on starboard side |
| 03 | 0915 | 1 seal | Havik B-41 | by #7 anchor wire |
| 04 | 0925 | 1 seal | Havik B-41 | by #8 anchor wire |
| 04 | 2200* | 1 seal | Havik B-41 | swimming on port side |
| 05 | 2150 | 1 ringed seal | Havik B-41 | starboard side of ship; feeding |
| 07 | 1800 | 1 ringed seal | Havik B-41 | swimming among ice floes |
| 09 | 1420 | 1 bearded seal | 70°20';132°13' | swimming and diving |
| 18 | 0925 | 1 seal | Havik B-41 | in open water between floes |
| 19 | - | 1 ringed seal | Havik B-41 | off port side of ship |
| 25 | 1800 | 1 seal | Havik B-41 | |
| 25 | 1500* | 1 ringed seal | Havik B-41 | stuck head out of new ice and looked about |
| 26 | 1100* | 1 ringed seal | Havik B-41 | looking around near ship |
| Oct. 02 | 1810 | 1 seal | 70°20';132°13' | surfacing 100 m away |
| 03 | 1750 | 1 seal | 70°20';132°13' | swimming port side of ship |
| 05 | 1700 | 1 seal | outside Mckinley Bay | surfacing, diving |
| **Bears** | | | | |
| Aug. 29 | - | 1 polar bear | Havik B-41 | on ice; seen from helicopter 12 n. mi. 22°T from ship |

| DATE | TIME | NUMBER / SPECIES | LOCATION | COMMENTS |
|---|---|---|---|---|
| **Bears** | | | | |
| Sep. 14 | 1900* | 5 polar bears | Havik B-41 | on ice floes in vincinity of ship |
| 15 | 0800 | 1 polar bear | Havik B-41 | on ice 6 n. mi. NW of drilling location |
| 15 | 1400 | 1 polar bear | Havik B-41 | lying on ice floe near ship; same one as in morning |
| 15 | 1500* | 1 polar bear | Havik B-41 | lying on ice floe 2 n. mi. from ship |
| Oct. 03 | 1845 | 1 polar bear | 70°21';132°30' | ship en route to McKinley; ship passed within 0.2 n. mi. of bear on ice floe |
| **Other Sightings** | | | | |
| July 23 | 0950 | 1000+ scoters | McKinley Bay | all over bay; feeding |
| 24 | 1100* | 100 scoters | McKinley Bay | in water |
| 26 | 1100* | 30 scoters | McKinley Bay | in water; spread out |
| 27 | 1500* | 30-40 scoters | Mckinley Bay | in water 1/2 n. mi. SE of ship |
| Aug. 17 | 0845 | 100+ ducks | McKinley Bay | feeding all around bay |
| 18 | all day | 500+ ducks | McKinley Bay | feeding all over bay |
| 19 | 1500* | 500+ ducks | McKinley Bay | all around bay |
| 27 | 1900* | 14 glaucous gulls | Havik B-41 | flying over wake of supply boat - feeding |
| 27 | 2300* | 30+ glaucous gulls | Havik B-41 | feeding among ice floes |
| Sep. 04 | 2200* | 7 glaucous gulls | Havik B-41 | feeding in supply vessels' wake |
| 07 | 0700* | 2 black-legged kittiwakes | Havik B-41 | flying about ship |
| 18 | 0835 | 40+ ducks | Havik B-41 | flying W low over ice |
| 18 | 0840 | 40+ ducks | Havik B-41 | flying W low over ice |
| 18 | 1500* | 60+ ducks | Havik B-41 | flying W low over ice |
| 19 | 1040 | 10 ducks | Havik B-41 | flying W low over water |
| 19 | 1205 | 16 ducks | Havik B-41 | flying SW low over water |
| 19 | - | 33 ducks | Havik B-41 | flying low over water |
| 22 | 0840 | 13 ducks | Havik B-41 | flying SW low over water |
| 25 | 1945 | 30 ducks | Havik B-41 | flying SW |
| Oct. 10 | 1400 | 1 raven | McKinley Bay | landed on ship |

