Diets of Baird's Beaked Whales, *Berardius bairdii*, in the Southern Sea Of Okhotsk and Off the Pacific Coast Of Honshu, Japan

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DIETS OF BAIRD'S BEAKED WHALES, *BERARDIUS BAIRDII*, IN THE SOUTHERN SEA OF OKHOTSK AND OFF THE PACIFIC COAST OF HONSHU, JAPAN

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ABSTRACT

Stomach contents were analyzed from 127 Baird's beaked whales, *Berardius bairdii*, taken in coastal waters of Japan. During late July–August of 1985–1987, 1989, and 1991, 107 samples were collected from off the Pacific coast of Honshu. An additional 20 samples were collected from whales taken in the southern Sea of Okhotsk during late August–September of 1988 and 1989. Prey identification using fish otoliths and cephalopod beaks revealed the whales fed primarily on deep-water gadiform fishes and cephalopods in both regions. Prey species diversity and the percentage of cephalopods and fish differed between the two regions. Off the Pacific coast of Honshu the whales fed primarily on benthopelagic fishes (81.8%) and only 18.0% on cephalopods. Eight species of fish representing two families, the codlings (Moridae) and the grenadiers (Macrouridae), collectively made up 81.3% of the total. Thirty species of cephalopods representing 14 families made up 12.7%. In the southern Sea of Okhotsk, cephalopods accounted for 87.1% of stomach contents. The families Gonatidae and Cranchiidae were the predominant cephalopod prey, accounting for 86.7% of the diet. Gadiform fish accounted for only 12.9% of the diet. Longfin codling, *Laemonema longipes*, was the dominant fish prey in both regions. Depth distribution of the two commonly consumed fish off the Pacific coast of

Honshu indicate the whales in this region fed primarily at depths ranging from 800 to 1,200 m.

Key words: Baird's beaked whale, *Berardius bairdii*, Ziphiidae, diet, cephalopods, Moridae, Macrouridae, *Laemonema longipes*, *Coryphaenoides cinereus*, *Coryphaenoides longifilis*.

The deep-diving behavior of Baird's beaked whale, *Berardius bairdii*, is well known (Balcomb 1989). Prolonged dives for periods of up to 67 min have been reported for this species (Kasuya 1986). Despite historically large numbers of *B. bairdii* taken in whaling operations throughout its range in the northern North Pacific, little is known about their foraging behavior and role in the marine ecosystem.

The diet of *B. bairdii* is poorly known and most of the literature accounts rely on small sample sizes. Pike (1953) and Rice (1963) reported on eight whales taken in the eastern North Pacific. Betesheva (1961) reported on the stomach contents of 12 whales taken off the Kurile Islands, whereas Tomilin (1957) did so for five whales presumably taken off the Kamchatka Peninsula (precise localities were not given). Nishiwaki and Oguro (1971) summarized findings based on a cursory examination of stomach contents of 383 whales taken along the Pacific coast of Honshu, Japan, to the northern coast of Hokkaido in the southern Sea of Okhotsk. Though they had access to a large sample of whales, they limited their findings almost exclusively to regional accounts on general qualitative observations of the numbers of stomachs predominantly containing remains of "deep sea fish" or "squid."

This study is based on a detailed examination of stomach contents collected from 127 Baird's beaked whales taken off the Pacific coast of Honshu, Japan, and in the southern Sea of Okhotsk off the northern coast of Hokkaido. It not only represents the first detailed quantitative prey species description for this species of whale, but also constitutes the most comprehensive diet study conducted on any member of the family Ziphiidae.

Methods

Field Collection

Stomach samples collected in this study were from whales taken in the coastal, shore-based small whaling fisheries currently operating under permit by the Japanese Ministry of Agriculture and Forestry. These operations employ the use of high-speed catcher vessels of approximately 40 tons with a deck-mounted 50-mm bore harpoon gun (Ohsumi 1975). The whale fisheries take of *B. bairdii* off the coast of Japan is seasonal and corresponds to the whales' natural migratory movements. It first appears off the continental slope of the Pacific coast of Honshu at approximately 34°N in early summer and moves northward as the season progresses through late fall (Kasuya *et al.* 1997).

Due to time constraints, logistics, and stomach condition, all whales processed at any given whaling station were not necessarily sampled. With the exception of the work at Abashiri in 1988 that was performed by a Japanese Fisheries

