Harbor Porpoise, *Phocoena phocoena* (L.), in the coastal waters of northern Japan

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Abstract.–Little is known of the distribution, life cycle, and status of the harbor porpoise *Phocoena phocoena* in the northwestern Pacific Ocean and adjacent seas. In the present study we assess information in the literature and re-examine 15 specimens in the National Science Museum, Tokyo, in conjunction with data from 45 new animals collected from a variety of sources between 1983 and 1989. Maximum recorded lengths of harbor porpoises from Japanese waters are 158 cm for males, and 185 cm for females, and maximum age was 11 years. All females exceeded the average length of North Sea females at given ages. Size at birth is probably about 80 cm, and parturition likely occurs in May–June in northern Japanese waters, as in the North Atlantic. Known and historical geographical limits are given and compared with the equivalent habitat conditions extant in the western North Atlantic. The most southerly winter record is from Taiji, Wakayama, at latitude 34°15'N and the most northerly confirmed sighting from Shelikhova Bay in the northeastern Sea of Okhotsk at 57°–58°N, in August 1989. The latter is unlikely to represent the northern limit of the summer-fall distribution. Seasonal migrations, especially in and out of the Sea of Okhotsk, must occur because of extensive ice coverage in winter, but in Japanese waters there are confirmed records of porpoises as far north as the northern tip of Hokkaido Island in January.

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Harbor porpoises, *Phocoena phocoena*, are confined to the northern hemisphere; a near-circumpolar distribution is found in temperate latitudes (Tomilin, 1957; Gaskin, 1984). Although most often sighted in coastal waters, they also occur over adjacent offshore banks, and sometimes over deep water (Jones, 1984; Stenson and Reddin, 1990). There are populations around relatively isolated land masses, such as Iceland, and harbor porpoises also occur in subarctic and arctic waters, especially in summer months (Van Bree et al., 1977).

Interest in the harbor porpoise has increased significantly in recent years and Hohn and Peltier (1990) published a useful bibliography of articles on this species, although detailed life history and distributional data are still sparse in many regions. Population surveys and life history studies of the harbor porpoise have been concentrated in the coastal waters of western Europe, the northwestern Atlantic, and northeastern Pacific. Some pertinent references are the following but the list is not exhaustive: **Western Europe**: Møhl-Hansen (1954), Fraser (1974), Noldus and de Klerk (1984), Kinze (1985, 1990a, 1990b), Anderson (1990), Bjorge and Kaarstad (1990), Bjorge and Oien (1990), Evans (1990), and Sequiera (1990); **Black Sea**: Zalkin (1940), Tomilin (1957) and Celikkale (1990)· **Northwestern Atlantic**: Fisher and Harrison (1970), Gaskin (1977, 1984), Gaskin and Blair (1977), Prescott and Fiorelli (1980), Kraus et al. (1983)[1], Gaskin et al. (1984), Gaskin and Watson (1985), Yurick and Gaskin (1987), Polacheck (1990), Polacheck and Wenzel (1990), Read (1990, a and b), Fontaine et al. (1991), Read and Gaskin (1990); **Northeastern Pacific**: Flaherty and Stark[2], Taylor and Dawson (1984), Hannan et al.[3], Barlow (1988), Barlow et al. (1988),

[1]Kraus, S. D., J. H. Prescott, and G. S. Stone. 1983. Harbor porpoise, *Phocoena phocoena*, in the U.S. coastal waters of the Gulf of Maine: A Survey to determine seasonal distribution and abundance. Report to the Director, National Marine Fisheries Service, Northeast Region, Woods, MA, 15 p.

[2]Flaherty, C., and S. Stark. 1982. Harbor porpoise (*Phocoena phocoena*) assessment in "Washington Sound." NOAA, NMFS, National Marine Mammal Laboratory, Seattle, WA, Final Rep. for Subcontract 80-ABA-3584.

[3]Hanan, D. A., S. L. Diamond and J. P. Scholl. 1986. An estimate of harbor porpoise mortality in California set net fisheries April 1, 1984 through March 31, 1986. National Marine Fisheries Service, Southwest Region, Terminal Island, CA, Admin. Rep. 5WR-86-16, 38 p.

Barlow and Hanan (1990), Hohn and Brownell (1990), Dalheim et al. (1991), Forney and Barlow (1991), Rosel and Haygood (1991) and Stacey et al. (1990).

The life history of the harbor porpoise has been well studied in the North Atlantic and northeastern Pacific, but little is published about the distribution, movements and life history of the species in the waters of Japan and adjacent regions of eastern Russia. Jones (1984) recorded 10 specimens taken incidentally in salmon nets from 1978 to 1981 near the eastern Aleutians and one male at 57°N some 700 miles east of central Kamchatka. Miyashita and Doroshenko (1990), and Miyashita and Berzin (1991) reported a few recent summer sightings of harbor porpoises in the northeastern and northwestern Sea of Okhotsk and between southeastern Sakhalin and the southern Kurile Islands. Earlier, Nishiwaki (1966) concluded that the harbor porpoise was less common off Japan than in North American waters. Ohsumi (1972), however, regarded it as common around northern Japan, including the northern Pacific coast of Honshu, and Hokkaido; Hawley (1960) noted it was taken incidentally in the herring fishery in this region. Some catches of harbor porpoise have been reported (Table 1) in Japanese coastal fisheries statistics provided to the International Whaling Commission (1984, 1985, 1986, 1987, 1988, 1989, 1990) and by Miyazaki (1983), but identifications in the catch statistics are not always reliable and could include some Dall's porpoises[4]. Miyazaki et al. (1987) made preliminary comparisons of growth and skull morphology of Japanese porpoises with samples from the North Atlantic and northeastern Pacific. Recently Amano and Miyazaki (1992) repeated the analyses of skull morphology with larger samples and compared their results with those of Yurick and Gaskin (1987), using more sophisticated analysis than Miyazaki et al. (1987).

