DISTRIBUTION AND BEHAVIOR OF BAIRD'S BEAKED WHALES OFF THE PACIFIC COAST OF JAPAN

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ABSTRACT

Aerial sighting records from the last 25 years and ship board sightings in 1984 indicate that the Baird's beaked whales which occur off the Pacific coast of Japan in summer through autumn live in schools of 1 to 30 individuals (average <10). The schools stay underwater for up to about one hour, 4 to 5 times longer than the time at surface. Baird's beaked whales in the area are seasonally distributed on the continental slope at depth of 1,000 to 3,000 m, and north of 34°N latitude under the influence of the subsurface cold Oyashio Current. The whales appear off the Boso Peninsula near the southern limit of their range on the Japanese Pacific coast in early summer reaching a peak in August, and then move north along the continental slope, peaking in October–November off the Pacific coast of Hokkaido. This seasonal movement is discontinuous to that of this species in the Sea of Japan and Okhotsk Sea, suggesting that these three areas are inhabited by separate populations. However, the northern range of the Pacific coast population is still unconfirmed and their distribution in December to May is unknown.

INTRODUCTION

Omura, Fujino and Kimura (1955) analyzed the catch records of Baird's beaked whale, *Berardius bairdii* Duvernoy 1851, by Japanese small-type whaling, and concluded that they arrived off Boso Peninsula in early summer and moved to the north presumably to arrive off the east coast of Hokkaido in early autumn. They also suggested that such individuals might belong to a population which was different from those using the Sea of Japan or in the Okhotsk Sea.

Nishiwaki and Oguro (1971)'s analysis of subsequent data from the same source supported many of Omura *et al.*'s conclusions. In addition, they concluded that Baird's beaked whales were distributed off the Pacific coast of Japan in waters deeper than 1,000 m. Because of the coastal nature of the whaling, no information was available on the offshore limit of the distribution of this species. (see Study of also Kasuya (1971)).

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Ohsumi (1983) analyzed sighting records collected by scouting vessels of the Japanese factory ship whaling fleets and by research vessels chartered by the Japan Fisheries Agency, and concluded that the distribution of Baird's beaked whales off the Pacific coast of Japan extended to offshore waters. His data were later reanalyzed by Kasuya and Ohsumi (1984) who were unable to reinforce this conclusion because sightings in offshore water were scarce and because they observed an area of low density between coastal and offshore high density areas.

The present study analyzes the distribution and migration of Baird's beaked whales off the Pacific coast of Japan using the results of sighting cruises conducted in the summer of 1984 plus aerial sighting records accumulated over 25 years by Fishery Aviation Co. Ltd.

MATERIALS AND METHODS

Aerial sightings

Aerial sightings records of marine mammals were provided by Fishery Aviation Co. Ltd. The records were accumulated during chartered flights to make oceanographic observations (e.g. water temperature, marine pollutant, red tide and floating algae) or to search for fish schools in order to provide information for purse seiners. The data cover the period from April 1959 to December 1983. Information from this series collected before April 1970 was also used by Kasuya (1971).

Observation was conducted at an altitude of 500 m along track lines that were arranged by the person who chartered the flight to scan his objective area. The observers (usually the Fishery Aviation Company personnel) were allowed to diverge from the predetermined track line or to descend for occasional observation or for photography of their sightings. In principle the area was searched using transect of infinite width, but the distribution of observers effort probably changed depending on the main objective of each

TABLE 1. LIST OF AIRCRAFTS THAT COLLECTED AERIAL SIGHTING RECORDS OF BAIRD'S BEAKED WHALES FOR THE PRESENT STUDY

Year	Type of Aircraft*	Engine	Sighting speed	Cruising distance
1953–'58	Piper Tripacer PA22	135Hp	95kt	4.5 hours
1958–'64	Cessna 175	175Hp	100kt	7.5 hours
1965–'79	Cessna 182 Skylane	230Hp	105kt	7.5 hours
1979–'82	Cessna 182 Skylane	230Hp	105kt	7.5 hours
	Aero Commander 680F	380Hp × 2	140kt	7.5 hours
1982–'83	Cessna 182 Skylane	230Hp	105kt	7.5 hours
	Cessna U206G	300Hp	120kt	9.0 hours
	Aero Commander 680F	380Hp × 2	140kt	8.0 hours

* All high wing type.

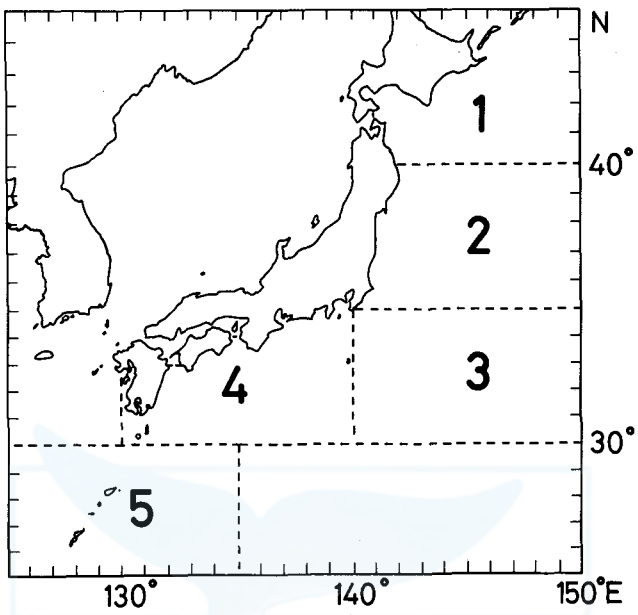

Fig. 1. Geographical areas used in the analysis of the aerial sighting data collected between April 1959 to December 1983.

flight and type of the aircraft used.

There were considerable changes over the years in the size, cruising speed, and range of the aircraft used as detailed in Table 1. In 1965 large engined aircraft was introduced, then in 1979 the company obtained a twin-engined aircraft. These changes resulted in the expansion of the survey area and increased survey effort in offshore waters (Fig. 3).

The number of observers was usually two (pilot and navigator) for single-engine air-craft, and three (pilot, navigator and engineer) for twin-engine aircraft. The view from the front was superior in the latter. Before 1981, both observers in the single-engine aircraft sat in the port seats, causing an unbalanced search effort. Since 1981, however, an observer was located on each side of the single-engine aircraft. In the twin-engine aircraft (used since 1979), the pilot searched front and port side, the engineer front and starboard side, and navigator the starboard side only.

These changes in aircraft and sighting technique, and search area affected sighting efficiency making it impossible to use these sighting records to monitor changes in the relative density of Baird's beaked whales. However, they provide useful information on distribution. The 25 years of aerial sighting data were stratified by geographical area (Fig. 1) and month. Data collected by observers in single- and twin-engine aircraft were separated in Table 2, but were combined in the later analyses.

