FEEDING MODES OF THE HUMPBACK WHALE, *MEGAPTERA NOVAEANGLIAE*, IN SOUTHEAST ALASKA

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ABSTRACT

Three methods of feeding by humpback whales (*Megaptera novaeangliae*) are described based upon twelve years and over 15,000 hours of observation in Southeast Alaska. " Lunge feeding " is a method used by a single whale or by a group in unison. The whales emerge abruptly through the water's surface, mouth open, as they engulf euphausiids (*Euphausia pacifica*), herring (*Clupea harengus*) or capelin (*Mallotus villosus*). Lunge feeding includes three basic variations: " lateral lunge feeding ", " vertical lunge feeding ", and " inverted lunge feeding "; the adjective refers to the angle of the sagittal plane of the whale to that of the water's surface. Sometimes during lunge feeding a sound described as " castanetting " is produced when the whale's mandibles repeatedly strike the rostral margins producing in air a sound analogous to that of a castanet. " Bubblenet feeding " involves a release of a discrete sequence of bubbles underwater that form a ring or closing spiral at the water's surface. Within the ring or " net ", the target feed is concentrated and contained as the whale emerges, mouth open within the ring. Sequences of sounds have been heard only when two whales fed co-operatively using a bubblenet to capture herring. In " flick feeding ", a whale lashes its tail forward at the water's surface, concentrating euphausiids, then rapidly dives forward into the feed, mouth open. It has been concluded that feeding methods used by humpback whales vary depending on the kind and quantity of feed available.

INTRODUCTION

Although the foods of the humpback whale (*Megaptera novaeangliae*) have become well-known through the examination of carcasses at whaling stations and stranded specimens (Mathews, 1937; Lillie, 1915; Nemoto, 1970), few observations have been made and recorded of the actual feeding behavior of living whales. It has sometimes been suspected that observed whales were feeding, but direct evidence of feed was not found (Perkins and Whitehead, 1977; Schevill and Backus, 1959).

One of the few references to feeding behavior prior to the present study of humpbacks in Alaskan waters was given by Andr. Ingebrigtsen (1929). He described two methods; one in which a humpback swam around in a circle lashing the sea into a foam with its flukes, then diving below the frightened krill only to appear a moment later in their midst with its mouth open. In the second method,

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the humpback whale appeared to dive a short distance below the water's surface and then released air while swimming in a circle. The rising bubbles rose to the surface like a thick wall of air bubbles, and these formed a net.

The present study began in 1966 with observations on feeding humpback whales near Juneau, Alaska and was expanded to adjacent areas of Southeast Alaska over the next twelve years (Fig. 1). We have found that Alaskan humpback whales have a varied diet and employ three basic feeding modes with several variations. Data documenting these feeding modes were gathered during more than 15,000 hours of observation.

DESCRIPTION OF THE STUDY AREA

Southeast Alaska, currently the summer home for approximately 60 humpback whales is characterized by an intricate system of protected bays and inlets with numerous small islands (Fig. 1). The areas under observation include Glacier Bay, Lynn Canal and Frederick Sound. Air temperatures in summer (June—September) average 14°C with a range from 5°C to 27°C; surface water temperatures range from 5°C to 14.4°C. Fresh water runoff from rivers, and melting snow and ice creates variable surface salinities, ranging from 1‰ to 25.9‰ in 1977 and 1978. During the summer daylight lasts for 18 to 20 hours.

Little hydrographic data are available, but the latest charts by the National Ocean Survey and the U.S. Coast Guard indicate depths to approximately 160 meters. Average tidal amplitude is 2 to 3 meters with a maximum of 8 meters.

METHODS

A 3-meter fiberglass skiff powered by a 20 hp outboard was used as an observation platform for the first five years, 1966–1971. Since 1971, the 15-meter *R/V Ginjur*, a wooden-hulled diesel-motored vessel equipped with silencers, has served as the research platform and laboratory for from four to ten observers. Observation distances are commonly 20-meters and sometimes as little as 4-meters. Observations often extend over the full 18 to 20 hours of daylight.

Visually, whales were sighted and approached. Most whales were identified individually by the color pattern of the underside of the flukes in addition to other body characteristics. The whales were tracked visually and their behavior recorded. A battery-operated stop watch was employed to time submergence intervals of whales and to insure that noted behavior is recorded in sequence. Feeding environs, behavior and temporal aspects of the sequences were recorded and photographed. These still photographs aided in the analysis of sequences of events during feeding activities.

