Chukotskiy Peninsula (footnote 11).

The objectives of the *Western Viking* survey were essentially met. Since no bowheads were sighted, it does not appear that a major correction factor is needed for the spring 1978 population estimate.

Acknowledgments

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Summer Distribution of Bowhead Whales in the Eastern Beaufort Sea

MARK A. FRAKER and JOHN R. BOCKSTOCE

Introduction

Nearly all bowhead whales, *Balaena mysticetus*, of the western Arctic stock migrate each spring from wintering grounds in the Bering Sea to summering grounds in the eastern Beaufort Sea and Amundsen Gulf where they stay for up to 4 months (Fraker et al., 1978; Fraker, 1979). The whales begin their spring journey soon after ice conditions permit (late April) and they remain on the summering grounds nearly until freeze-up. Although the summering area must be of major significance in the ecology of these animals, little is known about its geographical extent or the reason for its importance.

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

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Methods

Whaling Ship Observations (1891-1906)

Because there are few recent sightings of bowheads from the eastern Beaufort Sea and Amundsen Gulf, the best information about bowhead distribution comes from logbooks kept by commercial whalers who operated extensively in this region from 1890 to about 1910 (Bockstoce, 1977). The locations and dates of sightings and captures have been extracted from original logbooks (held by the Whaling Museum, Old Dartmouth Historical Society, New Bedford, Mass.; the Providence [Rhode Island] Public Library; and Harvard University) of vessels operating in the eastern Beaufort Sea from 1891 to 1906 (Table 1). The only logbooks selected were those of cruises which took place entirely in the eastern Beaufort Sea region, and thus were preceded and followed by overwintering in the Arctic. We selected these records to