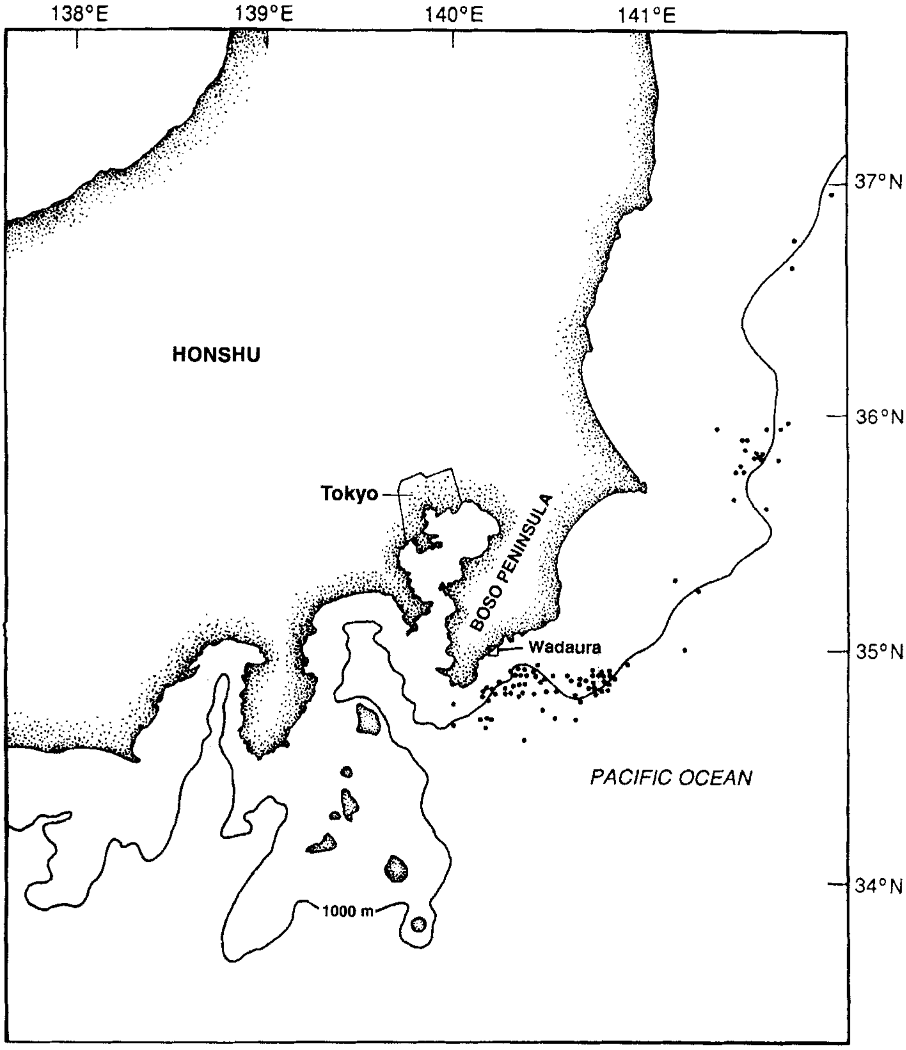

Figure 1. Approximate capture locations for *Berardius bairdii* stomach samples collected off Pacific coast of Honshu, Japan 1985–1987, 1989, and 1991.

Agency biologist, all other fieldwork was conducted by one or more of the authors.

The sample collected off the Pacific coast of Honshu, Japan, was taken off the Boso Peninsula and Sanriku coast in an area extending from approximately 34°30′ to 36°50′N (Fig. 1). Stomach contents from a total of 107 whales were collected during the 1985–1987, 1989, and 1991 seasons in late July through August of each year. Of these, 104 were processed at the Gaibo whaling station at Wadaura, Chiba Prefecture, whereas, three were sampled from the northern part of this region in 1991 at Ayukawa, Miyagi Prefecture.

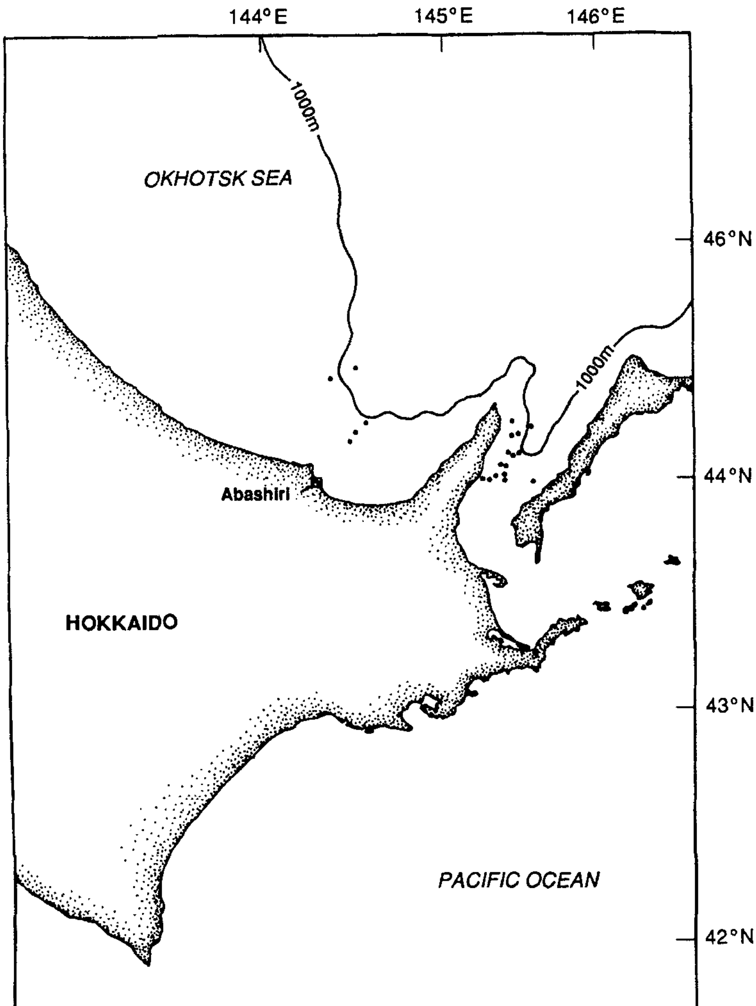

Figure 2. Approximate capture locations for *Berardius bairdii* stomach samples collected in southern Sea of Okhotsk 1988–1989.

The Sea of Okhotsk sample was collected during late August through September off Abashiri, Hokkaido, and in the Nemaro Strait between the eastern side of the Shirotoko Peninsula and Kunashir Island (Fig. 2). A total of 20 whales were sampled during the 1988 and 1989 seasons.