The bubblenet has been recorded underwater for further analysis by Dr P. O. Thompson of the Naval Ocean Systems Center, Dr Roger Payne of the New York Zoological Institute and Dr Sylvia Earle of the California Academy of Science.

When whales were feeding, the target feed was photographed within the gape

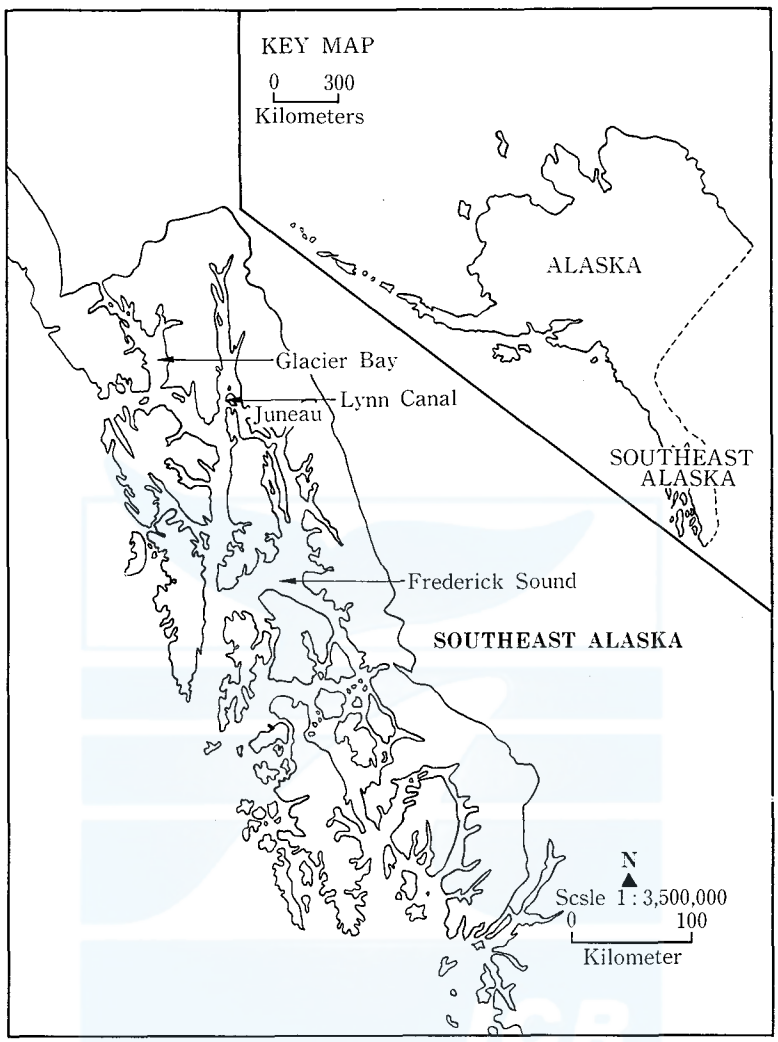

Fig. 1. Map of Study Area in Southeast Alaska.

of the whale's open mouth. Collections of food species were made with plankton tows and fish trawls to verify the species. Samples were submitted to National Marine Fisheries Service, Auke Bay, Alaska, and to the NMFS Laboratory at Tibinon, California for identification. Voucher specimens have been deposited at the California Academy of Science, San Francisco, California.

Feed in Southeast Alaskan waters appears for the most part to consist of euphausiids (*Euphausia pacifica*), herring (*Clupea harengus*), or capelin (*Mallotus villosus*).