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

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

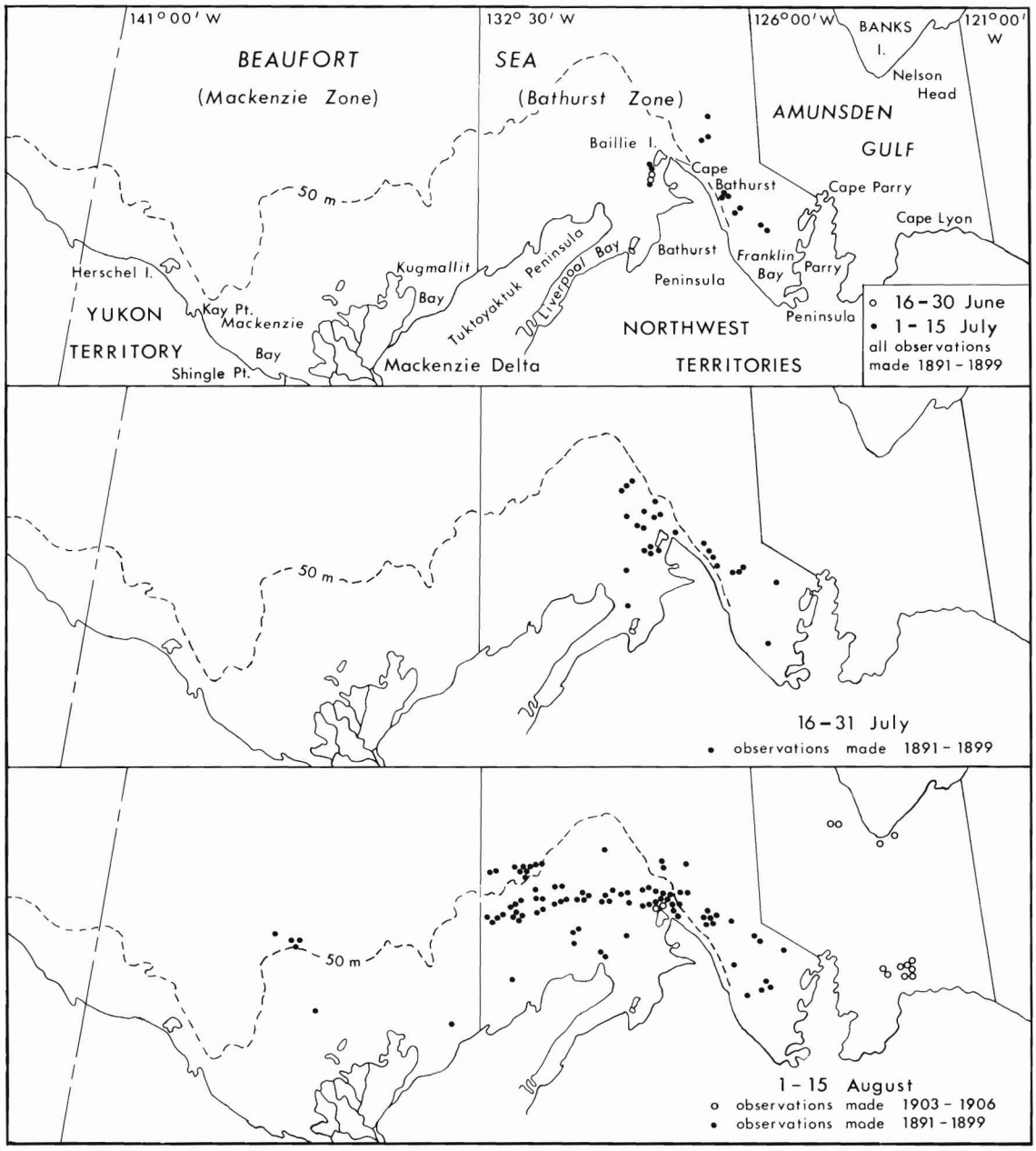

Figure 1. —Locations of bowhead whale observations made from whaling ships, 1891-1906. Each symbol represents an observation of one or more whales.

ensure that the searches by the whalers spanned the greatest possible time period in this region. Because of ice conditions to the west (near Point Barrow, Alaska), vessels from "outside" were unable to arrive in the eastern Beaufort Sea before August; vessels intending to leave the Arctic had to pass Point Barrow by early September (Cook, 1926; Bodfish, 1936; Bockstoce, 1977). We used data from only one cruise per year to minimize biases which might have resulted from peculiar conditions of particular years. We would have preferred to use data from one cruise from each year of the commercial fishery in the Beaufort Sea, but unfortunately, for certain years, documents meeting our requirements have not survived.

