ISSN 0083-9086

THE SCIENTIFIC REPORTS OF THE WHALES RESEARCH INSTITUTE

No. 38

THE WHALES RESEARCH INSTITUTE
TOKYO · JAPAN

MARCH 1987

Sci. Rep. Whales
Res. Inst., No. 38

THE
SCIENTIFIC REPORTS
OF
THE WHALES RESEARCH INSTITUTE

No. 38

THE WHALES RESEARCH INSTITUTE
TOKYO, JAPAN

MARCH, 1987

THE WHALES RESEARCH INSTITUTE
3-32-11 OHJIMA, KOTO-KU, TOKYO 136

THE SCIENTIFIC REPORTS OF THE WHALES RESEARCH INSTITUTE

CONTENTS OF NUMBER 38

目　次

THE OCCURRENCE OF TWO FORMS OF MINKE WHALES IN EAST AUSTRALIAN WATERS WITH A DESCRIPTION OF EXTERNAL CHARACTERS AND SKELETON OF THE DIMINUTIVE OR DWARF FORM

PETER ARNOLD*, HELENE MARSH** AND GEORGE HEINSOHN**

ABSTRACT

Two forms of minke whales occur in eastern Australian and adjacent southwest Pacific waters: a dark shouldered form previously widely reported from southern hemisphere temperate to Antarctic waters, and a cold temperate to tropical diminutive form, referred to in this paper as the dwarf minke whale. We have examined in detail a 7.1 m sexually mature female dwarf minke whale and photographs of 15 other individuals for external characters. Skeletal features were examined on the 7.1 m female and two juveniles.

Dwarf minke whales had a light rostral saddle, blowhole streaks, dark throat patch, white shoulder patch containing a dark flipper oval, grey shoulder blaze, white flipper base and light peduncle patch. This characteristic colour pattern varied only slightly over a wide geographic range (Australia, New Zealand, New Caledonia, South Africa). Dwarf minke whales appeared to differ from southern hemisphere dark shoulder minke whales in size, position and shape of the dorsal fin. Previously reported characters of the baleen plates of dwarf minke whales were generally confirmed. Skeletal features of the dwarf minke whale are described for the first time, and compared with descriptions of other forms from both hemispheres. The majority of features suggested a greater affinity with the northern hemisphere forms than with the southern hemisphere dark shoulder form. Within Australia, the dwarf minke whale has been recorded from Victoria (lat. 38° S) to northern Queensland (lat. 11°55′ S) during May to December.

Our observations generally confirmed previously reported colour patterns for the southern hemisphere dark shoulder form. Examination of skulls in Australian museums also confirmed previous information, especially concerning the form of the vertex. Records of dark shoulder minke whales within Australia ranged from Tasmania (42°50′ S, identification tentative) to central Queensland (23°08′ S), overlapping with the dwarf form at the latter locality.

---

* *Department of Marine Biology*, ** *Department of Zoology, James Cook University of North Queensland, Townsville, Queensland 4811, Australia*

Sci. Rep. Whales Res. Inst.,
No. 38, 1987, 1–46

INTRODUCTION

The occurrence of a southern hemisphere minke whale which lacks the white flipper band of the northern hemisphere *Balaenoptera acutorostrata* Lacépède 1804 has been recognized since the last century. The species *B. bonaerensis* Burmeister 1867 and *B. huttoni* Gray 1874 were erected for specimens of this form collected near Belgrano, Argentina and Otago Head, New Zealand respectively. There have also been scattered reports of a white-flippered form from the southern hemisphere (Lillie, 1910; Taylor, 1957; Kasuya and Ichihara, 1965; Gaskin, 1976; Wada and Numachi, 1979; Best, 1982; Wada, 1983; Singarajah, 1984) but it has only recently been well illustrated (Baker, 1983) and clearly documented (Best, 1985). In addition to differences in colour pattern, Best showed that this second form of minke whale was reproductively mature at a smaller size than the form having flippers with a single or two tones of grey. He thus called it the "diminutive" form. In this paper we will refer to this form as the dwarf minke whale, and to the other southern hemisphere form as the southern hemisphere dark shoulder minke whale.

The taxonomic status of the various forms of minke whales in both hemispheres is still unclear, despite studies on colour pattern, morphometrics, osteology and electrophoretic patterns (Kasuya and Ichihara, 1965; Omura, 1975; Omura and Kasuya, 1976; Doroshenko, 1979; Wada and Numachi, 1979; Best, 1982, 1985; Wada, 1983; Singarajah, 1984). In the case of the dwarf minke whale documented by Best (1985), this is partly a function of limited material. Morphometrics, for instance, were available for only two very small individuals (1.9, 2.5 m long) and detailed information on colour pattern of the animal and baleen plates was primarily from one locality (South Africa). There is also little information on the distribution of the dwarf minke whale, which to date has been reported from South Africa (Best, 1985), Australia (Best, 1985; Marsh, 1985), New Zealand (Baker, 1983) and Brazil (Best, 1985).

In this paper, we describe the colour pattern of the body and baleen plates, external morphometrics, and skeletal morphology of the dwarf minke whale based primarily on material from eastern Australia. Limited data are also given on colour pattern and skeletal morphology of the dark shoulder form from Australia. Both forms are compared with minke whales from other areas, based on a review of the literature.

Finally, we give preliminary information on the distribution of both forms in eastern Australia and the seasonality of their occurrence.

MATERIALS AND METHODS

Detailed information is available for a 7.1 m female dwarf minke whale which was first reported in a lagoon at Hook Reef, Qld (19°52′ S) on August 31, 1982. It was observed and photographed, both from the surface and underwater, between September 6 and November 28, 1982 when it died. A necropsy was carried out on the 29–30 November, allowing detailed measurements and further observations of colour pattern. Measurements were as recommended by Norris (1961). All ventral grooves were counted, in line with the eye. All characters identified as of potential systematic value by Doroshenko (1979) and Wada and Numachi (1979) were examined. An attempt to recover ear plugs was unsuccessful; Sergeant (1963) has noted that ear plugs of minke whales decompose unless removed within about six hours of death. A liver sample was taken for electrophoresis but the specimen was subsequently lost due to a freezer breakdown.

Data on the reproductive status of the animal are in Marsh (1985), who also included a preliminary account of the necropsy, with observations on pathology by R. Speares (School of Tropical Veterinary Science, James Cook University).

The complete skeleton was recovered and is registered with the Queensland Museum (JM 3861). Measurements of the skeleton generally follow Omura (1975) and Omura and Kasuya (1976). A skull discussed by Omura (1975) was re-measured by Marsh to ensure consistency when taking similar measurements on the Hook Reef specimen. Additional measurements were taken on the hyoid bones as recommended by Satake and Omura (1974).

The entire baleen plate series from each side of the animal was kept dry. Following Williamson (1973), we counted anterior hairs and baleen plates, but ignored posterior hairs (*sensu* Williamson). We had difficulty in determining the number of posterior plates, and our figures may be underestimates (but only by one or two plates). The longest baleen plate in the series was measured as outlined by Omura and Fujino (1954). A length of string was placed along the outer edge of the plate to follow its contour and the length marked off, to be measured with a ruler. There was difficulty in determining the level of the base of the bristles, which may introduce some error. Breadth of the plate was a straight line measurement taken with vernier calipers across the baleen plate series. There was some warping of the baleen plates in series and the breadth will be somewhat lower than if the plates were pressed flat and measured. Further, the measure could include some dried gum. Thickness of the dried gum was measured with vernier calipers and this value subtracted from the breadth of the baleen plate series. The breadth of the dark lateral border of baleen plates was measured with vernier calipers. Measurements for breadth/length ratios and width of dark border (just above the gum) were taken on the longest plates, to be comparable with data in Best (1985).

Information is also available for a 4.0 metre female dwarf minke whale stranded at Wonga Beach, Qld (16°28′ S) on August 24, 1982. This animal was not examined by us, however 29 colour photographs were taken, mostly of the left side but also including ventral and oblique dorsal views. The carcass was buried and the skeleton recovered approximately a year later. The skull was disarticulated and partially damaged in recovery. Mandibles and

TABLE 1. SIGHTINGS OF MINKE WHALES IN EASTERN AUSTRALIA

Record location number	Coordinates	Date D.M.Yr.	Number of whales	Sighting circumstances	Length (m)	Sex	Colour pattern Flipper	Colour pattern Shoulder patch	Colour pattern Baleen	Observer	Documentation
				1. QUEENSLAND							
*1. Lizard Island	14°40′S 145°28′E	7.80	4	seen and photographed underwater	–	–	white	white	–	–	xerox of photo of one at JCU, original at Museum of Victoria
*2. Crispins Reef	16°05′S 145°44′E$^{1)}$	5. 8.81	1	seen underwater	–	–	white	–	–	Prettejohn	drawing + description at JCU$^{2)}$
3. Point Lookout	27°24′S 153°27′E	18. 6.82	1	at sea, surfacing	–	–	–	–	–	Bryden	–
4. Point Lookout	27°24′S 153°27′E	13. 7.82	2	at sea, surfacing	–	–	–	–	–	Bryden	–
5. Point Lookout	27°24′S 153°27′E	13. 7.82	1	at sea, surfacing	–	–	–	–	–	Bryden	–
*6. Milne(?Milln)Reef	16°47′S 146°16′E$^{3)}$	16. 7.82	3	seen and photographed underwater	"15,15–20,20ft" (4.5,4.5–6.1,6.1m)	–	white	white	–	Waugh	photos at JCU of one of the three whales
*7. Wonga Beach	16°28′S 145°23′E	24. 8.82	1	stranding	4.04	♀	white	white	cream	Wall	photos at JCU
*8. Hook Reef	19°52′S 149°10′E	31. 8.82	1	trapped in reef lagoon, seen and photographed underwater; necropsied	7.1	♀	white	white	cream	Heinsohn, Marsh, Arnold	photos, measurements and skeleton at JCU
*9. Kelso Reef	18°24′S 147°00′E	15. 9.82	1	seen and photographed underwater	"about 18ft" (5.5m)	–	white	white	–	Ward, Springett, Johnson	photos at JCU
10. 12 miles NWW North Reef	23°11′S 151°54′E	4-18. 9.82	3	at sea, surfacing	–	–	–	–	–	Titmarsh	–

+11. Yeppoon	23°08′S 150°45′E	11. 8.83	1	stranding	–	–	dark base, distally grey, with thin white transverse line separating two tones	no patch	apparently dark posteriorly on right side	Simmons	photos at JCU
*12. Yeppoon	23°08′S 150°45′E	~30. 8. 83	1	stranding	4m	–	white	white	apparently light	–	photo in Rockhampton Morning Bulletin, held at JCU
*13. One Tree Island	23°31′S 152°03′E	5. 6.85	2	aerial survey sighting	–	–	white	white	–	Simmons	photo at Q.NPWS
*14. Ribbon Reef No.8	15°05′S 145°44′E	18. 6.85	1	seen and underwater	"8–10m" photographed	–	white	white	–	Oke	photos at JCU
?*15. Ashmore Banks, near Star Reef	11°55′S 143°50′E	19.11.85	4(5?), separated	aerial survey sighting	–	–	–	–		Marsh	–
?*16. Between Ross Reef and Hewitt Reef	19°50′S 149°35′E	3.12.85	1	aerial survey sighting	–	–	–	–	–	Marsh	–
*17. Marion Reef	19°10′S 152°17′E	.85	8	seen and photographed underwater	–	–	white	white	–	Rockman (1986a,b)	article at JCU
*18. Lizard Island region	14°40′S 145°28′E	seen "often" May–July	–	seen and photographed underwater	–	–	white	white	–	Gladstone (1984)	article at JCU
*19. Grub Reef	14°02′S 143°51′E	4. 7.86 5. 7.86	1 2–3	seen and photographed underwater	"15ft" (4.5m)	–	white	white	–	Zann	photo at GBRMPA
?*20. Hope Reef	16°32′S 146°08′E	13. 7.86	2	at sea, surfacing	"20ft" (6.1m)	–	–	white	–	Alderson	sighting sheet at JCU
2. NEW SOUTH WALES											
+1. Minnie Waters near Grafton	29°47′S 153°18′E	8.81	1	stranding	4.0	–	see text	no patch	–	Goodall	photos at JCU

TABLE 1 (Cont.)