DISCUSSION

The main structures involved in the feeding of the humpback whale according to

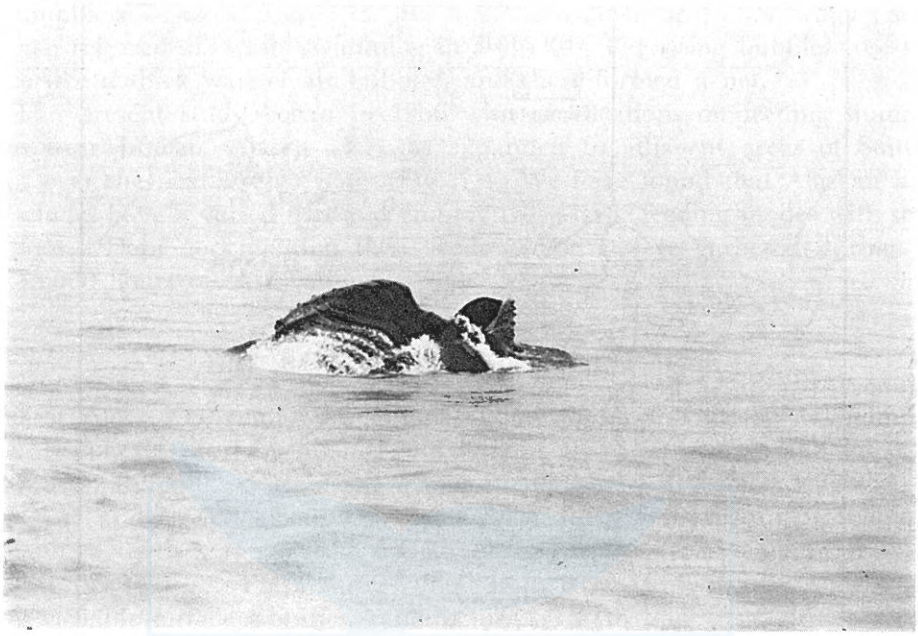

Fig. 2. The expanded throat of the feeding humpback whale.

Fig. 3. The closed mouth as the water is compressed out.

Nemoto (1970) are the baleen plates, the mouth opening, the tongue and the ventral grooves in the throat and abdomen. To feed the humpback whale takes water and feed in through its mouth causing the pleated throat to swell and expand (Fig. 2). The mouth is closed and water is compressed out of the mouth (Fig. 3). The retained feed is then swallowed. Humpback whales are in the " swallower " or " gulper " catagory rather than the " skimmer " catagory (Nemoto, 1970).

In addition, we have observed humpback whales occasionally using both flippers and flukes in feeding. The flipper is thrust toward the open mouth in a scooping fashion. The flukes are employed in one particular mode called, " flick feeding ", that will be discussed later in the text.

Humpback whales employ three different modes of feeding, depending on the species and the density of the feed. The modes are identified here as discrete activities that may vary in terms of body positions or angles of attack.

Lunge Feeding

One of the most commonly witnessed modes is designated as lunge feeding. This mode occurs when the feed is abundant. We have observed lunge feeding on euphausiids (*Euphausia pacifica*), herring (*Clupea harengus*), capelin (*Mallotus villosus*), and mixed schools of the latter two species.

In lunge feeding, the humpback swims vertically at approximately 5-knots through an aggregation of feed, opens its mouth in the upper 3-meters of water and engulfs the feed. The humpback's body is nearly vertical when its mouth is open to receive the food (Fig. 4). During this type of feeding, other species of feed may be incidentally ingested. There were many instances when walleye pollock (*Theragra chalcogramma*) were seen swimming leisurely at the surface feeding on krill. In some cases, the pollock were dispersed at the surface and in other cases they were schooled. When a whale is lunge feeding, it sometimes engulfs these pollock along with the krill. Since the mass of euphausiids seen within the mouth of the whale is far greater than the mass of pollock, the euphausiids appear to be the target feed.

When lunge feeding is employed by the humpback at a frequent rate, e.g., 12 lunges per hour, the results include an audible in-air characteristic occurring as a soft " clap ". The sound is produces by the rostral margin and the mandibular margins striking one another with the cupped effect of the partially filled aural cavity producing a resonance similar to that produced by a castanet, hence we have referred to it as " castanetting ". Castanetting is associated with those feeding procedures which, as in lunge feeding may have a significant amount of vertical motion, i.e., enough to bring the entire labial surfaces above water at the moment of rapid closure.

Other than vertical lunge feeding, there are two other variations in lunge feeding: lateral lunge feeding and inverted lunge feeding (Fig. 5). The adjectives refer to the angle of the sagittal plane of the whale to the plane of the water's surface. The position used appears to relate to the efficient use of body motion at the instant at which the feed is encountered and dense enough to engulf. The

Fig. 4 a. A vertical lunge. Herring can be seen flipping out of the mouth.