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

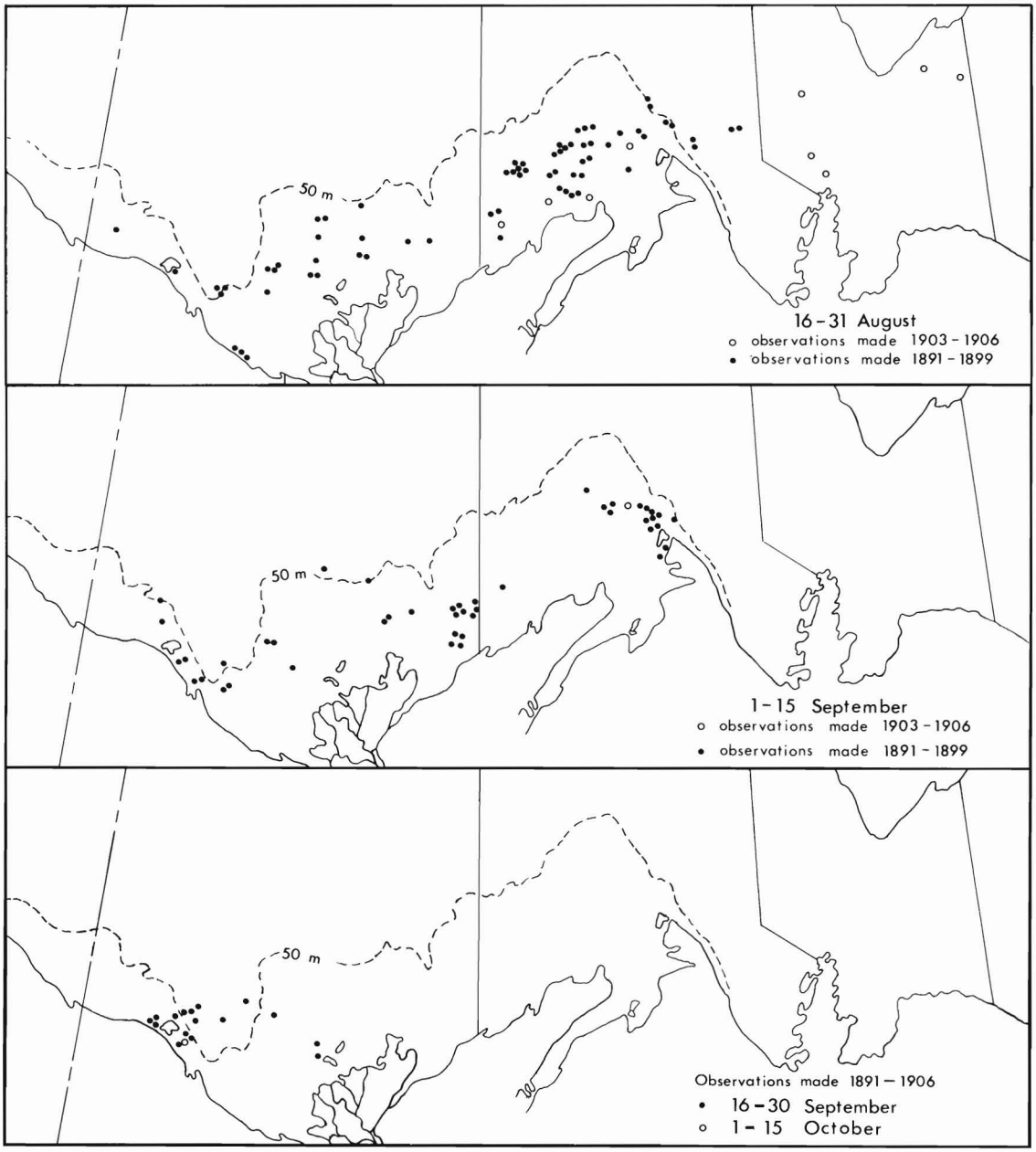

Figure 1. —Continued.

(10 nmi). Observations from uncertain locations were omitted.

Recent Observations (1974-78)

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

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

Results

Whaling Ship Observations (1891-1906)

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

percent and 6 percent made in the Mackenzie Zone and Amundsen Gulf (Table 2).

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

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

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

Table 2.—Area, time period, and number of bowhead whale observations made from whaling ships, 1891-1906.

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

Recent Observations (1974-78)

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

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

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

There has been a relatively large number of recent observations of bowheads along the Yukon coast between Shingle Point and Kay Point during August and September (Fig. 4). Each of these sightings was of one to seven individuals. Most were within 3.2 km (2 miles) of the shore. On 13 September 1976, a minimum of 33 was observed in the area between Shingle Point and Kay Point.[1]

Don McWatt,[2] on about 31 August 1975, observed four bowheads as he walked along the beach from Sabine Point to Shingle Point. They were swimming southeastward along the coast at the rate of a man walking. The whales were observed for about an hour, during which time they made several dives, each with an estimated duration of 10-15 minutes. McWatt suspected that these animals may have been feeding.

Not shown on Figure 4 are observations made by Mr. and Mrs. George Allen[3] who regularly camp at Shingle Point and travel along the Yukon coast from early July to about mid-September. They say that bowheads

[1]William Koski, Biologist, LGL Limited, Edmonton, Alberta, T5N 1P6, pers. commun., 14 September 1976.
[2]Don McWatt, resident, Aklavik, N.W.T. X0E 0A0, pers. commun., July 1976.
[3]Mr. and Mrs. George Allen, residents, Aklavik, N.W.T. X0E 0A0, pers. commun., July 1976.

