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MMS 86-0125

DISTRIBUTION OF BOWHEAD WHALES IN THE SOUTHEAST BEAUFORT SEA, SEPTEMBER 1986

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and

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PN RESEARCH PROJECTS
SIDNEY, B.C., CANADA V8L 3S1

for

DEPARTMENT OF INDIAN AND NORTHERN AFFAIRS, CANADA
HULL, QUEBEC, CANADA KIA OH4
DIAND Contract 25ST.A7135-6-0034

and

U.S. DEPARTMENT OF THE INTERIOR
MINERALS MANAGEMENT SERVICE, ALASKA OCS REGION
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ABSTRACT

A systematic aerial survey of the southeast Beaufort Sea was completed between September 07-14, 1986. Favorable weather allowed for most of the area to be surveyed under optimal conditions. Forty-two bowheads were seen on-transect, and a total of ~100 were seen off-transect and on reconnaissance flights. The estimated number of bowheads in the region at the time of the survey was 2590 (59% of the estimated population). Percent calves in the on-transect sample was 4.7%.

With few exceptions, bowheads observed during September were congregated in three areas: in Yukon coastal waters, primarily between Kay and Shingle points; in Mackenzie Bay, at the interface between the Mackenzie River plume and clear/cold ocean water; and in an area approximately 100 km offshore of the Tuktoyaktuk Peninsula between McKinley Bay and Cape Dalhousie. One bowhead was observed on-transect in the central portion of the study area which encompassed the hydrocarbon exploration zone. There were two active offshore drilling sites, each with vessel and aircraft support, during September 1986.

The apparent age, behaviour, and habitats where bowheads were observed varied among the three congregation areas, and indirect and/or direct evidence of feeding was noted in each. Since the number of bowheads estimated for the region was comparable in both late August (another study) and September, and bowhead movements during September showed no net directionality which could be equated with migration, a large-scale movement of bowheads from the southeast Beaufort probably did not begin until after the September survey was complete. Substantial numbers of bowheads were probably still present in the McKinley Bay/Cape Dalhousie congregation area until at least September 23, 1986, as many were seen on that date during a separate study of seal distribution. Bowheads were congregated near King Point until at least October 03, 1986, although the number seen there was considerably lower than-that-in early-September.

Further analysis and interpretation of the September survey data will be included in ESL's report to ESRF for the August bowhead survey and photogrammetry work (Ford et al., in prep). The survey findings will also be discussed in LGL's report to DIAND for the Bowhead Food Availability Study which was conducted at the same time as part of this September survey (Bradstreet et al., in prep).

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ACKNOWLEDGEMENTS

The September survey was jointly and equally funded by the US Dept. of the Interior, Minerals Management Service (MMS) and the Department of Indian and Northern Affairs, Canada (DIAND) through the Northern Oil and Gas Action Program (NOGAP). We are particularly grateful to Dr. Jerome Montague (MMS) and Mr. Ricki Hurst (DIAND) for their cooperation, support and encouragement throughout the field work, and for their review of the draft report. We also thank Dr. Ian Stirling of the University of Alberta (U of A) for his support and suggestions, and Dr.'s David Stone (DIAND), Cleve Cowles (MMS) and Jerry Imm (MMS) for their assistance with timely program initiation.

The systematic survey was conducted by the authors, and Lawrence Turney of ESL Environmental Sciences Ltd. (ESL). Wendy Calvert of the Canadian Wildlife Service was third observer on September 10 and 14 flights, and Jill Pangman and Gord Stenhouse, Government of the Northwest Territories, Inuvik, NWT, joined as observers on the October 03 reconnaissance flight. We thank each for their participation and interest in the work, and all of us together thank Kenn Borek Air Ltd. and pilots Brian McKinley and Matt Gacek for a safe and successful field season. Cooperation among researchers and projects was maximal in 1986, and involved the real-time exchange of findings and ideas. We gratefully acknowledge managers and researchers from the Dept. of Fisheries and Oceans, Canada (DFO), DIAND, ESL, Environmental Studies Revolving Funds (ESRF), LGL Ltd., MMS and Naval Ocean Systems Center (NOSC) for their contributions and cooperation.

Weather reports provided by the Atmospheric Environment Service (AES) in Inuvik, and by radio operators in Tuktoyaktuk (Beaudril) and McKinley Bay (Canmar), were essential and much appreciated. Ice reconnaissance personnel of AES in Inuvik provided information on current ice conditions. We also thank the Western Arctic Scientific Resource Center in Inuvik for office space and accommodation, the Boreal Institute for Northern Studies at the U of A for a portion of travel and living costs, and the Dept. of Zoology at the U of A for adminstrative assistance and support. Finally, we thank Brian Sawyer of Victoria, B.C. for drafting the figures.

INTRODUCTION

The western Arctic population of bowhead whales (Balaena mysticetus) winters in the Bering Sea, and migrates annually to summering areas in the Beaufort Sea and Amundsen Gulf. The most recent estimate of the population size is 4417 (IWC 1986). Prior to commercial exploitation, however, the population has been estimated to have contained 14,000 to 26,000 individuals (Breiwick et al. 1981).