The harbor porpoise is now considered to be seriously threatened in several parts of the world, for example in the Baltic Sea, Black Sea, and Bay of Fundy—Gulf of Maine, where indirect and direct catches (Hohn and Peltier, 1990) may have contributed to dramatic declines in numbers in recent years (IWC, 1984; Read and Gaskin, 1990; Gaskin, 1992). Given the high fishing effort involving gill nets and trap nets in Japanese coastal waters (Tobayama et al., 1991) and the dearth of data for the harbor porpoise population in this region, any new information is useful. A systematic assessment of the status of the species around Japan would be desirable.

The objective of the present study was to increase the data base for harbor porpoise in Japanese waters. We collected new material; examined and measured harbor porpoises in Oceanaria; and verified documented but unpublished captures and stranding records from museums, fisheries institutions and other agencies in Japan. We tabulate data from 45 new specimens, together with the 15 originally examined by Miyazaki et al. (1987). We present for the first time, the apparent changes in seasonal distribution of the harbor porpoise in the waters of Japan and adjacent regions. We combine and re-analyze the new data in conjunction with those published by Miyazaki et al. (1987) to improve insights into the life history of harbor porpoise in the region. We reinforce the length-age relationships reported by Miyazaki and his colleagues and estimate the length at birth, and probable season of parturition of harbor porpoises in northern Japanese waters.

Table 1

Summary of reported catches of harbor porpoises in Japanese waters, taken from domestic fisheries statistics incorporated in national progress reports on cetacean research (IWC 1984–1990).

Year of capture	Months	Locations	Numbers	Annual totals	Gear	Year of IWC volume
1983	[1–12]	Iwate Pref.	20	20	Hand harpoon[1]	(1985)
1984	—	Hokkaido	6		Gillnets	(1986)
	—	Hokkaido	30	36	Pound nets	
1985	[1–12]	Iwate Pref.	55		Pound nets	(1987)
	[6–8]		1		Pound nets	
	[6–12]	Hokkaido	1	66	Gillnets	
1986	[6–9]	Hokkaido	30		Hand harpoon[1]	(1988)
	[4–9]	Hokkaido	36	66	Pound nets	
1987	[4–12]	Hokkaido	17		Pound nets	(1989)
	[1–12]	Nagasaki	4	21	Pound nets[1]	
1988	—	No breakdown	71		Gillnets	(1990)
		by region given	6	77	Hand harpoon[1]	

[1]Specific identification particularly doubtful. Because of the level of uncertainty about identifications of animals taken in the hand harpoon fishery, the totals reported for each year should be cited with caution. We also note the following known omissions: 1983: 1 more from Hokkaido gill nets; 1984: 2 more from northern Honshu pound nets; 1985: 21 more from Hokkaido gill nets and pound nets. These are not included in the body of the table to avoid potential confusion with the officially reported statistical data.

[4]Toshio Kasuya, Far Seas Fisheries Research Laboratory, Shimizu, Shizuoka, Japan, pers. commun. 1985.

Materials and methods

We re-examined the 15 harbor porpoise specimens in the collection at the National Science Museum in Tokyo, and obtained data on 45 new specimens, bringing the total sample size to 60. One of us (A.K.) encouraged local fishing companies and the Oceanaria in Hokkaido and northern Honshu to collect, sex, measure and preserve specimens or designated samples (e.g., teeth, testes, ovaries, and pieces of blubber) of *Phocoena phocoena*, killed in fishing gear from 1983 onwards. This program yielded 12 animals, mostly from gill nets. In April and May of 1985 and 1986, the authors arranged frequent inspections of the floating pound nets operated by the Nomura Fishing Company of Usujiri, Hokkaido, which are set to catch tuna, squid, and salmon, depending on the season. Salmon are the target species during April and May. From these nets we collected another 16 specimens: 11 in 1985 and five in 1986. During the same period we were invited to the three Oceanaria which held captive harbor porpoises, Otaru Aquarium in western Hokkaido, Asamushi Aquarium in Aomori, northern Honshu and Sunshine City Aquarium in Tokyo. We obtained measurements and body weights of 14 live or frozen specimens in these facilities. Additional confirmed records of three more stranded specimens, presently with few data, were obtained by A.K. through telephone conversations, and descriptions, from Noshiro (February 1987, sex unrecorded), Niigata (February 1989, ♂) and Nishiyama (March 1987, sex unrecorded) (Fig. 1). All measurements of porpoises were made to the nearest 0.5 cm and weights to the nearest 0.1 kg.

Causes of entrapment were known in almost all cases (Tables 1 and 2). Ages are now known for 28 animals, 14 males and 14 females, of which ages of 6 males and 9 females were determined by Miyazaki et al. (1987). Age determinations of newly acquired specimens were made from thin longitudinal sections of dentine according to the methods of Gaskin and Blair (1977). Ages of the National Science Museum specimens were estimated from decalcified sections by Miyazaki et al. (1987), based on both dentine and cementum layers in each specimen.

The reproductive status of males was determined by using the criteria of Gaskin et al. (1984): 1) Immature, ie. single testis volume much less than 90 cc; and 2) Mature but inactive, ie. single testis volume greater than 90 cc but with no seminal fluid present in the seminiferous tubules or epididymis. No mature males were taken with testes in an active state.

Female porpoises were classified as mature if one or more corpora albicantia or a corpus luteum were present, or immature if none could be found, again according to Gaskin et al. (1984).