*2. Terrigal	33°27′S 151°27′E	7. 9.82	1	stranding	4.1	–	white	white	–	Ted Smith	photo at JCU
3. Ocean opposite Ulladulla	36°22′S 150°23′E	–	1	at sea	7.6	–	white	–	–	Tuna spotter, via Bryden	–
				3. VICTORIA							
+1. Portland Bay	38°21′S 141°38′E	13.10.46	1	stranding	"6–7ft" (1.8–2.1m)	–	dark	no patch	from photos appears light	Wakefield (1967)	2 photos in article at JCU
*2. Reeves Channel, Lakes Entrance	37°53′S 147°55′E	3. 6.66	1	stranding	2.2m	♀	white	white	light	Warnecke	xerox of photo (lateral & ventral view) at JCU, originals at Mus. of Victoria; skull C24936
*3. Point Leo, Westernport Bay	38°25′S 145°04′E	26. 6.76	1	stranded	4.54m	♀	–	–	light anteriorly	Dixon	xerox of photos at JCU
				4. SOUTH AUSTRALIA							
+1. Brownlow Beach Kangaroo Island	35°50′S 137°06′E	29. 9.75	1	stranding	–	♀	dark	no patch	dark posteriorly	Aitken	photo in Ling & Aitken[4]
+2. Tulka, Eyre Peninsula (Port Lincoln)	34°44′S 135°52′E	19. 9.78	1	stranding	10′10″ (3.3m)	♂	dark	no patch	–	Aitken	photo in Ling & Aitken; photo of skull at JCU
				5. TASMANIA							

?1. Lenasham	42°50′S 147°37′E	7. 6.57	1	stranding, thought to have been dead 4–6 wks	2.16	?	light band about half way along flipper; much decomposed specimen	–	–	Davies, Guiler	Davies & Guiler (1958), article at JCU
?2. Tomahawk	40°50′S 147°45′E	8.72	1	stranding	5.48	♀	–	–	–	Guiler	identification by Guiler from photograph; Guiler (1978)
?3. Fortescue Bay	43°08′S 147°57′E	6. 8.73	1	stranding, thought to have been dead over a month	3.65	♂	–	–	–	Guiler (1978)	Guiler (1978), article at JCU

* dwarf minke whale
\+ southern hemisphere dark shoulder form
1) position for St. Crispins Reef, Roberts (1978)
2) JCU = School of Biological Sciences, James Cook University of North Queensland
3) position for Milln Reef, Roberts (1978)
4) identified as Bryde's whale; 3 additional photos seen and returned to South Australian Museum
GBRMPA = Great Barrier Reef Marine Park Authority
Q.NPWS = Queensland National Parks and Wildlife Service

most of the post-cranial skeleton were also recovered. A portion of the left hand baleen plate series was also available for examination. Although incomplete, the additional skeleton has allowed confirmation of certain features noted in the Hook Reef specimen.

The skull of a 2.23 m female dwarf minke whale from Lakes Entrance, Victoria (Museum of Victoria number C24936) was examined and photographed by Heinsohn.

Photographs of the vertex and posterior underside of two skulls of minke whales in the Australian Museum (S272 and S1396) were also examined. As indicated later (Dwarf minke whale Results: Skull) these showed the characters of the dwarf minke whale, but data on external appearance were not available for confirmation of the identification.

All known records have been collated, based on published and unpublished photographs of both forms of minke whales. Details of those records from eastern and southeastern Australia are given in Table 1. Coordinates of reefs along the Queensland shelf are from Roberts (1978). The account of variation in colour pattern of dwarf minke whales is based largely on photographs of 16 individuals, which are referred to in the text by site locality. The photographs are retained at James Cook University.

A southern hemisphere dark shoulder minke whale skull (not listed in Table 1) in the Queensland Museum (J2 1708) was examined by Marsh and photographs taken. An additional skull of this form in the South Australian Museum (M 11,375) was also examined for us by Museum staff, and photographs taken of the dorsal side.

DWARF MINKE WHALE

RESULTS

Colour pattern

The rostrum is predominantly dark slate grey, however there may be a rim of light grey just above the gum. In underwater photographs of animals from Hook Reef, Kelso Reef, Grub Reef, Ribbon Reef 8, Milne Reef, Marion Reef (Rockman, 1986a,b), apparently in an animal from New Caledonia (Laboute and Magnier, 1979), as well as a surfacing animal from the subantarctic (Kasamatsu, unpublished photograph) there is a saddle of lighter grey. This was of variable extent, but could cover most of the head, at least back to the level of the flipper base (Fig. 1a, rs; Fig. 3e). It was particularly obvious in photographs of the animal from Ribbon Reef 8, but the lighter pigment was not seen in photographs of stranded animals.

The lower jaw overlying the mandible is light slate grey in living animals, but may darken rapidly after death. On the Wonga Beach specimen the grey extended downward over about six ventral grooves, just in front of the downturn in the angle of the mouth. The extent of grey at the angle of the

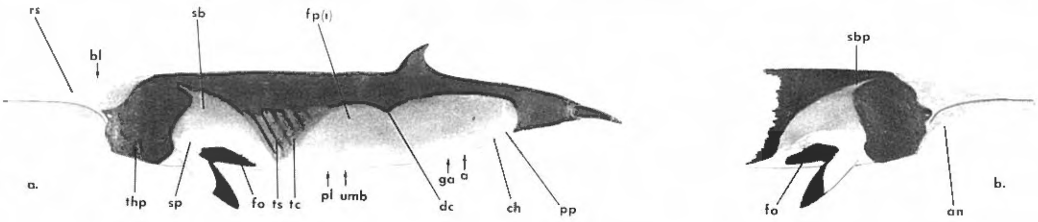


Fig. 1. Generalized colour pattern of the dwarf minke whale, incorporating terminology from Best (1985). Body proportions based on a 7.1 m female. a. View of left side. b. View of right anterior side. Abbreviations: a= anus, an= extension of white at angle of jaw, bl= position of blowhole, ch= chevron, dc= dorsal cape, fo= flipper oval, fp(1)= anterior of flank patch (thorax blaze of Best, 1985), ga= position of genital aperture, pl= posterior extent of plicae, pp= peduncle patch (Best, 1985), rs= rostral saddle, sb= shoulder blaze, sbp= anteriorly directed peak of shoulder blaze, sp= shoulder patch, tc= thorax cape, thp= dark throat patch (Best, 1985), ts= thorax streak, umb= position of umbilicus.

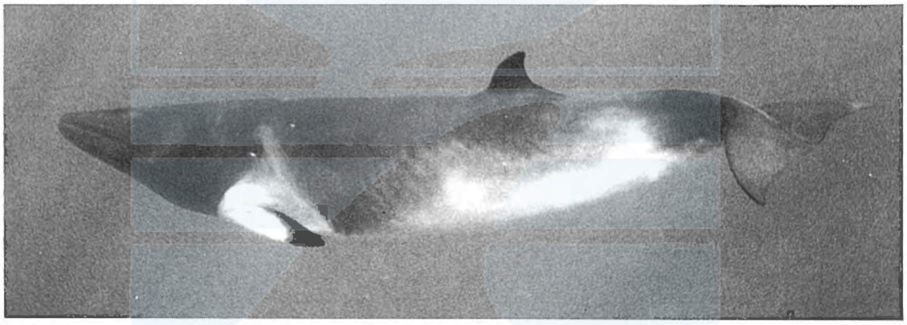


Fig. 2. Dwarf minke whale, approximately 4.5 m long, at Grub Reef. Note light rostral saddle, flipper colour, shoulder blaze shoulder patch, thorax cape and thorax streaks, peduncle patch and chevron. Photograph by Dr L. Zann, courtesy Great Barrier Reef Marine Park Authority.

mouth may be reduced by a pocket of white from the throat (Fig. 1b, an), but always rapidly extends ventrad between the gape and flipper as a broad throat patch (Fig. 1a, thp). On the Wonga Beach animal, this patch extended onto the left side, just behind the eye, to about the sixteenth ventral groove (Fig. 3a). In the animal figured by Gladstone (1984), the patch (apparently on the right side) extended to the twelfth ventral groove. We cannot say, however, whether the throat patch was asymmetrically developed on any individual animal. When seen from the side underwater, the throat appears predominantly dark grey, with only a narrow band of white along the lower edge (Fig. 2; Fig. 3e)

The throat patch extends to just in front of the flipper base. It forms the anterior margin of a white shoulder patch (Fig. 1a, sp) which contains the flipper base and extends along the side to completely surround the flipper

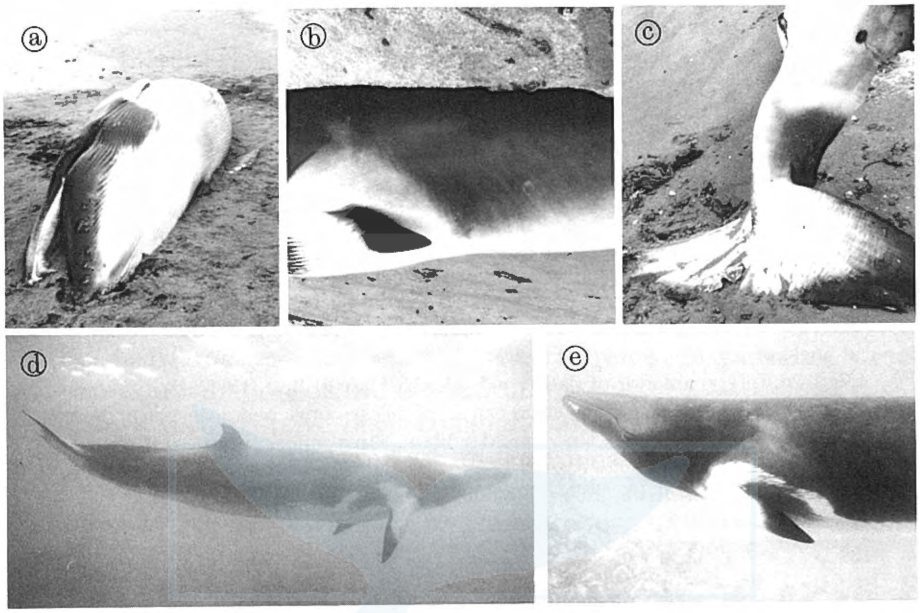


Fig. 3. Dwarf minke whale. a-c, 4.04 m female at Wonga Beach, photographed by D. Wall. a. Antero-lateral view showing throat patch and light baleen. b. Lateral view, showing flipper colour, shoulder patch, shoulder blaze and thorax streaks. c. Postero-ventral view showing chevron, peduncle patch and coloration of undersides of flukes. d-e, 7.1 m female at Hook Reef, photographed by L. Zell. d. View of right side showing flipper oval and anterior extension of margin of shoulder patch. e. View of left side showing more extensive white of shoulder patch, light rostral saddle and anteriorly directed peak of shoulder blaze. Photographs d and e courtesy of the Great Barrier Reef Marine Park Authority.

when it is held in against the body. The shoulder patches appeared to be of comparable size on both sides of animals from Hook and Kelso Reefs.

Within the shoulder patch, on both sides of the animal, is an elongate dark oval, about the size of the flipper and hidden by it when the flipper is held in against the body. This patch, which we call the 'flipper oval' (Fig. 1, fo), was evident in animals from Hook, Kelso and Grub Reefs, Wonga Beach, Lizard Island (Gladstone, 1984), Ribbon Reef 8, New Caledonia (Laboute and Magnier, 1979), and Marion Reef (Rockman, 1986a,b).

The shoulder patch is rimmed with a thin grey border, actually an extension of the light grey shoulder blaze (Fig. 1a, sb) which lies dorsal to the shoulder patch (see below). This grey rim extends in a band from the posterior edge of the shoulder patch to link with the flipper oval. On animals from Hook and Kelso Reefs, for which we have photos of both sides, this connection was narrow on the left side, but much broader on the right (Fig. 1; Figs 3d and 3e). On the Wonga Beach specimen, the flipper oval on the left side was connected with the posterior margin of the shoulder patch only by scattered dark grey streaks (Fig. 3b). The effect of this asymmetry was quite striking when the Hook Reef animal was observed underwater. On the left side, the connecting band was hardly visible and the flipper, when held against the body, seemed to be contained in a continuous band of white. On the right hand side, the broad connecting band merged with the distal dark portion of the flipper, so that the white was much less extensive.

Dorsal to the shoulder patch is a roughly triangular, light grey shoulder blaze. Its anterior margin extends obliquely backwards until level with the upper jaw, then is reflexed forward to a shoulder blaze peak (Fig. 1b, sbp). In the animals from Wonga Beach (Fig. 3b) and Marion Reef (Rockman, 1986a), this extension ran almost directly forward, while in other animals (e.g. from Ribbon Reef 8) it extended obliquely forward and dorsad. The posterior margin of the shoulder blaze runs in a broad arc from this reflexed peak back to a level just beyond the flipper when it is pressed in against the body (Fig. 2; Figs 3b and 3e). In an underwater photo of the top of the head and shoulder of the Hook Reef animal, the shoulder blazes appeared of comparable size on both sides of the animal. They could be seen to run forward in parallel, rather than extending onto the top of the shoulder region to link up as a white crescent *sensu* Best, 1985, for the southern hemisphere dark shoulder form: see Southern hemisphere dark shoulder form Results: colour pattern. However, in the animal from Grub Reef, the right shoulder blaze appeared to extend almost to the midline of the back, while the left shoulder blaze extended more anteriad and not onto the back of the neck.

A dorsal view of an animal from Marion Reef (Rockman, 1986a,b) clearly showed blowhole streaks running posteriad and curving to the left.

Behind the flipper, about half way to the dorsal fin, there is a dark grey cape which extends down almost to the belly (Fig. 1a, tc). This divides the sides into the shoulder patch and shoulder blaze anteriorly and the light grey flank patch posteriorly. Often it has a series of 6–10 oblique dark rib-like streaks (Fig. 1a, ts; Figs 2 and 3b; see also Gladstone, 1984). The flank patch (Fig. 1a, fp (1)) continues past the level of the dorsal fin and onto the caudal peduncle, the posterior half of which is again dark grey. In most animals from Australia for which we have photos, this flank patch seemed entire, however there were indications of a dorsal cape (Fig. 1a, dc; Fig. 2) on the animal from Grub Reef.

On the caudal peduncle, within the light grey flank patch, the white of the underside may continue as a narrow band at least half way up the tail stock. Dorsally it may continue further as a grey-white band (Fig. 1a, pp). This feature was very conspicuous on the left side of the Wonga Beach specimen (Fig. 3c) and evident on the right side of the Kelso Reef animal. The band appears to be present on the animals illustrated by Rockman (1986b), Laboute and Magnier (1979) and Baker (1983) from Marion Reef, New Caledonia and New Zealand respectively.