EXPLORER III

| DATE | TIME | NUMBER / SPECIES | LOCATION | COMMENTS |
|---|---|---|---|---|
| Whales | | | | |
| Aug. 05 | - | 1 whale | Adlartok | 10 n mi. to NE; believed to be beluga |
| 11 | 1045 | 1 beluga | Adlartok | swimming inside buoy pattern |
| Seals | | | | |
| Aug. 04 | - | 1 seal | Adlartok | looking at ship |
| 04 | - | 1 ringed seal | Adlartok | swimming in area |
| 06 | - | 1 seal | Adlartok | looking at ship |
| 06 | 2030 | 1 seal | Adlartok | in water |
| 07 | 0030 | 1 seal | Adlartok | in water |
| 07 | 1805 | 1 seal | Adlartok | watching ship |
| 08 | 1815* | 1 seal | Adlartok | in water forward of ship |
| 10 | 2225 | 1 seal | Adlartok | swimming near anchor wire |
| 10 | 2315* | 1 seal | Adlartok | swimming along port side |
| 11 | 1735 | 2 seals | Adlartok | swimming close to bow |
| 11 | 1910* | 2 seals | Adlartok | swimming around #2 anchor cable |
| 11 | 2300* | 1 seal | Adlartok | diving and surfacing at 2-4 min. intervals; a large mature grey seal |
| 12 | 1815 | 1 seal | Adlartok | swimming near anchor wire |
| 12 | 1900* | 1 seal | Adlartok | swimming off starboard side |
| 12 | 2225 | 2 seals | Adlartok | in water |
| 12 | 2245 | 1 seal | Adlartok | swimming close by bow |
| 13 | 1915* | 1 seal | Adlartok | swimming and diving |
| 13 | 2120 | 1 seal | Adlartok | on port side |
| 13 | 2315* | 1 seal | Adlartok | starboard side |
| 14 | 0400* | 1 seal | Adlartok | swimming away from port side |
| 14 | 1800 | 1 seal | Adlartok | swimming close by starboard bow |
| 16 | 1800 | 1 seal | Adlartok | too distant to identify |
| 17 | 1815 | 1 seal | Adlartok | swimming off port bow |
| 17 | 1900* | 1 seal | Adlartok | too far away to identify |
| 18 | 1400 | 1 ringed seal | Adlartok | port side |
| 18 | 1900* | 1 ringed seal | Adlartok | |
| 19 | - | 1 seal | Adlartok | 1/2 mile east |
| 24 | - | 1 seal | Adlartok | |
| 27 | 1243 | 1 seal | Adlartok | |
| 28 | 0150 | 1 ringed seal | Adlartok | swimming around anchor wires |
| 28 | 2050 | 1 seal | Adlartok | swimming around anchor wires |
| 31 | - | 1 seal | Adlartok | swimming around anchor wires |
| Sep. 02 | - | 1 seal | Adlartok | swimming near anchor wires |
| 03 | - | 1 seal | Adlartok | swimming near anchor wires |
| 04 | 0820 | 1 ringed seal | Adlartok | |
| 05 | - | 1 ringed seal | Adlartok | swimming near anchor wires |
| 06 | 0300 | 1 ringed seal | Adlartok | |
| 06 | 1100* | 1 ringed seal | Adlartok | |

| DATE | TIME | NUMBER / SPECIES | LOCATION | COMMENTS |
|---|---|---|---|---|
| **Seals** | | | | |
| Sep. 07 | - | 1 seal | Adlartok | swimming near ship |
| 07 | - | 1 ringed seal | Adlartok | swimming near ship |
| 08 | - | 1 seal | Adlartok | swimming near ship |
| 10 | - | 3 seals | Adlartok | swimming near ship |
| 10 | 1100* | 2 bearded seals | Adlartok | |
| 11 | - | 5 seals | Adlartok | swimming near ship |
| 12 | - | 3 seals | Adlartok | swimming near ship |
| 16 | - | 1 seal | Adlartok | swimming near ship |
| Oct. 03 | 0100 | 1 seal | Adlartok | swimming under flare |
| 03 | - | 1 seal | Adlartok | swimming between #2 & 3 wires |
| 04 | - | 1 seal | Adlartok | swimming between #1 & 2 wires |
| 06 | 2345 | 1 seal | Adlartok | swimming close by port side forward; too dark to identify species |
| 07 | 2030 | 1 seal | Adlartok | in water |
| 09 | - | 1 seal | Adlartok | in water |
| 13 | 1815 | 1 seal | Adlartok | in water |
| 14 | - | 1 seal | Adlartok | in water |
| 16 | 1220 | 1 seal | Adlartok | by ice floe |
| 16 | 1405 | 1 seal | Adlartok | |
| **Bears** | | | | |
| Aug. 02 | - | 1 polar bear | in transit to Adlartok | on ice floe |
| **Other Sightings** | | | | |
| Aug. 03 | - | 15 glaucous gulls | Adlartok | on ice floe |
| 08 | 1730 | 1 hawk | Adlartok | approx. 12" in length; resting on ship |