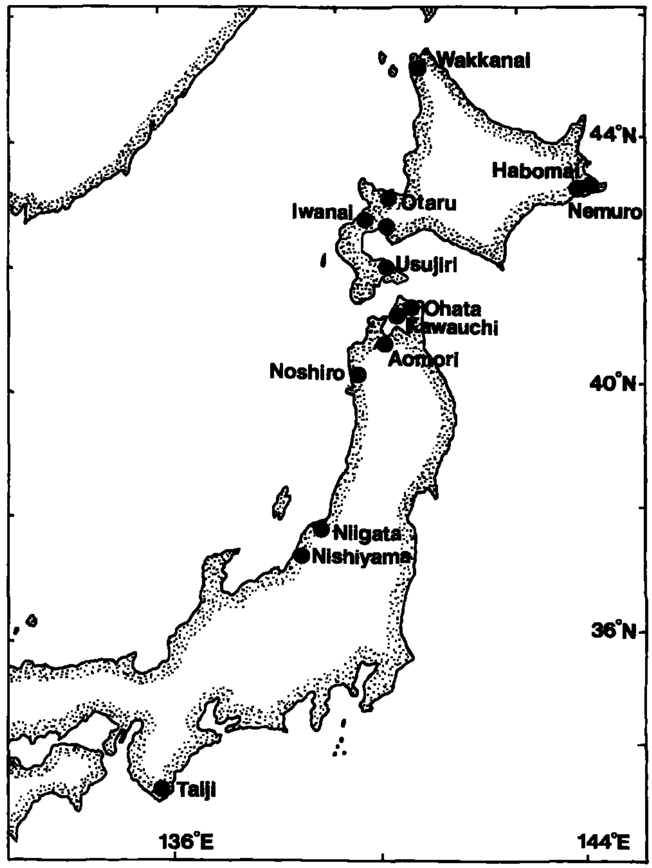

Figure 1
Localities of confirmed harbor porpoise records in Japan, as listed in Tables 2 and 3.

A few collections of stomach contents were obtained from the porpoises killed in fishing gear and were preserved in 70% ethyl alcohol.

All materials obtained during this study have been lodged at Hokkaido University (Hakodate campus) and the National Science Museum, Tokyo.

Results

Japanese localities used in the text are shown in Figure 1. Location, date of capture, lengths, body weights, age and reproductive condition are given in Table 1 for males and Table 2 for females. Specimens previously examined by Miyazaki et al. (1987) are clearly distinguishable by the National Science Museum collection prefix (M-)[5].

[5]One male, M2490 from Nemuro, was not used by Miyazaki et al. (1987).

Table 2

Summary of basic data of male harbor porpoises, *Phocoena phocoena*, from Japanese waters, 1977–86, including specimens examined by Miyazaki et al. (1987), which are identified by the National Science Museum Prefix (M-). Localities shown in Fig. 1.

Year	Date	Body length (cm)	Body weight (kg)	Age (yr)	Reprod. cond.	Collection no.	Locality/ fishing gear
1977	31 May	120.5	32.0	2.0	Im[1]	M24961	Habomai, Hokkaido
	— May	161.5	64.0	3.0	—	M27387	Habomai, Hokkaido
	08 Dec.	127.0	30.2	2.0	Im	M24960	Nemuro, Hokkaido
	12 Dec.	118.0	—	—	Im	M24959	Nemuro, Hokkaido
1983	01 Jan.	126.0	26.5	—	Im	85.28	Wakkanai, Hokkaido gill net
	22 Apr.	149.0	34.8	—	Mt[2]	85.11	Ohata, Honshu pound net[3,4]
1984	06 Mar.	158.0	60.0	7.0	Mt	85.16	Kawauchi, Honshu[3,4]
	19 Apr.	145.5	41.0	8.5	—	M27139	Usujiri, Hokkaido pound net
	20 Apr.	117.0	25.0	2.0	Im	M27140	Usujiri, Hokkaido pound net
	14 May	132.0	40.0	—	Im	85.17	Aomori, Honshu gill net
	29 May	127.0	23.0	—	Im	85.15	Usujiri, Hokkaido pound net[3,4]
1985	21 Jan.	142.0	—	—	—	85.19	Otaru, Hokkaido gill net
	17 Mar.	120.0	—	—	Im	85.20	Iwanai, Hokkaido gill net
	13 Apr.	129.0	31.5	—	Im	85.14	Usujiri, Hokkaido pound net[5]
	04 Apr.	147.5	37.3	7.0	Mt	85.02	Usujiri, Hokkaido pound net
	04 Apr.	157.0	—	—	Mt	85.22	Otaru, Hokkaido octopus hook trap
	13 Apr.	134.0	41.0	—	—	85.12	Usujiri, Hokkaido pound net[5]
	28 Apr.	145.5	31.0	8.0	Mt	85.18	Usujiri, Hokkaido trap net
	30 Apr.	139.0	36.0	—	—	85.26	Usujiri, Hokkaido pound net[3,6]

Table 2 (Continued)

Year	Date	Body length (cm)	Body weight (kg)	Age (yr)	Reprod. cond.	Collection no.	Locality/ fishing gear
1985	30 Apr.	112.0	23.4	1.0	Im	85.04	Usujiri, Hokkaido pound net
	01 May	121.0	32.8	1.0	Im	85.07	Usujiri, Hokkaido pound net
	01 May	149.5	46.9	11.0	Mt	85.08	Usujiri, Hokkaido pound net
	05 May	139.0	31.1	3.0	Mt	85.05	Usujiri, Hokkaido pound net
	15 May	123.0	—	—	Im	85.10	Usujiri, Hokkaido pound net
	15 May	129.0	24.3	2.0	Im	85.09	Usujiri, Hokkaido pound net
	17 May	134.0	40.0	—	—	85.23	Shizukari, Hokkaido pound net[3,6]
	24 May	119.0	33.0	—	Im	85.24	Shizukari, Hokkaido pound net[3]
1986	03 Mar.	30.0	—	0	Fetus	86.06a	Otaru, Hokkaido mother in gill net
	03 Mar.	144.0	45.0	—	Mt	86.05	Otaru, Hokkaido gill net
	05 Mar.	135.0	37.0	—	—	86.08	Otaru, Hokkaido gill net
	14 Apr.	138.0	37.0	—	—	86.10	Usujiri, Hokkaido pound net[3]
	24 Apr.	124.0	26.6	—	Im	86.01	Usujiri, Hokkaido pound net
	24 Apr.	58.5	3.7	0	Fetus	86.02a	Usujiri, Hokkaido mother in pound net
Unknown		133.5	45.0	3.0	—	M27392	Nemuro, Hokkaido