On the Wonga Beach specimen, the white peduncle band was separated

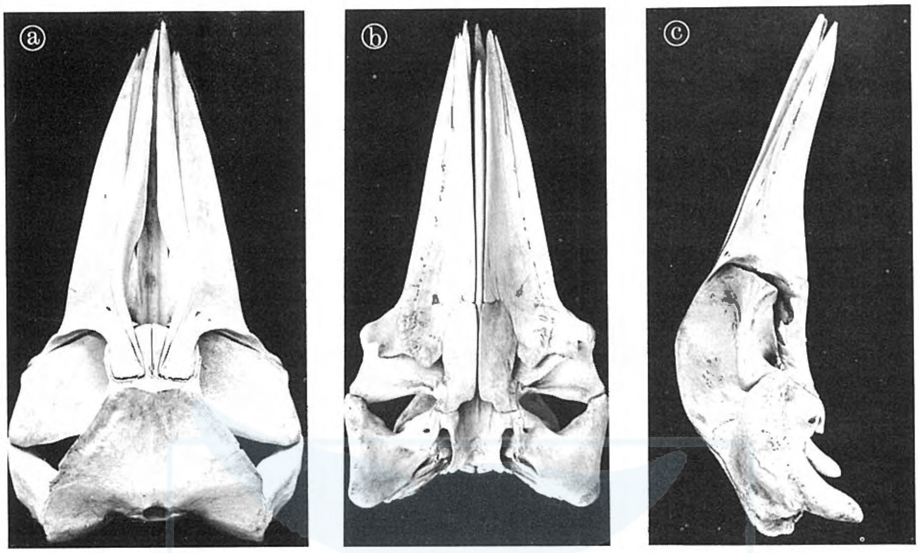


Fig. 4. Skull of 7.1 m female minke whale from Hook Reef. a. Dorsal view; b. Ventral view; c. Lateral view.

from the rest of the white belly by a thin grey streak, which was reflexed sharply forward at its base to form a reverse-L (Fig. 3c). The posterior border of the peduncle band was also reflexed forward (Fig. 3c; Fig. 1a, ch). A similar pattern was evident on photos of the Kelso and Grub Reef animals.

In summary, the body, when seen underwater, appears subtly banded in alternate shades of light and dark grey. Dark bands are (1) at the level of the throat patch and onto the back of the neck, (2) between the shoulder patch-shoulder blaze and the flank patch, and (3) at the base of the caudal peduncle. Lighter grey occurs on the rostrum, head and border of lower jaw; triangular blaze dorsal to white shoulder patch; and over most of the flanks.

The flippers are tri-tone. The distal portion is a dark slate grey, with a thin light grey band separating this portion from the white base. The line of separation is oblique, beginning about two-thirds of the way along the anterior margin. The edge of dark grey curves inward over the top of the flipper so that only about the basal third of the flipper along the posterior margin is white (Fig. 1). A variable number of dark grey streaks may run over the white basal portion of the flipper (Fig. 3b). The underside of the flipper is white at the base and along the anterior edge, but otherwise dark.

The dorsal fin appeared uniformly dark grey in all animals examined.

The upper surface of the flukes are dark grey. The trailing edge of the undersides of the flukes and a variable amount of the apices are also dark. (Compare Fig. 3c and Fig. 3d, showing undersides of flukes of Wonga Beach and Hook Reef animals respectively).

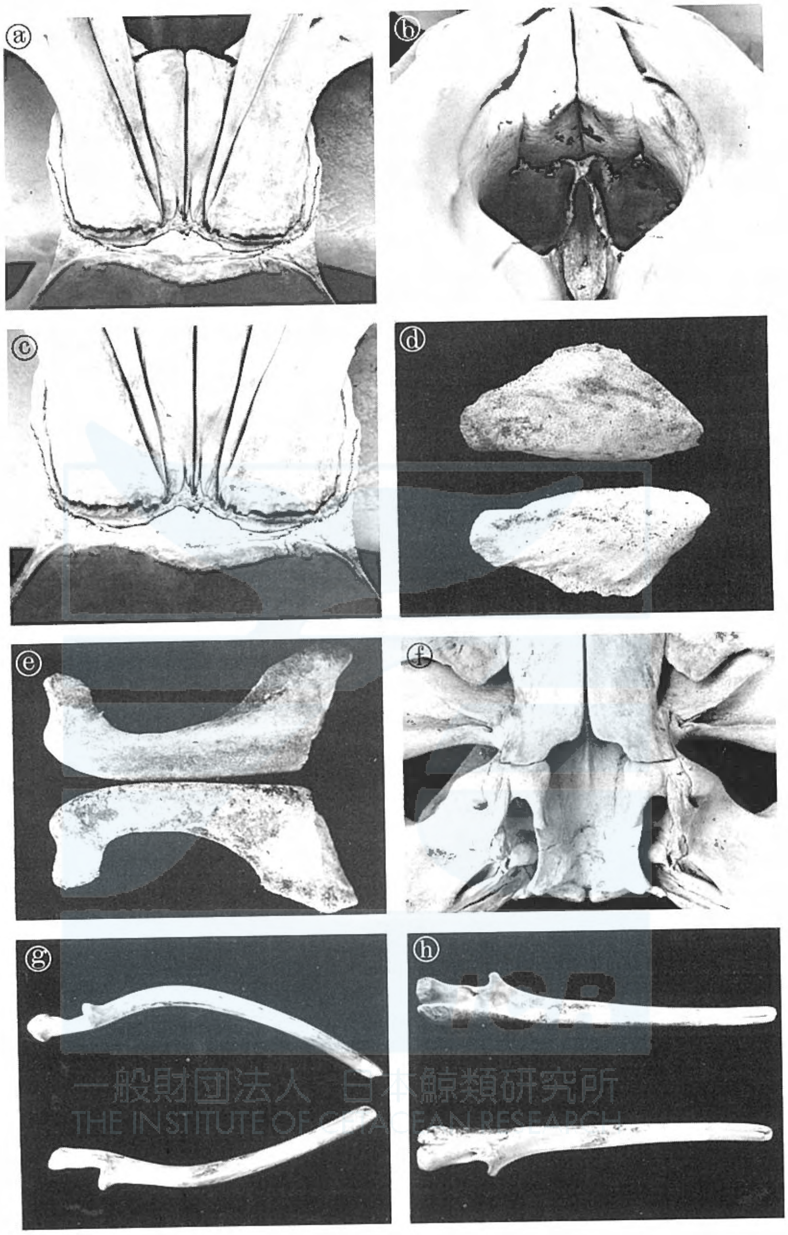


Fig. 5. Skeleton of 7.1 m female dwarf minke whale from Hook Reef. a. Detail of the vertex and nasal bones, dorsal view. b. Detail of nasal bones, showing inferior pit or groove, antero-ventral view. c. Detail of vertex showing relative positions of nasals, premaxillaries and maxillaries; frontal bone, inter-parietal and parietals, dorsal view. d. Lachrymal bones. e. Malar bones. f. Detail of posterior underside of skull showing angulate posterior margin of palatine bones and elongate hamular processes of the pterygoid bones. g. Mandibles, dorsal view. h. Mandibles, medial view.

TABLE 2. EXTERNAL MORPHOMETRICS OF MINKE WHALES

	Dwarf1) (Australia)		Dwarf2) (South Africa)	Dark shoulder southern hemisphere3) (Antarctic)	North Pacific4) (Japan)	North Atlantic5) (Norway)
	absolute (metres)	% total length	% total length (mean, range)	% total length (mean, range)	% total length (mean, range)	% total length (mean, range)
Total length	7.10	100.0	100.0 1.9m, 2.5m absolute sizes	100.0	100.0	100.0
Snout to centre anus	5.40	76.0	72.5, 72.8	73.0 (68.7–76.4)	73.5 (70.7–76.1)	74.0 (69.9–81.3)
to centre genital aperture	5.18	72.9	64.9, 65.6	68.1 (n=2)	70.7 (68.8–72.1)6)	–
to tip dorsal fin	4.94	69.6	71.5, 71.3	–	–	–
to centre umbilicus	3.96	55.8	54.3, 52.4	53.7 (47.5–62.4)	53.8 (51.6–57.7)	54.0 (48.0–62.7)
to posterior extremity of ventral grooves	3.76	52.9	51.5, 48.6	48.0 (43.5–54.8)	46.2 (39.5–54.4)	48.5 (41.3–56.5)
to anterior insertion of flipper	2.05	28.9	31.5, 28.9	29.3 (24.0–32.0)	30.8 (28.1–32.7)7)	–
to external auditory meatus	1.69	23.8	25.2, 24.2	25.1 (23.4–27.0)	21.6 (19.9–23.0)8)	–
to angle gape	1.21	17.0	18.2, 17.9	18.7 (17.1–20.5)	16.1 (13.3–18.7, n=10)	17.89)
to centre eye	1.27	17.9	19.2, 18.3	20.0 (18.3–22.0)	15.8 (13.3–18.6)	18.0 (15.7–19.3)
to centre blowhole	1.10	15.5	13.2, 14.0	14.3 (12.2–16.0)	13.3 (11.7–14.9)	13.2 (11.0–14.8)
Girth at axilla	3.06	43.1	46.5			
at anus	1.54	21.7	28.5, 27.0			
Projection lower jaw	0.07	0.98	1.0, 1.0			
Centre eye to external auditory meatus	0.36	5.1	6.1			
Centre eye to centre blowhole	0.68	9.6	10.8			
Blowhole length	0.20, 0.20 (R, L)	2.8, 2.7	4.0, 3.9			
Eye length	0.06 slit 0.11	0.8 slit 1.5	1.5, 1.4			
Eye height	0.08	1.1	0.3			
Length genital slit	0.46	6.5	4.6, 4.8			
Length anal opening	0.05	0.7	1.3, 1.4			
Flipper: anterior insertion to tip	1.02	14.3	19.2, 16.5	15.8 (12.5–17.5)	12.1 (9.4–15.8,)	–
: axilla to tip	0.75	10.6	12.6, 11.7	–	8.9 (7.3–11.4, 14)	10.0 (8.8–12.4)
: maximum width	0.26	3.7	5.3, 4.0	3.7 (2.8– 4.1)	3.8 (3.5– 4.0, 12)	3.6 (3.2– 3.9)
Dorsal fin height	0.34	4.8	5.6, 4.8	3.7 (3.0, 4.2)	4.2 (3.1– 5.0, 10)	3.6(2.9–4.4, 72)

Dorsal fin length base	0.6	8.4	8.3, 8.9	5.5 (3.7– 7.7)	7.4 (5.9– 8.8, 11)	5.6[9]
Flukes: width tip to tip	1.75[10] 0.94	24.6[11] 26.4	24.2, 23.0	29.0 (25.1–35.8)	30.6 (27.6–33.8)[12]	27.8 (24.0–30.8)[13]
: nearest point on anterior : margin to notch	0.48	6.8	8.3, 7.5	–	–	6.8 (5.8– 7.5)
: depth notch	0.07	0.9	1.7, 1.2	–	–	–
Centre eye to angle gape	0.13	1.8				
Girth half way from axilla to umbilicus	2.94	41.4				
Length mammary slit	0.29, 0.30 (R, L)	4.1, 4.2				
Diameter auditory meatus	9.5 × 4.5mm					
Blubber thickness: anterior to dorsal fin	38 mm					
: mid lateral, mid length	34.5mm					
: mid ventral, mid length	22 mm					
: anterior to flippers	48 mm					

---

1) this paper, 1 ♀. 2) Best 1985, (specimens = 2). 3) Ohsumi, in Best 1985 (10♂♂, 2♀♀). 4) Omura & Sakiura 1956 (15♀♀). 5) Jonsgård 1951 (75♀♀). 6) n = 6♀♀ 6.58–7.97m, measures 100%−(10+13). 7) n = 5♀♀ 6.58–7.97m, measures 6−17. 8) n = 6♀♀ 6.58–7.97m, measures 5+ 7. 9)1 ♀, Turner (1892). 10) left fluke damaged, second figure length of right fluke. 11) second % right fluke × 2. 12) 13♀♀, measure 23 × 2. 13)74♀♀, measure 12 × 2.

Morphometrics

Measurements of the Hook Reef specimen are given in Table 2.

Baleen plates

The longest baleen plates of the Hook Reef animal were 18.3 and 18.5 cm long for the right and left series respectively. The breadth of the right and left baleen plate series was 8.2 and 8.6 cm (7.9 and 8.3 cm with width of dried gum excluded). This gives a breadth/length ratio of 0.45–0.46 for both sides (0.43–0.45 with gum excluded).

There were 235+ baleen plates on the right side and 225+ on the left. It was impossible to separate consistently the most posterior plates. Using Williamson's (1973) criteria there were eight and nine anterior hairs in the right and left series.

The outer border of a baleen plate was considered dark if over a third of the length was darkly pigmented. On the right side, 5 plates had a dark grey to black border, while 24 plates had a dusky grey border. On the left side, 18 plates had a dark grey to black border, while 29 had a dusky grey border. Plates with only a lingual band or median strip were not counted, following Best (1985). The percentage of white baleen plates is thus 87.7 and 79.1 for right and left sides (see Figs 6g and 6h).

The outer dark border of baleen plates was most extensive on posterior plates, which were entirely dark except for the bristles. In order to be comparable with measurements by Best (1985), the width of the dark border was taken on the longest plates, about two-thirds of the way back in the series. Width of the border was 2.5 mm on both sides, (3.0% and 2.9% of total breadth of right and left plates respectively).

Skeleton

Unless otherwise noted, the description is based on the Hook Reef specimen.

Skull

Measurements of the skull are given in Table 3 (measurements 1–32, 41–54). These were compared with specimens from the Antarctic (Omura, 1975; Omura and Kasuya, 1976), N. Pacific (Omura, 1957, 1975) and N. Atlantic (Table 4). The features in which the dwarf minke whale differed from previously described forms included proportional lengths of both premaxillaries; median length of nasals; breadth of rostrum at the base; breadth of frontal across the nasals; breadth between the maxillaries at nares; and median length from the tip of the premaxillaries to the anterior end of the vomer. These and other differences will be considered in detail in the discussion.