From late June through September and October, the bowhead population summers within and migrates through areas of the Beaufort Sea which coincide with offshore oil and gas exploration activities. The potential effects of these activities on the bowhead population is an area of concern, and for this reason, an extensive research effort has been directed toward the bowhead since 1980. This report describes one of many projects conducted in 1986 as part of this research effort.

Systematic aerial surveys were conducted in the southeast (Canadian) Beaufort Sea during both late August and early-mid September in all years from 1980 to 1985. The surveys were designed to monitor bowhead distribution relative to hydrocarbon exploration activities, and were funded by industry (1980-82) and ESRF (1983-85). In 1986, ESRF funded the late August survey and concurrent photogrammetry, while MMS and DIAND together funded t-he September survey. The main objectives of the latter were to:

- monitor the distribution of bowheads in the southeast Beaufort Sea during early-mid September, thereby providing a data base for comparison of bowhead distribution patterns within 1986, among years, and with respect to industry activities and oceanographic features, and,
- provide infgrmation which, together with results of the ESRF August survey and surveys in the Alaskan Beaufort, could be used to document the timing and location of the 1986 bowhead fall migration through Alaskan waters..

Censusing seals incidentally to the bowhead search was a further objective, since the survey was coordinated with the senior author's concurrent M.Sc. project on ringed seal distribution.

Reporting of the survey results began with verbal communication of sighting locations to DIAND, Dome Petroleum Ltd., ESL, LGL Ltd., MMS and NOSC, and then circulation of rough maps depicting this same information. This report represents the final communication of results under the survey contract, and is intentionally descriptive and brief. Further analysis and interpretation of the survey data is being undertaken by ESL (Ford et al., in prep), to allow integration and discussion of results with that from the August bowhead survey and photogrammetric flights, and with bowhead sightings made during 1986 seal surveys. In addition, the information from the September survey will be included in LGL's report to DIAND describing the Bowhead Food Availability Study (Bradstreet et al., in prep). The latter involved a large-scale and systematic sampling program for zooplankton and other oceanographic features in the region during late August and September 1986.

METHODS

Survey Design

The study area extended from the Alaska-Yukon border (141° W longitude) to west of Cape Bathurst (127°20′ W), and from the 2 m isobath seaward to 25 km beyond the shelf break, except between 141° W and 138° M, where the seaward boundary was 70°20′ N latitude (Figure 1). The survey was conducted from September 07-14, 1986, and coverage was approximately 10%. Twenty-four north-south transect lines were surveyed, using a strip transect method (Eberhardt et al. 1977) and a transect width of.2 km. Transect positioning ---- along lines of longitude and the transect width used were consistent with past -surveys in the series. ' --

The study area was stratified to facilitate ESL's comparison of September bowhead densities with those from August 1986 and past "years. The stratum boundaries were the"same as 'those established in 1981 (Davis (1982), and used in subsequent years (Yukon, "Delta; Tuktoyaktuk Peninsula 'Tuk Pen' zones, Figure 1).

Reconnaissance flights were conducted over Yukon coastal waters and Mackenzie Bay on September 07 and October 03, 1986.