Once the viscera had been removed from the carcass, the esophagus and small intestine (just posterior to the duodenum) were tied off with twine. The entire stomach was then cut free from the surrounding organs and removed to a work area clear of the flensing operation. The stomach was opened in a systematic manner beginning at the esophageal junction and terminating with examination of the duodenum. All stomach contents were removed and placed in large containers. The final procedure in the removal of food remains was to gently rinse the entire mucosal surface with fresh water. All isolated otoliths and cephalopod beaks adhering to the mucosal folds were then collected. Stomach contents were weighed if estimated to exceed 5 kg. Contents were placed in trays and rinsed with water to remove excess prey tissue. All identifiable remains such as cephalopod beaks, otoliths, representative fish crania, and other diagnostic bones were preserved in 70% ethanol. Due to the practice of opening the body cavity at sea to cool the carcass and the effect of exploding harpoon heads, some stomachs were inadvertently damaged and the contents lost or partially lost while the animals were towed to the port facility. This study reports only on undamaged stomachs containing food remains. Due to the difficulty in interpreting the significance of empty stomachs, they were also excluded from the sample.

Laboratory Analyses

Prey species were identified from fish saggital otoliths and cephalopod beaks. Confirmation of beak and otolith identifications were aided through identification of fish cranial bones and intact, or partially intact, fish and cephalopod remains whenever possible.

The minimum number of individual prey ingested was determined by the greater number of left or right otoliths and upper or lower cephalopod beaks. In instances where badly eroded, but specifically identifiable, otoliths could not be determined to be left or right, the total number was divided by two to estimate the number of fish represented. Otolith length (OL), otolith width (OW), lower rostral length (LRL) of squid beaks and lower hood length (LHL) of vampyromorph and octopod beaks were measured to the nearest 0.1 mm with either vernier calipers or an optical micrometer. All otoliths and beaks were measured if they were judged to be in good condition. Damaged or eroded otoliths and beaks were not measured. Prey species taxonomy and nomenclature follow Nelson (1994) and Masuda *et al.* (1984) for fishes and Nesis (1987) for cephalopods.

Deep-water lanternfishes, juvenile squid, and a wide range of benthic invertebrates are reported as prey of macrourid fishes in the coastal waters of Japan (Okamura 1970*a*). Myctophid fishes and juvenile squid are also well-known diet components of numerous species of cephalopods. Beaked whales capture their prey primarily by means of suction (Heyning and Mead 1996), a feeding strategy conducive to incidental ingestion. Otoliths from small fishes, which were probably incidentally ingested in pursuit of larger prey or secondarily introduced as prey of larger prey consumed by the whales were evident in the stomach samples from both regions. These specimens are not listed in the prey species tables. These otoliths occurred infrequently and were from small fish estimated to be no more than 100 mm in length. Many of these otoliths were severely eroded and some exhibited sharp angular chips and breakage suggesting secondary introduction as prey of cephalopods. In the Pacific coast of Honshu sample, a total of 32 otoliths representing two families, Myctophidae (five genera; *Diaphus*, *Electrona*, *Stenobrachius*, *Myctophum*, and *Lampanyctus*) and Bathylagidae (*Bathylagus* sp.) were considered to be incidentally or secondarily introduced. In the southern Sea of Okhotsk sample, otoliths suspected to be of incidental or secondary origin were from small walleye pollock, *Theragra chalcogramma* (nine otoliths, 2–4 mm in length) and an unidentified species of small juvenile, zoarcid (seven otoliths). Similarly, beaks from infrequently occurring, small cephalopods were also considered to be incidentally ingested or introduced secondarily and excluded from the prey species lists. In the Pacific coast sample these were six beaks from *Abraliopsis felis* (0.5–1.0 mm LRL) and four *Helicocranchia* sp. beaks (0.5–0.9 mm LRL). In the Sea of Okhotsk sample, 11 beaks from small juvenile *Gonatus* spp. (0.5–1.0 mm LRL) were not included as prey.

Little is known about the life history of most of the prey species consumed by the whales. This is particularly true for many of the species of grenadiers. Literature reports on growth rates and length/weight relationships are almost non-existent for many of the common prey. This lack of information prevents estimation of prey size, weight, and contribution by mass for a large percentage of the sample. However, we recently developed otolith length/body length (fishes), lower beak rostral length/dorsal mantle length (cephalopods), and length/weight regressions for eight of the commonly ingested prey (Table 1). Otolith and cephalopod beak samples from specimens of known length and weight were obtained from specimens retained at the Northwest and Alaska Fisheries Science Center Seattle, Washington, and Scripps Institute of Oceanography, La Jolla, California.

Results

Pacific Coast of Honshu, Japan

Stomach content analysis of the 107 whales sampled from this region revealed the whales fed primarily on fish (81.8%) and to a lesser degree on cephalopods (18.0%). Two families of benthopelagic gadiform fishes made up 81.3% of the prey (Table 2). The codlings (Moridae) were represented by two species: the longfin codling, *Laemonema longipes* (43.5%), and the finescale mora, *Antimora microlepis* (0.5%) with a combined frequency of occurrence of 85.6%. Six species of grenadiers (Macrouridae) made up 37.3% of the prey by number, with a frequency of occurrence of 93.5%. Of these, three species of *Coryphaenoides* (*C. longifilis*, *C. cinereus*, and *C. acrolepis*) were predominant and collectively accounted for 33.2% of the prey consumed.

Despite the low numbers of cephalopod prey, the frequency of occurrence in the sample was high (92.5%). The species composition of cephalopods eaten by *B. bairdii* in this region was diverse. Thirty species encompassing 14 families of cephalopods were represented. Two families were dominant; eight species of the family Gonatidae accounted for 7.8% of the total prey with a frequency of 83.2%. The family Cranchiidae, represented by six species, accounted for 4.9% of the total prey in 98.1% of the stomachs.