The margin of the rostrum was slightly convex in dorsal view. An approximate measure of maximum curvature, taken at right angles to a ruler

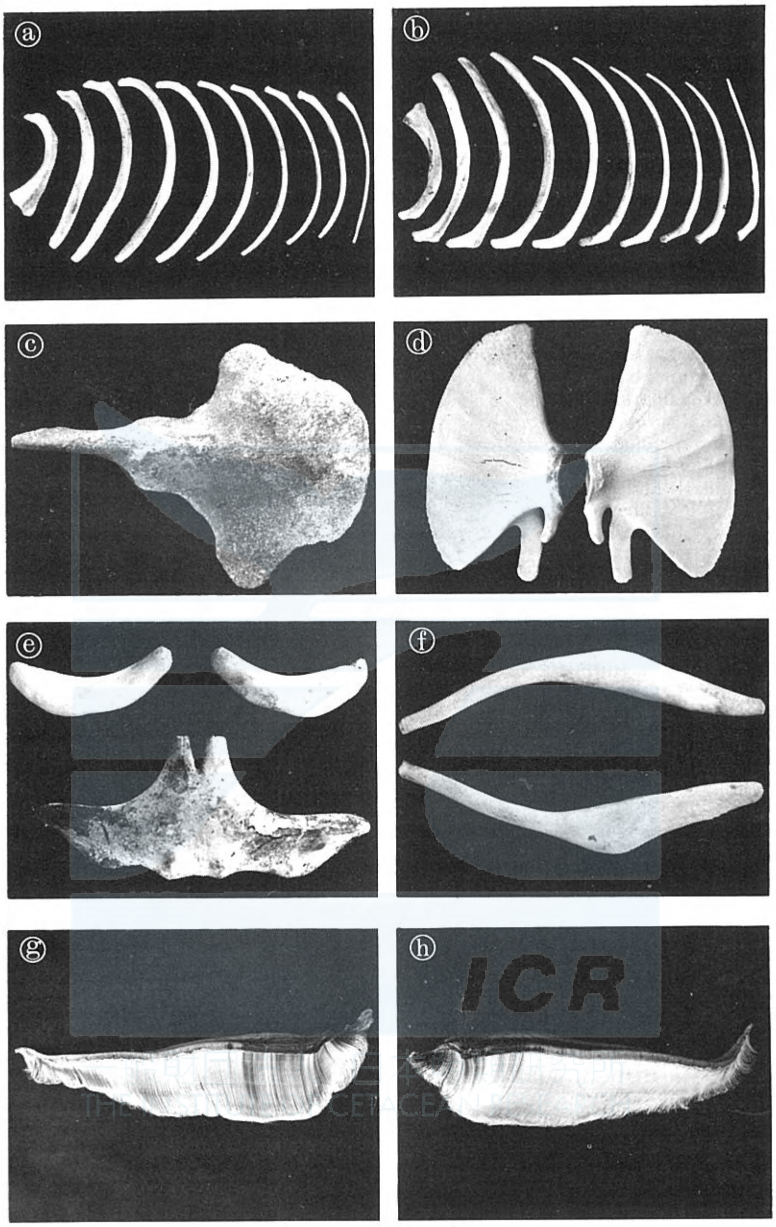


Fig. 6. Skeleton and baleen of 7.1 m female dwarf minke whale from Hook Reef. a. Ribs, left series, lateral view. b. Ribs, right series, lateral view. c. Sternum. d. Scapulae, medial view. e. Stylohyals (above) and fused basihyal-thyrohyals. f. Pelvic bones. g. Baleen plates, left series, lateral view. h. Baleen plates, right series, lateral view.

TABLE 3. OSTEOLOGICAL MEASUREMENTS OF HOOK REEF DWARF MINKE WHALE

Measurements*	Absolute measure (mm)	% of total length of skull
1. Condylo-premaxillary length	1640.0	100.0
2. Length of premaxillary, right1)	1252.0	76.3
3. Length of premaxillary, left1)	1248.0	76.1
4. Length of maxillary, superior, right	1182.0	72.1
5. Length of maxillary, superior, left	1191.0	72.6
6. Tip of premaxillary to vertex	1222.0	74.5
7. Tip of premaxillary to nasals	1038.0	63.3
8. Length of nasals, median	178.0	10.8
9. Breadth of nasals, anterior2)	105.8	6.4
10. Length of rostrum	1145.0	69.8
11. Breadth of rostrum at middle3)	381.3	23.2
12. Breadth of rostrum at base	604.1	36.8
13. Breadth across maxillaries at vertex	221.9	13.5
14. Breadth of frontal across nasals	257.8	15.7
15. Breadth between maxillaries at nares	244.2	14.9
16. Breadth of skull, squamosal	905.0	55.2
17. Breadth of skull, frontal	880.0	53.7
18. Breadth of skull, maxillaries	808.0	49.3
19. Length of orbit, frontal, right	167.3	10.2
20. Length of orbit, frontal, left	164.1	10.1
21. Breadth of occipital bone	647.0	39.4
22. Breadth across occipital condyles4)	174.9	10.7
23. Height of occipital condyle, right	98.3	6.0
24. Height of occipital condyle, left	101.5	6.2
25. Breadth of foramen magnum aperture	70.5	4.3
26. Height of foramen magnum aperture	65.7	4.0
27. Length from foramen magnum to vertex5)	427.0	26.0
28. Tip of premaxillary to ant. vomer, median	177.8	10.8
29. Tip of premaxillary to ant. palatine, median	1012.0	61.7
30. Tip of premaxillary to post. palatine, median	1314.0	80.1
31. Tip of premaxillary to post. pterygoid	1432.0	87.3
32. Breadth across hamular process of pterygoid	160.3	9.8
33. Length of mandible, straight, right	1602.0	97.7
34. Length of mandible, straight, left	1630.0	99.4
35. Length of mandible, curved, right	1756.0 1686.0	107.16) 102.87)
36. Length of mandible, curved, left	1788.0 1719.0	109.06) 104.87)
37. Height of mandible at coronoid, right	218.8	13.3
38. Height of mandible at coronoid, left	219.2	13.4
39. Height of mandible at condyle, right	179.5	10.9
40. Height of mandible at condyle, left	178.8	10.9
41. Tympanic bulla, length, right	79.5	4.8
42. Tympanic bulla, length, left	77.3	4.7
43. Tympanic bulla, greatest breadth, right8)	62.0	3.8
44. Tympanic bulla, greatest breadth, left9)	58.8	3.6
45. Tympanic bulla, thickness at middle, right	42.2	2.6
46. Tympanic bulla, thickness at middle, left	41.9	2.5
47. Malar length, right	202.1	12.3
48. Malar length, left	213.0	13.0
49. Malar breadth, right10)	71.6	4.4
50. Malar breadth, left10)	72.0	4.4
51. Lachrymal length, right	118.5	7.2
52. Lachrymal length, left	118.0	7.2
53. Lachrymal breadth, right	58.5	3.6
54. Lachrymal breadth, left	54.5	3.3
55. Scapula, greatest breadth, right	630.5	
56. Scapula, greatest breadth, left	631.5	
57. Scapula, greatest height, right	369.5	

TABLE 3 (Cont.)

58. Scapula, greatest height, left		376.5	
59. Length of acromion, inferior[11]	R 195.5		L 195.5
60. Breadth of acromion, distal end	R 57.9		L 49.3
61. Length of coracoid, inferior[12]	R 99.1		L 88.5
62. Breadth of coracoid, distal end	R 33.0		L 31.1
63. Length of glenoid fossa[13]	R 121.5[14]		L 140.5
64. Breadth of glenoid fossa	R 91.9		L 90.3
65. Scapula, ratio breadth/height	R 1.7		L 1.7
66. Stylohyal, length	R 244.8		L 252.2
67. Stylohyal, maximum width	R 64.8		L 63.3
68. Basihyal length, straight		452.2	
69. Pelvis, length	R 258.2		L 259.5
70. Pelvis, width	R 28.8		L 36.5
71. Pelvis, degree of curvature[15]	R 31.8		L 29.5
	(12.3)		(11.4)
72. Pelvis, point of maximum width from wider end	R 101.8		L 102.3
73. Sternum, length		329.5	
74. Sternum, maximum breadth		233.9	
75. Sternum, point of max. width, from wider end		116.0	
76. Sternum, point of base to wider end		143.9	
77. Sternum, shaft length		185.6	

1) broken at tip. 2) between premaxillaries at anterior end of nasals. 3) at 572.5mm from tip of premaxillae. 4) to base of spongy bone. 5) measured at posterior parietals. 6) outside curve. 7) inside curve. 8) on to process. 9) process broken. 10) max. ant. end obliquely across. 11) lateral tip to centre of base. 12) to base of glenoid fossa. 13) smooth bone to smooth bone. 14) cartilage present. 15) percentage of length in parentheses. *) After item 55, only absolute measure indicated.

laid along the edge of the maxillaries, ranged from 7–12 mm.

The anterior margin of each nasal bone was convex (Fig. 5a), with a groove (*sensu* Omura, 1975) ventrad (Fig. 5b).

Details of the vertex are shown in Fig. 5c. The supraoccipital curved gently posteriorly in the mid-line. Its anterior edge was bordered laterally by the parietals and antero-medially was fused with the inter-parietal. The inter-parietal was angulato-ovate (Stearn, 1973; Fig. 19) and was bordered along its entire anterior margin by the frontal. The frontal extended across the vertex of the skull and inter-locked with the posterior margin of the nasals. Laterally it was over-ridden by the premaxillaries and ascending processes of the maxillaries. The posterior margins of the nasals, premaxillaries and maxillaries were approximately in a straight line.

The vertex of skull S1396 agreed in all details with that of the Hook Reef animal. The nasal bones had a convex anterior margin, and were elongate, the posterior tip reaching the posterior borders of the ascending processes of the maxillaries. The nasals were widely separated from the interparietal by exposed frontal bone. Skull S272 also had the parietals and inter-parietal incorporated in the vertex and the anterior of the nasal bones convex. However, the posterior of the nasals appeared to be well in front of the posterior borders of the ascending processes of the maxillaries.

The skull of the Lakes Entrance specimen had elongate nasal bones with

TABLE 4. MEASUREMENTS OF SKULLS FOR THE VARIOUS FORMS OF MINKE WHALE AS PERCENTAGE OF SKULL LENGTH

	Dwarf[1]	Antarctic[2]	N. Atlantic[3]	N. Pacific[4]	N. Pacific[6]
Length rostrum	69.8	64.0– 69.4	60.8– 67.8	61.8– 64.0	57.4– 62.9
Breadth rostrum (mid length)	23.2	18.9– 22.7	20.7– 24.3	17.9– 20.7	18.0– 19.1
Breadth rostrum (base)	36.8	29.8– 32.8	32.9– 36.5	32.7– 35.0	30.9– 32.6
Breadth skull (at squamosal)	55.2	50.8– 53.4	54.6– 57.2	54.7– 57.3[7]	50.9– 53.9
Length premaxillaries	76.1, 76.3[5]	70.4– 72.8	73.8– 75.7	73.6– 75.9	69.3– 73.0
Length mandibles (straight line)	97.7, 99.4[5]	96.4– 98.1	100.0–101.4	–	88.2– 97.3
Length mandibles (outer curve)	107.1, 109.2[5]	102.8–106.9	105.0–109.3	109.8	91.7–101.8
Height mandibles (at condyle)	10.9	8.8– 9.9	9.3, 10.5	–	9.4– 10.2
Height mandibles (at coronoid)	13.3	11.8– 14.3	12.8– 13.1	12.7	12.3– 13.2

1) this paper. 2) Omura (1975); Omura and Kasuya (1976). 3) Turner (1892); True (1904); Allen (1916). 4) Tomilin 1967, table 64. 5) right and left sides. 6) Omura (1957; 1975). 7) Zygomatic width.

convex anterior margins and an inferior anterior groove (J. Dixon, personal communication to Heinsohn). The posterior margin of the nasals was in line with the posterior of the premaxillaries, however the ascending process of the maxillary extended further posteriad for about one-third the length of the nasals (0.35–0.37, based on measurements from three photographs). The maxillary processes were bordered on their posterior edges by frontal bone which formed a medial triangular area bounded laterally by maxillary, anteriorly by nasals and posteriorly by parietals and inter-parietal. The parietals and inter-parietal were similar to those of the Hook Reef specimen; the inter-parietal was clearly separated by a suture from the left parietal.

The skull of the Wonga beach specimen was damaged and disarticulated, with the nasals missing. However, the form of the vertex was similar to that just described. The anterior margin of the supraoccipital was somewhat more irregular but also curved posteriorly in the mid-line. The inter-parietal appeared to be partially fused to the right parietal, but was clearly separate on the left side and could be seen as a distinct bone on the inner roof of the skull. The frontal was oriented as described for the Hook Reef specimen.

Lachrymal and malar bones are shown in Figs 5d and 5e respectively; dimensions are given in Table 3 (measurements 47–54).

The posterior margin of the palatine was sharply angulate (Fig. 5f) in specimens from Hook Reef and Lakes Entrance, and possibly skull S1396, although that skull was damaged. The shape of the palatines could not be determined in skull S272 or the Wonga Beach specimen.

In the Hook Reef specimen, the hamular process of the pterygoid (Fig. 5f) was long (41% and 44% of the length between the tip of the process and the intersection of pterygoid and palatine bones on the medial side). The ratio of basal width/length of the hamular process was 0.68 for both right and left sides. Skulls of the Wonga Beach animal, S272 and S1396 were all broken on the underside so that details of the pterygoids could not be seen. The hamular processes were elongate in the Lakes Entrance specimen.

