bowhead whales. The Naval Arctic Research Laboratory at Barrow, Alaska, gave me institutional and individual support. The National Marine Mammal Laboratory, NMFS, Seattle, Wash., supplied data on fetuses and provided financial support, as did the Arctic Institute of North America, Calgary, Alberta, Canada, and the Office of Naval Research, Washington, D.C. I also thank James Mead, Jane Small, and David Schmidt of the National Museum of Natural History, Smithsonian Institution, Washington, D.C., for courtesies extended in making it possible for me to examine a frozen fetus on deposit there. Larry Rockhill, Field Coordinator, University of Alaska, X-CED Program, Rural Education Development Center, Barrow, Alaska, provided the photograph of the 37.5 cm long fetus from Wainwright, Alaska.

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Observations of Bowhead Whales During Spring Migration

GEOFFRY M. CARROLL and JOHN R. SMITHHISLER

Geoffry M. Carroll and John R. Smithhisler are with the National Marine Mammal Laboratory, Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 7600 Sand Point Way N.E., Bldg. 32, Seattle, WA 98115.

Introduction

Each spring bowhead whales, *Balaena mysticetus*, of the western Arctic stock travel through breaks in the sea ice, migrating from their winter grounds in the Bering Sea to their summer grounds in the Beaufort Sea (Braham et al., 1980). These breaks in the ice, or leads, form when winds blow the moving pack ice away from landfast ice, creating a flaw zone of open water and broken ice generally parallel to the shore. If conditions allow, most bowheads follow these nearshore leads while migrating along the northwestern coast of Alaska. This provides an excellent opportunity to observe their behavior.

There is little published information on the behavior of bowhead whales. Some whaling captains (Scoresby, 1820; Scammon, 1874; Cook, 1926; Bodfish, 1936) included comments on whale behavior in reporting their experiences in Arctic waters. Tomilin (1957), Sleptsov (1961), Maher and Wilimovsky (1963), McVay (1973), Marquette (1976, 1978), Everitt and Krogman (1979), Rugh and Cubbage (1980), Gilmore[1], Foote[2], Durham[3], Fiscus and Marquette[4], Braham and Krogman[5], and Marquette[6] include comments on bowhead behavior.

During April, May, and June 1975-78, National Marine Fisheries Service (NMFS) biologists were stationed at Point Hope and Point Barrow, Alaska, to census the bowhead whale population, maintaining a 24-hour watch (ice and weather conditions permitting) from camps established on the landfast ice (Braham and Krogman, footnote 5; Braham et al., 1979). They recorded the behavior of bowheads during their northward migration in the nearshore lead past the ice camp. Two categories of behavior were recorded: 1) General migrating behavior directly associated with rate and direction of migration, group size, size class distribution, dive profiles, and movements of whales through constantly changing ice fields; and 2) "extra-migratory" behavior such as reaction to human disturbance,

[1]Gilmore, R. M 1951. The Arctic right whale, Greenland whale, or bowhead. Unpubl. manuscr. [Vol. 15, Encyclopedia Arctica], 71 p. Avail. Dartmouth College Library, Hanover, NH 03755.

[2]Foote, D. C. 1964. Observations of the bowhead whale at Point Hope, Alaska. Unpubl. manuscr., 73 p. Geogr. Dep., McGill Univ., Montreal, Que., Can

[3]Durham, F. E. 1972. Biology of the bowhead whale (*Balaena mysticetus*) in the western Arctic. Unpubl. manuscr., 93 p. Dep. Biol., Univ. South. Calif., Los Angeles, CA 90007.

[4]Fiscus, C H., and W. M. Marquette. 1975. National Marine Fisheries Service field studies relating to the bowhead whale harvest in Alaska, 1974. Processed rep., 23 p. Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Bldg. 32, Seattle, WA 98115

[5]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., Bldg. 32, Seattle, WA 98115.

[6]Marquette, W. M. 1977. The 1976 catch of bowhead whales (*Balaena mysticetus*) by Alaskan Eskimos, with a review of the fishery, 1973-76, and a biological summary of the species. Processed rep., 80 p., Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Bldg. 32, Seattle, WA 98115.

resting, exuberant displays, and feeding. The objective of this paper is to describe the behavior of migrating bowhead whales as interpreted from observations, literature, and conversations with Eskimo whalers.