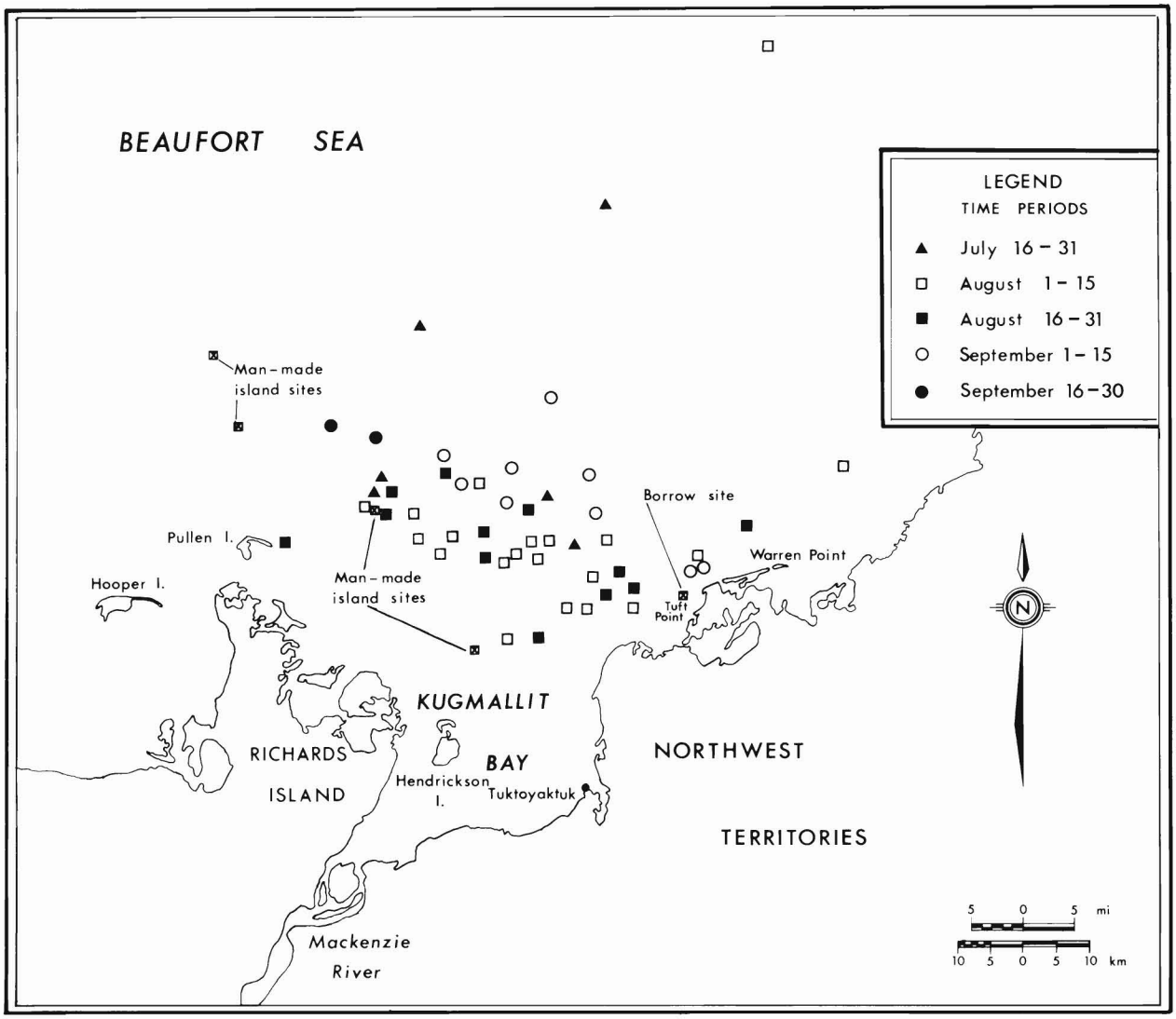

Figure 2. — Bowhead whale observations in the Mackenzie River estuary region of the Beaufort Sea, 1976-78. Each symbol represents an observation of one or more whales.

usually appear in this area in late August or early September. Commonly the bowheads approach to within a few meters of the beach.