Mandibles are shown in Figs 5g and 5h. Measurements are included in Table 3 (measurements 33–40).

Axial skeleton

The epiphyses were completely fused to the posterior caudal and first two cervical vertebrae only; they were unfused to thoracic vertebrae.

The main feature previously identified as of potential systematic value is the presence or absence of the parapophysis on the seventh cervical vertebra. It was present as a tubercle in the Hook Reef specimen.

Ribs

There were ten pairs of ribs, with one possible pair of much reduced ribs (18.2 and 25.8 cm long). Proportions can be seen from Figs 6a and 6b (reduced ribs not shown). The Wonga Beach specimen had eleven pairs of ribs.

Sternum

The sternum was roughly T-shaped, with the point of maximum breadth 71.0% of the total length (Fig. 6c). The point of maximum breadth was reached 35.2% from the wider end, while the shaft of the sternum was 56.3% of the total length. Measurements of the sternum are given in Table 3 (measurements 73–77).

Scapula and flipper bones

The scapulae are shown in Fig. 6d. Measurements are given in Table 3 (measurements 55–65). The maximum breadth/length ratio was 1.71 and 1.68 for the right and left scapulae.

The phalangeal formula for both flippers (based on X-radiographs) was 4,7,7,4. In the left flipper, the terminal phalanges of II and III (numbering system from Omura, 1975) were minute.

Hyoid bones

The hyoid bones are shown in Fig. 6e. The posterior margin of each wing of the fused basihyal-thyrohyals curved posteriad sub-medially but then ran obliquely forward toward the anterior margin which was almost at right angles to the mid-line.

Measurements are given in Table 5. The tips of the right and left wings

TABLE 5. MEASUREMENTS OF HYOID BONES OF HOOK REEF DWARF MINKE WHALE[1]

	Absolute measure (mm)	% total length
Fused basihyal and thyrohyals		
Total length	533.0	100.0
Straight length	452.2	84.8
Greatest height	152.0	28.5
Height at centre	118.9	22.3
Forward notch, depth	32.3	6.1
Height at middle of right wing	70.5	13.2
Height at middle of left wing	72.1	13.5
Thickness at middle of right wing	33.2	6.2
Thickness at middle of left wing	38.5	7.2
Height at distal end, right	33.8	6.3
Height at distal end, left	34.5	6.5
Stylohyal		
Total length, right	244.8	100.0
Height at middle, right	58.0	23.7
Thickness at middle, right	23.8	9.7
Degree of curvature, right	34.5	14.1
Total length, left	252.2	100.0
Height at middle, left	56.3	22.3
Thickness at middle, left	23.3	9.2
Degree of curvature, left	35.3	14.0

1) See Satake and Omura (1974) for definitions of measurements.

of the fused basihyal-thyrohyals and the tips of the anterior projections of the basihyal were eroded so that proportions based on overall lengh (Table 5) will be over-estimates. Nonetheless, the stylohyals were proportionately short (length of the right and left stylohyal was 45.9 and 47.3% of the overall length of the fused basihyal-thyrohyals). The stylohyals were strongly curved (degree of curvature 14.1 and 14.0% of total length of the right and left stylohyal).

Pelvic bones

The pelvic bones are shown in Fig. 6f. They were long (258.2 and 259.5 mm for right and left bones) and knife-like. The maximum width (11.2 and 14.1% total length) was reached 39.4% of the distance from the wider end. The bones were strongly curved (maximum curvature 12.3 and 11.4% of total (straight line) length of right and left bone). Further measurements are given in Table 3 (measurements 70–72).

Other features

Unless otherwise noted, the following observations are for the Hook Reef speciman.

The longest ventral groove did not reach to the umbilicus; this corresponds to the type B animals of Wada and Numachi (1979).

The flukes had a deep median notch, corresponding to type 2 of Doroshenko (1979).

The palate was uniformly cream coloured.

Jacobsen's organ was represented by two pairs of pits. The anterior and posterior pairs were 28 and 52 mm from the tip of the snout, while the anterior fringe of baleen was 50 mm from the tip.

The lateral edge of the left liver lobe was even.

The animal was reproductively mature. Further details were given by Marsh (1985).

Healed skin lesions were evident on the Hook Reef specimen and at least one open, circular lesion was noted on the Wonga Beach specimen.

Distribution

Known records of dwarf minke whales are given in Table 1. Sight records from Queensland with a question mark lacked detailed notes on colour pattern or photographs, but were made by observers familiar with the appearance of dwarf minke whales at sea. The record from Point Leo, Victoria was based primarily on the dark throat patch visible in one photograph, but other colour features could not be determined from material available. The stranded animals were 4.04 m (Wonga Beach), 4.1 m (Terrigal), 4 m (Yeppoon, length estimated), 2.23 m (Lakes Entrance) and 4.5 m long (Point Leo, Victoria). The Hook Reef specimen was 7.1 m, while estimates of animals observed at sea ranged from 15 ft (4.5 m) to 10 m. The fourteen records from central and northern Queensland (11°55′–23°08′S) were from July to December, with most sightings from July (5) and August (4).

The stranding at Terrigal, N.S.W. (33°27′ S) occurred in early September, while the two records from Victoria (about 38° S) occurred in June.

Six of the records were of single animals (including three single strandings). Five sightings were of pairs, one of three animals and two of four animals. A sight record west of Barrow Island, Western Australia (20°28′ S) of four animals seen on June 23, 1983 (Pattenden, pers. comm.) appears to have been of dwarf minke whales.

Sight records on the northern Queensland shelf are from the mid- to outer shelf.

DISCUSSION

Colour pattern

The colour patterns of the various forms of minke whales are compared in Table 6.

Our observations confirm Best's (1985) description of the dark throat patch, flipper pigmentation, and presence of a white shoulder patch and shoulder blaze. These, in combination, separate the dwarf minke whale from all other forms.

TABLE 6. COMPARISON OF COLOUR PATTERNS OF MINKE WHALE FORMS

Colour pattern	Dwarf minke whale				Southern hemisphere dark shoulder minke	North Pacific	North Atlantic
	Best (1985)	Baker (1983)	Magnier Laboute (1979)	Present Study[1]			
1. Rostral saddle	–	–	×	×	–	–	–
2. Dark throat patch	×	×	×	×	–	×	×
3. White shoulder patch	×	×	×	×	–	–	–
4. White flipper base	×	×	×	×	–	–	–
5. Thorax blaze	×	×	×	×	–	–	–
6. Gray crescent dorsad	×	?	?	×	×	×[2]	?
7. Blowhole streaks	×	?	?	×	×	?	?
8. Flank patch	×	×	×	×	×	×	×
9. Dorsal cape	–	× (indistinct)	–	× (indistinct)	×	×	?
10. Caudal chevron	×?	×	×	×	×	×	×[3]
11. Peduncle patch	×	×	×	×	–	×?[4]	?
12. Dorsal fin flare	–	–	–	–	×	×?[2]	?
13. Speckling	–	–	–	–	×	×?[5]	?

1) including photos from Gladstone (1984); Rockman (1986a,b). 2) Leatherwood *et al.* (1982). 3) Blake, in Allen (1916). 4) Norris and Prescott (1961). 5) Stern, unpublished photograph.

TABLE 7. AVERAGE SEA SURFACE TEMPERATURES (°C) ON QUEENSLAND SHELF AT TIMES OF REGULAR SIGHTINGS OF MINKE WHALES. DATA FROM BRANDON

Month	Latitude					
	25°	23°	20°	18°	16°	14°
June	21.3	21.7	22.3	23.0	23.5	23.8
July	19.4	20.9	21.2	22.2	22.7	23.7
Aug.	21.5	20.5	20.5	22.8	22.8	24.3
Sept.	22.7	21.3	22.7	23.3	24.5	24.8

The dark throat patch contrasts sharply with the light lower jaw of the southern hemisphere dark shoulder form but is similar to the pigment in specimens from the North Pacific and North Atlantic (see figures in Omura and Sakiura, 1956; Sergeant, 1963).

Best (1985) did not report what we have called the flipper oval within the shoulder patch, nor did he comment on the asymmetrical development of dark pigment running into the shoulder patch from its posterior margin. This asymmetry was confirmed on two of the animals for which we have photos of both sides and is suggested by photographs of other animals taken from different angles. The asymmetry also seems to be present in South African material, based on a comparison of Best's (1985) Fig. 1c (right side) and Fig. 8 (left side).

Best (1985) reported that one of the stranded dwarf minke whales had a crescent-shaped mark running towards the mid-dorsum. This statement is supported by his Fig. 8 in which the pigment does run onto the back. He considered this analagous to the crescent marks extending onto the back of dark shoulder minke whales and further noted that there were indications of a similar pattern in the dwarf minke whale from New Zealand illustrated by Baker (1983). On our material, this streak ran more anteriad and did not appear to meet on the back. This feature was seen especially clearly in specimens from Hook Reef and Wonga Beach, although in other animals it appeared to run obliquely dorsad. The animal from Grub Reef seemed to be asymmetrically coloured with the right shoulder blaze extending further onto the back. The orientation and extent of the blaze thus may be variable.

Dorsal views of animals from South Africa (Best, 1985) and Marion Reef (Rockman, 1986b) showed a medial patch of light pigment between the blowhole and level of the flipper insertion.

Best (1985) reported blowhole streaks in a dwarf minke whale from South Africa. We did not see these in the Hook Reef animal, nor are they apparent in any photographs of this or other dwarf minke whales from the Barrier Reef region. However, Rockman (1986a,b) has a dorsal view of a dwarf minke whale from Marion Reef, Coral Sea, which clearly shows these streaks.

The light head and rostral saddle may be apparent only in living or recently dead animals; it has not been previously noted in the dwarf minke or other forms.

Neither we nor Best (1985) have seen a dorsal fin flare (such as he reported in the southern hemisphere dark shoulder form) in the dwarf minke whale.

Best (1985) described a flank patch reaching to the level of the dorsal fin and a peduncle patch, or extension of white up the side of the tail stock. On animals of which we have photographs or have examined, the flank patch extends past the dorsal fin, onto the latter half of the tail stock. In most cases, it appears to be entire, but in the animal from Grub Reef and the one illustrated by Baker (1983) there is an obscure dorsal cape (Fig. 1a, dc), just in front of the dorsal fin, dividing the flank patch into two parts. On our animals, the extension of white up the tail stock, which appears to be the peduncle patch of Best, occurred within the flank patch, and was bordered on either side by light grey. The tail stock darkened just behind the peduncle patch. These features can also been seen in the photograph of the New Zealand specimen (Baker, 1983).

The shoulder blaze is a consistent feature which may not be found in other forms. In a dwarf minke whale from New Zealand illustrated by Baker (1983) there is a clear shoulder blaze dorsal to the flipper, plus a dusky dorsal cape just in front of the dorsal fin, which divides the flank patch into two parts. The anterior part of this flank patch is of similar form and overlaps in position the 'thorax blaze' described in the southern hemisphere dark shoulder form by Best (1985), and seen in other minke whales from the North Pacific (Leatherwood, Reeves, Perrin and Evans, 1982; Figs 104 and 105). We thus distinguish between the shoulder blaze, above the flipper and reported only from the dwarf minke whale, and the flank patch, which may be divided into two parts, the anterior of which has been called a "thorax blaze".

In our specimens of dwarf minke whale, the light grey either side of the peduncle patch continued ventrad, then turned sharply anteriad, forming a chevron. Best (1985) noted 'indications' of a chevron on a stranded specimen from South Africa and the chevron can be seen in the specimen illustrated by Baker (1983).

Both the chevron and peduncle patch appear to be variably developed in the east Australian specimens, both being very clear on the Wonga Beach and Kelso Reef animals but poorly developed (peduncle patch) or absent (chevron) in the Hook Reef specimen.

The caudal chevron appears to occur in the North Pacific and both southern hemisphere forms, based on photographs of animals from those regions. A caudal chevron is shown in the illustration by Blake of a minke whale from Massachusetts (Allen, 1916), so that it appears to be a general feature of all forms.

The peduncle patch may be a characteristic feature of the dwarf minke, as suggested by Best (1985). However, an eastern North Pacific minke whale illustrated in Norris and Prescott (1961) shows an extension of white and grey on the peduncle, similar to the patch we have seen in eastern Australian dwarf minke whales.

Speckling of the sides was not noted in the east Australian dwarf minke whales, nor has it been reported by Best (1985).

The dorsal fin flare has been documented only in the southern hemisphere dark shoulder form but may occur in the North Pacific from (Leatherwood *et al.* 1982; Fig. 104).

Comparison of morphometrics with other dwarf minke whales

Best (1985) included a full set of measurements for two specimens of dwarf minke whale 1.9 and 2.5 metres long. The Hook Reef specimen differed from these in: (1) greater distance from snout to anus (76% versus 72.5, 72.8%); (2) more anterior position of dorsal fin (69.6% versus 71.5, 71.3%); (3) shorter mouth (17% to angle of gape, versus 17.9, 18.2%); (4) greater breadth of flukes (26.4% versus 23.0, 24.2%); (5) shorter (14.3% versus 16.5, 19.2% – insertion to tip) and narrower (3.7% versus 4.0, 5.3%) flippers.

The height and basal length of the dorsal fin of the Hook Reef specimen (4.8 and 8.4% of total length) agreed well with the figures given by Best (1985; 5.6, 4.8% and 8.3, 8.9% respectively).