[1]Im (Immature).
[2]Mt (Mature).
[3]Live to Otaru Aquarium, Otaru.
[4]Died later in captivity.
[5]Live to Asamushi Aquarium, Aomori.
[6]Transferred from Otaru Aquarium to Tokyo.

Males

Including those examined by Miyazaki et al. (1987), males ranged in length from 112 cm to 161.5 cm (N = 34); in addition, two male fetuses of 30 cm and 58.5 cm were obtained. Ages were determined for 14 animals, based on one growth layer group (GLG) per annum (Gaskin and Blair, 1977; Miyazaki et al., 1987; Watts and Gaskin, 1989) and ranged from one (112–121 cm, N = 2), 2 (117–129 cm, N = 4), 3 (133.5–161.5 cm,

N = 3), 7 (147.4, 158 cm, N = 2), 8 (145.5 cm, N = 2), to 11 (149.5 cm, N = 1) (Table 2). Testis samples were available for eight mature males of known age. All were captured in March, April or May, 1983–1986, and all specimens had inactive testes.

Females

Including those examined by Miyazaki et al., 1987), females ranged in length from 92.4 to 185 cm (N = 25); in addition, one fetus of 62 cm was obtained. Ages were determined for 14 specimens, ranging through 0.5 (92.4 cm, N = 1), 2–2.5 (121–143.5 cm, N = 6), 3 (131.5–140 cm, N = 3), 4 (140 cm, N = 1), 8–8.5 (162–166 cm, N = 2) to 9 years (173 cm, N = 1) (Table 3). Seven animals were mature, with one or more corpora albicantia. Four of these specimens were pregnant, but none were lactating, based on the non-distended nipples and gross sections of mammary gland which revealed no traces of milk.

Fetuses

These were collected on 03 March 1986 (30 cm, N = 1) by the Otaru Aquarium (one other was not retained and not measured), at Otaru on the west coast of Hokkaido, and on 24 April 1986 (58.5, 62 cm, N = 2), at Usujiri on the Pacific coast of southern Hokkaido. Miyazaki et al. (1987) recorded a 73 cm fetus on 3 May 1986, from a female taken at 42°37'N, 144°28'E.

Immature animals of both sexes

Samples (Tables 2 and 3) from Wakkanai, Nemuro, Habomai, Aomori, Usujiri, Shizukari, Iwanai, and Taiji and in all months sampled other than March (January, April, May, October, and December) showed evidence of immature animals of both sexes. All were ≤143.5 cm in length (N = 25). Although seven animals were collected from Otaru in March and one in April, there were no immature animals in the samples.

Length-Age relationships

Miyazaki et al. (1987) plotted the age/length relationships of nine males and six females from Japanese waters against those from other regions. We have replotted these data (Fig. 2), incorporating the new specimens obtained in the present study, giving a total 28 specimens (14 males and 14 females) of known age from Japanese waters. The small samples and clustering still preclude valid statistical comparison and legitimate calculation of age-length curves, but female porpoises from Japan are still shown to be larger than females from the North Sea at given ages, as Miyazaki et al. (1987) observed.

Stomach contents

We examined the stomachs of 16 porpoises from trap nets near Usujiri and were given samples from four more taken from gill nets by staff at the Otaru Aquarium near Otaru, in April–May of 1985 and 1986. Fifteen stomachs were nearly empty. All contained varying numbers of round worms, *Ascaris* spp. A small quantity of seaweed was found in one 129 cm male; a large quantity of seaweed and a 1-m length of 0.25 cm fishing gear twine were found in a 139-cm male in poor condition (sunken dorsal musculature and blubber only about 1 cm in thickness). The twine was caught distally at the entrance to the oesophagus and stretched into the second stomach compartment. Food items in the remaining five porpoises were similar. They included small squid beaks (probably Ommastrephidae) and eroded otoliths in varying quantities, tentatively identified as herring *Clupea* sp., anchovy *Engraulis* sp., and hake *Merluccius* sp. The condition of the remains was poor, and because stomach contents from porpoises from trap nets probably represent only coincident prey trapped with them, we do not report these items in detail.

Discussion

Body length at birth and probable season of parturition

Lengths of three fetuses collected from females caught off Japan were compared with fetal growth curves from the western and eastern Atlantic populations (Fig. 2 in Gaskin, 1984). Their lengths fell on or just above the growth curves for Atlantic porpoises. Length at birth in the Hokkaido population, therefore, is probably close to 80 cm, and parturition in northern Japanese waters is probably in May–June, judged not only by comparison with the neonatal growth curve of Gaskin et al. (1984) and coincident length/month relationship but also by the parallel degree of development of the fetuses examined from Usujiri and the North Atlantic.

Life history pattern

Based on published literature, there is considerable synchrony in the seasonal breeding of the harbor porpoise throughout its range (Gaskin, 1984). From the limited data presently available from Japanese waters (eg., sizes of fetuses in spring and state of mature testes), we expect the timing of the cycle in the northern Japanese population to be similar to the North

Table 3

Summary of basic data of female harbor porpoises, *Phocoena phocoena*, from Japanese waters collected 1973–86, including specimens examined by Miyazaki et al. (1987), which are identified by National Science Museum Codes (M-). Localities shown in Fig. 1.