## EXPLORER IV

| DATE | TIME | NUMBER / SPECIES | LOCATION | COMMENTS |
|---|---|---|---|---|
| **Seals** | | | | |
| Aug. 11 | 1130 | 1 ringed seal | Edlok N-56 | swimming toward ship |
| 28 | 1650 | 1 bearded seal | Edlok N-56 | in water on starboard side of ship |
| 30 | 1620 | 1 bearded seal | Edlok N-56 | swimming near #8 buoy |
| Sep. 11 | 2058 | 2 bearded seals | Edlok N-56 | swimming near starboard side |
| 12 | 1920 | 1 seal | Edlok N-56 | swimming near port side |
| 13 | 0900 | 1 seal | Edlok N-56 | playing around #8 buoy |
| 26 | 0840 | 1 seal | Arluk | swimming around ship |
| 28 | 0005 | 1 seal | Arluk | swimming and diving |
| Oct. 05 | 1900 | 1 seal | 70°19';135°12' | swimming on port side |
| 07 | 1900 | 1 ringed seal | Arluk | swimming on starboard side |
| 09 | 1335 | 1 seal | Arluk | swimming on surface between floes |
| 11 | 1845 | 1 ringed seal | Arluk | among ice floes |
| 13 | 1900 | 1 seal | 70°19';135°26' | |
| **Other Sightings** | | | | |
| Aug. 10 | 2040 | 1 arctic loon | Edlok N-56 | flying E |
| 11 | 1124 | 22 glaucous gulls | Edlok N-56 | swimming close to ship |
| 12 | 1400 | 1 arctic loon | Edlok N-56 | swimming |
| 12 | 1608 | 1 pomerine jaeger | Edlok N-56 | flying SE |
| 13 | 1900 | 21 glaucous gulls | Edlok N-56 | swimming |
| 14 | 1100* | 15+ glaucous gulls | Edlok N-56 | flying behind supply boats as they break ice |
| 14 | 1620 | 1 jaeger | Edlok N-56 | flying S |
| 15 | 0625 | 40 common eiders | Edlok N-56 | flying W in straight line |
| 15 | 0915 | 4 pomarine jaegers | Edlok N-56 | flying about ship |
| 15 | 2130 | 2 pomarine jaegers | Edlok N-56 | flying about ship |
| 17 | - | 1 jaeger | Edlok N-56 | flying W |
| 18 | 1500 | 1 "pigeon hawk" | Edlok N-56 | flying around helideck |
| 19 | 1045 | 1 pomarine jaeger | Edlok N-56 | flying E |
| 19 | 1100* | 1 black-legged kittiwake | Edlok N-56 | |
| 20 | 0750 | 1 pomarine jaeger | Edlok N-56 | flying NW |
| 20 | 0800 | 40 oldsquaw | Edlok N-56 | flying W |
| 24 | - | 10 ducks | Edlok N-56 | flying W in straight line approx. 100' above water |
| 28 | 0725 | 3 common eiders | Edlok N-56 | flying W about 0.3 n. mi. from ship |
| 29 | 0925 | 1 murre | Edlok N-56 | flying by port side |
| 31 | 0805 | 2 common jaegers | Edlok N-56 | in water near port bow |
| 31 | 1340 | 10 glaucous gulls | Edlok N-56 | in water near port bow |
| 31 | 1340 | 3 common jaegers | Edlok N-56 | in water near port bow |
| Sep. 05 | - | 1 "pigeon hawk" | Edlok N-56 | landed on top of shut-down helicopter |
| 11 | 1140 | 1 short-eared owl | Edlok N-56 | resting on top of testing boom |
| 13 | 1220 | 5 common eiders | Edlok N-56 | flying W |

EXPLORER IV (continued)

| DATE | TIME | NUMBER / SPECIES | LOCATION | COMMENTS |
|---|---|---|---|---|
| Other Sightings | | | | |
| Sep. 14 | 0600 | 1 short-eared owl | Edlok N-56 | landed underneath helideck |
| 14 | 1553 | 1 jaeger | Edlok N-56 | flying E |
| 15 | 1115 | 10 common eiders | Edlok N-56 | flying W |
| 26 | 1100* | 15+ glaucous gulls | Arluk | sitting on ice floe and flying about |
| 05 | 1900* | 10 glaucous gulls | 70°19'135°12' | in water around ship |