General Migratory Behavior

Rate and Direction of Migration

When ice was not obstructing their passage, bowhead whales moved through the nearshore lead at a steady rate, seldom altering course. Depending on the direction and velocity of the water current, their rate of travel relative to the observers ranged from 1 to 11 km/hour. Nearly all the whales traveled northeastwardly; fewer than 1 percent traveled in the opposite direction. When they traveled southwest it was usually because of closed leads stopping their progress to the northeast.

Group Size

During the spring migration, bowheads usually travel alone, though they are occasionally seen in pairs and small groups, with individuals separated by a few meters. Of 2,406 bowheads that we observed over the 4 years, 1,815 (75.4 percent) were traveling singly; 470 (19.5 percent) were in pairs; 105 (4.4 percent) were in groups of three, and 16 (0.7 percent) traveled in groups of four animals. Usually one individual of a pair was distinctly smaller than the other but not small enough to be a calf-of-the-year. Foote (footnote 2) suggested that these may be young whales that stay with the cow for more than 1 year.

During the migration there were noticeable peaks in the numbers of whales passing our camps. These peaks, or pulses, could be thought of as loosely associated groups of whales, possibly in communication with each other. This could have been a function of ice conditions, as bowheads sometimes accumulate in open water areas until a blocked lead becomes passable. However, we recorded the most distinct pulses of whales in 1978, when the lead was open all season, suggesting that there may be pulses inherent in the migration of these whales—pulses which are altered but not caused by ice conditions. The Eskimos describe three major pulses each spring. Durham (footnote 3) concluded from his bowhead catch statistics that there were four pulses. Our results show a varying number of pulses from year to year with no strong consistency except that two pulses were distinct between 15 April and 30 May each year from 1976 to 1978 (Braham et al., 1979; Krogman, 1980).

Size Class Distribution

Smaller and presumably younger whales were more prevalent early in the season. From mid-April through early May, when bowheads first appeared in the leads off Barrow, most of the whales were judged to be small. From late May to early June, the majority of whales were large. This is consistent with observations made by Eskimos. Calves-of-the-year have been seen migrating with their mothers during April, May, and June, indicating that at least some calves were born shortly before or during the spring migration (Braham et al., 1980). Small calves generally stay close to their mothers' sides and are difficult to see particularly if they are on the offshore side of the mother. On two occasions, very small calves were seen riding their mothers' backs, apparently grasping the mothers with their flippers.

Dive Profiles

Bowheads progressed with long, presumably deep, sounding dives interspersed with shorter periods near the surface during which they surfaced, exhaled (ventilated or "blew"), inhaled and dove several times in succession. Viewed from the ice, the prominent bowed head and blowhole appeared first, usually accompanied by the high "V" shaped vapor trail of an exhalation or "blow." This was followed by the broad, rounded back, lacking a dorsal fin, which appeared as the head submerged. Several seconds after the back submerged, the head reappeared beginning the next roll. After the last blow in a series, the whales arched their backs sharply before sounding. Occasionally bowheads were seen to display flukes on a sounding dive.

Each whale observed surfaced 2-14 times in a dive sequence, beginning with the first blow and ending with an apparent sounding dive. Of 63 observations of rolls from undisturbed whales from 1975 to 1977, the mean number was 6.57 ± 3.08 (standard deviation, SD) per dive sequence. Of 41 recorded dive sequences during 1978, the mean number of blows per rise was 6.53 ± 2.84 (SD). Undisturbed bowheads most often ventilated seven to nine times per dive sequence, but it was not unusual for them to blow as few as two or three times (Fig. 1). However, a blow is not always visible each time a whale rolls, and thus the data may be biased slightly downward.

For determining the average time that whales were at or near the surface, only the 1978 data were used because of greater precision obtained in timing observations with the use of time-lapse digital stopwatches. Surfacing sequences were recorded for eight bowheads that provided a total of 31 timed periods. The mean time at the surface for these whales was 4.7 seconds (2.0 SD). Mean time below the surface between blows, determined from 30 timed periods for all eight whales, was 10.8 seconds (5.2 SD).

The mean total time a bowhead was visible to observers (30.9 seconds), was derived by multiplying the mean number of rolls by the mean time of each roll. The mean duration of a rise, 91.2 seconds, was determined by adding the mean time above the surface to the mean time between blows. This was

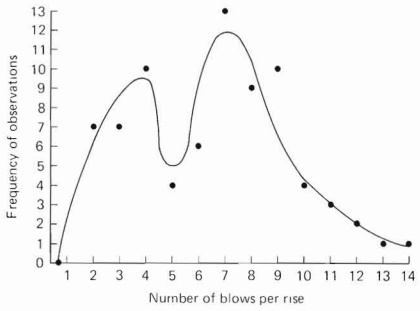

Figure 1.—Frequency of blows per rise for bowhead whales observed during spring migration near Point Barrow, Alaska, 1975-77.

the time between sounding dives when a whale was at or near the surface and presumably visible from an aircraft.