Year	Date	Body length (cm)	Body weight (kg)	Age (yr)	Reprod. cond.	Collection no.	Locality/ fishing gear
1973	27 Jan.	135.0	30.0	2.0	Im	M24902	Taiji, Wakayama Honshu
1977	14 Oct.	131.5	38.0	3.0	Im	M24958	Nemuro, Hokkaido
	— May	137.6	36.0	2.0	Im	M27389	Habomai, Hokkaido
	— May	140.2	—	3.5	—	M27388	Nemuro, Hokkaido
	— May	143.5	48.0	2.5	Im	M27890	Habomai, Hokkaido
1984	17 May	129.0	35.0	2.0	Im	M27141	Usujiri, Hokkaido
1985	23 Mar.	143.0	—	—		85.21	Otaru, Hokkaido gill net
	04 Apr.	138.0	38.6	3.0	Mt	85.01	Usujiri, Hokkaido pound net
	08 Apr.	121.0	29.8	2.0	Im	85.03	Usujiri, Hokkaido pound net
	14 Apr.	152.0	45.5	—	Mt	85.13	Usujiri, Hokkaido pound net[1]
	30 Apr.	134.0	35.0	—	—	85.25	Usujiri, Hokkaido pound net[2,3]
	05 May	132.0	36.7	2.0	Im	85.06	Usujiri, Hokkaido pound net
1986	03 Mar.	141.0	50.0	—		86.04	Otaru, Hokkaido gill net
	03 Mar.	146.0	45.0	—	Mt	86.07	Otaru, Hokkaido gill net
	03 Mar.	185.0	73.0	—	Preg.	86.06	Otaru, Hokkaido gill net
	10 Apr.	133.0	31.0	—	Im	86.09	Usujiri, Hokkaido pound net[2]
	14 Apr.	126.0	—	—	Im	86.11	Usujiri, Hokkaido pound net[2]
	14 Apr.	134.0	33.5	—	—	86.12	Usujiri, Hokkaido pound net[2,4]
	24 Apr.	162.0	69.1	8	Preg.	86.02	Usujiri, Hokkaido pound net
	24 Apr.	173.0	69.9	9.0	Preg.	86.03	Usujiri, Hokkaido pound net

Table 3 (Continued)

Year	Date	Body length (cm)	Body weight (kg)	Age (yr)	Reprod. cond.	Collection no.	Locality, comments
1986	24 Apr.	62.0	5.2	0	Fetus	86.03a	Usujiri, Hokkaido mother (86.03) in pound net
	03 May	166.0	86.0	8.5	Preg.	M27024	42°37'N 44°28'E
Unknown		92.4	16.0	0	Im	M27391	Nemuro, Hokkaido
Unknown		137.5	41.0	4.0	—	M27393	Nemuro, Hokkaido

[1]Live to Asamushi Aquarium, Aomori.
[2]Live to Otaru Aquarium, Otaru.
[3]Died later in captivity.
[4]Transferred from Otaru Aquarium to Tokyo.

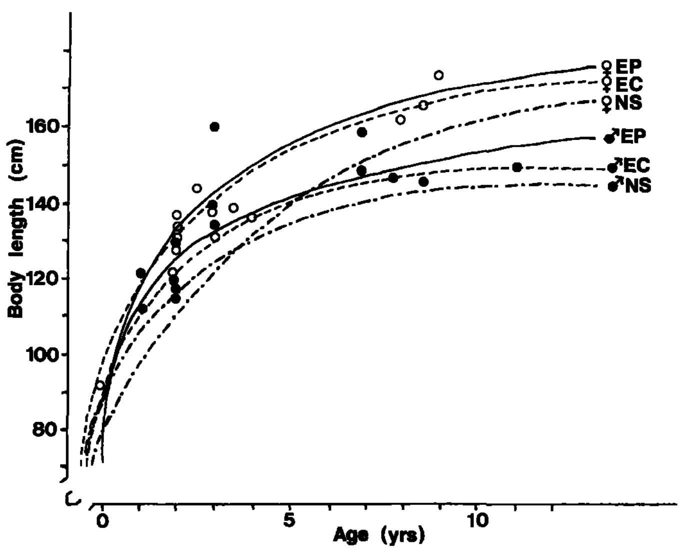

Figure 2
Age-length records for harbor porpoises in Japanese waters determined by Miyazaki et al. (1987) and the authors. Plotted against average growth curves for male and female harbor porpoises from the eastern North Pacific by Stuart and Morejohn (1980) (solid lines), eastern Canada by Gaskin and Blair (1977) (broken lines) and the North Sea by Van Utrecht (1978) (broken and dotted lines). Solid circles indicate male and open circles female porpoises from Japan.

Atlantic pattern of births in late spring or early summer and to mating between early and late summer. These populations are distributed in the same latitudinal zone and hence the same photoperiod regime. Sea surface temperature regimes are also similar, eg., Winn[6] and the Japan Meterological Agency (1986).

Harbor porpoises have testes that are large in proportion to body size (Fisher and Harrison, 1970; Gaskin et al., 1984). Miyazaki et al. (1987), comparing their material to data of Fisher and Harrison (1970), noted that adult harbor porpoises from Japanese waters had smaller testes than those from the North Atlantic and had weight ranges that did not overlap. They concluded that the difference in sampling periods in the two areas was not a factor (April–May off Japan v. May–September in the eastern North Atlantic, respectively). However, Gaskin et al. (1984) demonstrated a seasonal cycle of spermatogenesis, including a dramatic change in testis volume/size in adult harbor porpoises during June–August in the Bay of Fundy region. Read (1990a) concluded that the active mating period extended only from late June into July or occasionally early August. The specimens examined by Miyazaki et al. (1987) in April–May appear to have been collected before adult males had begun to exhibit seasonal spermatogenesis and testis enlargement.