# KIGORIAK

| DATE | TIME | NUMBER / SPECIES | LOCATION | COMMENTS |
|---|---|---|---|---|
| **Whales** | | | | |
| June 29 | 0510 | 2 bowheads | 70°05';131°40' | moving ENE |
| Aug. 06 | 1700 | 1 whale | 70°04';131°50' | on surface; species uncertain |
| 17 | 0000 | 1 bowhead | 69°50';140°20' | on surface swimming SE |
| Sep. 04 | 0801 | 1 beluga | 70°19';131°53' | swimming ESE |
| 10 | 2218 | 2 bowheads | 69°55';132°31' | swimming SW |
| **Seals** | | | | |
| June 18 | 2100 | 4 seals | 70°06';131°25' | on ice |
| 23 | 0700 | 15 seals | 70°08';131°21' | on ice |
| 23 | 1600 | 5 seals | 70°06';131°05' | on ice |
| July 04 | 2015 | 5 seals | 70°03';131°43' | on ice |
| Aug. 07 | 1300 | 1 seal | 69°56';135°19' | on surface |
| 09 | 1620 | 1 seal | 69°43';140°05' | on surface |
| 20 | 1530 | 2 seals | 70°20';132°10' | swimming |
| 21 | 0700 | 1 seal | 70°18';132°12' | swimming |
| 24 | 1410 | 5 seals | 70°20';132°18' | swimming |
| 27 | 1300 | 2 seals | 70°21';132°00' | swimming |
| 27 | 2120 | 6 seals | 70°19';131°54' | swimming |
| Sep. 04 | 0850 | 2 seals | 70°18';131°49' | swimming |
| 11 | 1115 | 1 seal | 70°14';133°40' | on ice |
| **Bears** | | | | |
| June 16 | 0500 | 1 polar bear | 70°12';131°11' | on ice; very mature |
| July 21 | 0715 | 1 polar bear | 69°45';138°17' | on ice; mature |
| Aug. 06 | 2230 | 1 polar bear | 69°58°;134°58' | on ice floes |
| 26 | 1502 | 1 polar bear | 70°20';132°14' | swimming; young bear |
| 27 | 1820 | 1 polar bear | 70°16';131°51' | on ice floe |
| 29 | 0715 | 1 polar bear | 70°07';132°39' | on ice |
| Sep. 03 | 1036 | 3 polar bears | 70°30';132°12' | on ice floe; female and 2 cubs |
| 11 | 1246 | 3 polar bears | 70°03';133°39' | on ice; female and two cubs |
| 14 | 0700 | 1 polar bear | 70°19';132°08' | on ice |
| 14 | 1600 | 2 polar bears | 70°16';132°08' | on ice |
| 15 | 1400 | 1 polar bear | 70°21';132°11' | prone on ice |
| Oct. 22 | 1000 | 2 polar bears | 70°00';135°40' | female and cub; killed a seal |
| **Fox** | | | | |
| Nov. 03 | 0520 | 1 arctic fox | McKinley Bay | on ice near Explorer I |