Of 63 sounding dives timed during 1975-78, the estimated mean duration of such dives was 15.6 minutes (5.0 SD). Sounding dives as short as 3.0 minutes and as long as 26.7 minutes were recorded.

Using the above results the percentage of time spent at and near the surface was calculated. Combining the 15.6 minutes mean sounding dive time with the derived 91.2 second mean rise time, a time of 17.1 minutes was calculated for the complete cycle. On the basis of these calculations some part of the whale was visible above the surface 3.1 percent of the time and was above or near the surface between sounding dives 8.4 percent of the time. The whales were below the surface and not visible from ice level 96.9 percent of the time and not visible from an aircraft 91.6 percent of the time. This is consistent with the findings of Braham and Krogman (footnote 5) that more whales per effort (time) were seen during aerial surveys than from counting camps.

Sounding dive times of three cow-and-calf pairs ranged from 5.9 to 7.0 minutes, with a mean duration of 6.6 minutes. The calf usually surfaced with its mother and often blew twice during a surfacing period. Cows with calves appeared to adapt their surfacing patterns to the diving capabilities of their offspring.

Eskimo whalers are aware of the breathing pattern of undisturbed bowheads and utilize this knowledge to maneuver their boats into position where they can strike the animal when it surfaces. Hunters at Barrow often note the time that a bowhead sounds and utilize radios to notify crews farther along the lead to watch for it to resurface 15-20 minutes later. If a whale's normal breathing pattern was disrupted, for example if it dove because it was being pursued by Eskimo whalers, it took fewer breaths and surfaced sooner than during an undisturbed sounding dive. Foote (footnote 2) stated that wounded, frightened, or otherwise extremely disturbed bowheads could stay underwater for up to 1.25 hours. When they resurfaced, such whales were lethargic and slow to react.

Maneuvering in Ice

During their northward spring migration, bowheads encounter constantly changing ice conditions. Leads open or close as the wind and/or current shifts throughout the season, or refreeze during periods of calm, cold weather. When whales encounter a partially closed lead interposed with polynyas (areas of open water surrounded by ice), they adjust their diving and surfacing sequences to the size and location of the open water. Whales encountering a small polynya would surface and blow as many times as space allowed while traveling at normal speed; then they would dive at the far edge of the polynya. If another polynya was close, the whales would surface there, take a few more breaths, and continue on. In this way they were able to move steadily through flaw zones that were mostly covered with ice.

It is not known how bowheads maneuver or navigate from one polynya to another. Because the irregularly shaped edges of pack and fast ice do not usually fit tightly together, there is generally open water and/or patches of thin ice seaward of the shorefast ice edge. The subsurface of the flaw zone seems sufficiently different in appearance from solid pack and shorefast ice that whales could follow it and successfully find open water or thin, breakable ice. Using scuba gear we have observed that holes in the ice and areas with no snow cover (i.e., new ice) are easy to detect when visibility is fair to good, as there is greater light penetration there. Presumably, these areas are apparent to the whales.

During the spring of 1978 near Point Barrow, Smithhisler observed three bowheads surfacing together near the southwestern side of the only polynya within several miles. The opening was about 150 × 800 m, with the longest axis perpendicular to the edge of the frozen lead. The three whales dove at the same time and, minutes later, surfaced within 10 seconds of one another on the northeastern edge of the polynya several hundred meters apart. They blew several times along the edge of the ice, dove within 10 seconds of one another, and were not seen again. It looked as if the whales had separated to search a wider area. These simultaneous movements suggested to us that the whales were somehow communicating with one another.

Occasionally a lead closed so tightly that the whales' progress was hindered, and the polynyas were too far apart to be reached in a single dive. Some whales proceeded though the lead appeared closed, but fewer did so than when the lead was open. We heard blows though there was no visible open water. It appeared that the whales dove, searched, and, if they did not find another polynya, returned to mill in the available polynya, thus keeping the surface water from freezing. Bowheads can break new ice as thick as 22 cm[7]. Sea ice is more flexible than freshwater ice, and bowheads and white whales, *Delphinapterus leucas*, have been sighted pushing up young ice, forming hummocks to breathe.