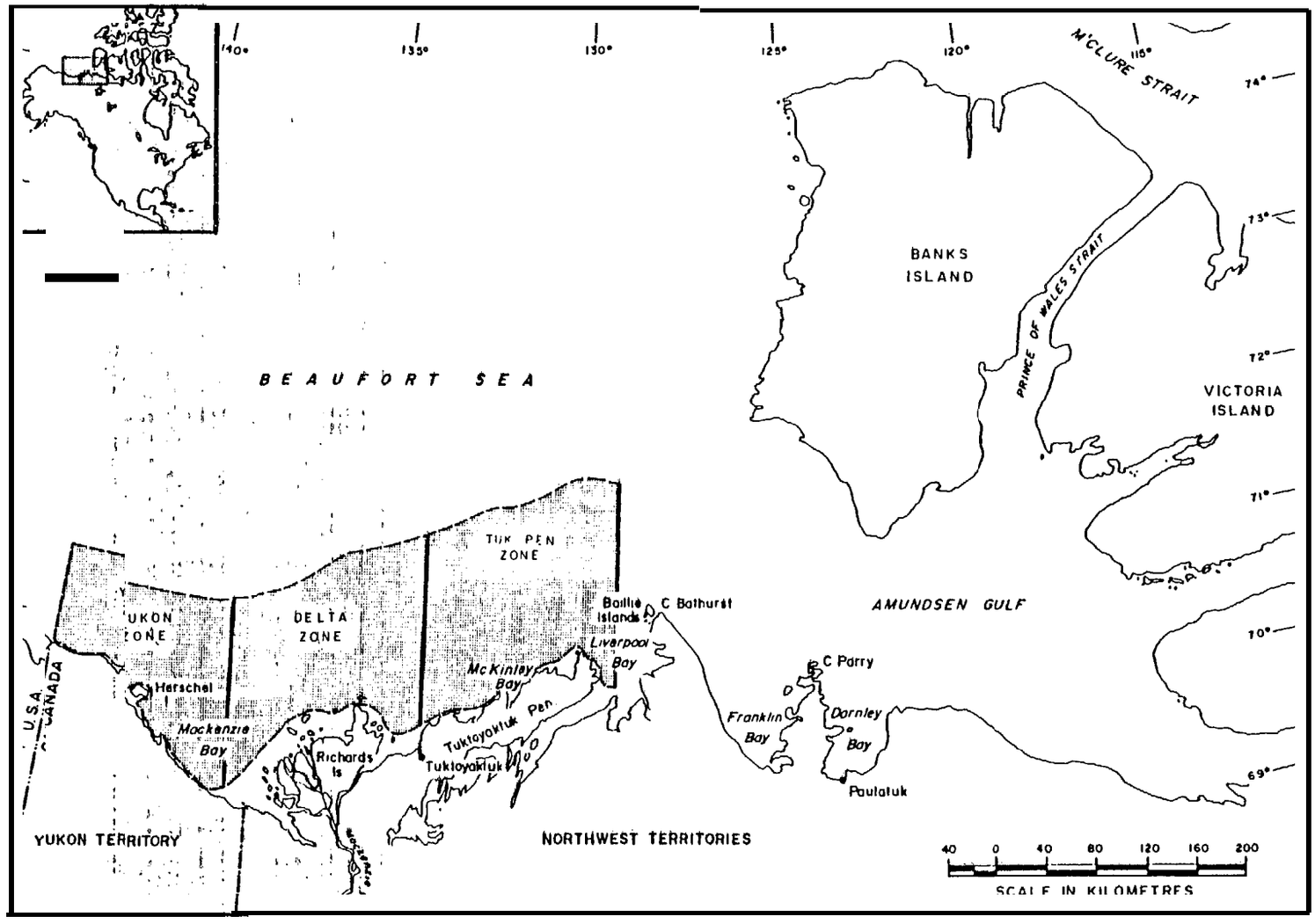

FIGURE 1. STUDY AREA AND LOCATION OF BEAUFORT SEA BOUNDARIES

Survey Procedures

All surveys were conducted from a Series 200 de Havilland Twin Otter (C-GNTA) based out of Inuvik, NWT, and chartered from Kenn Borek Air Ltd. Two primary observers were present on each flight, and each searched through bubble windows installed at the second rear seat positions behind the cockpit. Continous and visual searches were conducted during surveys of all transects, and on flights between consecutively flown transects and all ferrying flights over marine areas. Sightings made by the primary observers within the prescribed transect width were designated as on-transect, while those outside the strip, on connecting legs, and those made only by the third observer (September 10 and 14) and pilot were designated as off-transect.

Survey altitude for the systematic coverage was either 152 m (49% of the area surveyed) or 305 m (51%), and was dictated on the basis of ceilings and sea state. Planned survey speed was 200 km/h, although mean speed along the specific transects ranged from 189-226 km/h due to effects of wind. Reconnaissance flights were conducted from an altitude of 305 m at cruise speed (250-260 km/h). Surveys were not attempted or were terminated if there was cloud below 152 m, fog, or if sea state exceeded 5 on the Beaufort Scale of Wind Force. Transects where survey conditions were considered less than adequate are indicated on the bowhead distribution map (Figure 2, Results) with a dashed line, and were not used in the calculation of bowhead densities.

The aircraft was equipped with a Collins LRN-70 for navigation, and a radar altimeter for monitoring and maintaining survey altitude. An intercom system was used to maintain communication between pilot and observers on all flights. Flight paths are depicted in Figure 2 (Results) as straight transects following line-s of longitude, but should be interpreted as an approximation (± 2 km) of the actual route flown since aircraft heading must constantly be adjusted due to the effects of crosswinds.

Observers recorded information on all whales, seals and polar bears sighted during the surveys, with bowhead whales being the priority when more than one species was present. Observations were recorded onto audio cassette tapes, and later transcribed to standardized data sheets. Whenever possible, the following information was recorded:

- Species
- location of sighting (noted off navigation system)
- time of sighting
- number of individuals
- distance between individuals and group organization
- degrees from horizontal (see below)
- age, on basis of colour, relative size, and behaviour
- apparent behaviour
- direction and relative rate of movement
- presence of mud trails, feces, seabirds

Observers also recorded information on weather (wind, fog, precipitation), wave direction, sea state, water colour, oceanographic fronts, type and concentration of ice, and the presence of debris slicks or accumulations.

A 'group' of bowhead whales was defined as two or more whales within close physical proximity (< 5 whale lengths), or two or more whales moving in the same direction and/or engaged in the same apparent activity within approximately 500 m. A group of whales, or a solitary whale, constitute a 'sighting'. Calves were distinguished on the basis of size (approximately half the length of an adult), and colour (calves light gray in colour and adults black). While immature animals (non-calf) are also black, they too are smaller than mature-adults', and lack the characteristic white markings on peduncle, back and rostrum of mature animals. Therefore, it was also possible in some instances to estimate if an animal was an immature or a mature adult. The visual technique generally limits scrutiny of bowheads with respect to colour, relative size and markings to sightings on the inner half of the transect. Consequently, the number of calves and immature animals identified in the sample was undoubtedly underestimated.

Suunto PM-5/360S inclinometers were used to measure the angle of depression from horizontal of each sighting when the whale(s) was abeam of the aircraft. This angle and survey altitude were then-used to calculate the approximate distance of a sighting from the center line of the transect, and therefore whether it was on- or off-transect.