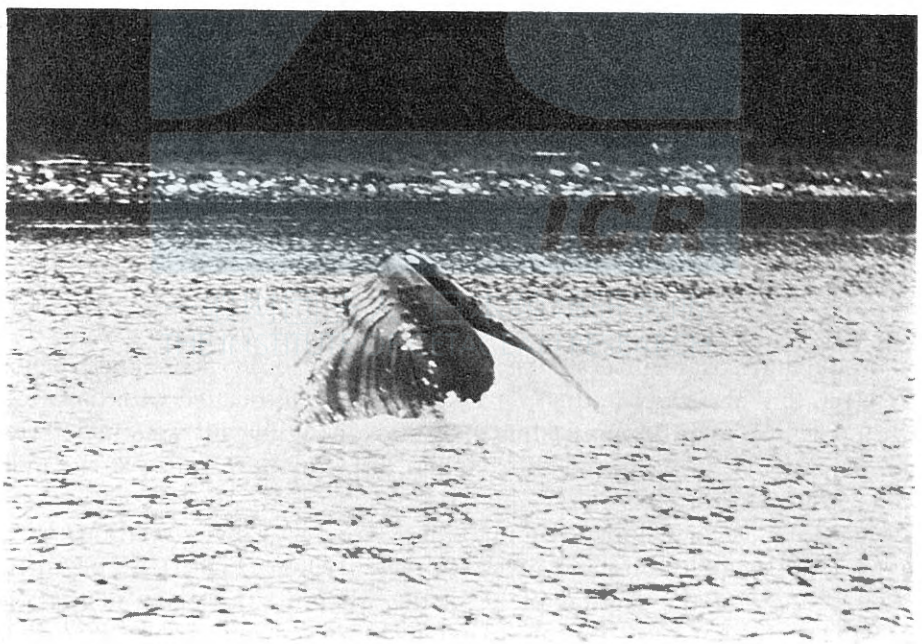

Fig. 4 b. A vertical lunge after the mouth is closed.

singular exception to this is the inverted lunge, in which case the taking of breath at the surface is postponed, increasing the length of time the whale spends recovering from one feeding lunge longer than other variations (Fig. 6).

The general direction and distance at which a single, lunge feeding whale will next surface has no apparent pattern. But as the number of whales involved in feeding increases, the direction and body positions become increasingly predictable. When two or more whales are lunge feeding together, the frequency of the lateral feeding lunge is significantly increased, although instances of one whale lunging in a vertical position and its partner ending in the lateral position were not uncommon (Fig. 7).

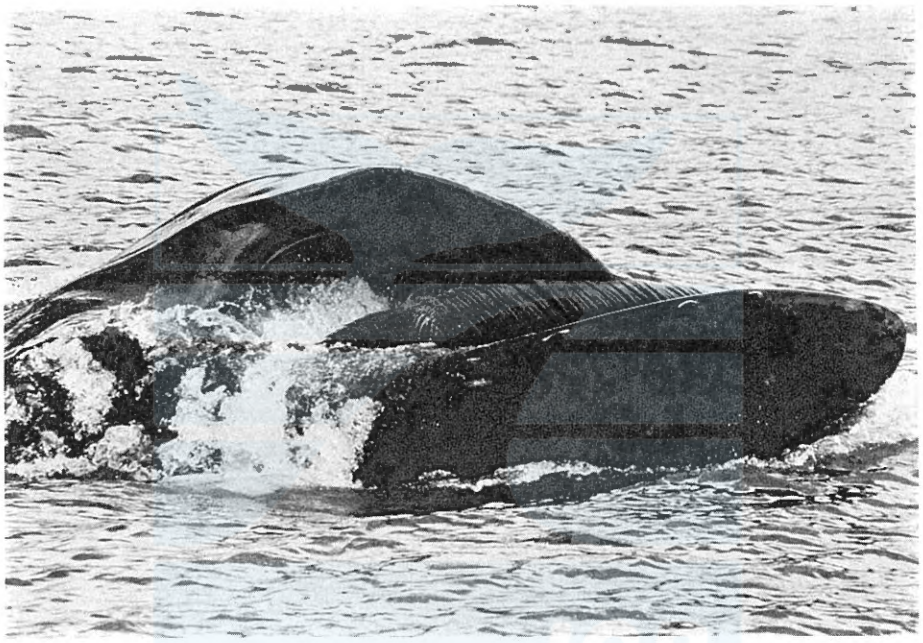

Fig. 5. A lateral lunge.