Tomilin (1957) mentioned several instances of bowheads being trapped in the ice in Soviet waters. Sleptsov (1961) stated that bowheads have been trapped in heavy pack ice in various gulfs along the Chukchi Peninsula, U.S.S.R., and that a mass mortality of bowheads occurred in Karaginskiy Bay, U.S.S.R., in 1932. Unfortunately, no other details were available. Southwell (1898) quotes Eschricht and Reinhardt as saying that bowheads perished in the ice in Disko Bay near Greenland. Bowhead whales, then, are not always successful at finding or forming a breathing hole in the ice.

For periods of hours or days, whales seemed to follow a similar course, surfacing on the same side of the lead and often in nearly the same location as the whales that preceded them. There could be several explanations for this. Foote (footnote 2) interviewed some Eskimos who believed that whales follow a cloud of bubbles left by the preceding whale. Water currents, which at times appear

[7]J. J. Burns, Alaska Dep. Fish Game, Fairbanks, AK 99701, pers. commun.

to move in different directions in different parts of the lead, may influence their direction of travel. Bowheads tended to surface in bights (small embayments in the ice); their behavior may then be related to the way a lead forms and the shape it assumes.

Extra-Migratory Behavior

Reaction to Human Disturbance

When bowheads are pursued by Eskimo whalers their usual reaction is docile escape. When they perceive something as threatening, bowheads quickly dive and do not resurface in the immediate area. At the Point Barrow ice camp in 1976, Carroll was observing a partially closed lead with several polynyas in view. Bowheads and white whales traveling through the lead surfaced in one particular polynya even though there were larger and apparently equally suitable openings in the ice nearby. The whales surfaced in this opening at a rate of about one every half hour, proceeded north to the far edge of the polynya, and then sounded. Carroll had been observing this activity for 3 hours when an Eskimo hunter fired a shot while a bowhead was surfacing within view of the observation site. The whale dove and was not seen again. During the next 3 hours of observation, no bowheads surfaced in or near that polynya, though an observer who was watching the lead 3 miles to the northeast reported that bowheads passed steadily all day, even several hours past the time they stopped surfacing in front of Carroll. We speculate that the startled bowhead somehow communicated a warning signal, and following whales avoided that particular polynya.

Using a hydrophone in the lead at Point Barrow, NMFS personnel distinctly heard sounds made by aircraft, snowmobiles, and outboard motors. Bowheads do not seem to be habituated to machine sounds. Aircraft flying below 152 m, particularly helicopters, sometimes appeared to cause bowheads to make a sounding dive. Walking or operating a snowmobile near the edge of the lead appeared to cause whales to avoid surfacing near the disturbance. Outboard motors seldom are used in spring whaling at Barrow or Point Hope because they cause the whales to avoid the area. During autumn whaling, Barrow and Barter Island hunters are occasionally successful at taking bowheads from boats propelled by outboard motors because the sea is generally clear of pack ice and quite rough. The whalers think that this turbulence masks the sound of the outboard, thus allowing them to approach the whales.

Oars and paddles used to propel boats can be a disturbing factor in the hunt for bowheads. A whale which is being approached by hunters will usually dive if a paddle strikes the side of the boat or makes a loud splash in the water. Bodfish (1936), a commercial whaler, stated that bowheads reacted to the disturbance of oars in the water and that he was most successful when hunting under sail. Eskimo whalers at St. Lawrence Island have retained the method of using skin boats rigged for sailing when pursuing bowheads. Many skilled Eskimo whalers wait for a whale to blow before they slide their boats into the water, believing that the blow will mask the sound of a boat scraping across the ice.

Eskimo whalers also believe that bowheads have good eyesight. Accordingly, the hunters take great care not to be seen by the whales. Traditionally, clothing and boats used on the ice blend into the white surroundings. Bright colors, particularly red, are seldom worn on the ice. Whalers cover bright red floats that are attached to harpoons for fear the whales will see the color and flee. Flat pieces of ice frequently are set on edge in front of whaling camps to reduce the possibility of whales seeing movements of the Eskimos at their camps. The whalers also avoid standing on mounds near the ice edge, thus creating dark silhouettes which they feel frighten the whales away. Eskimo whalers attempt to approach bowheads head-on or from the rear to decrease the chance of the whales seeing the boat with their laterally located eyes.