Sighting locations were determined by recording coordinates off the navigation system at the time of the sighting. Synchronized digital watches were used to record the actual time of the sighting. This information was used as a back-up procedure for plotting sighting locations, and for calculating mean plane speed along each transect.

Data Analysis

This study was not designed or intended to provide an accurate estimate of the number of bowheads present in the study area, but rather to examine general trends in distribution and relative abundance. Accurate estimation of actual numbers would require (1) a priori knowledge of bowhead distribution in order to stratify the study area into blocks where bowhead densities were similar, (2) study-specific estimation of the time that 'towheads spend at the surface to correct for submerged bowheads that were therefore 'undetectable, and (3) study-specific estimation of the number of surfaced bowheads missed by observers to correct for within and among observer differences in ability, alertness, and experience. As outlined below, abundance during the survey has been estimated to allow comparison of numbers between August and September 1986, but these estimates should be interpreted in the broad sense intended given limitations of the procedure.

Bowhead densities were calculated for each zone, using the following formula:

$$\text{zone density.} \frac{\text{\# of on-transect bowheads}}{\text{transect length x transect width}}$$

Zone densities were multiplied by the area of the zone to obtain an uncorrected estimate of the number of whales present. The size of each zone was determined from a 1:500 000 Mercator projection chart. The east and west boundaries were the longitudes located 10 km to the east and west of the first and last transects surveyed, respectively. The southern boundary was the 2 m isobath, and the northern boundary the most northerly point on the transect.. Island and shallow water (<2 m) areas were then subtracted from the total.

Estimates are most precise when densities within a stratum are similar, and this condition was not met in September 1986 -(-whale distribution clumped, see Figure 2, Results). Nevertheless, estimates based on arbitrary strata tend to be more precise than estimates produced from unstratified sampling (Caughley 1977). Further, Ôguss and Robertson (1985) concluded that differences in estimated bowhead densities using transect segments as strata would be small (e.g. 10%) in comparison to the larger sources of error associated with the survey technique used in 1986 and past surveys in the series.

The uncorrected estimates of bowhead abundance were then corrected for surfaced whales missed by observers (counts multiplied by 1.46), and for whales submerged during the passage of the survey aircraft (counts multiplied by 3.165, 4.505, or 7.812, depending on water depth where they were observed). These factors were adopted from Davis et al. (1982) and Würsig et al. (1985), respectively. The applicability of these factors to whale surfacing behaviour, observers, and observation conditions in 1986 is not known, but is expected to be reasonable if the resulting estimates are interpreted as general indicators of trends in relative abundance only. A detailed discussion of the derivation of these factors and the limitations associated with applying them to 1986 survey results will be included in ESL's report for the August survey (Ford et al., in prep). The latter will also present an analysis of bowhead distribution according to habitat type, and how habitat can further influence the interpretation of bowhead densities calculated for both the August and September 1986 bowhead surveys.

Seal Surveys

Localized and systematic surveys were also conducted off the Tuktoyaktuk Peninsula (August 21 and September 23) and over Mackenzie Bay (September 05), as part of the concurrent seal project. Bowheads were observed during each survey. Survey design and procedures were similar to that" used in the bowhead surveys, except that seal surveys were always conducted from an altitude of 152 m and using a transect width of 400 m per side. Bowhead sightings made during the seal surveys will be presented in Ford et al. (in prep), but are referred to in the following discussion where useful for interpretation of September survey results.

RESULTS AND DISCUSSION

The survey was conducted on September 07, 138', 10 and 14, 1986. It was completed in the planned west to east progression, and with minimal gaps in temporal coverage as the result of particularly favorable weather. Survey conditions were 'excellent' for transects 1-8 and 11-18, 'inadequate' for transects 9-10, and varied from 'poor-good' for lines 19-24. Most of the surveyed area (99.3%) was ice-free. Two industry sites were active in the offshore during the survey, and both were located seaward of Kugmallit Bay

near 70° N latitude (Figure 2). Each site had a drilling platform, a complement of supply and support vessels, and helicopter activity associated with it (Norton and McDonald, in prep).

In total, 42 bowheads (33 sightings) were seen on-transect, and nine (eight sightings) were seen off-transect. An additional ~90 bowheads were seen during reconnaissance flights on September 07 (Figure 2) and on October 03 (Figure 3). Sightings made during reconnaissance flights were not necessarily distinct, nowever, since some of the whales may have been included in the systematic coverage or during a return reconnaissance flight. A further 34 bowheads were seen during seal surveys on August 21, September 05, and September 23.

Bowhead Abundance and Percent Calves in Sample

For each stratum, Table 1 lists the area surveyed, size of stratum, bowhead densities therein, and uncorrected and 'corrected' estimates of bowhead abundance. Appendix I lists all bowhead sightings from the systematic coverage, along with sighting location, on- or off-transect designation, and estimated age.

The total number of bowheads estimated for the region during the September 1986 survey was 2590, or 59% of the population based on the IWC (1986) estimate for population size. This estimate corresponds closely with the number estimated for the region during late August (58%, see Ford et al., in prep), suggesting fall migration from the region did not begin until after the completion of the September survey. The fact that the percent estimates for August and September correspond so closely should be interpreted in view of the limitations of the abundance estimation procedure described earlier (Data Analysis, Methods).