The two dominant fish prey, *L. longipes* and *C. cinereus*, collectively made up 58.4% of the total prey in this region. The estimated mean standard length of *L. longipes* in the sample was 510.1 mm. The estimated mean pre-anal fin length and weight for *C. cinereus* were 119.2 mm and 199.6 g, respectively (Table 3).

The presence of gravel and stones up to 9 cm in diameter in the stomachs of the Pacific coast of Honshu sample was high. They were present in all of 98 stomachs surveyed for these non-food items.

Southern Sea of Okhotsk

In the southern Sea of Okhotsk the dominant prey of *B. bairdii* shifted considerably. Cephalopods dominated the diet, collectively accounting for 87.1% of the

Table 1. Regression equations and information used in estimating body lengths and masses of eight prey species in diet of Baird's beaked whales, *Berardius bairdii*, taken off Pacific coast of Japan and southern Sea of Okhotsk.

Species	Regression	n	r^2	Size range (mm)	y	x
Fish						
Laemonema longipes[a]	$y = 63.29x - 160.76$		0.99		Stand length (mm)	Otolith length (mm)
Antimora microlepis	$y = 44.41x - 205.59$	71	0.97	160–560	Stand length (mm)	Otolith length (mm)
Coryphaenoides cinereus	$y = 21.44x - 13.75$	248	0.91	23–164	Pre-anal fin length (mm)	Otolith length (mm)
	$Ly = 3.21 (Lx) - 10.05$	242	0.99	29–164	Mass (g)	Pre-anal fin length (mm)
Coryphaenoides acrolepis	$y = 16.67x - 27.71$	281	0.96	30–290	Pre-anal fin length (mm)	Otolith length (mm)
	$Ly = 2.99 (Lx) - 9.16$	281	0.99	30–290	Mass (g)	Pre-anal fin length (mm)
Albatrossia pectoralis	$y = 15.64x - 21.77$	122	0.96	39–486	Pre-anal fin length (mm)	Otolith length (mm)
	$Ly = 3.31 (Lx) - 10.65$	120	0.99	39–339	Mass (g)	Pre-anal fin length (mm)
Cephalopods						
Berryteuthis magister	$y = 33.81x + 36.78$	49	0.92	91–365	Dorsal mantle length (mm)	Lower beak rostral length (mm)
	$Ly = 2.78 (Lx) - 9.11$	72	0.98	58–365	Mass (g)	Dorsal mantle length (mm)
Gonatopsis borealis	$y = 36.00x + 11.4$	217	0.97	30–318	Dorsal mantle length (mm)	Lower beak rostral length (mm)
	$Ly = 2.70 (Lx) - 8.66$	212	0.99	32–318	Mass (g)	Dorsal mantle length (mm)
Taonius borealis	$y = 40.53x + 45.29$	158	0.94	82–445	Dorsal mantle length (mm)	Lower beak rostral length (mm)

[a] The length regression equation for *L. longipes* was provided by Mr. Nobetsu, Hokkaido University, Hakodate, Japan.

prey consumed with a frequency of occurrence of 100% (Table 4). The number of cephalopod species represented was less diverse than that of the Pacific coast of Honshu sample. Only four families of cephalopods were represented. However, the two families Gonatidae and Cranchiidae remained the dominant cephalopod prey and collectively represented 86.7% of the total prey consumed. Six species of gonatid squid were represented and accounted for 75.8% of the total. Of the gonatids, the schoolmaster gonate squid, *Berryteuthis magister*, was dominant species and accounted for a total of 31.7% of the prey and occurred in all the stomachs. The family Cranchiidae was represented by three species, accounting for 10.9% of the prey with a frequency of occurrence of 95%.

Fish were less important in this region representing only 12.9% by number with an occurrence of 90%. Four families of fishes were represented. Moridae and Macrouridae remained the dominant fish prey and collectively made up 9.2% of the total. Morids were represented by a single species, *L. longipes*, which accounted for 3.4% of the total with an occurrence of 45.0%. Three species of Macrouridae (*C. cinereus*, *C. acrolepis*, and *Albatrossia pectoralis*) made up 5.8% of the total prey in 50.0% of the stomachs examined. The walleye pollock, *Theragra chalcogramma* (Gadidae) and two species of eelpout (Zoarcidae) collectively made up the remaining 3.7% of the total prey.

Though the longfin codling, *L. longipes*, remained the dominant fish species in the sample, the estimated mean length of 358.2 mm was smaller than those consumed by the whales off the Pacific coast of Honshu (Table 5). The estimated mean length and weight of the dominant cephalopod in the sample, *B. magister*, was 213.7 mm and 331.2 g, respectively.

The presence of non-food items in the stomachs of the southern Sea of Okhotsk whales was comparatively low. Gravel and stones were found in only two (10.0%) of the 20 stomachs examined.

Discussion

The results of this study are generally similar to the qualitative findings of Nishiwaki and Oguro (1971). Their observation that Baird's beaked whales feed primarily on squid off the northern coast of Hokkaido and on "deep sea fish" off the Pacific coast of Japan is supported by our findings. They also reported "sardine" (presumably *Sardinops melanosticta*) and "mackerel" (presumably *Scomber* sp.) as prey of whales taken off the Pacific coast of Honshu north of 37°N. Sardine and mackerel are primarily inhabitants of the epipelagic zone. If their observations are correct this would indicate a shift in Baird's beaked whale feeding behavior in this region. We are unable to confirm this observation since all our stomach samples off the Pacific coast of Japan were collected from south of that latitude.