## KULLUK

| DATE | TIME | NUMBER / SPECIES | LOCATION | COMMENTS |
|---|---|---|---|---|
| **Whales** | | | | |
| Sep. 08 | 1100 | 1 bowhead | 70°27;133°20' | heading towards SW |
| **Seals** | | | | |
| Aug. 16 | 1030 | 1 seal | Nerlerk | surfaced several times in small open patch of water in 8-9/10 ice |
| 16 | 2100 | 2 ringed seals | Nerlerk | |
| 17 | 0730 | 1 seal | Nerlerk | surfaced twice in small patch of water in 9/10 ice concentration |
| 21 | 0704 | 1 ringed seal | Nerlerk | 10 m from stern |
| 24 | 1310 | 2 ringed seals | Nerlerk | approx. 20 m off #3 crane |
| 25 | 1653 | 5 ringed seals | Nerlerk | two 20 m off bow & three 100 m off stern |
| 27 | 0925 | 1 ringed seal | Nerlerk | seal in small patch of open water |
| 28 | 0220 | 1 ringed seal | Nerlerk | in wake of Terry Fox 20-70 m off stern of Kulluk |
| 28 | 0930 | 1 ringed seal | Nerlerk | |
| 29 | 1400 | 2 ringed seals | Nerlerk | in 2/10 ice |
| 30 | 1330 | 1 ringed seal | Nerlerk | |
| 31 | 1946 | 2 ringed seals | Nerlerk | 50 m off side |
| Sep. 04 | 1920 | 2 ringed seals | Nerlerk | |
| 19 | 1110 | 4 ringed seals | Nerlerk | approx. 100 m off side |
| 19 | 1305 | 3 seals | Nerlerk | in wake of Miscaroo |
| 24 | 1326 | 3 ringed seals | Nerlerk | approx. 100 m off stern of Kulluk |
| 25 | 0941 | 2 ringed seals | Nerlerk | approx. 100 m off bow of Kulluk |
| 30 | 0154 | 1 ringed seal | Nerlerk | near side of Kulluk |
| Oct. 14 | 1501 | 1 ringed seal | Nerlerk | approx. 50 m off stern |
| 17 | 1122 | 1 ringed seal | Nerlerk | in area for 2 hours |
| 18 | 1651 | 1 ringed seal | Nerlerk | up for air then dove as ice flows collided below contol room |
| **Other Sightings** | | | | |
| Aug. 19 | 0945 | 50-75 common eider | Nerlerk | flying WSW low over ice (3-4') |
| 19 | 1100 | 4 parasitic jaeger | Nerlerk | heading WSW |
| 19 | 1100 | 8 arctic tern | Nerlerk | flying WSW in loose group - with parasitic jaegers |
| Oct. 12 | 0920 | 100 ducks | Nerlerk | flying SW low over ice |

KIGORIAK (continued)

| DATE | TIME | NUMBER / SPECIES | LOCATION | COMMENTS |
| --- | --- | --- | --- | --- |
| Other Sightings | | | | |
| July 04 | 2000 | 2000+ white-winged scoters | 70°02';131°49' | on water |
| 07 | 0115 | 150 white-winged scoters | 69°57';131°13' | on water |
| Oct 11 | 0630 | 1 snowy owl | 69°36';137°40' | on ice |

## SUPPLIER 2

| DATE | TIME | NUMBER / SPECIES | LOCATION | COMMENTS |
|---|---|---|---|---|
| **Whales** | | | | |
| Aug. 24 | 1218 | 4-6+ whales | 70°01';132°42' | swimming/blowing; dark in colour; in two groups about 300 m apart |
| Sep. 18 | 1115 | 1 whale | 69°42';138°58' | unable to determine species |
| 18 | 1140 | 3 whales | 69°42';140°15' | feeding |
| **Seals** | | | | |
| July 05 | 0622 | 1 seal | Mckinley Bay | swimming |
| 13 | 0800 | 6 seals | Tuk Channel | on ice |
| 18 | 0225 | 2 seals | 69°59';131°09' | on ice |
| 26 | 0330 | 1 seal | 69°57';131°14' | swimming around ice floes |
| Aug. 03 | 1400 | 3-4 seals | 69°40';137°45' | apparently feeding; surrounded by lots of gulls |
| 05 | 0930 | 2 seals | 69°40';137°10' | |
| 07 | 1300 | 3-4 seals | 69°43';139°44' | around large grounded floes |
| 10 | 1900 | 1 bearded seal | 69°47';140°12' | curious |
| 14 | 1825 | 1 seal | 69°39';137°47' | curious |
| Sep. 07 | 1600 | 1 seal | 70°17';132°06' | swimming on surface |
| **Bears** | | | | |
| Sep. 13 | 1330 | 1 polar bear | 70°18';132°27' | on ice floe |
| 15 | 1430 | 1 polar bear | 70°23';132°15' | on ice floe |
| Oct. 02 | 1755 | 1 polar bear | 70°20';135°25' | swimming |