TABLE 2. AERIAL SIGHTING RECORDS OF BAIRD'S BEAKED WHALES BY MONTH, DIVISION AND YEAR

Division 1	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1959–'63 (single-engined plane)													
NM flown	–	–	–	–	94	–	77	1,845	4,808	3,389	598	–	10,811
No. schools	–	–	–	–	–	–	–	2	3	6	–	–	11
No. whales	–	–	–	–	–	–	–	10	22	27	–	–	59
1964–'68 (single-engined plane)													
NM flown	–	–	–	106	717	63	–	1,083	7,812	4,000	–	–	13,781
No. schools	–	–	–	–	–	–	–	–	3	1	–	–	4
No. whales	–	–	–	–	–	–	–	–	6	6	–	–	12
1969–'73 (single-engined plane)													
NM flown	29	–	–	–	–	–	317	2,720	8,013	6,708	37	–	17,824
No. schools	–	–	–	–	–	–	–	1	4	3	–	–	8
No. whales	–	–	–	–	–	–	–	4	24	20	–	–	48
1974–'78 (single-engined plane)													
NM flown	–	–	–	–	–	112	315	3,202	5,866	3,794	3,159	–	16,448
No. schools	–	–	–	–	–	–	–	–	2	–	1	–	3
No. whales	–	–	–	–	–	–	–	–	40	–	10	–	50
1979–'83 (single-engined plane)													
NM flown	–	–	171	–	–	137	–	555	4,786	1,272	858	61	7,840
No. schools	–	–	–	–	–	–	–	–	2	–	1	–	3
No. whales	–	–	–	–	–	–	–	–	9	–	8	–	17
1979–'83 (twin-engined plane)													
NM flown	–	–	–	–	105	25	128	2,223	6,591	398	–	–	9,470
No. schools	–	–	–	–	–	–	–	–	1	–	–	–	1
No. whales	–	–	–	–	–	–	–	–	4	–	–	–	4
Division 2													
1959–'63 (single-engined plane)													
NM flown	210	–	651	1,035	2,956	4,610	5,476	4,679	2,738	4,568	8,458	1,040	36,421
No. schools	–	–	–	–	1	4	17	9	5	–	1	–	37
No. whales	–	–	–	–	2	12	86	40	20	–	6	–	166
1964–'68 (single-engined plane)													
NM flown	1,865	1,615	387	383	5,256	4,270	3,497	2,532	5,695	7,168	11,569	5,310	49,547
No. schools	–	–	–	–	1	1	11	3	10	3	5	1	35
No. whales	–	–	–	–	2	2	42	16	61	14	15	1	153
1969–'73 (single-engined plane)													
NM flown	1,367	730	233	308	1,106	8,348	4,025	4,904	6,491	5,713	3,779	2,233	39,237
No. schools	–	–	–	–	–	3	5	4	–	2	1	1	16
No. whales	–	–	–	–	–	9	53	16	–	5	4	13	100
1974–'78 (single-engined plane)													
NM flown	–	–	1,560	1,123	1,785	2,298	1,331	2,219	2,156	2,242	4,342	1,679	20,735
No. schools	–	–	–	–	–	1	–	–	–	–	–	–	1
No. whales	–	–	–	–	–	12	–	–	–	–	–	–	12
1979–'83 (single-engined plane)													
NM flown	524	408	1,911	571	5,599	1,066	1,180	957	2,436	4,524	4,825	356	24,357
No. schools	–	–	–	–	–	–	–	6	3	–	–	–	9
No. whales	–	–	–	–	–	–	–	62	10	–	–	–	72
1979–'83 (twin-engined plane)													
NM flown	–	–	2,201	101	7,419	6,379	5,140	4,797	4,539	677	–	–	31,253
No. schools	–	–	–	–	–	1	7	3	–	–	–	–	11
No. whales	–	–	–	–	–	3	75	16	–	–	–	–	94

(Continued)

TABLE 2. (Continued)

Division 3													
1959–'63 (single-engined plane)													
NM flown	–	–	75	185	–	–	–	–	–	–	125	–	385
No. whales	–	–	–	–	–	–	–	–	–	–	–	–	–
1964–'68 (single-engined plane)													
NM flown	1,460	547	462	662	1,447	–	326	783	399	508	1,497	2,167	10,260
No. whales	–	–	–	–	–	–	–	–	–	–	–	–	–
1969–'73 (single-engined plane)													
NM flown	177	48	82	718	1,128	488	379	624	77	438	207	32	4,398
No. schools	–	–	–	–	–	–	3	–	–	–	–	–	3
No. whales	–	–	–	–	–	–	15	–	–	–	–	–	15
1974–'78 (single-engined plane)													
NM flown	158	124	541	1,109	2,761	–	460	42	292	165	81	395	6,128
No. schools	–	–	–	–	–	–	2	–	–	–	–	–	2
No. whales	–	–	–	–	–	–	40	–	–	–	–	–	40
1979–'83 (single-engined plane)													
NM flown	248	257	140	26	3,000	–	625	532	–	–	–	–	4,828
No. schools	–	–	–	–	–	–	–	3	–	–	–	–	3
No. whales	–	–	–	–	–	–	–	9	–	–	–	–	9
1979–'83 (twin-engined plane)													
NM flown	–	232	660	1,525	3,391	699	108	–	–	–	–	–	6,615
No. whales	–	–	–	–	–	–	–	–	–	–	–	–	–
Division 4													
1959–'63 (single-engined plane)													
NM flown	–	–	220	–	–	–	–	–	–	–	98	–	318
No. whales	–	–	–	–	–	–	–	–	–	–	–	–	–
1964–'68 (single-engined plane)													
NM flown	380	300	310	721	1,000	–	488	2,200	371	1,845	1,771	1,186	10,572
No. schools	–	–	–	–	–	–	–	1	–	–	–	–	1
No. whales	–	–	–	–	–	–	–	2	–	–	–	–	2
1969–'73 (single-engined plane)													
NM flown	2,444	4,833	7,134	6,012	10,346	645	1,069	574	964	2,937	2,814	3,154	42,926
No. whales	–	–	–	–	–	–	–	–	–	–	–	–	–
1974–'78 (single-engined plane)													
NM flown	1,319	3,327	7,861	12,497	9,799	–	1,690	782	749	2,142	3,350	3,778	47,294
No. whales	–	–	–	–	–	–	–	–	–	–	–	–	–
1979–'83 (single-engined plane)													
NM flown	1,740	595	3,560	10,933	8,462	–	573	962	–	5,147	821	617	33,410
No. schools	–	–	–	–	–	–	1	–	–	–	–	–	1
No. whales	–	–	–	–	–	–	15	–	–	–	–	–	15
1979–'83 (twin-engined plane)													
NM flown	–	2,804	663	2,793	2,582	51	–	–	–	–	–	–	8,893
No. whales	–	–	–	–	–	–	–	–	–	–	–	–	–
Division 5													
1959–'83 (single- and twin-engined planes)													
NM flown	3,938	14,395	19,963	3,847	2,020	–	48	1,096	–	–	384	130	45,821
No. whales	–	–	–	–	–	–	–	–	–	–	–	–	–