The least frequently seen configuration is that of the paired vertical lunge, a procedure that has involved up to four whales. These forms of lunge feeding in which two to four whales are involved clearly demand a cooperative routine and an implied communication. Escheloned lunge feeding is such a routine. Two or three whales coordinate their breathing in such a manner that the surface displays of breathing and lunging are synchronous. In this form of " cooperative feeding ", the lunging is reduced and the velocities of the emerging whales are slowed to 3 to 4 knots. They appear at the surface on their sides with their mouths open to nearly 90° so that the mandible of the first whale comes close to resting upon the rostrum of the one " below " it, and so on down for each of the remaining animals.

Although the velocity of the feeding lunge appears to be reduced when ac-

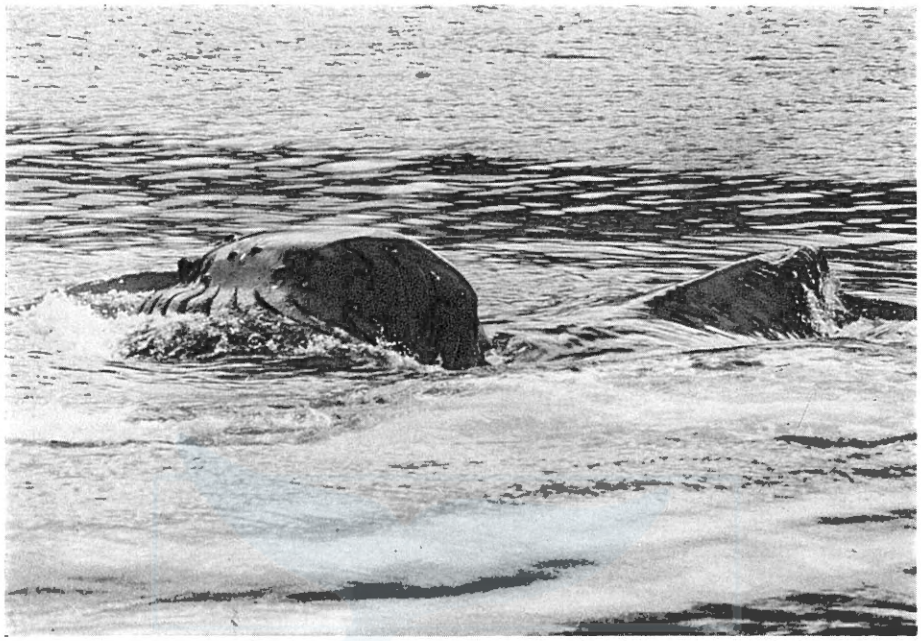

Fig. 6. A inverted lunge.

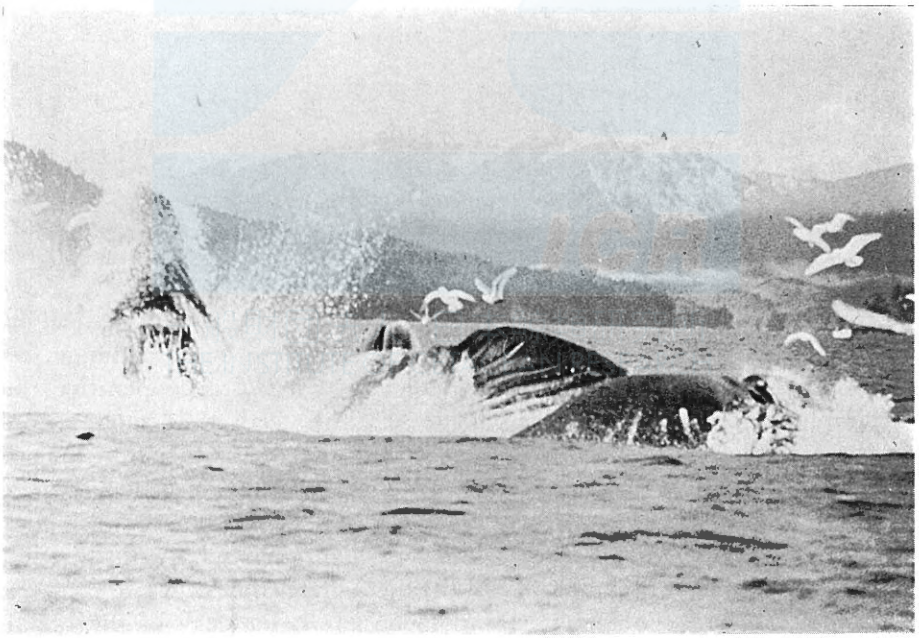

Fig. 7. A cooperative feeding lunge; Three whales are pictured. The gulls are feeding on the wounded herring left by the whales.