P. phocoena appear to be a relatively asocial odontocete which has also undergone selection for sperm competition and for consequent development of proportionately large testes like some other cetaceans (Brownell and Ralls, 1986). In

[6]Winn, H. E. 1982. A characterization of marine mammals and turtles in the Mid- and North Atlantic areas of the U.S. outer continental shelf. U.S. Dep. Interior, Bureau of Land Management, Washington D.C., Final Rep. of the Cetacean and Turtle Assessment Program, 437 p.

the case of small marine mammals there is energetic advantage in evolving a limited mating period, together with a reduction in testis size out of the breeding season (Gaskin et al., 1984). Field observations of *Phocoena phocoena* populations suggest that there is little coherent school structure (eg., Amundin and Amundin, 1971; Watson, 1975; Watts and Gaskin, 1989); there is a mean group size of only two or three individuals, often mother, calf and yearling. Larger groups are generally temporary feeding aggregations. Similar results were obtained in studies of *Neophocoena phocoenoides* by Kasuya and Kureha (1979).

Distributional limits

The most southerly record of harbor porpoise from Japanese waters (Taiji, Wakayama, 34°15'N) quite closely parallels that for the oceanographically similar western North Atlantic (Cape Fear, southern N. Carolina) (Gaskin, 1984). The confirmed northernmost limit for the western North Pacific in recent years is represented by a number of sightings on the eastern side of the entrance of Shelikhova Bay, between 57°–58°N and 157°–159°E on 10–11 August 1989 (Miyashita and Doroshenko, 1990). On the eastern side of the North Pacific there are verified records in the Beaufort Sea as far as the MacKenzie Delta at about 70°N (Van Bree et al., 1977). Tomilin (1957), citing Sleptsov (unpublished data in manuscript report) who made observations in 1947–48, noted that the harbor porpoise was known in the USSR as far south as Peter the Great Bay, through the Sea of Okhotsk, around Kamchatka (where it was sometimes trapped in fishing nets), and northwards at least to Olyutorskii Bay at 60°N. A similar distribution was indicated by Klumov (1959). Tomilin (1957) thought its range might extend into the western part of the Chukchi Sea but gave no records. Sleptsov had also recorded porpoises in summer months around the Komandorski Islands and on both the east and west sides of the Kurile Islands. Miyashita and Berzin (1991) observed harbour porpoises just west of the southwestern Kuriles in early August 1990 and to the northwest of these islands and close to southeastern Sakhalin in mid-late August of the same year. Recent records from Alaska and the eastern Aleutian Islands are summarized by Gaskin (1984); and from the Attu island group in the western Aleutians, by Jones (1984).

Postulated seasonal changes in distribution in the N.W. Pacific

Given the similarities of life history parameters of harbor porpoise populations in both major oceans of the northern hemisphere, one way to estimate the likely range of the species in the western North Pacific and Bering Sea is to plot surface isotherms for values which generally appear to be limiting in regions where distribution is better known (Figs. 3 and 4). Winn[6], working off the eastern United States, found the species were confined almost entirely to coastal shelf waters and 90% of sightings were concentrated over water depths of 18–224 m off the east coast, in sea surface temperatures of 6.5–17.0°C. Barlow (1988) found that sightings off the west coast of the United States were most abundant over depths of 18–37 m and there were no sightings at depths greater than 110 m. Surface temperatures were not specified in this study. The areas of the North Pacific and Bering Sea which approximate these average conditions are shown for winter and summer in Figures 3 and 4. There is no doubt, however, that this species must sometimes follow productive convergence zones away from the coastal shelf, or it could not have attained its present distribution (Gaskin, 1992). Following the important offshore North Pacific record of Jones (1984) (see Introduction), Stenson and Reddin (1990) reported harbor porpoises over deep water in the Labrador Sea. Given the timing of seasonal occurrence in this region (Gaskin, 1984), these animals may have been travelling between the coastal shelves of Canada and West Greenland.

The surface temperature regime in the western North Atlantic indicated by Winn[6] more or less defines the productive, well-mixed boundary interaction zone between the cold, southward-flowing Labrador Current and its lesser branches and the warm northeastward-flowing North Atlantic Drift; but the temperature regime also defines the general range of the harbor porpoise. The range of the species in the northwestern Pacific, therefore, may be similarly defined by the interactions of the cold Oyashio water masses coming out of the western Bering Sea and Sea of Okhotsk with the northward and northeastward flow of the Kuroshio current and its subsidiaries around Japan (Hikosaka and Watanabe, 1957; Fukuoka, 1962). The Sea of Okhotsk is significantly colder in winter than the surrounding ocean regions, and the northern and western zones of it are characteristically ice-covered from late December to April, as is the Tartary Strait between Sakhalin Island and Siberia from early December to May (eg., Japan Meteorological Agency, 1986). While a small number of harbour porpoises either stay in or visit the western Bay of Fundy in winter (November–April) when water temperatures range from 1° to 4°C (Gaskin, 1984), any *P. phocoena* that stay around northern Japan during the winter months can be no further north in coastal waters than the extreme southeastern Sea of Okhotsk adjacent to the central and northern Kuriles and southwest of Sakhalin. The situation in most of the Sea of Okhotsk