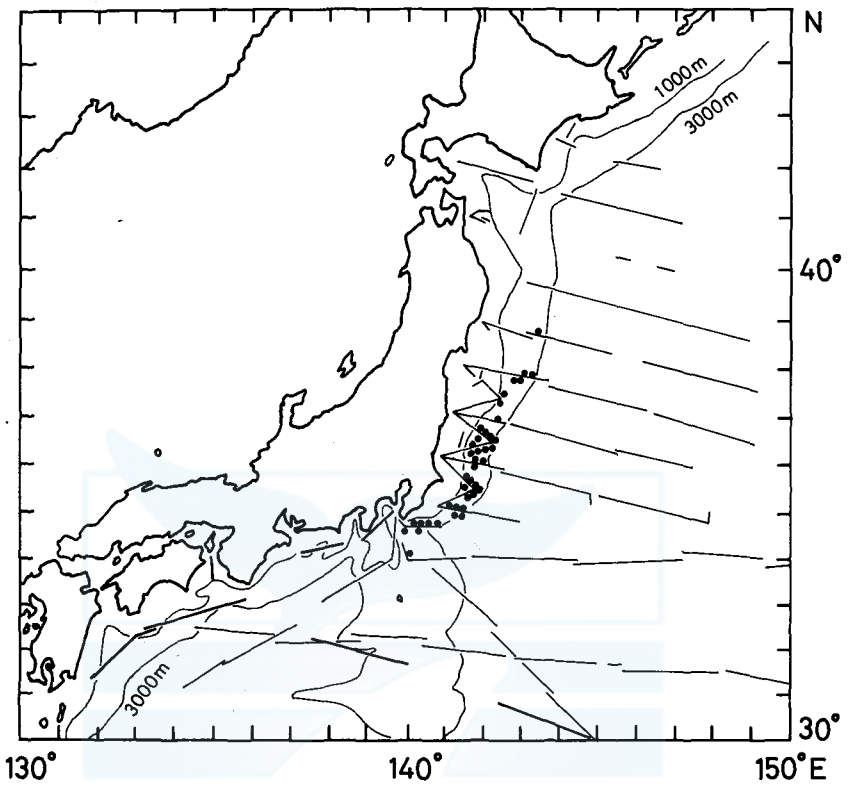

Fig. 2. Track lines of the Baird's beaked whale sighting cruises in 1984 by the *Toshimaru No. 25* (thin solid lines) and *Shonanmaru* (thick solid lines). Each closed circle indicates the position of a Baird's beaked whale school. Only track lines cruised with mast-top observers (normal sighting effort) are indicated.

Shipboard sightings

Data were obtained in 1984 during two whale sighting cruises in the western North Pacific using whale catcher boats *Toshimaru No. 25* (750 gross tons) and *Shonanmaru* (917 gross tons) chartered by the Japan Fisheries Agency. The cruises lasted 88 days (9 June to 4 September) and 80 days (9 June to 27 August), respectively. The track lines in the study area cruised with sighting effort are shown in Fig. 2. Additional areas west of 170°E and north of 10°N were also searched during the cruises as detailed by Miyashita (1985a), but no sightings of Baird's beaked whales were recorded.

I was on board the second cruise of the *Toshimaru No. 25* which surveyed Japanese coastal waters north of 34°30'N from 7 July to 6 August. This survey was conducted from the northern leg to the southern leg of the surveyed grid while the range of the distribution of the Baird's beaked whales was extending from south to north. Each leg was arranged approximately perpendicular to the coastline, i.e. along the expected density gradient of

Baird's beaked whales. I verified all sightings (303 individuals in 42 schools including secondary sightings). In addition, one school of four Baird's beaked whales was sighted on the first leg of the third cruise (from 7 August to 4 September) of the same vessel on 8 August in 34°07'N, 140°00'E. Although I did not verify this sighting, I have used it in the present study.

Sightings were conducted by both vessels during the entire cruising period (from port to port) except for night time and unfavorable weather conditions. Sightings during the second and third cruises of the *Toshimaru No. 25* were conducted using the methodology developed for the Antarctic minke whale sighting cruises (Best and Butterworth, 1980) on a predetermined courses at a speed of 12 knots (second and third cruises of the *Toshimaru No. 25*) or 11.5 knots (other cruises). The length of each leg varied from about 300 nautical miles of major legs to about 60 n. miles of subsidiary legs. The latter were designed to investigate details of the distribution of Baird's beaked whales in the high density area. Each of the former legs was completed spending about 3 days, but the latter a half day. Although the geographically biased density of sighting effort needs to be taken account in estimating the whale population (Miyashita, 1985b), such corrections are unnecessary for the analysis of pattern of distribution of whales in the present study.

All marine mammal schools sighted were approached to confirm specific identification and school structure. Data were collected on the position of the ship at sighting, the direction of the school from the track line, the radial distance from the position of sighting to the school, species, school size, estimated size composition (if available), surface water temperature, visibility, Beaufort scale of wind. Radial distances were estimated visually (for near sightings) or by summing an estimate based on the time required to approach to near distance and visual estimate of the rest of the distance. Position of the vessel was estimated using loran. Two mast-top observers (eye height of observers were 17 m above sea level for the *Toshimaru No. 25*, 20 m for the *Shonanmaru*) and five or six upper wheel-deck observers (*Toshimaru No. 25*, 10 m above sea level; *Shonanmaru*, 11 m) were used during the daytime from 15 minutes after sunrise to 15 minutes before sunset during periods when visibility was over 3 n. miles (usual maximum sighting distance of the Baird's beaked whale) and Beaufort scale less than 5. The mast-top observers rotated positions (mast-top, upper-wheel deck, and recess) every two hours. Two mates were alternately in charge of recording sighting data and position of the vessel. The captain and one to three scientists in charge of sighting spent the entire working time on the upper-wheel deck.

When wind was 5 or more in Beaufort scale or the visibility was less than 0.5 n. mile, observations ceased and the vessel was allowed to drift as far as time permitted. When visibility was between 0.5 and 3 n. miles and the wind less than Beaufort scale 5, sightings were conducted for Dall's porpoise, *Phocoenoides dalli*, using only upper wheel-deck observers. (Sightings of this species usually occur within 0.5 n. mile of the vessel (Bouchet, 1981; Kato,

1983)). No Baird's beaked whales were sighted in the northern area where these poor sighting conditions occurred.

The mast-top observers continuously used 50mm × 7 binoculars. The upper-wheel deck observers used them occasionally (they tended to search close to the boat). Polarized sunglasses were worn by most observers. Through speaker system every sighting was relayed between scientists, observers and a mate on duty; and this communication was also monitored by engineers. The mast-top observers commanded the vessel when it was approaching whale schools.

During the entire *Shonanmaru* cruise and the first cruise (9 June to 6 July) of the *Toshimaru No. 25*, sightings were mostly done under good conditions.

