DIET AND FEEDING BEHAVIOR OF FIN AND BRYDE'S WHALES IN THE CENTRAL GULF OF CALIFORNIA, MEXICO

Bernie R. Tershy[1], Alejandro Acevedo-G.[2], Dawn Breese[3] and Craig S. Strong[1]

[1]Moss Landing Marine Laboratories, P.O. Box 450 Moss Landing, CA 95039-0450, U.S.A.

[2]CRIP- La Paz, 23000 La Paz, B.C.S. MEXICO

[3]Environmental Studies Department, University of California, Santa Cruz, CA 95064 U.S.A.

ABSTRACT

The diet and feeding behavior of fin whales (*Balaenoptera physalus*) and Bryde's whales (*B. edeni*) was studied in the central Gulf of California, México, during 3,100 hours of research from 1983-1986. Fin whales were only observed feeding on invertebrates, primarily the euphausiid *Nyctiphanes simplex* (n=30 feeding events). Bryde's whales fed on small schooling fish, such as the Pacific sardine (*Sardinops sagax*) in 88.6% of feeding events and on invertebrates in the remaining 11.4% (n=88 feeding events). Both species formed feeding aggregations. Within feeding aggregations fin whales spent 60-80% of their time in feeding groups of 2-4 whales, but Bryde's whales did not form feeding groups.

RESUMEN

La dieta y el comportamiento alimenticio de los rorcuales comunes (*Balaenoptera physalus*) y los rorcuales de Bryde (*B. edeni*) se estudio en la región central del Golfo de California durante 3,100 horas de observación de 1983 a 1986. Los rorcuales comunes se observaron comiendo unicamente de invertebrados, principalmente el eufaúsido *Nyctiphanes simplex* (n=30 observaciones de alimentación). Los rorcuales de Bryde se alimentaron de cardúmenes de peces pequeños, tales como la sardina del Pacífico (*Sardinops sagax*) en 88.6% de las observaciones de alimentación y de invertebrados en el 11.4% restante (n=88 observaciones de alimentación). Ambas especies formaron agregaciones de alimentación. Dentro de las agregaciones de alimentación los rorcuales comunes estuvieron el 60-80% del tiempo en grupos de alimentación de 2 a 4 ballenas, a diferencia de los rorcuales de Bryde quienes no formaron grupos de alimentación.

Until the 1970's, knowledge of the diet and feeding ecology of mysticete whales was limited to analysis of distribution data and stomach contents (e.g. Nemoto and Kawamura 1977). In areas with no history of modern commercial whaling, such as the Gulf of California, México, there has been little if any information available on mysticete diet and feeding ecology.

In the last twenty years, observational studies have provided information on the diet and foraging behavior of humpback whales, *Megaptera novaeangliae*; gray whales, *Eschrichtius robustus*; minke whales, *Balaenoptera acutorostrata*; and bowhead whales, *Balaena mysticetus* (Jurasz and Jurasz 1979; Hain *et al.* 1982; Oliver *et al.* 1984; Würsig *et al.* 1984; D'Vincent *et al.* 1985; Hays *et al.* 1985; Hoelzel *et al.* 1989). However, there have been fewer observational studies on the larger whales in the genus *Balaenoptera*, perhaps because they are relatively more pelagic, spend

little time at the surface, and do not aggregate on low latitude breeding grounds.

We studied fin whales (*Balaenoptera physalus*) and Bryde's whales (*B. edeni*) in the calm near-shore waters of the central Gulf of California, México, where we were able to make detailed observations of foraging behavior from a small boat and a coastal cliff. There have been good descriptions of fin whale feeding behavior in north Atlantic (Watkins and Schevill 1979; Gaskin 1982) and Antarctic (e.g. Gunther 1949) waters, but none from low latitude areas such as the Gulf of California. Bryde's whales are confined to tropical and subtropical waters and are perhaps the least studied of all whales in the genus *Balaenoptera*. To our knowledge there have been no observational studies of their feeding behavior.

METHODS

We observed fin and Bryde's whales feeding in the Canal de Ballenas, Gulf of California, Mexico (113°20' W, 29°00' N), during 3,100 hrs of research from May - September 1983, April - September 1984, April - December 1985, and January - April 1986.

Observations were made from a 4.2 m skiff and a 28 m high cliff when visibility was greater than 5 Km and wind speed less than 11 Km/h (Beaufort 2 or less). Individuals were identified from photographs of distinctive features of their dorsal fin and dorsal surface (for a detailed description of the study area and methods see Tershy *et al.* 1990; Tershy *et al.* 1991). During feeding aggregations individuals were repeatedly photographed to examine the stability of groups. Although only 33% of all individuals in both species were distinctive enough for long-term identification (Tershy *et al.* 1990), most individuals could be identified for the duration of a feeding event using characteristics such as the position of soft bodied barnacles (*Xenobalanus* sp).