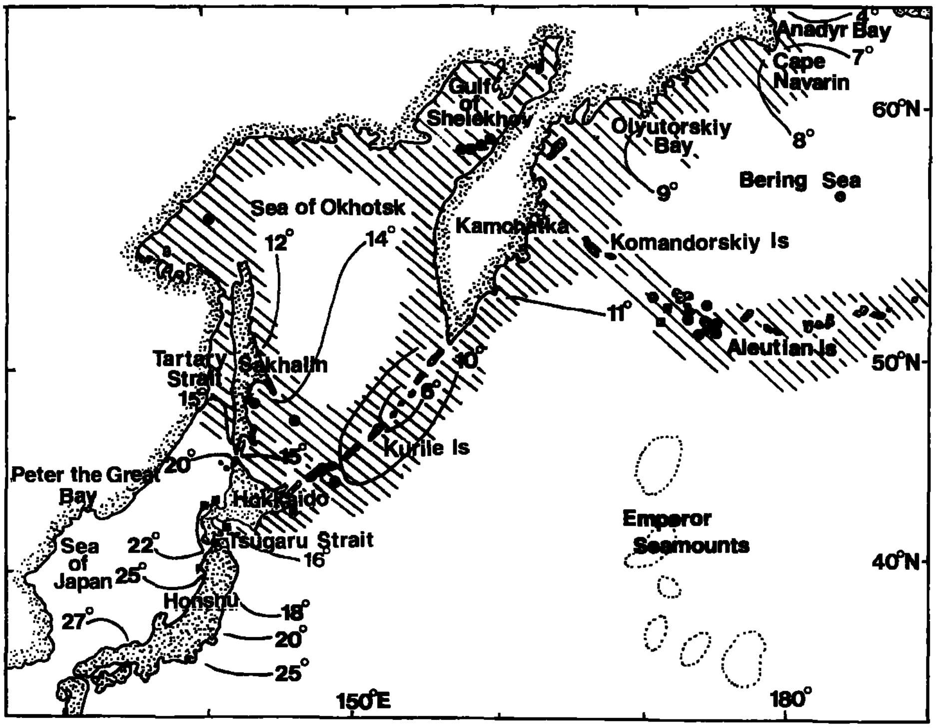

Figure 3

The western North Pacific and western Bering Sea, showing average summer surface isotherms (July–September) (Japanese Meteorological Agency 1986; Miyashita and Kasuya 1988; and Nasu 1963, 1966). Diagonal hatching indicates postulated summer range of about 90% of the harbor porpoise population based on criteria of Winn[6]. Solid circles indicate confirmed summer records. Solid squares are confirmed spring (April–June) records.

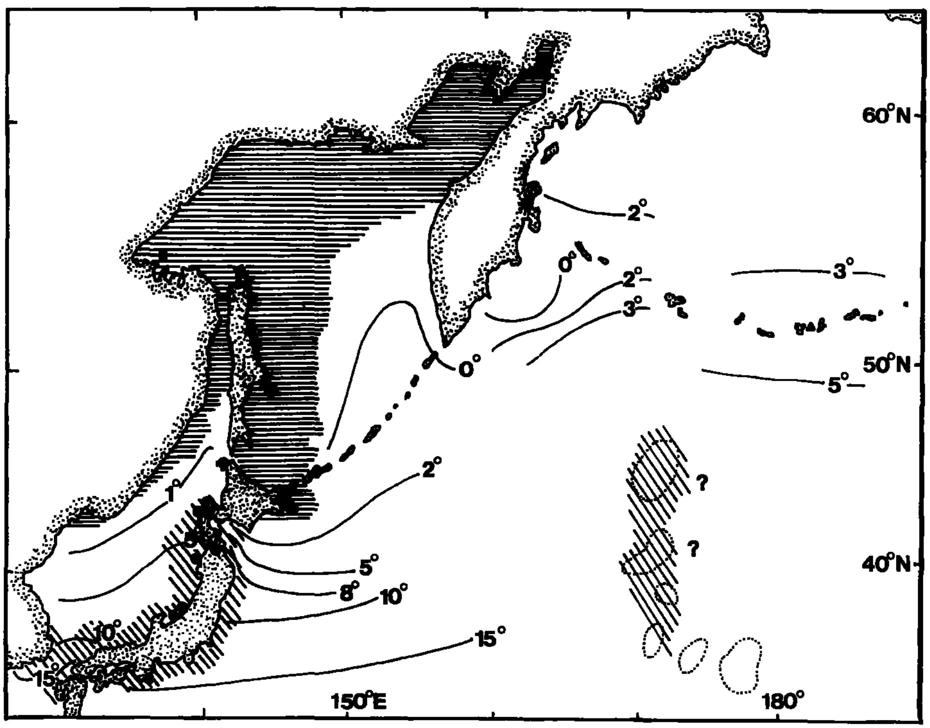

Figure 4

The western North Pacific and western Bering Sea, showing average winter surface isotherms (December–March) (Japanese Meteorological Agency 1986; Miyashita and Kasuya 1988; and Nasu 1963, 1966). Horizontal hatching indicates postulated winter range of about 90% of the harbor porpoise population based on criteria of Winn[6]. Solid circles indicate confirmed winter records.

must be analogous to that of the outer Estuary and inner Gulf of the St. Lawrence in eastern Canada (Laurin, 1976) and the Baltic Sea (Møhl-Hansen, 1954), where harbor porpoises leave ahead of the ice formation. The situation is likely to be different in the Sea of Japan, which in general has a much less severe marine climate than the Sea of Okhotsk (Hirano, 1957).

The records from Wakkanai show that harbor porpoises occur off northern Hokkaido during early winter in some years. In December 1986, a small zone of inshore surface water off Wakkanai was still at 9°C (Japan Meterological Agency, 1986). Some specimens have been taken incidentally by the gill-net fishery around the Shakotan Peninsula in January and February[7] where sea surface temperatures are about 4–5°C. The seasonal isotherm distributions suggest that in mid-winter *P. phocoena* might be expected to be found sometimes as far south as eastern Shikoku, to the southern tip of western Honshu and also along the east coast of the Korean peninsula (Fig. 3). Nevertheless, it has yet to be confirmed further south than Nishiyama (about 39°N) on the Japan Sea coast of Honshu (Institute of Cetacean Research, 1989). On the east coast of Honshu, the known southern limit of range at Taiji also coincides with the intrusion of deep water associated with the Fossa Magna geological discontinuity, which is a feature of the northern extremity of the Philippine tectonic plate margin (Pinet, 1992). The west coast manifestation of this structure occurs in Toyama Bay, at about 37°N.