The school size and body length composition was estimated by the mast-top observers. Schools of Baird's beaked whales were identified without difficulty as a group of individuals swimming in a same direction in a close distance and surfacing almost simultaneously (see photographs in Kasuya, 1971; Kasuya and Ohsumi, 1984; Nishiwaki and Oguro, 1971).

Diving intervals were recorded for 18 schools of Baird's beaked whales containing from one to 25 individuals (mean = 9.1) while I was on board of the second cruise of the *Toshimaru No. 25*. We usually started timing at the initial sighting of blows continuing until the school composition was confirmed at a close distance. The number of observed dives ranged from one to six per school. Since whales dive when scared, schools were approached after the main engine was stopped 0.5 to 1 n. mile from the school. The main engine was always slowed down step by step prior to stopping. The vessel usually waited for the next surfacing after stopping its main engine close to the place of the dive. Schools which were chased by the vessel or found close to other school(s) were excluded from the analysis of diving interval because of the possibility that their behavior was unnatural or because the difficulty of identifying individual schools. The resurfaced individual school was identified based on the position and the size of the schools.

RESULTS

Range of distribution and seasonal movements

All the aerial and shipboard sightings of Baird's beaked whales were limited to waters north of 33°N, and most were east of about 140°E. In spite of considerable aerial and shipboard sighting effort few Baird's beaked whales were sighted west of 140°E, and all these were close to 140°E (Figs 2, 3 and 4). These data agreed with the range reported by Omura *et al.* (1955), Kasuya (1971), Nishiwaki and Oguro (1971), Ohsumi (1983) and Kasuya and Ohsumi (1984).

The distribution of Baird's beaked whales was also limited to coastal waters west of 144°E despite considerable searching effort further offshore (to

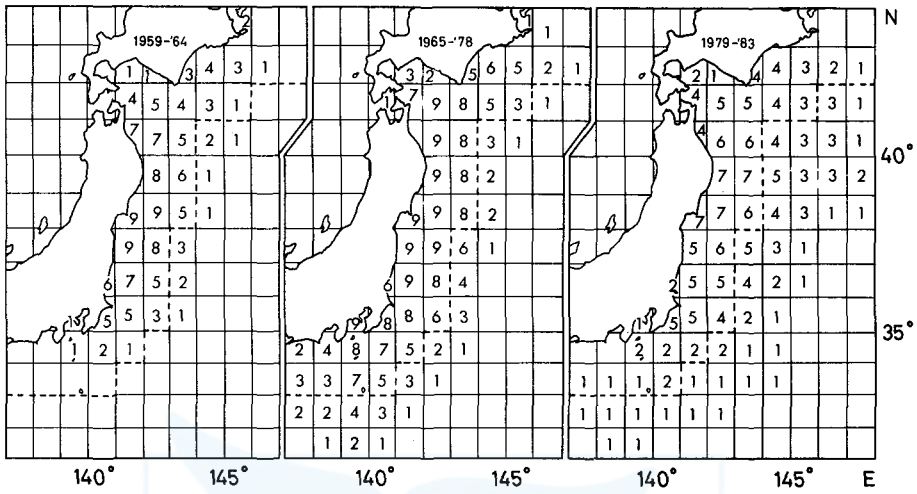

Fig. 3. Distribution of the aerial sighting effort in June to December (1959 to 1983) when most of the sightings of Baird's beaked whale occurred. The index of effort is expressed for each one degree squares of latitude and longitude by the number of times entered by the aircraft while it was conducting sightings (surveyed distance is not indicated). The scale for the number of times entered is, 1: 1–4, 2: 5–9, 3: 10–19, 4: 20–29, 5: 30–39, 6: 40–59, 7: 60–89, 8: 90–129 and 9: 130–169 times in the 27 years. Seasons are grouped based on change in aircraft types.

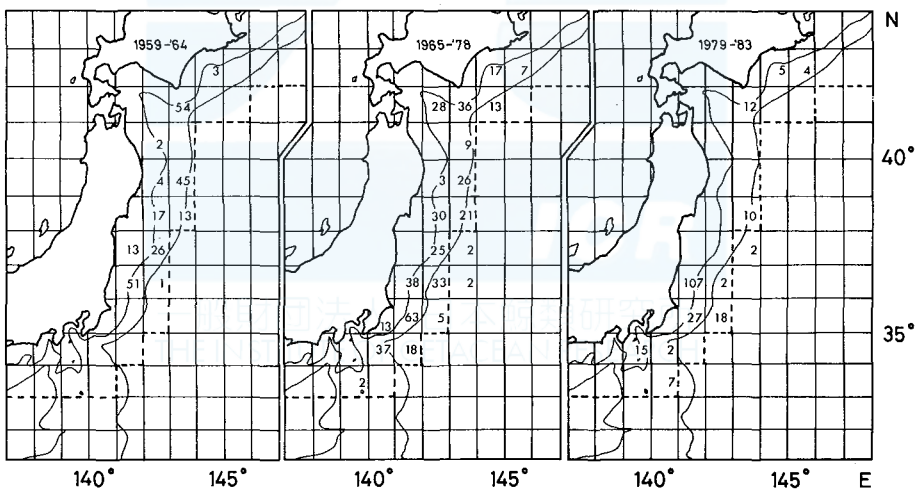

Fig. 4. The number of Baird's beaked whales sighted by the flights indicated in Fig. 3 of this study. The thin solid lines indicate 1,000 and 3,000 m contours, and the dotted lines one degree squares within 60 nautical miles from the coast of the major island. In addition to the sightings listed here, there were recorded in May four individuals in two schools in 36°–37°N, 141°–142°N and 36°–37°N, 142°–143°N, respectively.

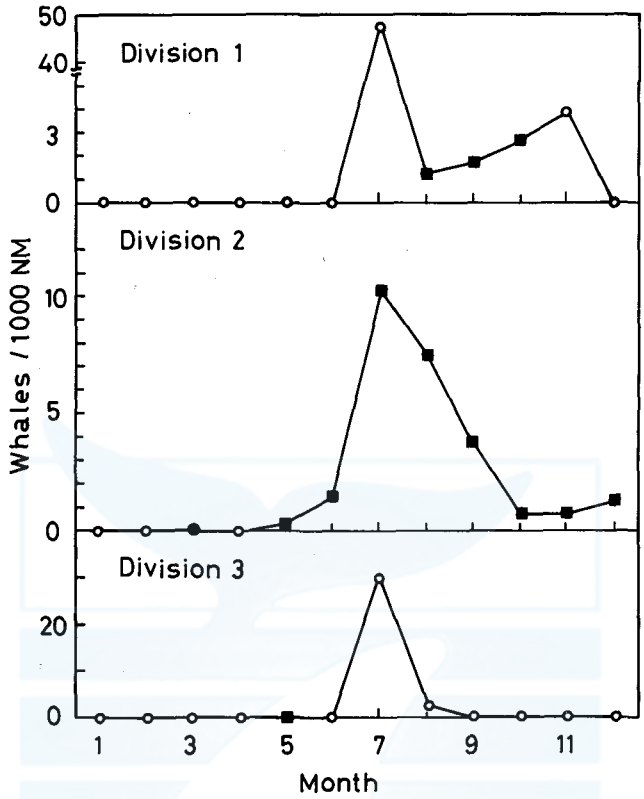

Fig. 5. Seasonal changes in the density of Baird's beaked whales based on aerial sighting records from April 1959 to December 1983. Square: flown for more than 10,000 nautical miles, closed circle: 5,000 to 10,000 nautical miles, open circle: less than 5,000 nautical miles.