complished as a cooperative effort, another factor which has direct bearing on the whales' speed is the motility of the feed. The whale must swim faster to catch faster feed. Euphausiids are the slowest; herring are the fastest. The frequency of lunges is related not only to the species of feed, but also the abundance and distribution of feed. Hence with any given feed the frequency with which lunge feeding is applied to that species is consistent with the increased or decreased levels of availability of that feed.

During the seasonal transitions of feed caution must be exercised to scrutinize the feed involved in each case. In late September to October, although euphausiids are the most common feed taken at the surface, herring are occasionally present. Subtle differences in the feeding behavior were found to be an indicator of a change in conditions. Lunge feeding may have value as an indicator of local feed level rather than as an indicator of the seasonal population fluctuation of a single feed species.

On 20 April 1974, sixteen instances of lunge feeding were observed involving a single whale during one hour. The target feed was herring and the location, the western side of Douglas Island (seven miles from Juneau, 58°13'N 134°30'W) had until recent years supported both a healthy stock of herring and at least six whales during the summer months. In contrast, twenty-eight feeding lunges were observed during 10 minutes on 13 August 1976, in Glacier Bay with euphausiids as the target feed.

Bubblenet Feeding

A feeding procedure having a high degree of sequencial continuity has been called " bubblenet feeding " because of the strong physical resemblance to the deployment and effect of a seining net. The major differences lie in the whale's advantages of being able to blow a new net each time, to deploy the net from below rather than above, and to have its digestive apparatus at the base of the purse. In sequence, the whale apparently locates a body of feed, dives below the feed, and discharges a line of bubbles from its blowhole while swimming in a broad arc which has both vertical and horizontal components. The whale, outswimming the feed, deploys the bubbles while sweeping both ahead of the feed and towards the surface. The feed is blocked from below by the whale's body, laterally by the rising bubbles, and ultimately above by the surface. The feed is thus contained and since it is driven to the surface, it is condensed, by the same action. When the feed is herring, there is a frenzy of fish visibly boiling to the water's surface only within the confines of the blown net. The sequence of surface phenomena is as follows: The bubbles appear as discrete cantaloup-sized spheres rising to the water's surface (Fig. 8). This trail of bubbles forms a large ring or, in some cases, closing spiral that remains visible as smaller, later occurring pea-sized bubbles rise (Fig. 9). As the ring nears completion, the feed can be seen within the diameter of the thickening ring of bubbles. When the feed is herring, the fish flip about on the surface within the ring. If the feed is euphausiids, a blush or roughing of the water's surface occurs within the ring, as the feed leaps into the air. At the