The two major gadiform fish families represented in our study (Moridae and Macrouridae) are of confirmed deep-water, benthic habit and many are known to occur at depths in excess of 1,000 m (Okamura 1970*a*, *b*). The morid, *Laemonema longipes*, and the macrourids, *Coryphaenoides acrolepis* and *Albatrossia pectoralis*, are reported as prey of Baird's beaked whales taken off the Kurile Islands (Betesheva (1961). Rice (1963) reported the macrourid species, *C. acrolepis*, from *B. bairdii* taken off central California.

The longfin codling, *L. longipes*, was the dominant fish prey in both the southern Sea of Okhotsk and Pacific coast of Honshu samples. Yokota and Kawasaki

Table 2. Number and frequency of occurrence of prey recovered from 107 stomachs from Baird's beaked whales, *Berardius bairdii*, taken off Pacific coast of Honshu, Japan.

	Number		Occurrence	
	No.	% of Total	No.	% Frequency
Total prey	9,880	100	107	100
Fish	8,078	81.8	104	97.2
Synaphobranchidae				
Synaphobranchus affinis	1	<0.1	1	0.9
Alepocephalidae				
Alepocephalus sp.	2	<0.1	2	1.9
Alepisauridae				
Alepisaurus ferox	2	<0.1	2	1.9
Moridae	4,343	44.0	89	85.6
Antimora microlepis	46	0.5	18	16.8
Laemonema longipes	4,297	43.5	86	80.4
Macrouroididae				
Squalogadus modificatus	43	0.4	5	4.7
Macrouridae	3,683	37.3	100	93.5
Bathygadus antrodes	21	0.2	6	5.6
Albatrossia pectoralis	7	0.1	5	4.7
Coryphaenoides longifilis	1,347	13.6	76	71.0
Coryphaenoides acrolepis	467	4.7	63	58.9
Coryphaenoides cinereus	1,469	14.9	83	77.6
Coelorinchus japonicus	304	3.1	18	16.8
Unidentifiable macourid otoliths (worn)	68	0.7	13	12.1
Gempylidae				
Rexea solandri	4	<0.1	4	3.7
Cephalopoda	1,782	18.0	99	92.5
Enoploteuthidae	136	1.4	35	32.7
Enoploteuthis chuni	131	1.3	34	31.8
Ancistrocheirus lesueuri	5	0.1	4	3.7
Octopoteuthidae				
Octopoteuthis deletron	17	0.2	9	8.4
Onychoteuthidae	32	0.3	18	16.8
Onychoteuthis borealijaponica	13	0.1	8	7.5
Moroteuthis lonnbergi	19	0.2	14	13.1
Gonatidae	769	7.8	89	83.2
Gonatus onyx	28	0.3	11	10.3
Gonatus pyros	61	0.6	31	29.0
Gonatus berryi	103	1.0	39	36.5
Gonatus madokai	24	0.2	11	10.3
Gonatus sp. A	63	0.6	33	30.8
Gonatus spp.(damaged)	5	0.1	3	2.8
Gonatopsis sp. A.	68	0.7	26	24.3
Gonatopsis borealis	75	0.8	40	37.4
Eogonatus tinro	344	3.5	65	62.5
Histioteuthidae	29	0.3	15	14.0
Histioteuthis hoylei	27	0.3	15	14.0
Histioteuthis corona	2	<0.1	1	0.9
Architeuthidae				
Architeuthis sp.	1	<0.1	1	0.9
Ommastrephidae	61	0.6	21	19.6

Table 2. Continued.

	Number		Occurrence	
	No.	% of Total	No.	% Frequency
Todarodes pacificus	58	0.6	22	20.6
Unidentif. Ommastrephidae	3	0.1	3	2.8
Chiroteuthidae	12	0.1	3	2.8
Chiroteuthis calyx	4	<0.1	3	2.8
Chiroteuthis sp. A	8	0.1	3	2.8
Mastigoteuthidae				
Mastigoteuthis sp. cf. *M. dentata*	218	2.2	53	49.5
Cranchiidae	487	4.9	105	98.1
Leachia sp.	5	0.1	4	3.7
Megalocranchia sp.	5	0.1	4	3.7
Taonius borealis	388	3.9	81	75.7
Galiteuthis sp. A	5	0.1	5	4.7
Galiteuthis sp. B	14	0.1	7	6.5
Galiteuthis phyllura	69	0.7	34	31.8
Vampyroteuthidae				
Vampyroteuthis infernalis	8	0.1	8	7.5
Octopodidae				
Octopus dofleini	5	0.1	4	3.7
Alloposidae				
Alloposus mollis	5	0.1	5	4.7
Ocythoidae				
Ocythoe tuberculata	2	<0.1	2	1.9
Pyrosomata				
Pyrosoma atlanticum	20	0.2	11	10.3

(1990) report that mature individuals migrate south along the Pacific coast of Honshu in winter to spawn in an area just south of the tip of the Boso peninsula (~34°N) in late winter to spring. Subsequent to spawning, they then migrate northward back up the coast of Honshu. It is interesting to note that in this region the seasonal movements of *B. bairdii* and seasonal spawning and northward migration of its primary prey, *L. longipes*, coincide. The occurrence of *B. bairdii* in the coastal waters of Japan is also seasonal (early summer to late autumn). The whales first appear off the Pacific coast of Japan at approximately 34°N latitude in early summer and spread northward as the season progresses (Kasuya 1986, Kasuya *et al.* 1997). It may be that the movements of Baird's beaked whales off the Pacific coast of Japan are related to the seasonal spawning migration of longfin codling. The minimum lengths of *L. longipes* at maturity for males and females are 358 mm and 410 mm, respectively (Hamatsu and Yabuki 1997). The estimated mean length of 510.1 mm for *L. longipes* consumed by *B. bairdii* off the Pacific coast of Honshu in July and August reveals most of these fish were mature and were probably eaten subsequent to spawning or in the early stages of their northward migration. The estimated mean length of *L. longipes* consumed by the whales in the southern Sea of Okhotsk during late August through September was much smaller (358.2 mm), indicating that the whales were feeding on a large percentage of immature fish.