Comparison with other forms

We have no measurements of Australian dark shoulder minke whales. Best (1985) compiled data on proportions of southern hemisphere minke whales, including data of Ohsumi, Masaki and Kawamura (1970) on 10 males and two females from the Antarctic. We also have examined data compiled from Omura and Sakiura (1956), Jonsgård (1951) and Turner (1892) for North Pacific and North Atlantic animals. It should be considered that not all the measurements were taken in the same manner, especially in those studies published before Norris (1961).

The distance from snout to anus (76%) was greater than the values for dwarf minke whale in Best (1985: 72.5, 72.8%). The difference may simply reflect the varying sizes of the specimens and is within the range of variation noted for other forms of minke whales.

The tip of the dorsal fin was further forward on the Hook Reef animal (snout to tip 69.6%, versus 71.5, 71.3% for Best's specimens). Best (1985) noted that the dorsal fin was placed more anteriorly in his two specimens of juvenile dwarf minke whales, than in six southern hemisphere dark shoulder minke whales of comparable size. The even more anterior position of the fin on the mature Hook Reef specimen supports this difference, and suggests that it is maintained, if not augmented, with growth. Exact comparison with larger specimens of other forms of minke whales is impossible as most authors have measured to the posterior emargination of the dorsal fin. However given that the tip of the dorsal fin is more posterior than the posterior emargination of the fin, the fact that the fin tip of the Hook Reef animal was more anterior than the posterior emargination of the fin in dark shoulder southern hemisphere (Best, 1985) and North Pacific (Omura and Sakiura, 1956) minke whales indicates that the fin was more anterior than in those forms. From data summarized by Omura and Sakiura (1956), the dorsal fin is situated further forward in northern hemisphere Atlantic minke whales than in those from the North Pacific, and may be similar in position to that of the dwarf minke whale.

The broad dorsal fin with strongly convex anterior margin and shallowly emarginate posterior border (Fig. 3d, Laboute and Magnier, 1979; Rockman, 1986a) may be characteristic of the dwarf minke whale. Photographs of animals from the North Atlantic (True, 1904; Plate 28.4), North Pacific (Leatherwood *et al.*, 1982; Figs 108 and 110) show a tall, more slender fin with deeply emarginate posterior margin. A similar form of fin may occur in the southern hemisphere dark shoulder form (Lillie, 1910; Plate 5.2).

The mouth of the Hook Reef animal was short (17.0% to angle of gape, which is below the figures given by Best (1985) for the dwarf minke whale and outside the range of the figures given for dark shoulder minke whales quoted from Ohsumi, Masaki and Kawamura (1970). Doroshenko (1979) figured marked differences in the length of mouth in southern hemisphere dark shoulder minke whales from different sectors of the Antarctic. A similar range of proportions could be expected for the dwarf minke whale. The value for our specimen is lower than in animals from the North Atlantic measured by Turner (1892) and Allen (1916): 17.4–22.6%, but within the range of specimens from the North Pacific. The wide variability in gape measurements may reflect different measuring techniques and the character seems of limited value.

The height and basal length of the dorsal fin of the Hook Reef specimen (4.8 and 8.9%) agree well with figures for dwarf minke whales by Best (1985) (5.6, 4.8% and 8.3, 8.9% respectively). They are outside the range reported in dark shoulder minke whales by Ohsumi *et al.* (1970) ($\bar{x}$ =3.7% (3.0–4.2) and $\bar{x}$ =5.5% (3.7–7.7) respectively) and for height, outside the range for North Atlantic animals given by Jonsgård (1951; n = 72 females). Both dorsal fin height and basal length are within the range given for North Pacific animals by Omura and Sakiura (1956).

The left fluke of the Hook Reef animal was damaged and the relative total width (24.6%) is thus suspect. Doubling the value of the right fluke gives a value of 26.4%, which is within the range reported for southern hemisphere dark shoulder (Ohsumi *et al.* (1970) cited in Best (1985) and North Atlantic minke whales (Jonsgård, n = 74 females), but outside the range of the North Pacific animals (Omura and Sakiura, 1956). The width of flukes is greater than that reported for the juvenile dwarf minke whales. That this may simply be a function of growth can be seen by comparing the figures in Best (1985;

Table 5) which shows that the proportional width of flukes in six small southern hemisphere dark shoulder minke whales was smaller than in the larger specimens quoted from Ohsumi *et al.* (1970).

The flippers of the dwarf minke whales described in Best (1985) were proportionately longer and broader than those of the Hook Reef animal. However, our figures for the mature specimen agree well with those for southern hemisphere dark shoulder minke whales (Ohsumi *et al.*, 1970) of comparable size. The discrepancy with Best's specimens may again simply reflect the markedly different ages of his and our specimens.

The number of ventral grooves (67) of the Hook Reef specimen is between the values for the two dwarf minke whales given by Best (1985) (76, 54 respectively), and does not differ from his figures for the dark shoulder minke whale juveniles ($\bar{x}$ =65.6 (44–76)). The summary of reported values for number of ventral grooves by Best suggest that the feature is either very variable or subject to large differences in counting by different observers. In this respect, we counted grooves at the level of the eye, which is anterior to the position recommended by Williamson (1973), and now apparently in general use.

In summary, the differences in measurements between our specimen and those documented in Best (1985) fall within the range of variation reported from other forms of minke whales. The greater size and more anterior position of the dorsal fin, compared with the dark shoulder southern hemisphere form, has been confirmed.

Baleen plates

The number of baleen plates is within the range reported for both the dwarf minke whales by Best and other workers on dark shoulder minke whales as summarized by Best (1985). We counted only anterior hairs and baleen plates so that our estimates may be lower than others given in the literature, but only by a few baleen plates. Doroshenko (1979) noted that in the southern hemisphere dark shoulder minke whale, there was a direct relationship between length of jaw and number of baleen plates. The relatively low numbers of plates thus may reflect the shorter mouth of the Hook Reef specimen (see Dwarf Minke Whale Discussion; Comparison of morphometrics with other dwarf minke whales and Table 2).

Although the method of measuring breadth of baleen plates differed from that given by Omura and Fujino (1954) and that used by Best (1985), the differences seem slight. Subtracting the width of the gum made little difference to the values. A greater potential error arises from the variability in the breadth of plates in the series even in the section with longest baleen plates. However, the ratio reported here (0.43–0.45) agrees well with the value given by Best (1985; $\bar{x}$ = 0.43, n = 5) for the dwarf minke whale.

The length of the longest baleen plates of the Hook Reef animal is in agreement with Best's (1985)report that plates of the dwarf minke whale are relatively shorter than those of the dark shoulder form, not exceeding 20 cm. The values of 18.3 and 18.5 cm for right and left side agree well with the mean of 18 cm reported by Best. Baleen length also appears to be shorter than in North Atlantic minke whales as reported by Jonsgård (1951), although that author noted a wide range of values and indicated that baleen plates of females were shorter than those of males, at least for specimens from the Lofoten area.

The colour pattern of the baleen plates is similar to that described by Best (1985) for the dwarf minke whale. However, Best (1985) noted that animals with predominantly white plates, with a few plates bearing a thin (about 0.3 cm wide) black border, as shown in his Fig. 1f, were scored as having all white baleen. The Hook Reef animal (Figs 6g and 6h) had a similar colour pattern to Best's Fig. 1f, and would probably be scored as having 100% white plates. This might explain the discrepancy between our value for the right hand series (87.7% white) and the figures in Table 4 of Best (1985), which showed completely white plates in the right series of all but one animal.

The width of the dark border of mid-series plates found in the Hook Reef animal also fits the pattern described by Best (1985). However, the posterior plates on both sides were increasingly dark and the most posterior plates were all dark, except for the bristles. This feature was not commented on by Best (1985), who extracted baleen plates more from mid-series, nor can it be seen in his Fig. 1f of the baleen series of a "Type 3" whale.

Skeleton

Our present observations represent the only available data on the skeletal features of the dwarf minke whale.

The Hook Reef animal was sexually mature (although physically immature) and should be comparable with specimens of the southern hemisphere dark shouldered form, as documented by Omura (1975) and Omura and Kasuya (1976). The two forms overlapped only in proportional breadth of the occipital bone, height of right occipital condyle and height of both mandibles at the coronoid. The disarticulated skull of the Wonga Beach specimen could not be measured. Clearly, more specimens (especially of the dwarf form) must be measured to establish if there are consistent differences in the proportions of the skulls.

Omura (1975) and Omura and Kasuya (1976) have indicated skeletal features of apparent systematic value in separating North Pacific and the southern hemisphere dark shoulder form. They noted, however, that the small number of animals from both localities, and their discrepancy in size (the North Pacific animals being much smaller) made comparisons difficult. In Table 4 we present data on the dwarf minke whale, the southern hemisphere dark shoulder form (Omura, 1975; Omura and Kasuya, 1976), small North Pacific minke whales (specimens with skulls less than 1.5m, from Omura, 1957), large North Pacific minke whales (from Tomilin, 1967), and large

North Atlantic animals (Turner, 1892; True, 1904; Lilljeberg in True, 1904; Allen, 1916; Tomilin, 1967). An examination of Table 4 (and Fig. 6 in Omura, 1975) shows that two features used by Omura (1975) to separate the North Pacific and Antarctic forms (breadth of skull, breadth of rostrum at base) differed only in the largest animals, listed by Tomilin (1967). The smaller North Pacific animals listed by Omura differed as much from the large North Pacific specimens listed by Tomilin (1967) as they did from the Antarctic specimens. Similarly, the large North Atlantic specimens agreed more closely with the large North Pacific specimens listed by Tomilin (1967) than they did with the smaller animals listed by Omura (1957). It would clearly be misleading to compare measurements of the dwarf minke with data on North Pacific animals measured by Omura (1957). Unfortunately, only the relatively few measurements given in Table 4 seem to be available for mature northern hemisphere specimens.

Of the nine measurements in Table 4, four refer to the mandible. The Hook Reef specimen overlapped in two and one of the four measurements with specimens from the Antarctic and North Atlantic respectively, while there was no overlap with specimens from the North Pacific.

The dwarf minke whale was closest to the southern hemisphere dark shouldered form in length of rostrum, although still outside the range for that form (69.8 vs 64.0–69.4%). True (1904) and M'Intosh (1917) noted that the rostrum was proportionately more elongate in the largest skulls of North Atlantic minke whale; their values overlap those of the dark shouldered form and approach that of the dwarf minke whale. However, even including the data from Tomilin (1967) North Pacific minke whales appear to have a shorter rostrum than either southern hemisphere form.

The basal breadth of the rostrum (36.8%) was larger in the dwarf minke than in all the Antarctic and North Pacific forms. Northeast Atlantic minke whales also seem to have a narrower rostrum ($\bar{x}=34.2$ (32.9–36.5) %, n = 5), although one specimen from Norway had a broad rostrum (Allen, 1916). More data are needed, but the basal breadth of the rostrum may be a distinctive feature of the dwarf form.

The dwarf minke whale overlapped the North Atlantic specimens in breadth of rostrum at mid-length and was close to Antarctic specimens in this value. Again it was the North Pacific animals which had a narrower rostrum at mid-length.

In breadth of skull at the squamosal, the dwarf minke whale differed from the dark shouldered form but overlapped with the Atlantic and possibly larger North Pacific animals, based on zygomatic widths from Tomilin (1967).

In length of premaxillaries, the dwarf minke whale was much closer to the North Atlantic and large North Pacific specimens than to those from the Antarctic.

Omura (1975) and Omura and Kasuya (1976) also noted several qualitative differences in skulls from North Pacific and Antarctic animals. Of these, the profile of the skull and margin of the rostrum as seen in dorsal view seem particularly subject to variable interpretation, and are difficult to measure consistently. Moreover, M'Intosh (1917) noted a prominent flattening of the premaxillary region of a large (1.83 m) skull, compared with a small (0.81 m) skull of a North Atlantic minke whale. The difference between young North Pacific whales compared with mature Antarctic specimens noted by Omura (1957) may thus simply reflect the different ages of the animals. However, the skull of the mature dwarf minke whale did more closely resemble in profile the North Pacific than the Antarctic specimens (compare Fig. 4c of the present study with Omura, 1975; Plate 3).

The anterior margins of the nasal bones in the dwarf minke whales from Hook Reef and Lakes Entrance were convex and had an antero-ventral groove. Skulls in the Australian Museum had nasal bones of similar shape, but the presence of an inferior groove has not been confirmed. This contrasts with the southern hemisphere dark shoulder minke but agrees with specimens from the North Pacific (Omura, 1975). Minke whales from the North Atlantic also have nasal bones with convex anterior margins (Flower, 1864; True, 1904) but the antero-ventral groove has not been recorded.

The vertex of the skull of the dwarf minke differed from previously described forms. The inclusion of parietals in the vertex and presence of an inter-parietal were as in specimens from the North Pacific (Omura, 1975) and North Atlantic (Carte and MacAlister, 1868; True, 1904), but differed from the dark shoulder form as described by Omura (1975). The configuration of the inter-parietal in the dwarf minke whale was rhomboidal, rather than triangular as in the northern hemisphere specimens. Moreover, the posterior margins of the nasals, premaxillaries and maxillaries all appeared at the same level in the mature dwarf minke whale. This agreed with southern hemisphere dark shoulder minke whales but differed from the northern hemisphere forms (Carte and MacAlister, 1868; True, 1904; Omura, 1975). In the juvenile specimen from Wonga Beach and skull S1396 both frontals and parietals were an obvious feature of the vertex. Moreover, in skull S272, there appeared to be a forward extension of the frontal bone between the ascending processes of the maxillaries, similar to the triangular region of inter-parietal and frontal bones described in the vertex of North Pacific minke whales. This was clearly the case in the 2.2 m specimen from Victoria. Thus the position of nasals, maxillaries and premaxillaries may be age dependent; this would fit with information in Miller (1923) on telescoping of the baleen whale skull (see Southern hemisphere dark shoulder form Discussion: Skeleton).