160°E). The absence of shipboard sightings of Baird's beaked whales north of 39°N was partially due to the small sighting effort the coastal waters of this region at depths between 1,000 and 3,000 m where the occurrence is expected (see below).

Table 3 and Fig. 5 show the seasonal changes in the density of Baird's beaked whales as observed in the aerial sighting records. The whales arrive in the southern part of the range (Division 2) in May, and the density reaches a peak in July and then declines towards October. This pattern agrees with that suggested by the limited data for Division 3. In northern waters (Division 1), the density apparently increases from August to November, although the absolute density seems to be lower than that in the sourthern waters.

Factors affecting the distribution of Baird's beaked whale

Fig. 2 shows the sighting track line of the *Toshimaru No. 25* and the *Shonanmaru*, the position of sightings of Baird's beaked whale and the

TABLE 3. SEASONAL CHANGE OF THE DENSITY OF BAIRD'S BEAKED WHALES OFF THE PACIFIC COAST OF JAPAN ESTIMATED FROM THE AERIAL SIGHTING RECORDS IN 1959 THROUGH 1983

Month	1	2	3	4	5	6	7	8	9	10	11	12
Division 1												
NM flown	29	–	171	106	916	337	837	11,628	37,876	19,561	4,652	61
No. schools	–	–	–	–	–	–	2	3	13	10	2	–
No. whales	–	–	–	–	–	–	40	14	65	53	18	–
Whales/1,000 NM	0	–	0	0	0	0	47.8	1.2	1.7	2.7	3.9	0
Division 2												
NM flown	3,966	2,753	6,943	3,521	24,121	26,971	20,649	20,088	24,055	24,892	32,973	10,618
No. schools	–	–	–	–	2	10	40	25	18	5	7	2
No. whales	–	–	–	–	4	38	256	150	91	19	25	14
Whales/1,000 NM	0	0	0	0	0.2	1.4	12.4	7.5	3.8	0.8	0.8	1.3
Division 3												
NM flown	2,043	1,208	1,960	4,225	11,727	1,187	1,898	1,981	768	1,111	1,910	2,596
No. schools	–	–	–	–	–	–	5	3	–	–	–	–
No. whales	–	–	–	–	–	–	55	9	–	–	–	–
Whales/1,000 NM	0	0	0	0	0	0	30.0	4.5	–	–	–	–

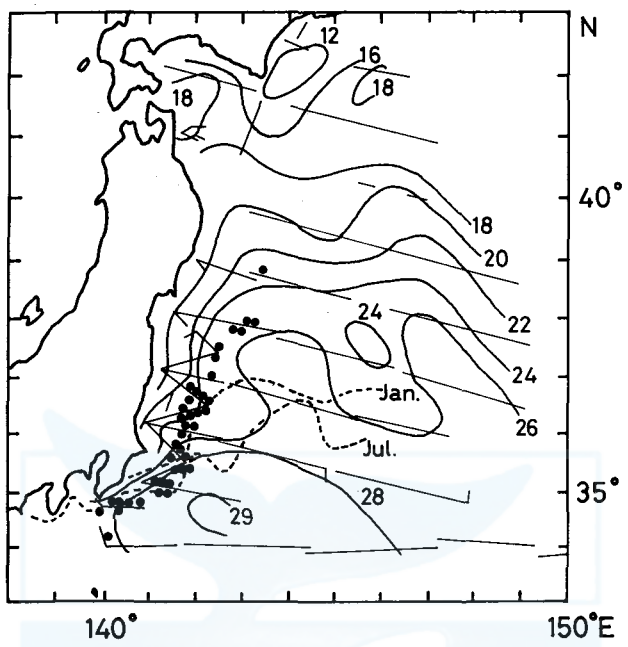

Fig. 6. The oceanographical environment at the position of Baird's beaked whale sighting (closed circle) during the *Toshimaru No. 25* cruise (The track lines are indicated by the thin solid line). The thick solid line indicates the surface water temperature observed during the cruise in July–August 1984 and the dotted line the 15°C isotherm at a depth of 100 m in January and July 1984 (Japan Meteorological Agency, 1984).

topography of the area. The whales were limited to water depths of 1,000 to 3,000 m on the continental slope. The same distribution pattern is seen from the aerial sighting records (Figs 3 and 4). The majority of aerial sightings were recorded in one degree squares (about 60 × 44 to 49 n. miles) which overlap with the above water depth range. Even in recent years when the aerial sighting effort expanded to waters further offshore, the range of sightings of Baird's beaked whales remained constant, indicating that the whales are concentrated in waters between 1,000 and 3,000 m deep at least from June to December. In contrast, Baird's beaked whales are not distributed at these depth off the Pacific coast of southwestern Japan, west of 138°E (Figs 2 and 4) indicating that distribution is influenced by some additional factors.

Fig. 6 shows the surface water temperatures measured during the cruises and the 15°C isotherms at 100 m below the surface in January and July 1984 cited from Japan Meteorological Agency (1984). Baird's beaked whales occurred at surface water temperatures of between 23° and 29°C, but the distribution did not agree with the range of the surface water isotherms.

The southern limit of the sightings coincides with the 15°C isotherm at a depth of 100 m (Fig. 6). The position of this isotherm changes little between

TABLE 4. SCHOOL SIZE FREQUENCIES OF BAIRD'S BEAKED WHALES OFF THE PACIFIC COAST OF JAPAN (DIVISION 1 THROUGH 4) BASED ON AERIAL SIGHTING DATA (1959 TO 1983) AND OBSERVATION ON BOAD OF THE *TOSHIMARU NO. 25* IN 1984

School size	Year						
	1959–'63	1964–'68	1969–'73	1974–'78	1979–'83	1959–'83	1984
1	11	9	0	0	0	20	3
2	9	10	7	0	5	31	3
3	5	7	3	0	1	16	6
4	4	3	2	0	2	11	8
5	4	1	5	0	4	14	4
6	4	2	1	0	3	10	3
7	1	3	1	0	0	5	2
8	3	2	2	0	1	8	3
9	0	0	0	0	0	0	0
10	2	1	3	2	4	12	2
11	1	1	0	0	0	2	0
12	0	0	0	1	1	2	0
13	1	0	1	0	0	2	0
14	2	0	0	0	0	2	0
15	0	0	1	0	5	6	3
17	0	0	0	0	1	1	0
18	1	0	0	0	0	1	1
20	0	0	1	2	0	3	3
25	0	0	0	0	0	0	1
30	0	1	0	1	0	2	0
Total	48	40	27	6	27	148	42
Mean	4.7	4.2	6.0	17.0	7.8	5.9	7.2
SE	0.6	0.8	0.9	3.2	1.0	0.4	0.9

seasons, suggesting that it represents a stable southern boundary of the cold Oyashio Current extending beneath the warm Kuroshio Current, the northern range of which moves widely between seasons.