Table 3. Information on beak and otolith measurements used for prey size estimates for Baird's beaked whales, *Berardius bairdii*, taken off Pacific coast of Honshu, Japan.

Prey species	Parameter[a]	Number measured	Length range (mm)	Mean length (mm)	Mean prey length (mm)	Mean prey mass (g)
Fish						
Antimora microlepis	OL	13	11.1–23.5	15.2	469.4	—
Laemonema longipes	OL	766	5.5–13.8	10.6	510.1	—
Squalogadus modificatus	OL	14	11.6–18.5	14.2	—	—
Bathygadus antrodes	OL	2	8.5–9.4	9.0	—	—
Albatrossia pectoralis	OL	5	7.9–23.5	15.0	212.8	1203.2
Coryphaenoides longifilis	OL	279	9.2–20.6	14.5	—	—
Coryphaenoides acrolepis	OL	55	4.1–18.9	14.9	220.7	1070.7
Coryphaenoides cinereus	OW	330	3.9–9.0	6.2	119.2	199.6
Coelorinchus japonicus	OL	44	11.7–14.8	13.1	—	—
Cephalopods						
Enoploteuthis chuni	LRL	107	2.7–4.5	3.3	—	—
Ancistrocheirus lesueuri	LRL	5	5.5–7.1	6.6	—	—
Octopoteuthis deletron	LRL	6	6.0–8.0	6.5	—	—
Onychoteuthis borealijaponica	LRL	12	1.5–3.2	2.3	—	—
Moroteuthis lonnbergi	LRL	13	2.0–7.0	4.8	—	—
Gonatus onyx	LRL	23	3.1–6.1	4.1	—	—
Gonatus pyros	LRL	55	2.4–3.6	3.0	—	—
Gonatus berryi	LRL	93	2.4–7.0	4.1	—	—
Gonatus madokai	LRL	24	2.2–9.0	4.7	—	—
Gonatus sp. A	LRL	47	3.1–7.3	5.6	—	—
Gonatopsis sp. A.	LRL	53	7.9–17.8	15.3	—	—
Gonatopsis borealis	LRL	56	2.2–8.3	4.6	177.0	203.5
Eogonatus tinro	LRL	313	3.2–6.9	4.4	—	—
Histioteuthis hoylei	LRL	21	2.3–7.3	5.2	—	—
Histioteuthis corona	LRL	2	1.9–2.1	2.0	—	—
Architeuthis sp.	LRL	1	12.0	—	—	

Table 3. Continued.

Prey species	Parameter[a]	Number measured	Length range (mm)	Mean length (mm)	Mean prey length (mm)	Mean prey mass (g)
Todarodes pacificus	LRL	48	1.8–5.5	3.3	—	—
Chiroteuthis calyx	LRL	4	3.1–7.5	4.4	—	—
Chiroteuthis sp. A	LRL	6	3.5–4.5	4.1	—	—
Mastigoteuthis sp. cf. *M. dentata*	LRL	140	2.1–6.0	3.4	—	—
Leachia sp.	LRL	4	1.4–1.8	4.0	—	—
Megalocranchia sp.	LRL	5	4.0–7.8	5.0	—	—
Taonius borealis	LRL	240	2.4–11.0	5.1	252.0	—
Galiteuthis sp. A	LRL	7	3.7–8.9	6.7	—	—
Galiteuthis sp. B	LRL	9	3.4–7.5	5.8	—	—
Galiteuthis phyllura	LRL	60	2.1–7.2	4.5	—	—
Vampyroteuthis infernalis	LHL	3	8.6–10.8	9.8	—	—
Octopus dofleini	LHL	7	6.8–10.7	9.0	—	—
Alloposus mollis	LHL	5	10.1–15.6	12.4	—	—

[a] OL = otolith length, OW = otolith width, LRL = lower beak rostral length, LHL = lower beak hood length. Lengths of all species of macrourids expressed as pre-anal fin lengths (PAF). All other fish species are standard lengths.

Table 4. Number and frequency of occurrence of prey recovered from 20 stomachs from Baird's beaked whales, *Berardius bairdii*, taken in southern Sea of Okhotsk.

	Number		Occurrence	
	No.	% of Total	No.	% Frequency
Total prey	2,432	100	20	100
Fish	315	12.9	18	90.0
Moridae				
Laemonema longipes	83	3.4	9	45.0
Gadidae				
Theragra chalcogramma	44	1.8	9	45.0
Macrouridae	140	5.8	10	50.0
Albatrossia pectoralis	62	2.6	5	25.0
Coryphaenoides acrolepis	4	0.2	3	15.0
Coryphaenoides cinereus	74	3.0	7	35.0
Zoarcidae	48	2.0	11	55.0
Bothrocarina microcephala	46	1.9	11	55.0
Bothrocara molle	2	0.1	1	5.0
Cephalopods	2,117	87.1	20	100.0
Gonatidae	1,843	75.8	20	100.0
Gonatus onyx	1	<0.1	1	5.0
Gonatus berryi	244	10.0	17	85.0
Gonatus madokai	355	14.6	19	95.0
Gonatopsis sp. A.	132	5.4	13	65.0
Berryteuthis magister	771	31.7	20	100.0
Eogonatus tinro	340	14.0	18	90.0
Histioteuthidae				
Histioteuthis hoylei	1	<0.1	1	5.0
Cranchiidae	265	10.9	19	95.0
Taonius borealis	64	2.6	16	80.0
Galiteuthis sp.A	83	3.4	12	60.0
Galiteuthis phyllura	118	4.8	16	80.0
Octopoda				
Octopus dofleini	8	0.3	1	5.0