The Hook Reef and Lakes Entrance dwarf minke whales had angulate palatines and elongate hamular processes unlike the southern hemisphere dark shoulder form but as in the North Pacific specimens (Cowan, 1939; Omura, 1975). The angulate palatine is not a general feature of northern hemisphere minke whales, however, as can be seen from Plate 24 of True

(1904) which shows North Atlantic minke whales from Massachusetts and Norway with elongate hamular processes but curved, rather than angulate posterior margins of the palatine.

The malars appear to be similar to those in other forms of minke whale as illustrated by Omura (1975). The lachrymals, however, appear to be closer to those of the North Pacific specimen than to the Antarctic specimen (Omura, 1975).

The presence of a tuberculate parapophysis on cervical vertebra 7 of the dwarf minke is a feature shared with northern hemisphere forms but not southern hemisphere dark shoulder minke whales.

The presence of ten pairs of ribs (plus one possible very reduced pair) in the Hook Reef animal was anomalous, but seems of no systematic value given that the Wonga Beach animal had the usual complement of eleven.

The sternum differed in shape only slightly from some of the many variants illustrated by Tomilin (1967). The fused basihyal-thyrohyals, and pelvic bones were not closely similar to any of these bones figured in Omura (1957, 1975), Omura and Kasuya (1976), or Satake and Omura (1974). All are subject to considerable variation as indicated in the articles just quoted. The proportional length of the stylohyals was outside the range given by Satake and Omura (1974) for the southern hemisphere dark shoulder form. It was closer to the short stylohyals of animals from the North Pacific (Satake and Omura, 1974) and North Atlantic (Turner, 1892; M'Intosh, 1917). The significance, if any, of differences in these bones, based solely on the Hook Reef animal, must await examination of further material.

The breadth/length ratio of the scapula was lower than for mature southern hemisphere dark shoulder minke whales but within the range for North Pacific animals (Omura, 1975). However, Tomilin (1967) has shown that this ratio is size dependent, with relatively greater growth in breadth in larger animals. This, with the small sample size and slight proportional differences (1.68–1.71 versus 1.76–1.81) make conclusions tentative.

The phalangeal formula of the Hook Reef specimen fell within the values for southern hemisphere dark shoulder minke whales (Omura, 1975) except for digit II and within the ranges compiled for northern hemisphere minke whales by Tomilin (1967).

Geographical range

Tomilin (1967) and Watson (1981) reported the minke whale to be rare in the tropics. Morzer-Bruyns (1971), while giving various sightings from tropical locations, especially in the Indian Ocean, noted that minke whales were "relatively rare" in the south-west Pacific. Stewart and Leatherwood (1985; Fig. 2) showed no records of minke whales around Australia, north of Tasmania. Clearly these impressions are misleading.

Within Australia, the dwarf minke whale extends into low latitudes (at least 11°55′ S on the east coast, and possibly 20°38′ S on the west). Although there are two records from Victoria, most sightings have been from northern New South Wales to northern Queensland; all confirmed records north of 23°08′ S have been dwarf minke whales.

Records of both forms of minke along the Queensland coast and off northern New South Wales have been in June to December, with most in July and August. Temperature data (Table 7) from Brandon (1973) show the expected decrease in temperature with increasing latitude, so that in August sea surface temperatures were 22.8°C. at latitudes 16°–18°, compared with 20.5°C at 23° S. Lowest temperatures at all latitudes occurred in July and August, which is the time of peak sightings.

Gladstone (1984) reported minke whales (apparently all dwarf form) near Lizard Island (14°40′ S) from May to July. This is somewhat earlier than our records. According to Brandon's (1973) data, animals near Lizard Island in May would experience much warmer water, with a mean surface temperature of 27.8°C, versus a June average of 23.8°.

Within New Zealand, the two forms overlap in the Cook Strait region (records in Baker, 1983; W.H. Dawbin, personal communication). Unpublished photographs of an animal stranded at Timaru, N.Z. (44°S) and referred to as a white flipper form by Gaskin (1976) show an extensive throat patch; the animal was almost certainly a dwarf minke whale. Miyashita (personal communication to Marsh) reported a possible dwarf minke whale with a "white flipper band" from the Tasman Sea (39°05′ S, 160°35′ E) – about half way between Australia and New Zealand – on Novembr 24, 1983. Otherwise, the most southerly record is Plimmerton, N.Z. (about 41°05′S) (Cawthorn, in Best, 1985). Baker (1983) described the dwarf minke whale as 'rare' in New Zealand. Given its predominance in warm waters along the east Australian coast, it may be at the edge of its range in New Zealand. Against this argument are records from Timaru and even further south in the sub-Antarctic (see below).

The minke whale from near the Isle of Pines, New Caledonia illustrated in Laboute and Magnier (1979) is clearly the dwarf form. Further details are unavailable (Laboute, personal communication to Arnold).

Best (1985) summarized records of dwarf minke whales from South Africa. The animals seem to be in low numbers at Durban (30°S), forming only 3–4% of the catch there. However, a stranding was reported at 34°09′S, close to the southern extremity of the Cape Province and Best noted that the low percentage of dwarf minke whales in the Durban catch could reflect selectivity by the gunners.

Best (1985) considered some of the records from Brazil tentative, but listed the occurrence of dwarf minke whales there, based on a specimen with a dark throat patch, reported by Williamson (1973). Singarajah (personal communication to Marsh) has not seen the dwarf form in the Brazilian fishery, however other Brazilian scientists have reported that the "diminutive form" of Best was regularly sighted but rarely captured off Brazil because of its small size (Anon, 1985). While the dwarf minke whale clearly occurs in the Brazilian region, more information on its distribution and abundance there is needed.

No specimens of dwarf minke were noted by Best (1985) in the Antarctic, nor have they been seen by Japanese workers (Wada, pers. comm. to Marsh). None of the 1179 photographs of minke whales from the Antarctic taken by Japanese scientists and examined by Marsh were of the dwarf form (Marsh, 1985). Best (1985) has already pointed out the difficulty in assessing the colour of the flipper at sea and one must question some of the sight records of white-flipper forms from the Antarctic (e.g. Lillie, 1910; Taylor, 1957). The most southerly records of dwarf minke whales, supported by photographs, appear to be at 52°57′ S, 112°32′ E and 53°08′ S 112°30′ E both on Dec. 26, 1984 (Kasamatsu, personal communication to Marsh). While this could suggest latitudinal migration, we also have records of dwarf minke whales at 11°55′ and 19°50′ S in late November and early December respectively. Thus nothing can be said about long distance movements of this form in the southwest Pacific.

Records in the literature of minke whales from the tropical Indo- Pacific are generally inconclusive. Deranyigala (1948, 1960) reported the southern hemisphere dark shoulder form from Sri Lanka, but with no details to support the identification. In 1963 he then described a new subspecies from Sri Lanka, *B. acutorostrata thalmaha*. This was based on differences in the colour of the baleen plates, with black and white plates anteriorly, but entirely black plates (except for bristles) posteriorly. There are some discrepancies in the description. Figures of "two feet, six inches" and "two feet, five inches" were given for the height and length of the dorsal fin respectively (about 8.6% total length). This is nearly twice the height reported for any form of minke whale, but is comparable to the length of the base of the dwarf form. The fluke width listed was 17.2% of the total body length. Deranyigala (1963) noted that this was narrower than reported in the southern hemisphere dark shoulder form. In fact, it is much smaller than for any form from either hemisphere. The length of the baleen plates (17 cm) suggests the dwarf minke whale, but only parts of the baleen series were available and the longest plates may not have been collected. The colour of the baleen, if it was as described, would seem to rule out the dwarf form. No information was given on diagnostic colour patterns of the body, while the illustrations and description of the skull are insufficient to establish the identity of the animal. The total body length of 28ft (8.5m) would suggest that it was not a dwarf minke whale, of which the largest specimen measured was a 7.8 m female (Best, 1985).

Lekagul and McNeely (1977) recorded minke whales from Thailand. They described the animals as having white flipper bands, but the account seems to be a compilation from the literature and the colour pattern may be based on descriptions of animals from higher latitudes of the northern hemisphere.

Harrison (1974) noted that records of *B. edeni* from Malaysia and Singapore "appear to be the local representative of the Lesser Rorqual *B. acutorostrata*". No description or other support for this statement is given. One of the records of minke, "Pulau Sugi in 1950" is suspiciously like the record of *B. edeni* from Pulu Sugi described fully by Junge (1950). Harrison stated that the colour of the minke whale in Malaysian waters is still unknown.

Herre (1925) reported a minke whale from the Philippines, but with no description which could confirm his identification.

On the basis of present records, confirmed sightings of the dwarf minke whale appear confined to the west Indian Ocean (South Africa), southwest Pacific (Australia, New Zealand, New Caledonia) and in the Atlantic, off South Africa and Brazil. Accounts of the minke whale in the Philippines, Thailand, Malaysia, Singapore and Sri Lanka need to be confirmed.

School size and distribution from shore

Most of the records of dwarf minke whales in northern Queensland were of single animals, with one sighting of three animals '15–20 ft' long. Gladstone (1984) reported diving with five dwarf minke whales off Lizard Island (14°40′ S). Rockman (1986a,b) reported a group of eight dwarf minke whales from Marion Reef (19°10′ S, 152°17′ E).

The predominance of sight records from the mid and outer Queensland shelf probably partly results from the concentration of reefs in those areas. Thus sport divers, fishermen and research scientists are more likely to spend time anchored in such spots, where they can be approached closely by minke whales. It is usually only under such circumstances that sufficient detail can be observed and/or photographed to allow positive identification of the dwarf minke whale. In the only systematic aerial survey of the region (111 cross-shelf transects between 11°30′ S and 20°30′ S during November–December 1985) dwarf minke whales were recorded only twice, both from the mid to outer shelf (Marsh, unpublished data). In contrast, Best (1985) showed that dwarf minke whales off Durban occurred closer inshore than other minke whales.

The length of sightings (up to several hours) and the high proportion of sightings supported by underwater observations and photographs suggests a behaviour similar to other forms of minke whale which have been reported to closely approach vessels (e.g. Leatherwood *et al.*, 1982).

SOUTHERN HEMISPHERE DARK SHOULDER FORM

RESULTS

Colour pattern

We have less extensive information on the dark shoulder form. Unless otherwise noted, the following notes are based on a 4 m minke whale stranded near Coff's Harbour, N.S.W. (29°47′ S) in August 1981, and photographed alive at the Pet Porpoise Pool, Coff's Harbour. Photographs (see Figs

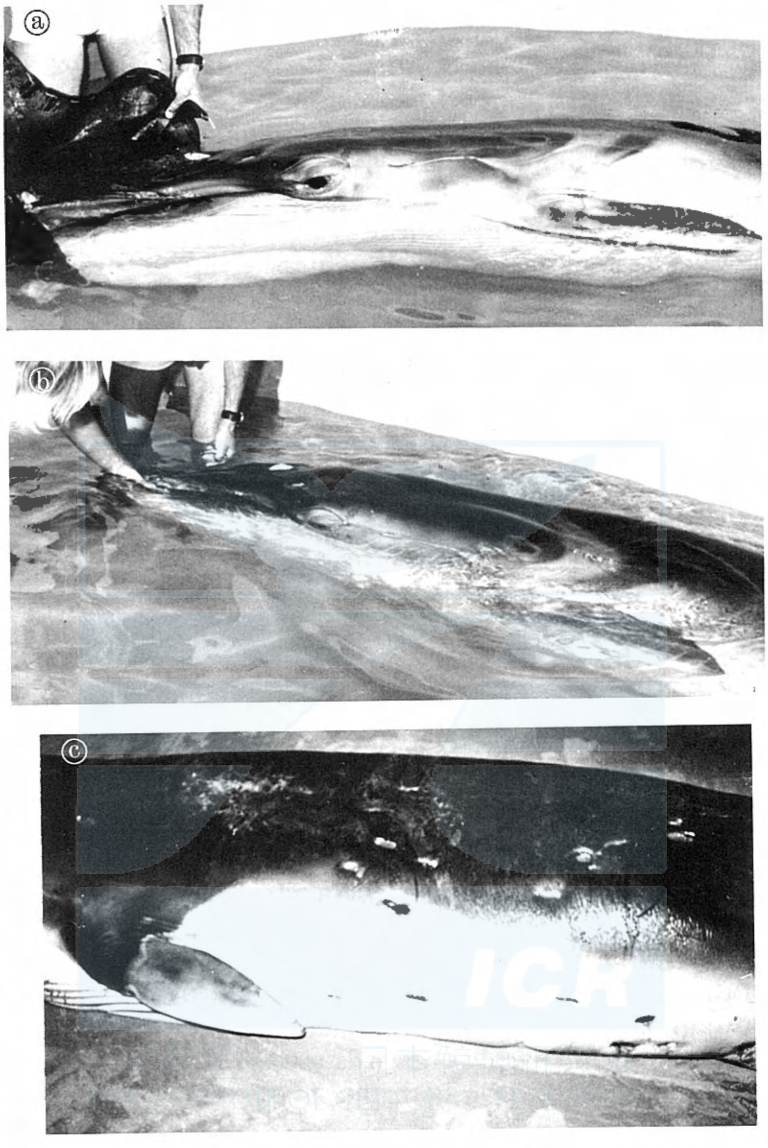


Fig. 7. Southern hemisphere dark shoulder minke whale. a,b 4.0 m individual, stranded near Grafton, New South Wales. a. Note light lower jaw, white ear stripe, light anterior edge of flipper with fine transverse dark band near flipper base. b. Note light crescent extending onto the neck region and circular deep lesions on rostrum. Photographs a and b courtesy of Pet Porpoise Pool, Coffs Harbour, N.S.W. c. Four metre individual stranded near Yeppoon, Queensland. Note dark base and light leading edge of flipper, light narrow transverse band near base of flipper, and numerous deep circular to elliptical lesions. Photograph courtesy of M. Simmons, Queensland National Parks and Wildlife Service.