## SUPPLIER 3

| DATE | TIME | NUMBER / SPECIES | LOCATION | COMMENTS |
|---|---|---|---|---|
| **Whales** | | | | |
| Aug. 18 | 0925 | 3 bowheads | 69°42';138°50' | |
| **Seals** | | | | |
| June 28 | 0415 | 1 seal | 69°51';133°06' | in water |
| Aug. 12 | 1025 | 1 seal | 69°40';138°05' | in water |
| 13 | 2200 | 1 seal | 69°47';140°13' | swimming around ice floe |
| 18 | 2315 | 1 seal | 69°42';140°21' | on ice |
| 19 | - | 1 seal | 69°43';140°16' | in water |
| 23 | 1015 | 4 seals | 70°22';132°18' | swimming |
| 24 | 1550 | 2 seals | Havik B-41 | swimming |
| 25 | 2045 | 1 seal | 70°20';132°12' | swimming |
| 31 | 0700 | 3 seals | Havik B-41 | swimming |
| Sep. 07 | 1500 | 1 seal | Havik B-41 | swimming |
| 08 | 2000 | 3 seals | Havik B-41 | swimming |
| 23 | 0900 | 3 seals | Havik B-41 | on ice floe |
| **Bears** | | | | |
| Sep. 16 | 1100 | 1 polar bear | Havik B-41 | feeding; young animal |
| 17 | 0930 | 1 polar bear | Havik B-41 | moving |
| **Other Sightings** | | | | |
| June 27 | 1530 | 30 scoters | 70°05';131°15' | flying |
| 27 | 1550 | 5000 scoters | 70°05';131°20' | flying; in water |
| July 04 | 1635 | 20 ducks | 69°50';133°10' | flying |
| 04 | 2000 | 1000-2000 ducks | 69°59';131°49' | flying |
| 12 | 1320 | 100+ scoters | 69°48';135°00' | flying |

## SUPPLIER 4

| DATE | TIME | NUMBER / SPECIES | LOCATION | COMMENTS |
|---|---|---|---|---|
| Seals | | | | |
| Aug. 10 | 0615 | 3 seals | 70°17';132°12' | on ice |
| 10 | 1250 | 1 seal | 70°21';131°12' | on ice |
| 10 | 1900 | 1 seal | 70°00';131°30' | swimming |
| 10 | 2155 | 1 seal | Tuk Fairway Buoy | swimming |
| 14 | 1600 | 1 seal | 69°39';137°46' | swimming |
| 17 | 2230 | 1 seal | 70°19';135°28' | swimming |

## SUPPLIER 6

| DATE | TIME | NUMBER / SPECIES | LOCATION | COMMENTS |
|---|---|---|---|---|
| **Whales** | | | | |
| Aug. 30 | 0700 | 2 bowheads | 69°49';133°25' | blowing, diving |
| Sep. 20 | 1912 | 2 whales | 8.3 n. mi. ESE Minuk Island | dark colour; under 3-5 min. between spouts |
| 22 | 1605 | 1 bowhead | 69°45';132°41' | very close to edge of ice |
| **Seals** | | | | |
| Aug. 19 | 0630 | 1 seal | McKinley Bay | |
| 28 | 1300 | 1 seal | 3 miles north of Herschel Is. | |
| 28 | 1326 | 1 seal | 3 miles northeast of Herschel Is. | |
| 30 | 0700 | 1 ringed seal | Adlartok P-09 | |
| Sep. 02 | 2052 | 1 seal | 69°45';136°00' | diving |
| 04 | 2230 | 2 seals | Havik | swimming |
| 05 | 1100 | 1 seal | Havik | swimming |
| 11 | 1900 | 2 seals | 70°02';131°21' | basking on ice |
| **Bears** | | | | |
| Sep. 27 | 1630 | 1 polar bear | Arluk | eating a seal; in area of 9/10 ice, 2 miles from rig |
| **Other Sightings** | | | | |
| July 13 | 1700 | 150+ scoters | McKinley Channel | flying, feeding; 3 large flocks |
| 13 | 1730 | 300 scoters | McKinley Bay | flying |
| 16 | 0030 | 200 white-winged scoters | McKinley Bay | feeding, flying |
| 17 | 1530 | 4 black guillemots | McKinley Bay | diving |
| 20 | 0905 | 7 black guillemots | McKinley Bay | swimming |
| 21 | 1558 | 9 black guillemots | McKinley Bay | on water |
| Aug. 14 | 0025 | 300± scoters | McKinley Bay | on water |
| Sep. 01 | 1930 | 150 scoters | 69°48';132°43' | flying |
| 21 | 1814 | 200± scoters | 69°47';132°30' | flying |