In August, the warm Kuroshio Current extends to latitude 40°N (represented by 25°C surface isotherm). The northward shift of the concentration of Baird's beaked whales from off the Boso coast (35°–36°N) in July–August to off Hokkaido (40°–43°N) in August through November may be an influence of this summer expansion of the Kuroshio Current. Thus it is probable that the southern range of Baird's beaked whales off the Pacific coast of northern Japan may be in some degree affected by the warm surface water of the Kuroshio Current.

School structure

Aerial and shipboard estimates of the size of Baird's beaked whale schools are listed in Table 4. The shipboard estimates ranged from 1 to 25

with a mode at 4 and a mean of 7.4 individuals. The relatively high frequencies at 10, 15 and 20 represent a rounding effect. These features are not significantly different from the school size frequencies reported by small-type whaling vessels (Ohsumi, 1983).

In the aerial sightings recorded before 1969 there were more singletons than in the aerial sightings in recent years, although the upper ranges of the school size frequencies were not different between the two data sets. Such apparent change in the school size composition could be produced by (1) a real change in school composition, (2) underestimation of school size in earlier aerial sightings, or (3) missing small schools in recent aerial sightings. The school size of the shipboard sightings in 1984 tended to be intermediate of the two patterns. During the *Toshimaru No. 25* cruise in 1984, I encountered several schools whose size apparently increased while the vessel was approaching quietly after stopping the main engine. I therefore consider that the last two cases were more probable for aerial survey which cruised faster than vessels and was done as an supplemental work of the chartered flights. Therefore the historical change in the school size composition of Baird's beaked whale is not known from the present data, school size of the present population is likely to be represented better in the shipboard sighting data.
data.

The body length estimates were made by mast-top observers (who had experience of whaling other than Baird's beaked whale). Of the 283 Baird's beaked whales in 36 schools sighted during the first and second cruises of the *Toshimaru No. 25*, 265 were estimated to be 33 feet (9.9 m) or over, and only 15 individuals (5.7 %) 32 feet (9.6 m) or less (1 individual (0.4 %) at 20 feet, 6 (2.3 %) at 30 feet, 8 (3.0 %) at 32 feet). Three individuals (all estimated to be 30 feet) were accompanying their presumed mothers. According to data presented by Ohsumi (1983), the proportion of small individuals (≤9.6 m) in the catch of whaling in 1977–1981 was 24.7 %, which was higher than the corresponding figure obtained above (5.7 %). Therefore the cruise data are not suitable for estimating birth rate, without further assessment of (1) the accuracy of the body length estimates, (2) the possibility of missing small calves in the tight school, (3) knowledge of the early postnatal growth of the species, and (4) knowledge of the still unconfirmed segregation of animals by growth and reproductive stages.

The pattern of surfacing and diving

While a school was at the surface, blows were usually observed continually, and this was used as an indication that the school was at the surface. Before the vessel arrived at the position of initial sighting, the target school often dived and surfaced several times. In one particular case of a school of eight whales, which was not used in the following analysis, the vessel was within sight of the school recognized by the color of shallow submerged bodies and rings for eight minutes. During the period the vessel followed the school with

TABLE 5. SURFACING INTERVAL OF BAIRD'S BEAKED WHALE SCHOOLS

Time in min.	At surface		Below surface	
	number	percent	number	percent
1	5	14.7	2	6.1
2	5	14.7	1	3.0
3	7	20.6	–	–
4	5	14.7	–	–
5	1	2.9	1	3.0
6	2	5.9	2	6.1
7	–	–	1	3
8	1	2.9	2	6.1
9	–	–	1	3.0
10	–	–	3	9.1
11	–	–	1	3.0
12	–	–	2	6.1
13	1	2.9	–	–
14	1	2.9	1	3.0
15	–	–	1	3.0
16–20	–	–	4	12.1
21–25	–	–	3	9.1
26–30	–	–	3	9.1
31–35	–	–	–	–
36–40	–	–	2	6.1
41–45	–	–	1	3.0
46–50	–	–	1	3.0
51–55	–	–	–	–
56–60	–	–	–	–
61–65	–	–	–	–
66–70	–	–	1	3.0
Not measured	6	17.6	–	–
Total	34	100	33	100
Mean (minutes)	3.9		18.2	

engines off by the force of its inertia. The school was observed to change the direction frequently. However as soon as the vessel slowly started the main engine, the school dived deeply resurfacing after 20 minutes. This illustrates the importance of the method of approaching schools to obtain correct data on diving behaviour of Baird's beaked whales.

The time spent by a school at the surface ranged from about one to 14 minutes, but usually less than five minutes (Table 5) as stated by Matsuura (1942). The longest time at the surface (14 minutes) was for a school of 25 whales. This observation was made while the vessel approached from a distance of 1.5 n. miles to about 400 m as described above. The length of the preceding dive was 22 minutes. The mean observed time at the surface (3.9 minutes)

(Table 5) is subject to error. It may be overbiased as a result of our failure to record short surface times, or underbiased due to our misidentification of surfacings in which the whales were not spouting continuously, as two separate surfacings.

Dive times ranged from one to 67 minutes. The longest dive was recorded for a school of 20 individuals. This record is rather ambiguous. This school dove 3 n. miles from the vessel just after being sighted at 1440 hour on 27 July 1984. It surfaced for one or two minutes at 1457, 1534 and 1546 hour. Then at 1653 (67 minutes after the last surfacing which was brief), one small individual (no body length estimate was available) was seen surfacing about 0.5 n. miles from the vessel. The remaining members of the school were found about 1.5 nautical miles from the vessel at 1704 hour (78 minutes after previous sighting) in the direction in which the small individual was travelling). We were uncertain whether or not the other whales in the school surfaced at the same as the small individual, so we have used the smaller more conservative dive time (67 minutes). I considered that the small individual which surfaced alone at 1653 hour belonged to the larger school because it would be unnatural for the small individual to live alone and it was travelling toward the larger school. I also considered that the school surfaced at 1704 hour was same with that dove at 1546, because the schools were so uncommon that confusion was unlikely (during that day's survey of 7 hours 27 minutes (about 90 n. miles) this was the only school seen).