The prey (fish or invertebrate) consumed during a feeding event was determined by direct observation of prey entering the mouth of lunging whales. When whales fed at the surface on schooling fish, the fish were easily seen by us, and usually attracted large numbers of piscivorous birds. When whales fed at the surface on invertebrates, we usually saw a reddish tint to the water in front of the lunging whale. We then identified the prey while snorkeling, or after capture with a hand-held plankton net.

Prey from past feeding events was determined by collecting fecal samples with a hand-held plankton net, then using a dissecting scope to examine the samples for either fish scales and bones, or invertebrate hard parts.

Prey consumed during a feeding event was inferred from the species composition of mixed species feeding aggregations. Piscivorous aggregations could include common dolphins *Delphinus delphis*, California sea lions *Zalophus californianus*, brown pelicans *Pelecanus occidentalis*, blue-footed boobies *Sula nebouxii*, brown boobies *S. leucogaster*, yellow-fin tuna *Thunnus albacares*, and pelagic thresher sharks *Alopias pelagicus*. Planktivorous aggregations could include Bonaparte's gulls *Larus philadelphia*, black storm-petrels *Oceanodroma melania*, least storm-petrels *O. microsoma*, red-necked phalaropes *Phalaropus lobatus*, pacific manta rays *Manta birostris*, and whale sharks *Rhincodon typus*. We tested the reliability of inferring prey type in this way by recording the composition of mixed species feeding aggregations when the prey of whales was determined by direct observation.

From 25 January to 4 February 1986, in the eastern Gulf of California near Isla Tiburón (112°13' W, 28°45' N), A.A. and B.R.T. observed

>60 fin whales feeding. From an 8 m boat we radio-tagged one of these fin whale and watched it feed at the surface for six hours. We continuously recorded its surface behavior and interactions with 9-11 associated feeding whales (eight of which were individually identified).

Two key words are defined following Wilson (1975). Aggregation: a number of individuals gathered in the same place but without obvious internal organization or cooperative behavior. Group: a set of organisms that remain together for a period of time while interacting with one another to a distinctly greater degree than with other conspecifics. Thus, there can be groups within an aggregation.

RESULTS

Diet. When the prey of Bryde's whales was identified as fish by direct observation, Bryde's whales were associated with piscivorous aggregations in 12 of 15 feeding events (80%) and were never associated with planktivorous aggregations. When the prey of fin whales was identified as euphausiids by direct observation, the whales were associated with planktivorous aggregations in 6 of 7 feeding events (86%), and never associated with piscivorous aggregations. Thus, the composition of mixed species feeding aggregations appears to be a relatively good indicator of prey type.

During the study Bryde's whales were primarily piscivorous and fin whales were only seen feeding on invertebrates (Figure 1). This pattern remains significant even if only data from direct observation and analysis of fecal samples is used (fin whale 0 fish : 15 invertebrate feeding events, $P < 0.005$ binomial probability test; Bryde's whale 19 fish : 9 invertebrates, $P < 0.005$).

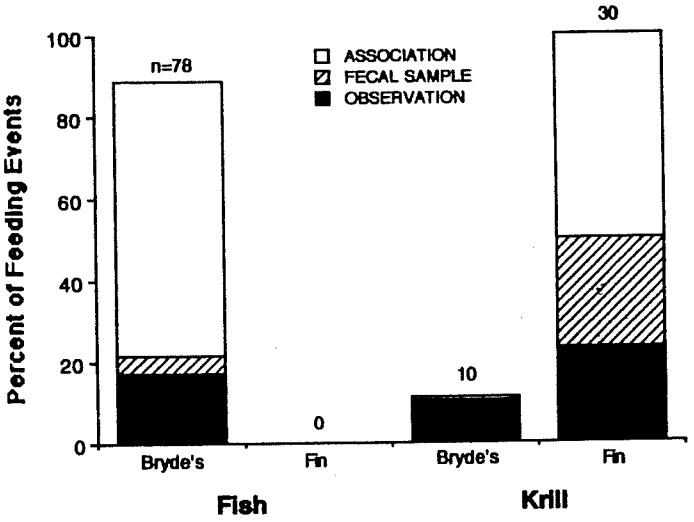

Figure 1. Percentage of 88 Bryde's and 30 fin whale feeding events in the Gulf of California, México, where the prey was either fish or krill (large zooplankton). Prey type was determined by direct observation of prey engulfed in feeding lunges and examination of fecal samples for fish scales and bones or euphausiid body parts. Prey type was inferred when whales were feeding in mixed species aggregations with either planktivores or piscivores (see methods). Fish were primarily Pacific sardines (*Sardinops sagax*) or thread herring (*Opisthonema libertate*). Krill was primarily the euphausiid *Nyctiphanes simplex*.