All whales do not react in the same way to an approaching boat. Smaller whales seem less wary, as boats can occasionally slide right up on their backs before they react. Also, smaller whales tend to travel closer to the nearshore edge of the lead than larger ones and are thus more susceptible to attack by the hunters. It is partly because of this availability along with the deliberate selection of small whales by most hunters (Marquette, footnote 6), that up to 85 percent of the whales harvested are immature (Maher and Wilimovsky, 1963).

On rare occasions bowheads react aggressively. Near Barrow in 1976, an umiak (skin boat) was capsized by a startled whale that apparently was resting when the boat approached; one of the crew was drowned. Also, near Barrow in 1977, a resting bowhead was startled when struck and one of the skin boats was broken when it ended up partially in the whale's mouth. Eskimo whalers say that bowheads that are copulating or courting are particularly dangerous and these whales are seldom approached by whalers.

Resting

Bowheads were occasionally seen in an apparent resting state (Fig. 2). They surfaced to blow and submerged in one spot instead of proceeding forward as during normal migration. Sometimes they stayed at the surface taking several shallow breaths before slipping beneath the water. Often there was no visible blow although a blow could be heard. Some whales exposed only their blowholes above the surface while staying in one place. Bowheads were seen apparently resting for over an hour on four occasions.

"Exuberant" Behavior

Approximately 95 percent of the time when bowheads passed our observation sites near Point Barrow and Point Hope they exhibited the normally expected migratory surfacing patterns. Occasionally they engaged in other activities.

Bowheads breach, leaping out of the water and exposing up to two-thirds of their bodies above the surface before falling back on their bellies, backs, or sides (Fig. 3); spyhop, exposing the anterior third of their bodies above the

surface and sliding back tail first; lobtail, hanging vertically in the water with only the tail above the surface and slapping the water several times with their flukes; swim with one flipper above the surface and slap the water with it; lunge; and swim on their backs and sides. One whale was observed 19 May 1977 near Point Hope and another on 8 May 1978 near Point Barrow, engaging in a series of these exuberant activities for over 90 minutes each. Along with numerous flipper slaps, tail lobs, and lunges, the whale seen near Point Hope breached 57 times in 96 minutes.

It is not known why whales breach. Eskimo hunters on St. Lawrence Island say that breaching occurs more frequently when atmospheric pressure is dropping. Rugh and Cubbage (1980) report that such behavior might be related to display or communication. We observed a whale breaching and lobtailing on 8 May at Barrow. A whale from farther out in the lead moved close to the first animal, and the two swam together, cavorting on their backs and sides, often with a flipper exposed above the surface. We do not know if the whales were of the same sex, or if anything more than a social encounter occurred, but the activities of one whale seemed to attract the other's attention.

On several occasions we have seen groups of whales rolling laterally and breaching in a tight group. In May 1978 near Point Barrow, Smithhisler and Ed Iten of the NMFS National Marine Mammal Laboratory observed such behavior at close range. They, along with an Eskimo whaling crew[8], observed four bowhead whales surfacing together for 15 minutes about 20 m away in a polynya approximately 50 × 100 m. The largest of the four whales was approximately 13 m long, the next was about 12 m, and the other two were about 10 m long. The whales breached and rolled laterally several times, often in unison. At times these whales grasped one another and rubbed each other with their flippers. All movements were slow, controlled, and quite graceful. Several times one of the smaller whales swam toward the edge of the ice, but each time the others pushed it back to the center of the polynya as they continued stroking, rolling, and showing their flukes as they dove. The largest whale exhaled with a controlled flatulent sound from its blowhole. It surfaced very high and swam backwards (behavior also reported by Bodfish, 1936), pushing itself up with its flippers and pulling down with its flukes, all the while making a low groaning sound. We assumed their behavior was associated with mating, but no obvious copulation was observed. The behavior of these whales was similar to the sexual behavior described by Everitt and Krogman (1979) (Fig. 4).

Figure 2. —Bowhead whale resting at the surface. White spot on back is believed to be ice or glare. Photographed by Bruce D. Krogman, Natl. Mar. Mammal Lab., NMFS, 13 June 1976.

Figure 3. —Breaching bowhead whale near Point Hope, Alaska. Note white chin patch. Photograph by Geoffry Carroll, 18 May 1977.

Feeding Behavior

Stomachs of bowheads harvested in the spring are generally empty or nearly empty, whereas stomachs of whales taken in the fall generally contain some

[8]R. Aiken, Barrow, AK 99723.