There were five major modes in the dive times; 1-2, 5-12, 14-29, 37-49 and over 60 minutes. Dives of 1-2 minutes may not have been true dives as discussed above. Excluding these, the mean dive time was calculated at 19.8 minutes (n = 30), which does not significantly differ from the figure in Table

TABLE 6. CORRELATION BETWEEN DIVING TIME AND THE FOLLOWING SURFACING TIME IN SCHOOL OF BAIRD'S BEAKED WHALES

Preceeding diving time in min.	Length of the next surfacing (minutes)									
	1	2	3	4	5	6	7	8	14	Total
1– 5	2		2							4
6–10	1	2	1							4
11–15		2		1						3
16–20			1			1				2
21–25			1		1				1	3
26–30				1						1
31–35										–
36–40			1							1
41–45								1		1
46–50				1						1
Total	3	4	6	3	–	2	–	1	1	20

5 (18.2 minutes) based on all recorded dives. The mean dive time was 4.7 times longer than the mean time at the surface. About half of the observed dives (17 of 33 dives) exceeded 13 minutes.

Although the number of sequential dives observed for each school was too small (maximum was six) to test the randomness of the sequence of long and short dives, there was an apparent tendency for long dives (over 20 minutes) to be followed by shorter ones below 13 minutes (6 dives by 4 schools). (However, one school of 20 individuals made two successive long dives of 41 and 67 minutes separated by 8 minutes of the surface.) Of 9 dives below 13 minutes, 7 were followed by a dive of over 13 minutes, but only one in 6 dives exceeding 13 minutes was followed by a dive of over 13 minutes. The difference was statistically significant (Chi-square test, $0.025 < p < 0.05$).

The comparison of length of a dive and that of the next surfacing revealed that long dives tended to be followed by a long period at the surface (Table 6). Significantly fewer number of short dives (< 15 minutes) were followed by long time (≥ 4 minutes) at the surface (Chi-square test, $0.01 < p < 0.025$).

DISCUSSION

Distribution in the western North Pacific

Baird's beaked whales is known in the eastern North Pacific from the Pribilof Islands to Baja California (Leatherwood, Reeves and Foster, 1983), and in the western North Pacific from the Bering Sea, Okhotsk Sea, Sea of Japan and Pacific coast of Japan north of the Tokyo Bay (Tomilin, 1967; Nishimura, 1970). Nishiwaki's (1967) claims that the northern bottlenose whale, *Hyperoodon ampullatus* (Forster, 1770) might exist in the Sea of Japan and that the beaked whales reported by the whalers in the Okhotsk Sea might represent this species, have not been confirmed (Nishimura, 1970). All 13 beaked whales caught in the Okhotsk Sea that were reported by Japanese small-type whaling boats between 1978–1982 were identified as Baird's beaked whales based on the largest pair of teeth collected from each individuals (Kasuya, unpublished). A skull of beaked whale taken off the Okhotsk coast and identified by a vernacular name of the area has been confirmed as Baird's beaked whale (Dr H. Omura, personal comm. in Oct. 1985). Thus there are no data to indicate the presence of *H. ampullatus* in the temperate and subarctic waters off Japan*.

Baird's beaked whales are known to dive deeply (Ohsumi, 1983) and for long periods (see above). The analysis of stomach contents recorded by whalers (Nishiwaki and Oguro, 1971) or those examined by a biologist (W. Walker, personal comm. in 1985) indicated that they feed mainly on bottom

* *This does not deny the possible existence in the tropical western North Pacific of hitherto unidentified Hyperoodon-like odontoceti, which were sighted and photo-recorded during the 1985 sighting cruises (Far Seas Fisheries Research Laboratory, unpublished).*

organisms (principally deep sea fish). The common occurrence of bottom substance such as pebbles in the whales' stomachs and the presence of scars attributable to hard substances other than teeth of the conspecifics on the tip of the upper jaw and melon region (Kasuya and Brownell, unpublished) also suggest bottom feeding. This information together with the distribution of Baird's beaked whales obtained by the present study suggest that the whales feed (at least in early summer to autumn) on organisms living on the ocean floor of a depth of 1,000 to 3,000 m and affected by a subsurface cold current. The distribution of the catch of Baird's beaked whales in the Sea of Japan and southern Okhotsk Sea reported by Omura *et al.* (1955) occurred in the Toyama Bay (Sea of Japan at about 37°N), off the Sea of Japan coast of southern Hokkaido (41°–42°N) and off Abashiri on the southern coast of the Okhotsk Sea. These grounds are also characterized by the presence of deep waters (> 1,000 m) near the coast.

However, Fedoseev (1985) reported that the species was abundant in April and May in the northern Okhotsk Sea north of Sakhalin where water depth is less than 500 m. This will presumably relate to the availability of food species in shallower waters in higher latitudes.

Seasonal movement of stocks in Japanese coastal waters

Fig. 7 shows the seasonal changes in density of Baird's beaked whales summarized using catch data of Omura *et al.* (1955) in 1948–'52 and sighting data of small-type whaling vessels in 1977–'82 reported by Kasuya and Ohsumi (1984). These data agree with the present results as well as those of Matsuura (1942) and Nishiwaki and Oguro (1971). Omura *et al.* (1955) concluded that the Baird's beaked whales which arrive off the Boso Peninsula in May–June move northwards to the waters off Sanriku (38°–40°N) after one month, peaking off the Pacific coast of Hokkaido (42°–43°N) in October and November. Although they were not sure whether Baird's beaked whale off the Pacific coast of Hokkaido belong to the same population as those off Sanriku and Boso Peninsula, the continuity of geographical (Figs 2 and 4) and seasonal (Figs 5 and 7) distribution suggest one population.

In the Okhotsk Sea, the catch of Baird's beaked whales has two peaks, one in May–June and the other in September–October. This bimodal distribution of the catch is unlikely to be caused solely by minke whales being the preferred target as claimed by Kasuya and Ohsumi (1984), because it is also reflected in the number of sightings per 100 operation hours of small-type whaling vessels (Fig. 7). Baird's beaked whales are present in the northern Okhotsk Sea in April–May (Fedoseev, 1985), slightly before their abundance in the southern Okhotsk Sea starts to decline.

The limited catch in the sea of Japan occurred on the two grounds (at about 37°N and 41°N) off Japan, from June to August. This is same as the seasonality of the catch off the Pacific coast in similar latitudes (off Boso Peninsula and Sanriku region).