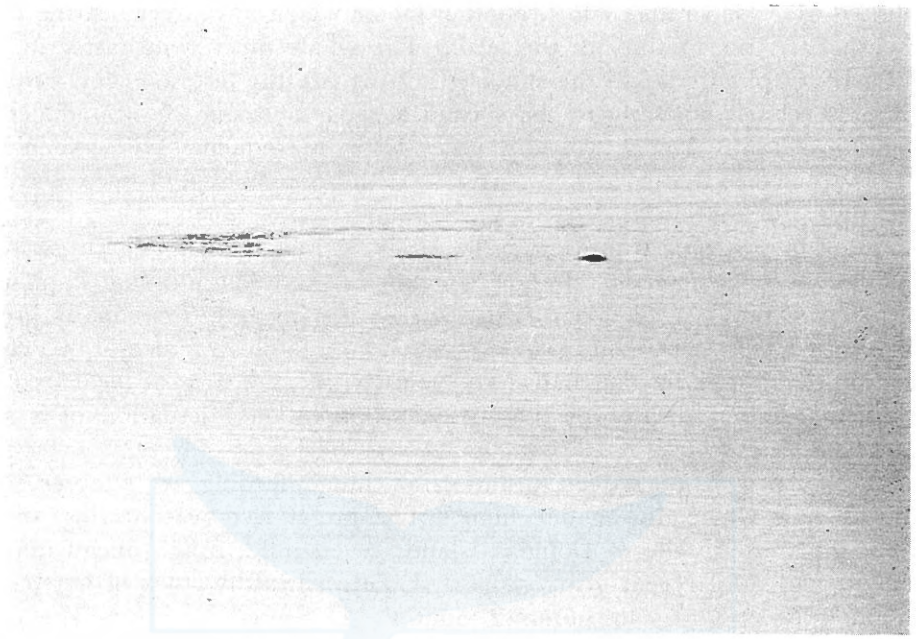

Fig. 8. The first bubbles of a bubblenet.

Fig. 9. The later pea-sized bubbles of a bubblenet.

air. At the point when the ring or spiral closes, the whale or whales appear. The whale engulfs the feed just below the water's surface causing a "flash of bubbles", as the mouth closes underwater (Fig. 10), or it employs a lunge feed. The whale surfaces in a viel of breath far more atomized than usual because the blowhole issues its blast continuously from a submerged point to one which is at the water's surface or above.

Bubblenets have been blown in both clockwise and counter-clockwise directions. The first bubbles appearing at the surface are distinct and range in size from a volley ball to a tennis ball depending upon the feed. Observations have shown that the larger more motile the feed, the larger the initial bubbles in the ring. The bubbles which initially outline the ring are larger than the bubbles which follow after the feed is taken. A period of effervescence occurs directly

Fig. 10. The flash of bubbles when the mouth is closed underwater.

after the feed is taken and leaves the water foamy in appearance. This is considered to be a phenomenon common to the release of any gas bubbles which in turn are torn as they expand upon rising, the largest appearing at the surface first.

Bates and Van DeWalder (1964) employed a similar technique to generate bubbles for directing fish by using a perforated pipe through which air was forced at a pressure of 38 to 48 lbs per sq. inch. A jet of approximately 2 cm high was formed underwater. The jet then changed into bubbles about 8 cm in diameter, each of which broke into smaller bubbles arriving at the surface with a diameter of 1 cm or less. Fish exposed to the bubble screen deflector under these conditions exhibited a definite response during daylight hours only. The bubblenet has only

been seen and heard via underwater acoustic gear during daylight hours. In areas where whales were seen using the bubblenet during the day, recordings were made throughout the hours of darkness but no bubbling sounds were heard. No observations have been made of the humpback whale feeding after dark.

Bubblenets were observed on 13 July 1974, from 1205 thru 1725 hours ADT at the southern tip of Shelter Island, near Juneau, Alaska. Two adult humpback whales feeding in 16 to 40 meters of water, produced bubbles beneath the surface of the water. The pattern of the bubbles formed a counter-clockwise circle of approximately 30 meters in diameter and required 55 seconds from the time at which the first bubbles were seen on the surface to the last bubbles of the circle. As the circle of bubbles closed, herring appeared at the surface within the circle in a " boil ". The sound produced by the herring at the surface resembled heavy rain on the water. Within approximately three seconds, two humpbacks appeared at the surface on their sides, mouths agape, with their blow holes oriented towards the center of the circle. The angle of the humpback's jaw rostrum to mandible during the feeding procedure frequently reached 90° and the herring could be seen flipping in the water engulfed by the cavernous mouths. The end of the activity was marked by the humpback whales righting themselves, blowing and diving only to repeat the activity within the next five to seven minutes at a distance, usually less than 100 meters, from the previous net. The two whales blew 25 bubblenets in the five hours they were observed. The whales continued to blow bubblenets and feed through the tide change at 1437 hours ADT.

During this incident the two whales were heard " singing " as the bubblenet was blown. The song began with a discernable buzzing pattern. As the final bubbles approached the surface, the song changed to a staccato of higher pitched sounds and a pause of a second or two could be noted prior to the herring's appearance at the surface within the net. This feeding song has been heard several times but only association with more than one whale feeding and when the feed was herring. The song pattern appears to be uniform.

One of the first bubblenets seen in connection with euphausiids was on 21 August 1975, at 1300 hours ADT. A single whale was observed for forty five minutes during which time four bubblenets were seen. The whale was bubblenet feeding midchannel, 4.0 km northeast of Five Finger Light in Frederick Sound. Euphausiids could be seen as a blush or cloud in the water.