On six occasions, both fin and Bryde's whales were observed feeding in close proximity to each other. In all cases fin whales ate euphausiids and Bryde's whales ate fish. On three occasions traveling fin whales passed through aggregations of Bryde's whales feeding on fish. The fin whales did not stop to feed, nor was there any noticeable change in their surface behavior, speed or direction of travel.

We identified some of the prey samples to species. The euphausiid *Nyctiphanes simplex* is the most abundant euphausiid in the study area (Brinton and Townsend 1980; Gendron 1990) and was the only prey identified in fin whale feeding events (n=4) and fecal samples (n=2). Bryde's whale prey was identified as Pacific sardine (*Sardinops sagax*) (n=6 feeding events), then the most common small schooling fish in the study area (Hammann *et al.* 1988), and thread herring (*Opisthonema libertate*) (n=1 feeding event).

Fin whale feeding behavior. Feeding fin whales formed groups of two - four closely associated animals. Individuals within a group swam less than 50 m apart and in an echelon formation (one whale is slightly ahead and to the side of the other). Individuals within feeding groups traveled in the same direction at the same speed with synchronized surfacings and dives. They lunged synchronously, right side down (Tershy and Wiley 1992), and in echelon formation. Within feeding aggregations separate groups could be discerned even when two or more groups passed within 50 m of each other.

We measured the percent of time feeding fin whales spent alone or in a group in three ways (Figure 2). In 1983 we photo-identified 125 feeding fin whales and at the same time determined if the whale was single, or in a group. In 1983 we also recorded the group size of all feeding whales (n=516) which surfaced within 300 m of our skiff. In 1985 we determined the percent of time

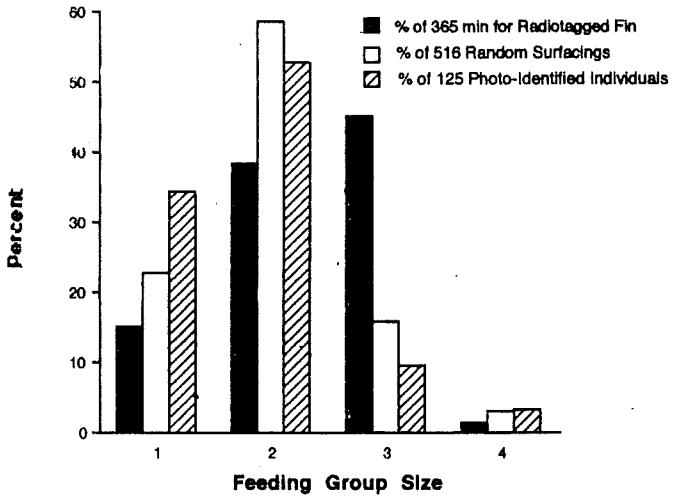

Figure 2. The percentage of time feeding fin whales in the Gulf of California, México, spent alone or in a group as determined from three different data sets.

that the radio-tagged fin whale spent alone or in a group during 6 hrs. of feeding.

The lead whale was to the right of the trailing whale in 91.5% of the fin whale feeding groups (n=35, $P< 0.0005$, one tailed binomial test) for which the position of each individual was recorded, but only in 60% of the traveling fin whale groups (n=7, P>0.25).

The mean estimated distance between the radio-tagged fin whale and the other whale(s) in the feeding group was less when it lunged (n=28 lunges, mean=7 m ±1SD=5.4) than when it surfaced to breathe without making a feeding lunge (n=87 surfacings, mean=17 m ±9.9; t_2=4.56, d.f.=93, P<0.001).

The composition of feeding groups was not stable; instead, membership and size changed frequently during feeding events. The radio-tagged fin whale had >8 different feeding partners during the 6 hrs. we observed it feeding (Figure 3). Repeated identifications of individual group members within large feeding aggregations also demonstrate that feeding group composition was dynamic: during a feeding event, only 13 of the 45 groups (28.9%) remained intact between identifications. Only four groups had the same membership composition on all identifications during one feeding event, and one member of three of these groups was identified on a later date either alone or paired with a different whale.

Bryde's whale feeding behavior. Bryde's whales formed feeding aggregations of 2->15 whales (Tershy 1992), but were not observed in coordinated feeding groups, even though individuals occasionally passed within 50 m of each other. Instead, each whale appeared to respond independently to the movements of its prey.