Detailed experimental fishery information on the depth distribution and relative abundance of two of the most common fish prey off the Honshu coast shed some light on the foraging behavior of *B. bairdii*. In the stomach samples collected from whales taken off the Pacific coast of Honshu, the longfin codling, *L. longipes*, and the longfin grenadier, *C. longifilis*, collectively made up 57.1% of the total number of prey. Shiratori and Kawasaki (1989) reported on a series of deep-water bottom trawls conducted at various depths on the continental slope at approximately 38°N off the Honshu coast (Fig. 3). In this region the bottom depth distribution of *L. longipes* ranged from 600 to 1,000 m, reaching their greatest abundance at 800–900 m. The bottom depth distribution of *C. longifilis* ranged from 1,000 to 1,500 m, with the greatest concentration of this species at 1,200 m. They also reported two species of gadids, walleye pollock, *Theragra chalcogramma*, and Pacific cod, *Gadus macrocephalus*, to be the most abundant fishes in trawl samples at bottom depths ranging from 100 to 400 m. The latter

Table 5. Information on beak and otolith measurements for prey remains and prey size estimates for Baird's beaked whales, *Berardius bairdii*, taken in southern Sea of Okhotsk.

	Variable[a]	Number measured	Range	Mean	Mean prey length (mm)[b]	Mean prey mass (g)
Fish						
Laemonema longipes	OL	41	7.4–9.3	8.2	358.2	—
Theragra chalcogramma	OL	17	9.4–20.3	16.9	—	—
Albatrossia pectoralis	OL	7	12.2–19.4	15.4	2,19.1	1,325.2
Coryphaenoides cinereus	OW	5	4.9–6.3	5.7	108.5	147.6
Bothrocarina microcephala	OL	3	1.8–2.0	3.0	—	—
Cephalopods						
Gonatus onyx	LRL	1	3.6	-	—	—
Gonatus berryi	LRL	212	2.8–7.5	5.5	—	—
Gonatus madokai	LRL	292	1.8–10.0	7.1	—	—
Gonatopsis sp. A.	LRL	85	8.0–17.5	15.1	—	—
Berryteuthis magister	LRL	697	2.2–8.8	5.2	213.7	331.2
Eogonatus tinro	LRL	304	2.1–7.3	5.3	—	—
Histioteuthis dofleini	LRL	8	6.9–8.2	7.3	—	—
Taonius borealis	LRL	85	2.3–10.0	6.8	320.9	—
Galiteuthis sp. A	LRL	75	2.4–10.2	5.6	—	—
Galiteuthis phyllura	LRL	104	2.7–7.2	5.6	—	—
Octopus dofleini	LHL	7	6.5–11.3	9.7	—	—

[a] OL = otolith length, OW = otolith width, LRL = lower beak rostral length, LHL = lower beak hood length.
[b] Lengths of all species of macrourids are expressed as pre-anal fin lengths (PAF). All other fish species are standard length.

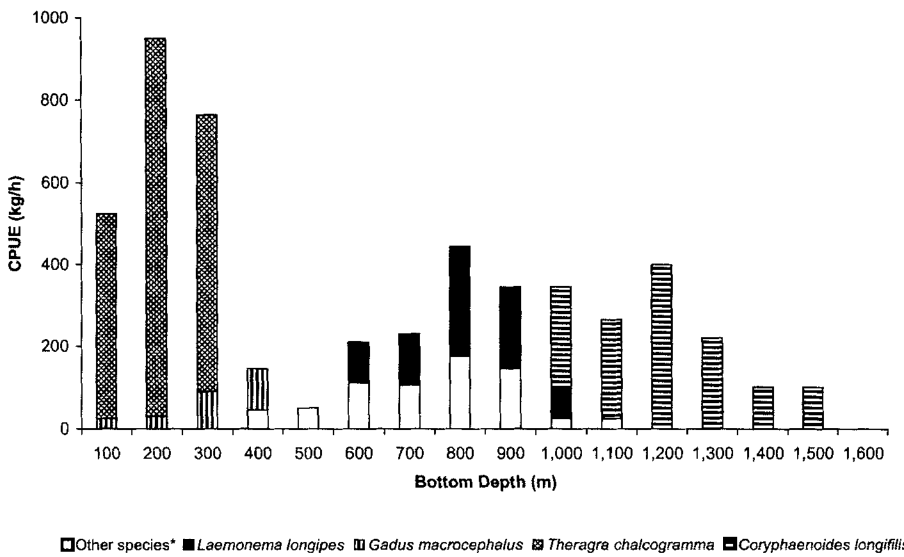

Figure 3. Bottom depth distribution and relative abundance of fishes taken by bottom trawl at approximately 38°N on continental slope of Pacific coast of Honshu (figure modified from Shiratori and Kawasaki 1989). * Other species taken from below 800 m were primarily roughscale sole, *Clidoderma asperrimum*, popeye grenadier, *Coryphaenoides cinereus*, Pacific grenadier, *C. acrolepis*, and gray cutthroat eel, *Synaphobranchus affinis*.

two species were totally absent in our stomach samples from this region. The total absence of walleye pollock and Pacific cod in the Baird's beaked whale stomach samples in spite of their abundance in the area is significant. It appears that while the whales are known to feed on *T. chalcogramma* in the Sea of Okhotsk, off the Pacific coast of Honshu they appear to prefer to feed in the benthopelagic environment on morid and macrourid fishes, probably at depths ranging from 800 to 1,200 m.