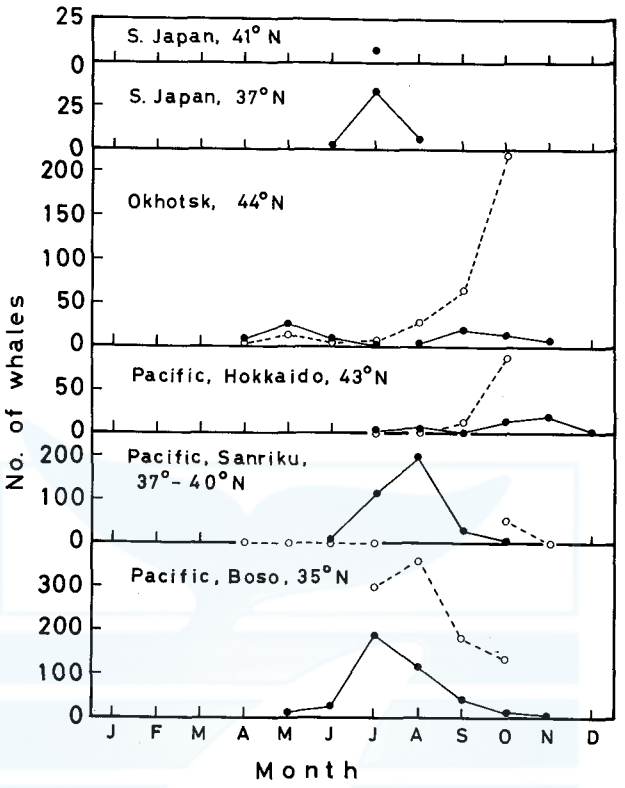

Fig. 7. Seasonal change in density of Baird's beaked whales in the Japanese coastal whaling ground (Sea of Japan, Okhotsk Sea and Pacific coast). The closed circle and solid line indicate the number of whales captured between 1948–1952 (Omura *et al.*, 1955), and the open circle and dotted line number of whales sighted per 100 hours of operation of small-type whaling vessels in 1977–1982 seasons (Kasuya and Ohsumi, 1984). Densities of whales based on less than 200 operation hours have not been indicated.

The seasonal changes in density summarized above could be explained by assuming three populations of Baird's beaked whale; in the Okhotsk Sea, the Sea of Japan, and off the Pacific coast of Japan as proposed by Omura *et al.* (1955), and assuming a seasonal north-south migration within the range of each population. La Perouse and Tatarskiy Straits (between the Sea of Japan and Okhotsk Sea) and Tsugaru Strait (between the eastern Sea of Japan and Pacific Ocean) presumably block migration between the three regions. These straits are less than 200 m deep (the maximum depths of these seas exceed 3,000 m). As Baird's beaked whale is found off the Pacific coast of Japan in the latitude of 33° to 44°N only in the waters between 1,000 and 3,000 m (see above), it is reasonable to assume that these straits will act as barriers between populations.

However, this does not necessarily mean that the Baird's beaked whales in the Okhotsk Sea do not pass through the Kuril Islands, where there is a strait (at about 47°N) exceeding 1,000 m in depth. Sleptsov (1955) reported the occurrence of Baird's beaked whales on the both coast of the Kuril Islands and on the east coast of the Kamchatka Peninsula. Although there are no data on the identity of the stocks in these areas, the likely incomplete isolation or the shorter geological history of isolation between the Okhotsk Sea and the Japanese Pacific coast populations may explain the lack of body length differentiation between the two stocks. According to Omura *et al.* (1955), the whales caught in the Sea of Japan were considerably smaller than those from other areas (modal length 30–32 feet in the Sea of Japan against 34–36 feet in the Okhotsk and Pacific coasts).

Behavior of Japanese Pacific coast "population"

The available data indicate that the Japanese Pacific coast "population" of the Baird's beaked whale is limited to the waters of the continental slope between the southern tip of Boso Peninsula (about 35°N) and the east coast of Hokkaido at 43°N. This distribution is similar to that of local stocks of the "true-type" population of Dall's porpoise, *Phocoenoides dalli* (True, 1885) in this region (Kasuya, 1978; Kasuya and Shiraga, 1985; Miyazaki, Jones and Beach, 1984), and the short-finned pilot whale, *Globicephala macrorhynchus* Gray, 1846, (Miyazaki, 1983; Kasuya and Marsh, 1984; Kasuya, unpublished). Presumably, some marine mammals in this relatively cold triangular-shaped area of coastal waters were isolated from the major subarctic North Pacific area by the island of Japan and by the offshore warm Kuroshio Current.

A seasonal northward movement of the Baird's beaked whale concentration along the continental slope is apparent from both catch statistics and sighting records. This phenomenon can be explained without assuming any significant northward movement of individual whales, by assuming offshore-inshore movements of whales which progress from south to north during July–November season. This assumption requires Baird's beaked whales to be distributed in the offshore waters of latitudes where they are known to be absent from the continental slope. This study showed that the whales were very scarce in the offshore area in summer through autumn. Therefore, this explanation seems impossible, and I consider that they migrate from early summer through autumn along the continental slope off the Pacific coast of Japan. However, this does not deny possibility of offshore dispersion of some individuals in autumn to winter season (see below).

Since the surface water temperature starts to decline in September off the Pacific coast of Japan, it is unlikely that the Baird's beaked whales which arrive off the Pacific coast of Hokkaido (presently identified northern limit of this "population") in September continue their northbound migration.

Although the available data are insufficient, due to scarcity of sighting effort and absence of whaling operation in winter to spring seasons, to suggest

where the whales winter after the disappearance from Hokkaido coast in November and till the reappearance off the Boso Peninsula in May. It seems likely that they migrate south and perhaps disperse in offshore waters. The offshore dispersion of the Baird's beaked whales in autumn is suggested by the rapid density decline during the northward migration in August through November (Figs 5 and 7). The magnitude of the density change seems to be too large to be explained on the basis of increased dispersion in the slightly wider 1,000–3,000 m deep continental slope in the northern area (Fig. 2).

Omura *et al.* (1955) showed that males predominated in the catch of Baird's beaked whales by Japanese small-type whaling in all of the fishing grounds mentioned above. Using catch statistics off Boso Peninsula, Ohsumi (1983) showed that males exceeded females in all of the 21 fishing seasons from 1947 to 1967, and that this changed since 1968 toward the dominance of females which lasted only for several seasons. Ohsumi's statistics showed also that the dominance of males in the catch resumed in 1977 as before 1968. Kasuya (1984), using statistics from 1947 through 1983, showed that the fishing seasons of Baird's beaked whales off Boso Peninsula in late 1950's to early 1970's (especially those for 1959 through 1972 seasons) apparently started earlier (in May) and ended later (in December) than the other seasons, and included months when the distribution of the species in the ground was very scarce. I suspect that the sex ratio may not have changed but that there were serious error in the catch statistics for seasons between presumably due in some degree to inclusion of other species such as sperm whales.

However, the dominance of males in the catch was also found in data collected by biologists. Among 29 Baird's beaked whales caught off the Boso Peninsula (near the southern limit of the population) in 1976 and 1977 seasons, 20 were males (Dr Y. Naito, personal communication), and of the 36 whales caught in the same area in 1985 season 24 were males (Kasuya, Brownell, Mead, Walker and Wada, unpublished). This overall sex ratio (44 males against 19 females) is significantly different from parity (Chi-square test, $0.01 < p < 0.025$). This imbalance of the sex ratio in the catch can occur for two reasons (1) geographical segregation by sex as suggested by Ohsumi (1983) or (2) higher catchability of males than females in the same school due to possible difference of ship-avoidance behavior or of position relative to other members of the school. If the first explanation is correct, then the range of the population off the Pacific coast of Japan must extend outside the area confirmed by the present study suggesting that the population is larger than the 4,220 (cv = 0.295) individuals estimated by Miyashita (1985b). However, a dominance of males was reported for samples from three "populations" discussed above and those captured at various parts of the range of their distribution, making the first explanation less likely than the latter (behavioural) explanation.

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