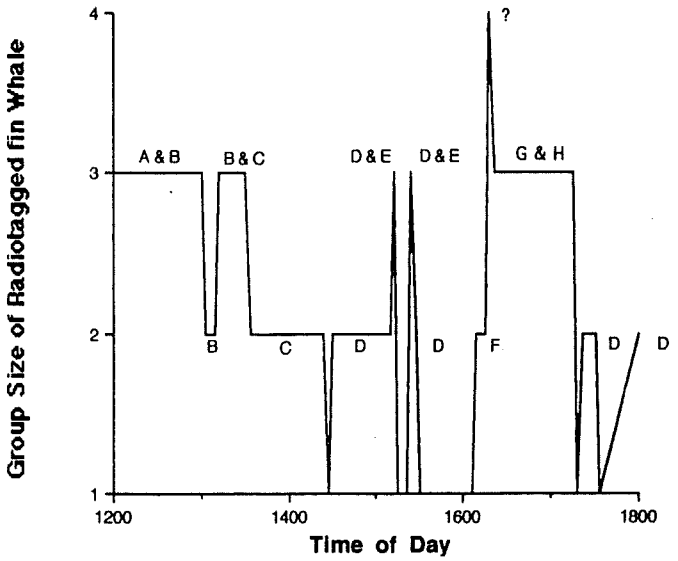

Figure 3. The group size and composition for a radio-tagged fin whale "Archie" observed feeding at the surface for 6 hours. Data were collected at 5 min. intervals during this time. "Archie" had 8 or more different feeding partners (A through H and three unidentified partners). From 12:00 - 12:55 "Archie" fed in a group with whales A and B. At 13:00 whale A left the group and "Archie" fed with whale B. At 13:10 whale C joined "Archie" and whale B, and so on until 18:00.

DISCUSSION

In other parts of the world Bryde's whales are primarily piscivorous (Best 1977). Fin whales feed on schooling fish such as herring (*Clupea pallasii*), capelin (*Mallotus villosus*), and sandlance (*Ammodytes americanus*) in the north Pacific and north Atlantic (Overholtz and Nicolas 1979; Watkins and Schevill 1979; Whitehead and Carscadden 1985). However, stomach content data suggest that in the north Pacific fin whales select euphausiids over fish (Nemoto and Kawamura 1977). During our study in the central Gulf of California, México, Bryde's whale fed primarily on schooling fish and fin whales were only observed feeding on invertebrates, primarily euphausiids. This difference in diet may be due to preference, rather than differential availability, since separate aggregations of fin whales feeding on invertebrates and Bryde's whales feeding on fish were seen in close proximity to each other. Furthermore, traveling fin whales did not stop to feed when passing through aggregations of Bryde's whales feeding on fish.

To our knowledge, feeding groups have not previously been described for any of the *Balaenoptera* whales. The fin whale feeding groups we observed were clearly discernable within a larger aggregation of whales, individuals within groups had consistent body orientations relative to each other (lead whale to right of trailing whale), and came closer together when lunging. Similar feeding groups in other species have been hypothesized to increase feeding efficiency (Swynnerton 1915; Bartholomew 1942; Emlen and Ambrose 1970; Pooley and Gans 1976; Würsig *et al.* 1984), however, more detailed observations of both fin and Bryde's whales are needed to determine the function of fin whale feeding groups.

ACKNOWLEDGEMENTS

We are grateful to H. and V. Ballance for sharing "Small World III" and their expertise during radio-tagging, and to D. Croll, L. Ballance and J. Guerrero for allowing us to use data we all collected. Our heartfelt thanks go out to the people who made this research possible: E. and R. Tershy; our advisors B. Würsig, K. Norris, and R. Luckenbach; our local support group - A. Reséndiz, M. Blanca, E. Valenzuela, J. Mercadé, C. and R. Espinosa and B.,K., and G. Starr; and especially our assistants E. VanGelder, V. Dollarhide, G. Meyer, E. Murphy, A. Lopez, S. Flores, J. Ramirez, G. Sanchez, C. Hansen, T. Rusk, D. Smalheer, J. Feldman, J. Terrazino, C. Paulson, J. Rowe, C. Heidenreich, B. Adams and D. Anderson. Research was conducted under Secretaria de Pesca permits (No. 3099, 1141, 1283, 0757 and 1960) and funded by the University of California, Santa Cruz Environmental Field Program, UCSC Chancellors Discretionary Fund, UC President's Undergraduate Fellowship Foundation, American Cetacean Society - Monterey, Los Angeles and National Chapters, Lerner-Grey Fund for Marine Sciences, Sigma Xi Grants-in-Aid of Research, the Packard Fund, and the Meyer Fund. D. Croll, M. Foster, J. Oliver, P. Sherman, B. Würsig and two anonymous reviewers helped improve the manuscript.

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Revista de Investigación Científica

PUBLICADA POR LA UNIVERSIDAD AUTONOMA DE BAJA CALIFORNIA SUR
SERIE CIENCIAS DEL MAR