The bubblenet when used for euphausiids can be as small as $1\frac{1}{2}$ meters across and is of smaller diameter than that used for herring which is usually around 50 meters. From the first bubble to the sight of the whale within the net the time for euphausiids ranges from ten to forty seconds as opposed to 50 seconds to 1 minute 10 seconds for herring.

Flick Feeding

Flick feeding was first observed in Glacier Bay in 1977. In flick feeding, the humpback whale begans a normal dive raising its flukes well above the surface of the water. When the tail has submerged to the base of the flukes, the tail is flicked

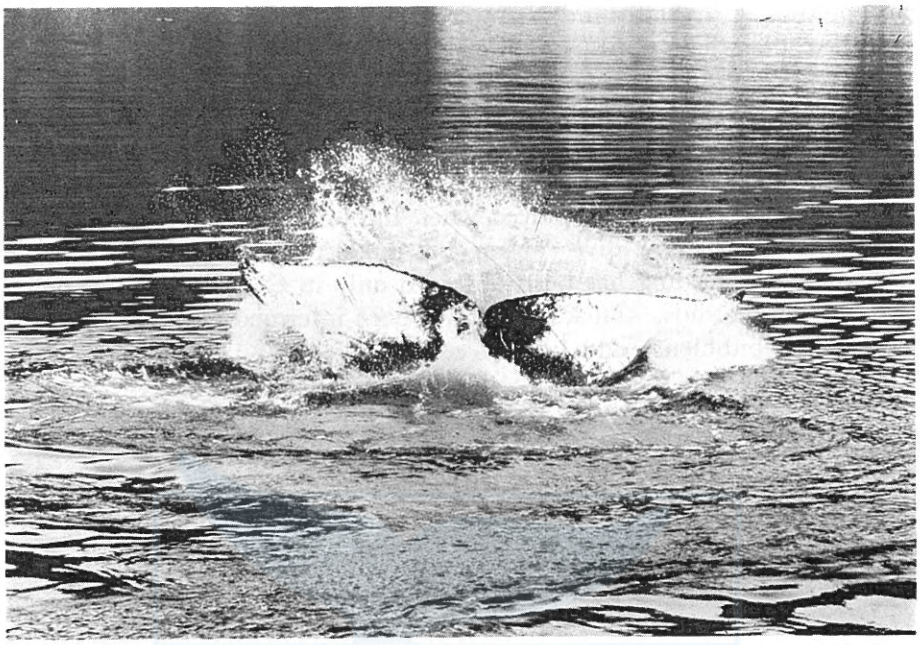

Fig. 11 a. Flick feeding, the tail flicked forward.

Fig. 11 b. The gulp of the mouth following the flick.

forward producing a splash and an internal wave. As the wave moves forward, the mouth of the whale appears at the surface admidst the wave (Fig. 11). The whole procedure occurs in approximately three seconds and follows this sequence: dive, flick, lunge.

Plankton tows have not yet been attempted during the procedure because of the short duration in the feeding mode, but it appears as if it could be a concentrating technique or it could be employed when the target feed is close to the surface and entails a very shallow dive causing the flukes to splash.

This mode of feeding has been observed only in Glacier Bay and only when the feed was euphausiids. Flick feeding has been intermixed with the other modes of feeding, i.e., bubblenet and lunge feeding.

CONCLUSION

Humpback whales employ a variety of feeding modes which appear to relate to the target feed and its density. All of the feeding modes have been observed intermixed and employed by one whale feeding in one location during one observation, e.g., on 28 July 1976, one humpback feeding on euphausiids employed; vertical lunge, lateral lunge, vertical lunge, bubblenet, vertical lunge, during the course of one hour. Similarily, on 2 August 1978, another humpback feeding on euphausiids employed; bubblenet, bubblenet, lateral lunge, vertical lunge, lateral lunge, vertical lunge, vertical lunge, bubblenet, bubblenet, vertical lunge, lateral lunge, flick feed within a twenty minute period. The total feeding time during this observation was two hours.

All of the feeding modes may be used by single humpback whales or by groups. Feed species and abundance varies with location and time of year. Feeding has been seen as early as April and as late as November. Heaviest feeding in Southeast Alaska appears to take place in July and August.

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