## SUPPLIER 8

| DATE | TIME | NUMBER / SPECIES | LOCATION | COMMENTS |
|---|---|---|---|---|
| **Whales** | | | | |
| July 26 | 1900 | 1 whale | 69°56';131°14' | grey in colour; young whale [probably beluga whale] |
| Sep. 08 | 1040 | 1 bowhead | 69°42';135°37' | swimming, blowing; young whale |
| **Seals** | | | | |
| Aug. 05 | 0545 | 1 seal | 69°46';134°50' | swimming |
| 09 | 1250 | 1 ringed seal | McKinley Bay | on surface between dry dock and island |
| 10 | 1853 | 1 ringed seal | McKinley Bay | swimming and diving |
| 08 | 1020 | 1 ringed seal | 69°45';140°14' | swimming |
| 08 | 1915 | 1 ringed seal | 69°45';140°12' | surfacing |
| 09 | 2130 | 1 seal | 69°44';140°03' | swimming |
| 15 | 1028 | 1 ringed seal | 69°40';137°27' | swimming |
| **Bears** | | | | |
| Sep. 13 | 2012 | 1 polar bear | 70°06';132°34' | running, swimming; young adult (8 ft.) |
| **Other Sightings** | | | | |
| July 12 | 2000 | 50 common eiders | 70°05';131°08' | flying S |
| 24 | 1950 | 1 varied thrush | 69°56';131°13' | sitting on crash rail |
| Aug. 06 | 1320 | 50 scoters | 69°50';133°30' | flying S |

## SEA EAGLE

| DATE | TIME | NUMBER / SPECIES | LOCATION | COMMENTS |
|---|---|---|---|---|
| Whales | | | | |
| Aug. 07 | 1100 | 1 beluga | McKinley Bay | sounding |
| Sep. 22 | 1423 | 1 bowhead | 70°10';134°22' | sounding |
| Seals | | | | |
| Aug. 10 | all day | 1 ringed seal | McKinley Bay | playing |
| 24 | 1350 | 2 ringed seals | 70°18';131°54' | on ice floes |
| Sep. 04 | 1600 | 1 ringed seal | 70°15';132°10' | swimming |
| 11 | 1210 | 1 bearded seal | 70°14';132°30' | on ice |
| Bears | | | | |
| Aug. 27 | 1200 | 1 polar bear | 70°13';132°07' | hunting; 9 ft. animal |
| Sep. 14 | 1852 | 1 polar bear | 70°21';130°10' | sitting on ice; large |

## CANMAR TUGGER

| DATE | TIME | NUMBER / SPECIES | LOCATION | COMMENTS |
|---|---|---|---|---|
| **Whales** | | | | |
| Aug. 15 | 2005 | 1 beluga | 70°14';131°51' | diving |
| 17 | 1645 | 1 bowhead | 70°02';131°39' | swimming |
| **Seals** | | | | |
| June 29 | 0730 | 1 seal | McKinley Bay | swimming; diving |
| Aug. 11 | 1910 | 1 seal | 69°43';139°38' | swimming |
| 12 | 1010 | 1 ringed seal | 69°37';137°48' | swimming |
| 12 | 1230 | 1 ringed seal | 69°40';137°48' | swimming |
| 13 | 2100 | 1 ringed seal | 69°40';137°48 | swimming |
| 13 | 2300 | 1 ringed seal | 69°41';137°48 | swimming |
| 14 | 1240 | 1 ringed seal | 69°50';135°46' | swimming |
| 14 | 1315 | 2 ringed seals | 69°48';135°27' | lying on ice |
| 15 | 1906 | 1 ringed seal | 70°08';131°24' | swimming |
| 15 | 1916 | 20-30 ringed seals | 70°08';131°31' | swimming, diving; on ice and in water |
| 16 | 2036 | 4 ringed seals | 70°19';131°09' | swimming and diving |
| **Other Sightings** | | | | |
| June 26 | 1307 | 17 eiders | 69°57';131°14' | flying easterly |
| July 01 | 1600 | 7 king eiders | McKinley Bay | sitting on ice |
| 08 | 1100 | 200 white-winged scoters | McKinley Bay | on water |
| 30 | 0808 | 150 ducks | 69°57';131°14' | swimming, diving |