In the summer months, harbor porpoises probably do not occur much further south on the west coast of Japan than the Tsugaru Strait and the western extremity of Hokkaido (Kawamura et al. 1983; Kawamura 1986) (Fig. 4), where surface temperatures of 12 to 16°C often persist through summer (Miyashita and Kasuya, 1988). The progression of seasonal reoccupation of northern waters in the western North Pacific is not well understood. The changes in distribution predicted here are based on the limits for the occurrence of about 90% of the population in the 6.5°–17.0°C range in the western North Atlantic (Winn[6]). Furthermore, Yurick (1977) noted that the greatest concentration of harbor porpoises in the lower Bay of Fundy was associated with the 8°–15°C surface isotherm zone.

Sea ice leaves the northern coast of Hokkaido usually in late April–early May and warmer surface waters of up to 8°C intrude into this region in May. By June surface temperatures of 5.0°–7.0°C occur as far north as the Komandorski Islands in average years, and by mid-July the same temperatures can be found off Cape Navarin at 63°N (Nasu, 1963, 1966). There is much year-to-year variation; in seasons with late development of summer conditions, the same regions can have surface temperatures as low as 2° to 4°C (Nasu, 1966). During August, surface waters reach 10°C both in this region and off Unalaska Island in the Aleutians (Nasu, 1966). Surface temperatures in the Sea of Okhotsk during June are often only 4°–5°C; but, by August–September 12°–15°C (Japan Meterological Agency, 1986). Although cooler intermediate water upwelling in summer around the central Kuriles is still only at 4°–6°C, highly productive boundary conditions for marine life are developed here (Hikosaka and Watanabe, 1957). The summer (August and early September) sightings of harbor porpoises in the Sea of Okhotsk during the extensive cruises of 1989 and 1990 (Miyashita and Doroshenko, 1990; Miyashita and Berzin, 1991) were almost all made over shelf regions; in contrast the pelagic central region was dominated by *Phocoenoides dalli*.

On the basis of distributional and energetic data from the western North Atlantic (Yasui and Gaskin, 1986), *P. phocoena* should tolerate a 6.5°–12°C surface regime with relative ease. Nevertheless, recent results of mitochondrial DNA comparisons of harbor porpoises in eastern Canadian waters (Wang et al., 1991) support the concept of distinct genetic demes coexisting within the regional range of the western North Atlantic population. We should not discount the possibility that some of these demes, either through differing dietary requirements or variation in thermoregulatory capacity, may be adapted to somewhat different surface temperature regimes. A specific area could be occupied by porpoises from one deme in summer and another in the winter, giving the appearance of continuous occupation by a single population. Migrations may exist but would be difficult to define without extensive tagging experiments.

In other areas of the northern hemisphere where the diet of harbor porpoises has been investigated (summarized by Gaskin, 1985), the main prey are schooling fishes of the coastal shelf, particularly herring *Clupea* sp., mackerel *Scomber* spp., squid, and small gadoids. Too little is known of the harbor porpoise in the western North Pacific to assess its dietary spectrum; in other areas, prey switches occur when herring availability is low (Recchia and Read, 1989). It seems, from the few data currently available, that harbor porpoises in Japanese waters eat sardines, anchovy, small hake, squid, and herring when encountered.

The intensity of inshore fishing activity in Japanese coastal waters is such that the harbor porpoise certainly has been subjected to some level of incidental catch historically, especially by set or drift nets of various kinds. Entrapments still occur; total annual incidental catches around the Shakotan Peninsula,

[7] Hiroshi Nitto, Otaru Aquarium, Otaru, Shakotan, Hokkaido, Japan, pers. commun.

Nemuro, and northwestern Honshu are possibly in the low hundreds[8]. Tobayama et al. (1991) noted that about 1,700 large trap nets and about 10 times that number of smaller-scale nets are in operation at some time of year in Japan. About 4,800 nets operate in Hokkaido waters; 2,500 on the Pacific coast of northern and western Honshu and perhaps about 1,500 on the northern half of the Sea of Japan coast of Honshu. All these regions are coincident with the distribution of the harbor porpoise in Japanese waters. Tobayama et al. concluded that where minke whale entrapments were concerned, the catches were largely unrecorded through the coastal fisheries statistics. Presumably this is also true of harbor porpoise entrapments. Given that we noted deaths of *P. phocoena* in gill nets not recorded in the annual statistics, there is significant under-reporting of incidental kills by gill netting too. We lacked the resources to conduct a survey to determine how large the incidental catch of harbor porpoises by fixed gear in Japanese waters might be.

The status of the harbor porpoise in Japanese waters is basically unknown. Anecdotal accounts from fishermen in the Usujiri region indicate that it is not particularly abundant in comparison to other dolphins (species not specified) and seasonal in occurrence (spring and fall). It is present in waters off Otaru in all but the months of July–September (Hiroshi Nitto, personal communication). A detailed assessment of its status in the western North Pacific is required. The species now appears to be threatened in some eastern and western North Atlantic waters (Gaskin, 1992). The limitations imposed by the fixed litter size of one, the relatively late age at first maturity and an annual reproductive cycle all point to little reproductive flexibility with which to respond to significant additional mortality from hunting or incidental capture (Woodley and Read, 1991; Gaskin, 1992).

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[8]A. Kawamura, Faculty of Bioresources, Mie University, Tsu 514, Japan, unpubl. data.

[9]Hiroshi Nitto, pers. commun.

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