The feeding preference of *B. bairdii* on benthic and epibenthic prey is similar to that of another deep-diving cetacean, the sperm whale, *Physeter macrocephalus*. Many of the fish species identified in our study have been reported from the stomachs of sperm whales taken off the Kurile Islands and the Pacific coast of northern Japan (Betesheva and Akimushkin 1955, Betesheva 1961, Berzin 1971). Almost all the cephalopod species from *B. bairdii* are known prey of sperm whales taken in the coastal waters of Japan (Okutani *et al.* 1976, Okutani and Satake 1978). An additional similarity between these two cetacean species is the common occurrence of stones and gravel in sperm whale stomachs (Berzin 1971). In the Pacific coast of Honshu *B. bairdii* sample, stones and gravel were noted in 100% of 98 stomachs surveyed for these non-food items. These were presumably ingested incidentally during benthic foraging. The southern Sea of Okhotsk sample demonstrated a different pattern. In this sample stones and gravel were found in only two (10%) of the 20 whales examined. This low frequency of occurrence is probably due to their cephalopod feeding preference. Most of the cephalopod species consumed by *B. bairdii* in this region are muscular swift-swimming species that are not predominantly associated with the benthic environment.

In general, it has been assumed that beaked whales feed predominantly on cephalopods (Clarke 1996). However, since few ziphiids have been taken in whale fisheries, most dietary information on beaked whales has been derived from a small number of whales which had stranded or were incidentally taken by fisheries (Mead 1989). *Berardius bairdii* and the northern bottlenose whale, *Hyperoodon ampullatus*, are the only ziphiid species that have been direct targets of whale fisheries. As a result, *H. ampullatus* is the species for which we have the best beaked whale dietary information to use for comparison. Like *B. bairdii*, *H. ampullatus* also demonstrates deep-diving behavior with dives up to 1,453 m for durations of up to 70 min (Hooker and Baird 1999). Benjaminsen and Christensen (1979) reported on the stomach contents of 47 whales examined off Iceland in 1967 and 108 from Labrador in 1971. Unfortunately, like the dietary study of *B. bairdii* off Japan conducted by Nishiwaki and Oguro (1971), the authors also limited their dietary study on *H. ampullatus* to general qualitative observations on the presence or absence of fish and squid, though they did make some attempt to identify some of the common prey species. Geographical differences in the diet of the northern bottlenose whale were evident. They reported less than 10% of the whales from Iceland had eaten fish, while about 50% of the whales taken off Labrador had fish in their stomachs.

In their sample all the squid examined were identified as a single species, *Gonatus fabricii*. However, their cursory examination of the cephalopod prey remains may have led to an overly simplistic presentation of the cephalopods represented. Clarke and Kristensen (1980) conducted a detailed analysis of cephalopod beaks from two stranded *H. ampullatus*: one in Jutland and one in the Faroe Islands. They reported that while *Gonatus fabricii* was the dominant prey by number (74%), the remaining 26% were represented by a wide variety of deep-water species representing seven other families.

Benjaminsen and Christensen (1979) reported, but did not quantify, the following fishes in their Iceland sample: *Brosmius brosme* (Gadidae), *Cyclopterus lumpus* (Cyclopteridae), and *Sebastes* sp.(Scorpaenidae). The Labrador sample included *Reinhardtius hippoglossoides* (Pleuronectidae), *Sebastes* sp. (Scorpaenidae), *Molva molva* (Gadidae), *Chimaera monostrosa* (Chimaeridae), *Squalus acanthius* (Squalidae), and *Raja* sp. (Rajadae). All of the above species are common inhabitants of the deep-water benthic and epibenthic zones. However, considering the large sample size of 155 stomachs, the total absence of grenadiers (Macrouridae) in their list of fishes eaten by *H. ampullatus* is surprising. Two species of grenadiers, *Coryphaenoides rupestris* and *Macrourus berglax* are very abundant off the Labrador coast and Iceland at depths of 500–1,000 m where they have supported extensive international trawl fisheries since the mid-sixties (Cohen *et al.* 1990). It is possible that the cursory examination of the fish remains in the *H. ampullatus* stomachs resulted in their being selectively overlooked. Digestion in ziphiids occurs at a faster rate than most other cetaceans. Macrourids are comparatively soft-bodied fishes, and the stomach anatomy of ziphiids differs from most cetacean species in that the esophagus empties directly into the glandular, main (fundic) stomach (Mead 1989). As a result, the rapid digestion of soft-bodied fishes could have resulted in the reported absence of macrourids. In our sample from Japan, the rapid digestive process of *B. bairdii* rendered all the macrourids unrecognizable, other than through detailed examination of otoliths and skeletal remains.

Though the methodology employed in the studies of *B. bairdii* and its North Atlantic congener, *H. ampullatus*, are not comparable in detail and may have excluded some species vulnerable to rapid digestion, it appears that the diet of these two species of large, deep-diving, ziphiids are generally similar. Geographic differences in the proportion of cephalopods and fish consumed are found in both species, and the prey species identified from the stomachs indicate both are feeding on benthic prey in at least some portions of their range.

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