Of the 42 bowheads seen on-transect, two were calves. One was solitary (unattended) at the surface, and the other interacting with one adult at the surface, and a third whale (an adult) was in close association. The proportion of calves in the on-transect September sample was 4.7%.

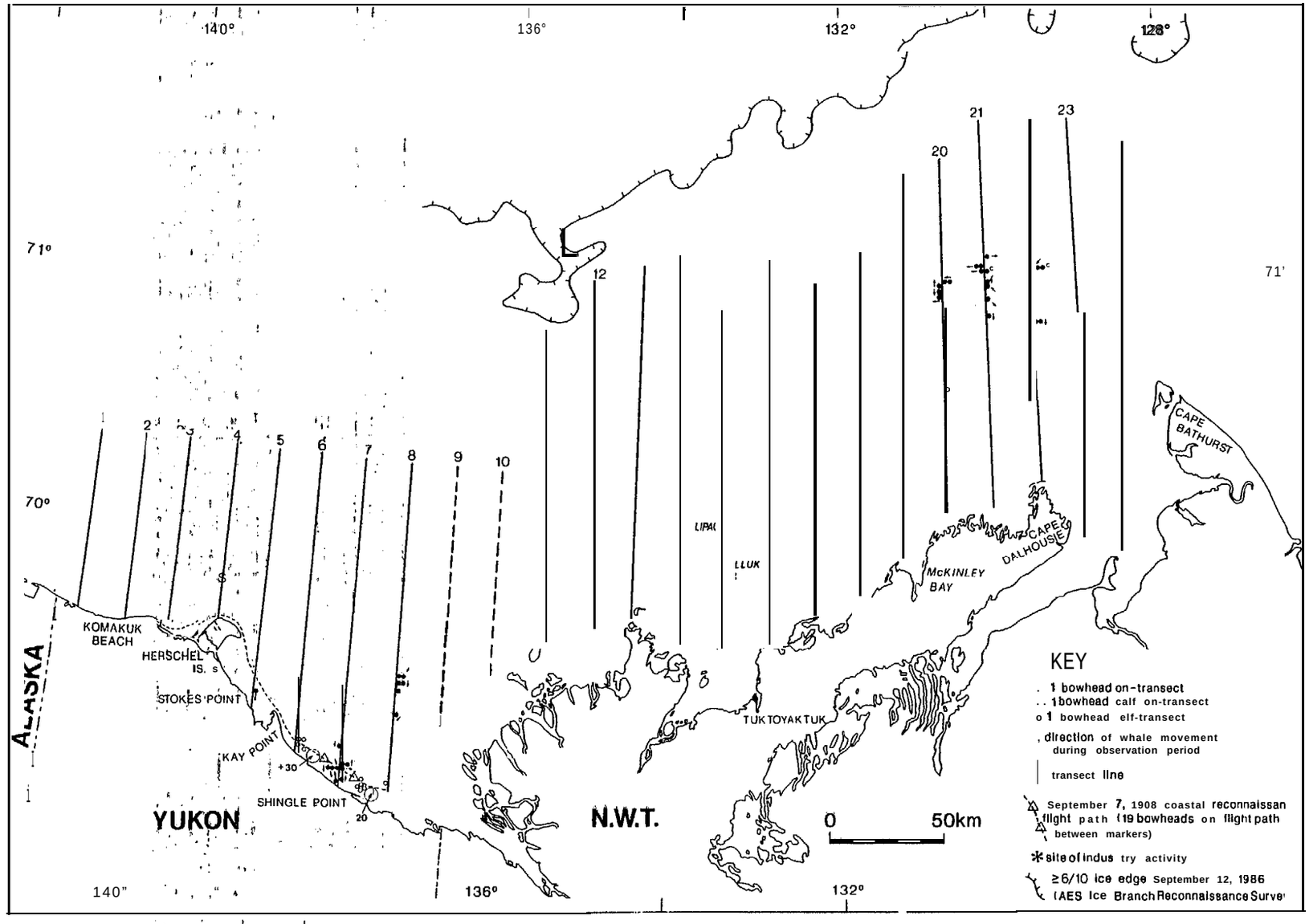

FIGURE 2. DISTRIBUTION OF BOWHEAD WHALES IN THE SOUTHEAST BEAUFORT SEA, SEPTEMBER 07-14/86

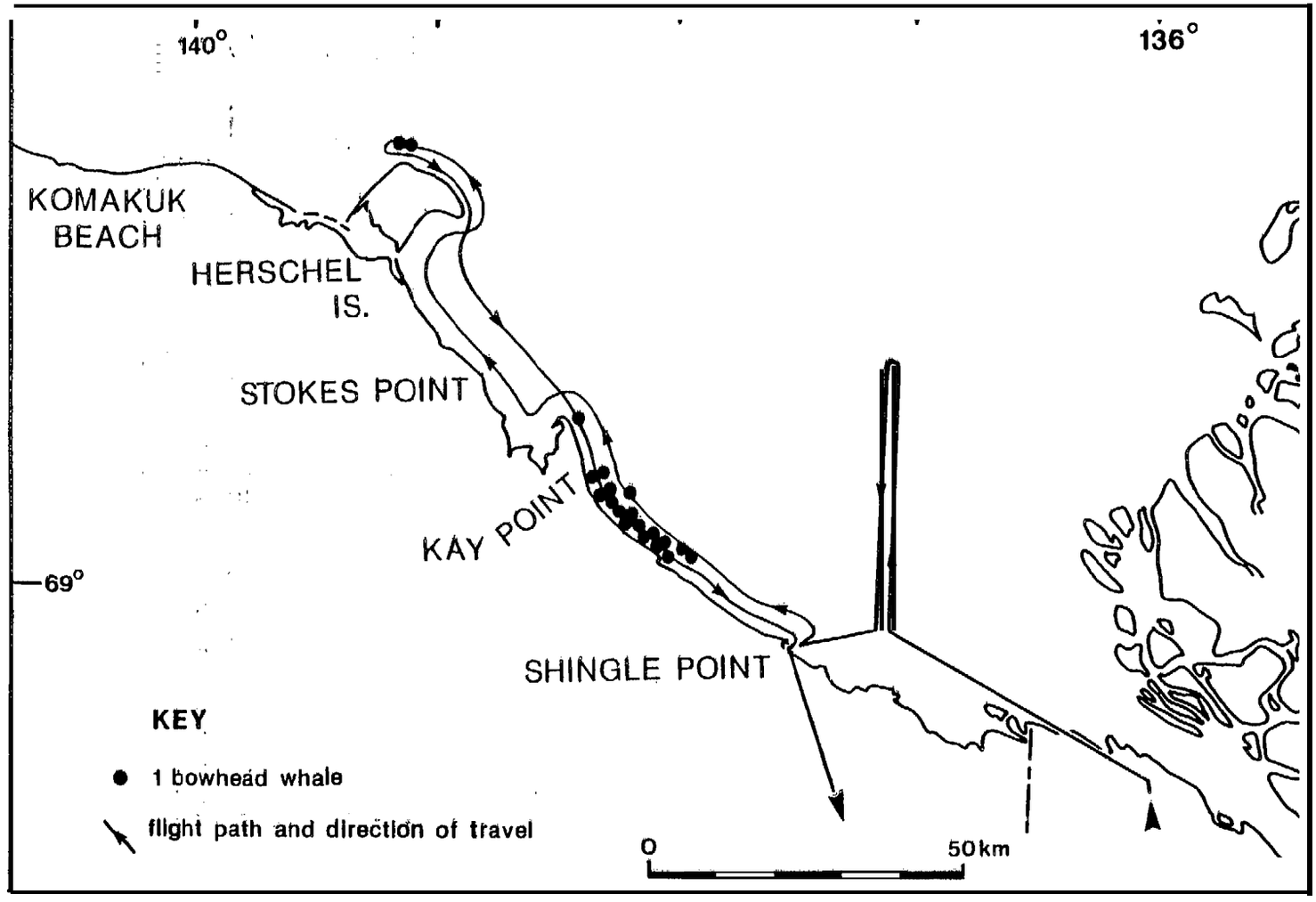

FIGURE 3. DISTRIBUTION OF BOWHEAD WHALES ON OCTOBER 03, 1986 THE YUKON COAST AND MACKENZIE RIVER PLUME INTERFACE

TABLE 1

, ABUNDANCE OF BOWHEAD WHALES IN THE SOUTHEAST BEAUFORT SEA, SEPTEMBER 1986

ZONE	AREA SAMPLED (km^2)	SIZE OF ZONE (km^2)	# OF BOWHEADS ON-TRANSECT	BOWHEAD DENSITY (#/1000 km^2)	UNCORRECTED ESTIMATE OF ABUNDANCE	CORRECTED ESTIMATE OF ABUNDANCE
Yukon	1423.1	14,218.2	10	7.02	100	481.8
Delta	1804.6	18,356.4	7	3.88	71.2	408.8
Tuk Pen	2926.9	29,380.3	25	8.54	250.9	1699.4
TOTAL	6154.6	61,954.9	42		422.1	259U

Distribution, Movements, Behaviour and Habitat Associations

During September, bowheads were congregated in three areas (Figure 2); (1) in Yukon coastal waters, primarily between Kay and Shingle points, (2) in Mackenzie Bay, at the edge of the Mackenzie River plume ('Interface') approximately 40-60 km seaward of Shingle Point, and (3) in an area 100 km offshore of the Tuktoyaktuk Peninsula between McKinley Bay and Cape Dalhousie. The apparent age structure and behaviour of bowheads varied among the three areas, as did the habitat in each area and the other species which occurred there also. Each congregation area is discussed separately below, while a discussion of bowhead distribution in the area of hydrocarbon exploration activity is provided in Ford et al. (in prep).

Area (1) - Yukon Coast

In 1983, 1984 and 1985 surveys, bowheads were congregated within 1-3 km of the Yukon coast, primarily between Kay and Shingle points (McLaren and Davis 1985; Harwood and Borstad 1985; Duval 1986). In some years, nearshore waters at Komakuk Beach were also frequented by relatively large numbers of bowheads. In September 1986, bowheads again congregated in Yukon coastal waters; nearshore waters at King Point appeared particularly important this year.