Discussion

The whalemen made the majority (67 percent) of their sightings and captures in the Bathurst Zone, particularly near Cape Bathurst (Fig. 1). The lesser importance to them of the Mackenzie Zone is particularly significant because most cruises began from Herschel Island (Table 1), and the vessels hunted while passing through this area en route to the Cape Bathurst "whaling ground" (Cook, 1926). It was not until after mid-August that many whales were recorded from the Mackenzie Zone (Table 2). The failure of the whalers to find whales west of the Cape Bathurst area until after July adds support to the theory that this stock undertakes its eastward spring migration relatively far offshore, rather than along the coast (Fraker et al., 1978; Fraker, 1979; Braham et al., 1980; Braham and Krogman[4]).

[4]Braham, H. W., and B. D. Krogman. 1977. Population biology of the bowhead (*Balaena mysticetus*) and beluga (*Delphinapterus leucas*) whale in the Bering, Chukchi and Beaufort Seas. Processed rep., 29 p. Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Seattle, WA 98115.

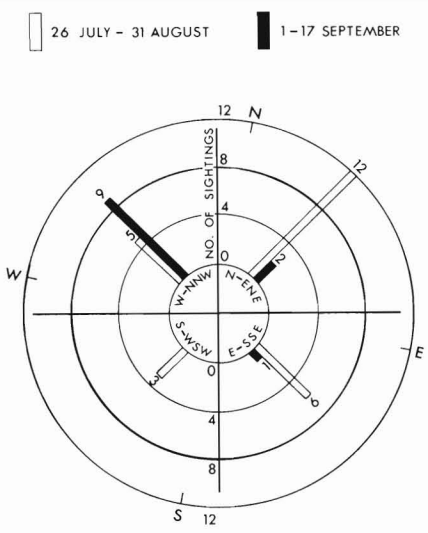

Figure 3.—Direction of movement and time period of bowhead whale observations in the Mackenzie River estuary region, 1976-78.