CANMAR TUGGER 2

| DATE | TIME | NUMBER / SPECIES | LOCATION | COMMENTS |
| --- | --- | --- | --- | --- |
| **Seals** | | | | |
| Aug. 10 | 1400 | 2 seals | 69°44';137°39' | swimming near ice floe |
| 10 | 1945 | 1 seal | 69°43';137°50' | swimming near ice floe |
| 11 | 1440 | 1 seal | 69°38';137°40' | swimming near ice floe |
| 13 | 0900 | 1 seal | 69°37';137°40' | swimming |
| 14 | 0030 | 1 seal | 69°40';136°11' | swimming |
| 16 | 1300 | 1 seal | 69°40';137°52' | swimming |
| 19 | 2120 | 1 seal | 69°40';137°48' | swimming |
| 22 | 1435 | 1 seal | 69°40';137°47' | swimming |
| 25 | 1645 | 1 seal | 69°39';137°43' | swimming |
| 26 | 0815 | 1 seal | 69°39';137°33' | swimming |
| 27 | 1230 | 1 seal | 69°40';137°40' | swimming |
| 27 | 1520 | 1 seal | 69°39';137°41' | swimming |
| 28 | 1100 | 1 seal | 69°37';137°50' | swimming near ice |
| 30 | 0830 | 1 seal | 69°37';137°30' | on ice floe |
| 30 | 1615 | 1 seal | 69°38';137°48' | swimming |
| 30 | 1815 | 2 seals | 69°38';137°45' | swimming near ice floe |
| 31 | 0830 | 1 seal | 69°38';137°48' | swimming near ice |
| Sep. 05 | 1210 | 1 seal | 69°41';137°50' | swimming |
| 06 | 1030 | 1 seal | 69°36';137°51' | swimming |
| 06 | 1324 | 4 seals | 69°39';137°50' | swimming |
| 10 | 1015 | 1 seal | 69°41';137°40' | swimming |
| 11 | 1630 | 1 seal | 69°40';137°41' | swimming |
| 26 | 1750 | 1 seal | 69°38';137°55' | swimming by ice floes |
| **Bears** | | | | |
| Sep. 28 | 0500 | 1 polar bear | 69°33';138°25' | on vast floe; checking ship out; about 8 feet long |
| Oct. 03 | 1845 | 1 polar bear | 70°18';132°42' | walking on floe |

## CANMAR TEAL

| DATE | TIME | NUMBER / SPECIES | LOCATION | COMMENTS |
|---|---|---|---|---|
| **Whales** | | | | |
| July 29 | 0500 | 3 beluga | 69°33';136°56' | |
| Aug. 18 | 1200 | 1 bowhead | 70°17';130°26' | swimming |
| 18 | 1506 | 1 bowhead | 70°13';131°26' | sounding |
| **Seals** | | | | |
| July 12 | 1300 | 1 seal | 69°30';136°52' | diving |
| 14 | 2200 | 1 seal | 69°30';137°29' | diving on approach of vessel |
| 14 | 2225 | 2 seals | 69°34';137°31' | diving on approach of vessel |
| 17 | 1415 | 1 seal | 69°33';137°39' | diving on approach of vessel |
| 19 | 1700 | 1 seal | 69°24';138°00' | diving on approach of vessel |
| 20 | 1040 | 1 seal | 69°26';137°28' | diving on approach of vessel |
| 23 | 1900 | 1 seal | 69°34';138°56' | diving on approach of vessel |
| 24 | 0745 | 1 seal | 69°34';138°55' | looking at vessel |
| 25 | 0120 | 1 seal | 69°34';138°55' | swimming |
| 30 | 0805 | 1 seal | 69°38';137°45' | |
| Aug. 14 | 1230 | 1 seal | 70°13';130°36' | looking at vessel |
| 14 | 2013 | 1 seal | 70°15';130°45' | on small ice floe |
| 16 | 1955 | 1 seal | 70°22';129°28' | swimming |
| 18 | 0700 | 1 seal | 70°21';129°38' | swimming |
| Sep. 07 | 0615 | 1 seal | 69°42';139°11' | swimming |
| 12 | 1030 | 3 seals | 69°45';136°46' | swimming |
| **Bears** | | | | |
| July 20 | 2100 | 1 polar bear | 69°42';138°15' | running on ice |
| Aug. 01 | 2000 | 2 polar bear | 69°39';137°47' | female with radio collar and cub |
| 15 | 0615 | 1 polar bear | 70°23';129°37' | swimming |

## CANMAR WIDGEON

| DATE | TIME | NUMBER / SPECIES | LOCATION | COMMENTS |
|---|---|---|---|---|
| **Whales** | | | | |
| Aug. 25 | 1225 | 1 bowhead | 69°52';134°01' | sleeping |
| 27 | 1355 | 1 bowhead | 69°58';131°51' | swimming |
| **Seal** | | | | |
| Aug. 23 | 0715 | 1 ringed seal | 69°49';134°59' | swimming |

JOHN WURMLINGER

| DATE | TIME | NUMBER / SPECIES | LOCATION | COMMENTS |
|---|---|---|---|---|
| Whales | | | | |
| Aug. 25 | - | 9 beluga | 69°58';131°17' | inside McKinley Bay |

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