R. Barnes (DFO, Inuvik, pers. comm.) reported having seen ~50 bowheads along the Yukon coast during an August 15 reconnaissance flight for white whales. Few were seen in this area during late August systematic surveys (Ford et al. in prep), but by early September, bowheads were again found congregated in this area (Figure 2). Observed direction of bowhead movement in this area ranged from N (3 sightings), S (2 sightings), SE (2 sightings), to E (1 sighting). Purposeful migratory movements or net directionality were not apparent; movements were generally slow, and many of the whales were perceived as milling.

Two reconnaissance flights over this area on September 07 confirmed findings and trends seen during the systematic coverage. During a westbound flight, ~50 whales were counted between Shingle and Kay points, with about 30 of these within 1 km of shore at King Point. Later that day, a further ~20 whales were seen off Shingle Point during an eastbound flight and With binoculars from the Shingle Point airstrip while stopped to refuel the plane.

The area was surveyed again on October 03 (Figure 3). Three whales were observed on the westbound track 3-4 km from shore near King Point, and two were seen off the northwest coast of Herschel Island just prior to the aircraft turning for the return flight. The eastbound return track was closer to shore, and 15 bowheads were counted within 1 km of the shore at Kay Point (1 whale) and between Stokes and King points (14 whales). None were seen near Shingle Point on this flight. Fast ice first appeared in the Yukon coast area and near Herschel Island within a week of this survey (Ice Forecasting Central, Environment Canada, Ottawa, Canada; pers. comm.)

During all survey visits to the Yukon coast, whales appeared to be feeding; a complex system of fronts was seen here and overflown twice on September 07 (off Shingle Point). Whales were concentrated at some of the frontal areas. One whale was observed defecating. Individuals close enough to the flight path for scrutiny did not have the characteristic white markings on peduncle or backs. No calves were seen in this area. Ringed seals were common, and were most often seen in association with bowheads near King Point.

Area (2)- Interface

The term 'Interface' is used to describe the area in Mackenzie Bay where the Mackenzie River plume meets the clear, cold and higher salinity ocean water. In some areas, this interface is gradual and diffuse, while in others it is exceptionally distinct. During the surveys, a distinctly visible interface was found parallel to transect 8 (between 69°20′ and 69030′) and bisecting transect 9 (at 69035′). Bowheads congregated in this area in September 1986, as was also noted during 1984 and 1985 surveys. The Interface was surveyed twice during September and once in October in 1986.

On a September 05 seal survey, 12 bowheads were seen in the area, all of which were observed at the Interface (both landward and seaward sides) or at adjacent frontal areas. On the September 07 bowhead survey, six-were seen on-transect at the Interface parallel to transect 8, and all were positioned along the seaward edge of the front. Whale movements in the area showed no net directionality, and ranged from N, S, to SW (1 on-transect sighting each). Whales were observed circling, producing mud trails, darting, and positioned along fronts, and again, noted as without markings on peduncle, rostrum or back. No bowhead calves were seen in this area, and

seals were not seen in association with whales during the systematic coverage.

Neither whales nor a distinct Interface were found in this area during the October 03 reconnaissance flight (Figure 3). Areas influenced by the Mackenzie River plume (muddy water) were beginning to freeze at the time of the survey, and by the second week of October, fast ice had formed (Ice Forecasting Central, Environment Canada, Ottawa; Canada; pers. comm.).

Area 3- Offshore McKinley and Dalhousie

Bowheads were congregated approximately 100 km offshore of the Tuktoyaktuk Peninsula, between McKinley Bay and Cape Dalhousie (at 70°50′ - 71010′) during the September survey. Of all the areas sampled in 1986, the density of bowheads there was the highest. If a 3000 km^2 rectangle centered over the bowhead congregation is considered (between transects 19 and 22, and 70°50′ - 71010′), the density of whales therein was 70.8/1000 km^2. Extrapolation and correction of this density produces an estimate of 1300 bowheads for this particular area. (Comparable numbers were probably still present in this area during the September 23 seal survey, although marginal survey conditions on that day must also be taken into account when interpreting bowhead estimates).

The water in the McKinley-Dalhousie congregation area was clear, homogeneous with respect to colour, and ice-free. No obvious frontal areas were noted. Whales that could be scrutinized at close range were on occasion perceived as larger than whales seen in the western congregation areas, and some had white markings on rostrum, peduncle and back. The two calves seen during the survey were in this area.

Direction of whale movement was again variable: 1 sighting was moving N, 1 was moving---S, 4 sightings had a westerly component (SW, NW) and 4 sightings had an easterly component (E, SE, NE). Fluking up (indicative of a 'deep-dive) and surfacing almost vertically (nose first) were noted, suggesting the whales were diving to depth. Water in this area ranges from 40-50 m in depth. Ringed and bearded seals were common in the area, and seen in association with bowheads and seabirds. The abundance and behaviour of whales, seals and seabirds in this area suggest it was a highly productive one.

LITERATURE CITED

Breiwick, K.M., E.D. Mitchell, and D.G. Chapman. 1981. Estimated initial population size of the Bering Sea stock of bowhead whale (Balaena mysticetus): an iterative method. US Fish. Bull. 78(4):843-853.

Davis, R.A., W.R. Koski, W.J. Richardson, C.R. Evans, and W.G. Alliston. 1982. Distribution, numbers, and productivity of the western Arctic stock of bowhead whales in the eastern Beaufort Sea and Amundsen Gulf, summer 1981. Prep. by LGL Ltd., Toronto, Canada, for Dome Petroleum Ltd., Calgary, Alta., Canada, and Sohio Alaska Petroleum Co., Anchorage, Alaska, USA. 135pp.