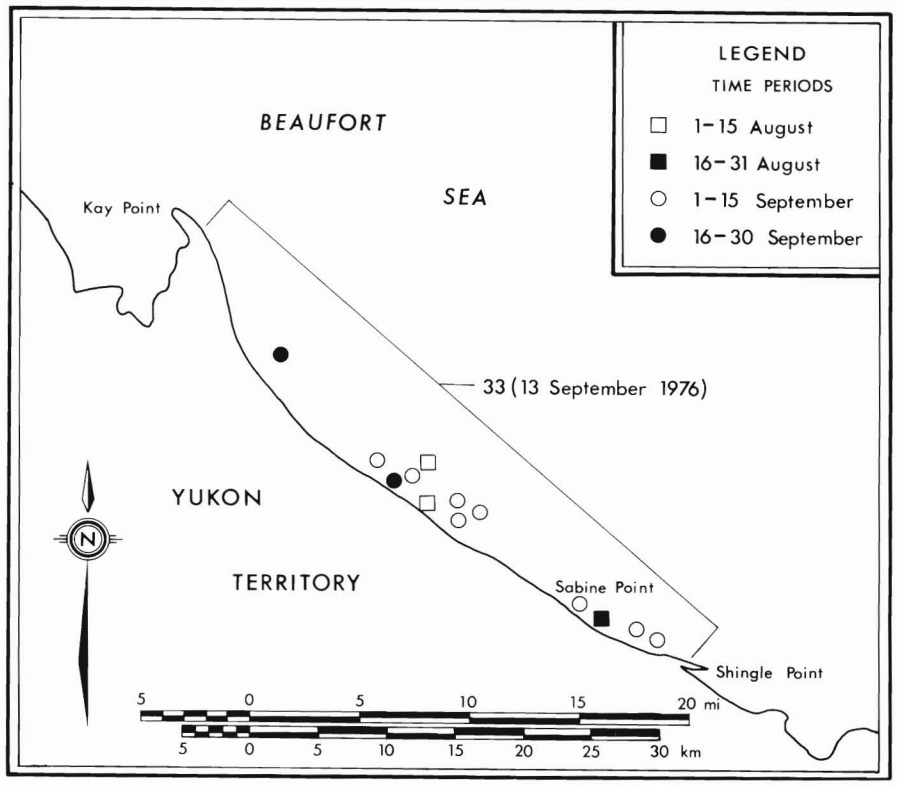

Figure 4.—Recent bowhead whale observations along the Yukon coast, 1973-76. Each symbol represents an observation of one or more individuals, except for a minimum of 33 whales which were observed on 13 September 1976 between Kay Point and Shingle Point.

The observations from Amundsen Gulf were all made after the turn of the century (Fig. 1). Until that time, the whalers had concentrated their attention on the productive whaling ground near Cape Bathurst and westward to near Herschel Island. But as the number of whales in the stock was reduced, the whalers extended their searches eastward. Cook (1926) also hunted farther eastward during this period, but not before, and he reported several sightings near Nelson Head in August of 1903 and 1905. Cook's sightings have been plotted by Fraker et al. (1978).

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

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

In the Bathurst Zone, bowheads were observed out to a depth of about 50 m (164 feet) (Fig. 1). It was on this "20-25 fathom ground" that Bodfish was par-

ticularly successful in pursuing bowheads (Bodfish, 1936; Bockstoce, 1977). Bodfish was a careful and observant individual who not only searched a wide area, but also was comparatively systematic in recording his observations. For example, he took soundings of depths where whales were taken, and the observations which are farthest north of the Tuktoyaktuk Peninsula on Figure 1 were his. Thus, his observations are particularly important in defining the probable extent of the outer boundary of the summering grounds in this area.

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

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

Observations during 1976-78 suggest that the present pattern of bowheads in the eastern Beaufort Sea is similar to that recorded three-quarters of a century ago. Many of the recent sightings were made from vessels operating between Tuft Point, a source of granular fill material, and the sites of man-made islands (Fig. 2); the locations and dates of these observations are similar to what would be expected from running a transect across the distribution shown in Figure 1.

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

Directions of movement differed significantly between the 26 July-31 August period and the 1-17 September period in 1976-78 (Fig. 3). During the earlier period, animals moved in all quadrants, but particularly those with an easterly component. Why such a large proportion should head eastward at this time is not clear. In September, 9 of 12 sightings were of bowheads moving W-NNW. Whales moving in these directions would eventually leave the Beaufort Sea, and we suspect that such movements are part of the fall migration.

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

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

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

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

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

Along the Yukon coast, where several recent observations of bowheads have been recorded, there are few data on zooplankton abundance. However, in the nearshore areas from Herschel Island to Shingle Point, Hsaio et al. (1977) found levels of primary productivity 4 to 10 times higher than elsewhere in the southern Beaufort Sea, and such an abundance may support a prolific growth of zooplankton upon which bowhead whales depend.

In discussing the major factors limiting primary production in the southeastern Beaufort Sea, Grainger (1975) identified the attenuation of light by

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

Conclusions

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

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

Acknowledgments

We thank Elizabeth Rex, Old Dartmouth Historical Society, for her assistance in extracting the whale observations from the original logbooks. The extraction of data from logbooks was funded by the U.S. Marine Mammal Commission and the National Marine Mammal Laboratory of the National Marine Fisheries Service. Kathy Bruce and Jacquie Langlands, LGL Limited, prepared the figures and typed the manuscript. Esso Resources Canada Limited has supported recent whale studies in the Beaufort Sea, and we gratefully acknowledge John Cooper, George Greene, Stan MacKay, Gerry Rempel, Jim Riley, and Tom Watmore of Esso for their continuing support. Special thanks go to Andrew Erigaktoak for his cheerful help during aerial surveys. W. John Richardson, Rolph Davis, and William Griffiths, LGL Limited, made helpful criticisms of this paper; its preparation was funded by LGL Limited and the Old Dartmouth Historical Society.

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