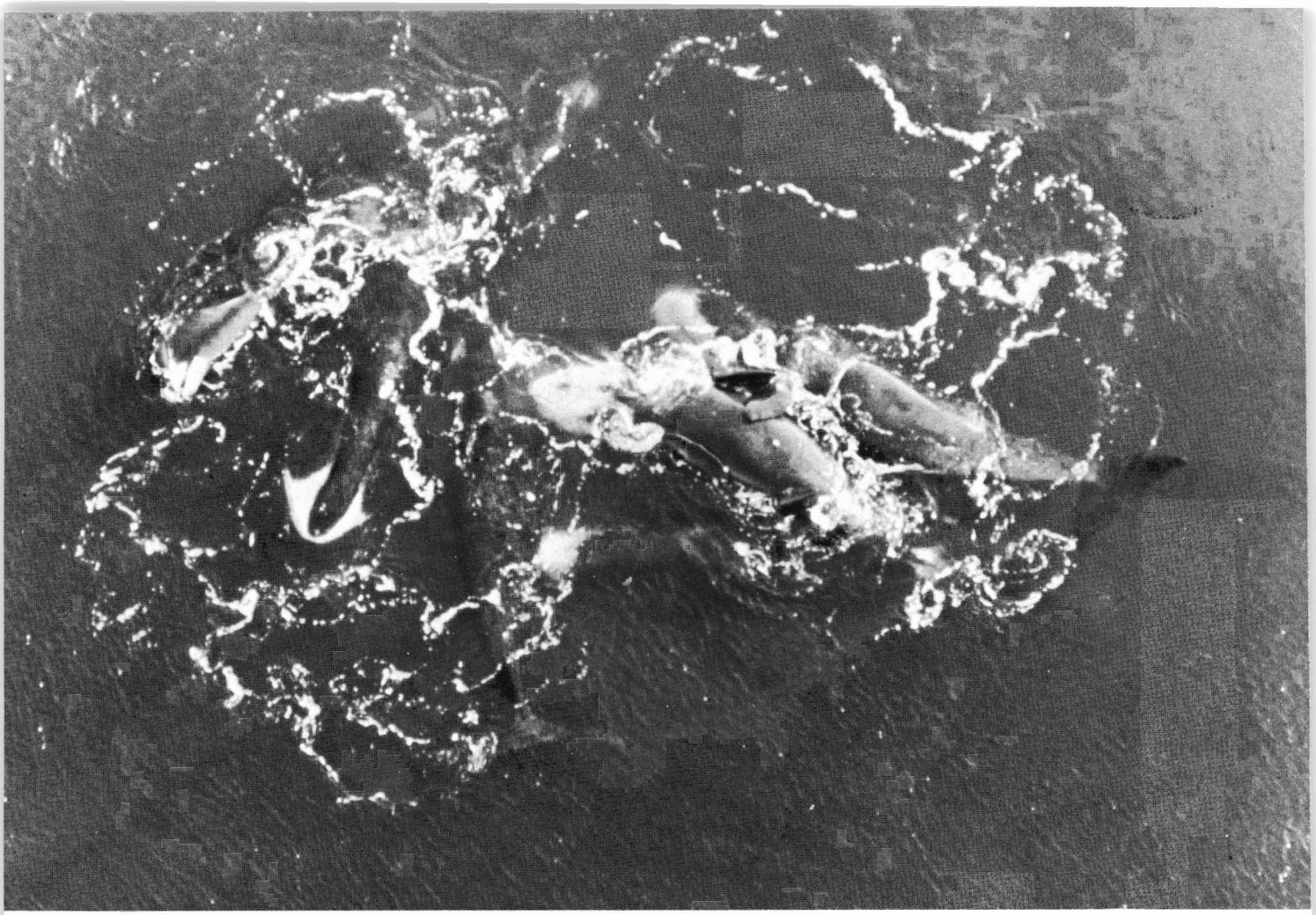

Figure 4.—Six bowhead whales engaged in sexual behavior near Point Barrow, Alaska. Photograph by Bruce D. Krogman, 8 May 1976 (from Everitt and Krogman, 1979).

food (Lowry et al., 1978; Marquette, 1978; Braham et al., 1979; Marquette, footnote 6). However, near Point Barrow in the spring of 1978, Jarrell[9] observed what appeared to be feeding by a few bowheads. The whales made surface trawls, rostrums up and mouths open, and short dives, coming up breaching with their mouths open and water streaming out of the baleen.

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[9]G. Jarrell, Inst. Arctic Biol., Univ. Alaska, Fairbanks, AK 99701, pers. commun.