Eberhardt, L.L., E.G. Chapman, and J.R. Gilbert. 1979. A review of marine mammal census methods. Wildlife Monograph No. 63. 46pp.

Harwood, L.A. and G.A. Borstad. 1985. Bowhead whale monitoring study in the southeast Beaufort Sea, July-September 1984. Environmental Studies Revolving Funds Report No. 009. Ottawa, Ontario, Canada. 99pp.

IWC (International Whaling Commission). 1986. Report of the Sub-Committee on protected species and aboriginal subsistence whaling. Report of the International Whaling Commission Annex i-l. Vol. 36: 95-111.

McLaren, P.A. and R.A. Davis. 1985. Distribution of bowhead whales and other marine mammals in the southeast Beaufort Sea, August-September 1983. Environmental Studies Revolving Funds Report No. 001. Ottawa, Ontario, Canada. 62pp.

Oguss, R. and I. Robertson. 1985. Assessment of-the value of stratified sampling for aerial surveys; a case study of bowhead whales in the Beaufort Sea. Oraft Report. Prep. by Ian Robertson Consulting Ltd., Surrey, B.C., Canada, for Dept. of Fisheries and Oceans, Canada, Winnipeg, Manitoba, Canada.

Würsig, B., E.M. Dorsey, W.J. Richardson, C.W. Clark, and R. Payne. 1985. Normal behaviour of bowheads, 1980-84. p.13-88, In: W.J. Richardson, cd., Behaviour, disturbance responses, and distribution of bowhead -whales (Balaena mysticetus) in the eastern Beaufort Sea, 1980-84. OCS Study MMS 85-0034. Prep. by LGL Ecological Research Associates Inc., Bryan, Texas, USA, for US Dept. of Interior; "Minerals Management Service, Reston, Virginia, USA. 306pp.

APPENDIX I

BOWHEAD WHALE SIGHTINGS DURING SYSTEMATIC SURVEY
IN THE SOUTHEAST BEAUFORT SEA, SEPTEMBER 1986

Latitude (°N)	Longitude (°W)*	Number (on/off trans)	Age**	Heading	Seastate+	Date (09/86)
69 21.3	138 37.0	1 (on)	A	S	1	07
69 10.2	138 06.6	2 (off)	A	?	2	07
69 08.7	138 06.5	1 (off)	A	?	2	07
69 03.0	137 34.7	1 (on)	A	N	3	07
69 06.5	137 34.7	1 (on)	A	SE	3	07
69 06.5	137 34.7	1 (on)	A	SE	3	07
69 06.5	137 34.7	1 (on)	A	S	3	07
69 10.7	137 34.7	1 (on)	A	S	3	07
59 03.1	137 34.7	1 (on)	I	N	3	07
69 06.4	137 34.7	1 (on)	I	E	3	07
69 06.6	137 34.7	2 (on)	A	N	3	07
69 29.4	137 02.8	2 (on)	A	NE	1	07
69 27.4	137 02.8	2 (on)	A	S	1	07
69 26.5	137 02.8	1 (on)	A	?	1	07
69 19.8	137 02.8	1 (on)	A	SW	3	07
69 04.1	137 02.8	1 (off)	A	?	2	07
70 11.9	134 57.2	1 (on)	I	SW	1	10
71 03.0	131 17.2	1 (on)	I	NE	4	14
71 04.5	131 17,2	2 (on)	A	N & N E	4	14
71 04.2	130 46.1	1 (off)	A	N	5	14
71 01.2	130 46.1	1 (off)	A	S	5	14
71 01.3	130 46.1	1 (off)	A	W	4	14
71 06.4	130 46.1	2 (on)	A	W	5	14
70 40.0	130 46.1	1 (off)	A	?	5	14
70 57.7	130 14.9	1 (on)	A	S	5	14
71 00.8	130 14.9	1 (on)	A	SE	5	14
71 04.4	130 14.9	1 (on)	A	NW	5	14
71 06.4	130 14.9	1 (on)	A	S	5	14
71 08.8	130 14.9	1 (on)	C	NE	5	14
71 11.0	130 14.9	1 (on)	A	E	5	14
71 08.8	130 14.9	1 (on)	A	W	5	14
71 08.8	130 14.-9	2 (on)	A	W	5	14
71 08.6	129 42.1	1 (on)	A	W	4	14
71 08.0	-129 42.1	1 (on)	A	S	4	14
71 31.9	129 42.1	1 (off)	A	?	3	14
71 08.1	129 42.1	3 (on)	2A, 1C	SW	4	14
70 54.2	129 42.-1	2 (on-)	A	S	4	14
70 45.4	128 39.9	1 (on)	I	SE	5	14
70 45.1	128 39:9	1 (on)	I	W	5	14
-70 57.5	128 39.9	1 (on)	A	S	5	14
71 26.9	128 39:9	1 (on)	A	S	2	14

* Longitude of Transect, sighting location may vary due to effects of wind on actual flight path (see Methods)

** A-Adult, (I-Immature, C-Calf; if detectable)

+ Beaufort Scale of Wind Force at time of sighting