7a, 7b) were taken of the left side only.

The rostrum was slate grey, with a margin of light grey to white along the gum.

The lower jaw overlying the mandible was light grey, but there was no dark throat patch. The head appeared light grey in colour. The area around the eye was light grey, but merged posteriorly with a darker grey band running posteriorly towards the base of the flipper. There was no white shoulder patch. Dorsal to the flipper the side was light grey, with a thin dark grey streak running obliquely forward and ventrad from the back, dividing the light grey into two parts. The anterior of these continued dorsally to form a distinct light crescent on the back of the neck (Fig. 7b). There was a dark streak, apparently level with the ear, which merged posteriad with a white stripe. This stripe ran dorsally, increasing in width, and merged with the anterior light grey patch above the flipper (Fig. 7a).

The flipper was light grey to white along the anterior edge, but was darker grey over most of the upper surface. A small oval patch of light grey to white extended onto the upper surface of the flipper base from the axilla. A fine dark line crossed the flipper at its base, gently curving outwards toward the tip of the flipper (Fig. 7a). A similar thin dark line continued across the light grey of the side towards the dark grey back. The underside of the flukes were white, except for a thin dusky margin.

Unpublished photos of a dark shoulder minke whale stranded on Kangaroo Island, South Australia (record in Ling and Aitken, 1981; 35°50′ S) also show the distinctly light grey to white leading edge of the flipper but with an otherwise dark upper surface (there appeared to be some white at the axilla as well, but no transverse band was seen). The thorax was light grey with two dark grey bands originating at the axilla and running upwards toward the back, becoming somewhat wider dorsally.

An animal stranded at Yeppoon (23°08′ S) had a light grey flipper, in which the anterior margin and most of the tip appeared lighter, almost white. The base of the flipper was much darker, contrasting sharply with the flipper itself. The two grades of grey were separated by a thin white line, the central portion of which curved sharply outwards toward the tip of the flipper (Fig. 7c). This white line occurred on both flippers.

Skeleton

The anterior margin of the nasal bones in skulls from Queensland and South Australia were flattened or concave; the nasals in the Queensland specimen definitely lacked an inferior elliptical groove. The South Australian skull definitely had the parietals excluded from the vertex. The parietals also seemed to be excluded from the vertex of the specimen from Queensland, however it was difficult to interpret the formation of the vertex due to a strong supraoccipital crest overhanging the peak.

The posterior margin of the palatines was curved and the hamular processes of the pterygoid bones were short and stout in the South Australian specimen. The hamular processes appeared to be stout in the Queensland specimen as well, but both pterygoids were damaged.

Finally, the nasals, premaxillaries and maxillaries all appeared at about the same level in both the skulls. This was obvious even in the South Australian skull, from a young animal only 3.3 m long.

Other features

A conspicuous feature of the southern hemisphere dark shoulder minke whales stranded near Coff's Harbour and Yeppoon was numerous circular to oval lesions, in which plugs of blubber were missing. At least 26 open lesions were present in a photograph of the one side of the Coff's Harbour animal. Over thirty open lesions were counted in photos of the Yeppoon animal.

Distribution

Animals from Tasmania reported by Davies and Guiler (1958) and Guiler (1978) are tentatively considered the dark shoulder form, but insufficient information was given to allow positive identification.

The smallest animals were recorded from Tasmania and Victoria, based on the reports in Davies and Guiler (1958) and Wakefield (1967). Estimated lengths of these animals were 2.2 m and 6–7 ft (1.8–2.1 m) respectively.

With the exception of a neonate (or late fetus) stranded in Tasmania (42°50′ S), probably in May, all records of dark shoulder minke whales from southeastern Australia and the central Queensland coast are from August to October. The most northerly record of a dark shoulder minke whale was the animal stranded near Yeppoon (23°08′ S); it stranded around August 11, 1983 while a dwarf minke whale was found nearby in the last week of August 1983. Sight records from southern Queensland (27°24′ S) of unidentified forms of minke whale were in June and July.

Records of the dark shoulder form are based on strandings and thus give no information on distribution of the animals offshore.

DISCUSSION

Colour pattern

Our material of the southern hemisphere dark shoulder minke whale confirms features such as the light grey to white lower jaw and absence of throat patch, which have been described previously. The white line behind the eye, noted in the Coff's Harbour specimen, is similar to that reported by Kasuya and Ichihara (1965). However, in their figure and in photographs of dark shoulder minke whales from the Antarctic which we have seen, the line was curved ventrally toward the flipper rather than dorsally as in the Australian specimen. The alternating light and dark grey of the body above the flippers and the dorsal extension of light pigment onto the back as a crescent agrees with previous descriptions of this form.

The specimens from Yeppoon and northern New South Wales both had a thin transverse band on the flipper, although one was dark and the other light coloured. The light coloured band separated a dark grey base from the lighter flipper. Both forms would fit Doroshenko's (1979) flipper type 2, which he reported from 75.2% of specimens taken in the New Zealand sector of the Antarctic. van Beek and van Biesen (1982) found that the differences in banding of the flipper between areas reported by Doroshenko were statistically significant but noted that his categories did not encompass the full variation in colour pattern reported from the Antarctic. Best (1985) documented asymmetry of colour pattern, in which on one side, the flipper was banded while on the other it was not. He found that bands occurred more frequently on the left side. The animal from Coff's Harbour, N.S.W. was only photographed from the left side, but the Yeppoon specimen was photographed from both sides and had bands on both flippers.

Skeleton

Observations of Australian material generally confirms previous reports based on specimens from the Antarctic (e.g. Omura, 1975). The frontals appeared to be proportionately more exposed in the skull of an immature dark shoulder minke whale (J2 1708), when compared with the larger skulls of this form illustrated by Omura (1975) and Omura and Kasuya (1976). However, there was no triangular region of parietal and frontal bone separating the nasals from the supraoccipital. In the South Australian skull, from an immature animal, the nasals, premaxillaries and maxillaries were at the same level as illustrated for Antarctic specimens by Omura (1975). Thus, although telescoping of the skull may be less developed in juveniles (see Miller, 1923), the differences noted between the southern hemisphere dark shoulder minke whale and other forms can not be simply attributed to differences in the ages of the specimens examined.

Other features

Shevchenko (1977) has used frequency of 'white scars' to separate stocks of sei whales from the southeast Atlantic and Indian Oceans. Such lesions have been for a long time associated with movement of baleen whales into tropical waters and have been attributed either to a deep-water squaloid shark, *Isistius* (Jones, 1971) or to shedding of parasitic copepods of the family Penellidae (Ivashin and Golubovsky, 1978). Neither the dwarf minke whales nor the dark shoulder minke whales which we have seen have the intensity of scars shown for sei whales by Shevchenko, although the few specimens of dark shoulder minke whales seem to be the more heavily scarred (Note, however, what appear to be numerous scars on the specimen of dwarf minke whale from New Caledonia figured by Laboute and Magnier (1979) and obvious lesions on Marion reef specimen in Rockman (1986a,b)). Shevchenko

(1977) suggested that intensity of scarring might be used to separate stocks of baleen whales from the east Indian Ocean and Tasman Sea. More material is needed to assess its use for minke whales.

Distribution

The few records of the dark shoulder form in Table 1 do not adequately reflect its distribution. Published records of minke whales from southern Australia usually contained inadequate information to identify the form or sometimes even the species. We have been unable, except in a few cases, to examine the skeletal material in Australian museums and have had to rely on photographs of animals and skulls (or even photocopies of these). It has been impossible to identify some of these records positively and they were not included in Table 1. A detailed examination of skeletal material in Australian museums would provide useful information on the distribution of minke whales, especially around the southern half of the continent and off Tasmania.

STATUS OF THE DWARF MINKE WHALE

Wada (1983) analyzed electrophoretic patterns of North Pacific, Antarctic and Brazilian southern hemisphere dark shoulder minke whales and one dwarf minke whale from South Africa. He suggested an uniformity of the southern hemisphere forms, which were considered to differ subspecifically from the North Pacific animals. His conclusions regarding the dwarf minke whale must be considered tentative given the single sample available.

Moreover, there are a range of osteological, morphometric and pigmentation differences between the dwarf minke whale and the southern hemisphere dark shoulder form. Some of these features (e.g. skull breadth, length of rostrum, profile of skull) are age dependent and must be compared between animals of similar size. Other features such as length of mouth and number of baleen plates appear to be inter-related and may be variable irrespective of age. Features such as size and form of baleen plates may be subject to short-term selection, possibly associated with diet. In this respect, Best (1977) has documented two forms of Bryde's whale which have different forms of baleen, different distributions off the South African coast, and different diets.

The differences in morphometrics and osteology which remain when comparing the two southern hemisphere forms of similar size are still impressive. Our examination of skulls of young dark shoulder minke whales (previously described on the basis of skulls from large animals) and morphometrics and the skull of a sexually mature dwarf minke whale (in which morphometrics were previously based on immature animals and osteology was previously undocumented) helps resolve problems of comparing forms of widely different sizes and thus ages. Some of the previously reported differences in the dwarf minke whale have been confirmed while we have been able to document further differences. There are also differences in size at reproductive maturity (Best, 1985, Marsh, 1985) and apparently in distribution (see Dwarf minke whale Discussion: geographical range) between the two southern hemisphere forms.

Differences in colour pattern between the two southern hemisphere forms further support a degree of genetic isolation. Although many variants in colour pattern have been described for the dark shoulder form (e.g. Doroshenko, 1979; Wada and Numachi, 1979), none approaches the flipper and shoulder colouration of the dwarf form. Throughout its wide range, the dwarf minke whale appears to have a remarkably consistent colour pattern. The lack of intermediates, despite known areas of overlap with the dark shoulder form in South Africa, Australia, and New Zealand, argues for a greater degree of genetic isolation than suggested by Wada (1983). A similar argument was used by Kasuya (1978) for genetic isolation between colour forms of Dall's porpoise in the North Pacific. However, unlike the Dall's porpoise (Kasuya, 1978), the dwarf minke whale appears to be separated from the southern hemisphere dark shoulder form by characters other than colour pattern, e.g. morphometrics, skull characters and size at reproductive maturity. In this respect, it is closer to the apparently isolated population of Commerson's dolphin, *Cephalorhynchus commersonii*, from the Kerguelin Islands which shows a range of character differences from the main South American population (Robineau and de Buffrenil (1985), in addition to retention of juvenile pigment pattern (Leatherwood and Cornell, 1985)).

Present data on skeleton and morphometrics strongly suggest a closer affinity of the dwarf minke whale with either of the northern hemisphere forms than with the southern hemisphere dark shoulder form. Omura (1975: fig. 14) identified 17 characters differentiating the geographical "populations" of minke whale. Three of these (dorsal view of rostrum, profile of skull, pelvic bone shape) we consider difficult to evaluate or too variable, while one (flipper colour) is unique to the dwarf minke whale. Of the remaining 13 characters, 11 differed between the two southern hemisphere forms but were shared between the dwarf minke and at least one of the northern hemisphere "populations". Of the two characters shared by the two southern hemisphere forms, only one (position of bones in vertex) was not also shared with one of the northern hemisphere forms. Moreover, that feature may be variable, especially with age. There appears to be sufficient grounds to recognize the two southern hemisphere forms as taxonomic entities, at least as subspecies. If the relative resemblances of the dwarf minke with the northern hemisphere forms are supported by examination of more material and the differences between the two southern hemisphere forms are maintained, then it could be argued that the dark shoulder form deserves full specific status, in which case *Balaenoptera bonaerensis* would have priority. Final resolution of these questions will require examination of more material from all oceans. However, it is easy to separate the two southern hemisphere forms on the following combination of features:

External morphology

Lower jaw overlying mandible grey, extending over ventral grooves as a dark throat patch; base of flipper white; thorax around flipper white, containing a dark patch (flipper oval, Fig. 1) and bordered dorsally by a triangular light grey shoulder blaze which may run obliquely anteriad onto the back; light grey flank patch extending past dorsal fin and containing an extension of white from the underside of the tail stock (peduncle patch, Fig. 1a); living animals with light grey on upper surface of rostrum and head; baleen plates predominantly light, with black at most as narrow band along lateral margin, except for most posterior plates which may be almost entirely black; dorsal fin well forward (69.6–71.5% total length to tip of fin), tall (4.8–5.6% total length) and long at base (8.3–8.4% total length)......dwarf or diminutive form

Lower jaw light grey with no dark grey pigment over throat; flippers with single or two tones of grey, especially light along the leading edge but never white at base; thorax in region of flipper insertion light grey, extending as forwardly directed crescent onto the back; light flank patch extending high on sides just in front of the dorsal fin, without peduncle patch; living animals with dark grey upper surface of rostrum and head; baleen plates asymmetrically coloured with light plates occupying $\bar{x}$=34–37% and 12–16% of the length of right and left baleen plate series respectively in specimens from the Antarctic and South Africa; dorsal fin further posterior (72.9–76.1% total length of juveniles to tip of fin); low (3.0–4.2% total length of adults) and short at base (3.7–7.7% total length of adults; Best, 1985) .... dark shoulder form

Skull

Anterior of nasal bones convex, with inferior elliptical groove; parietals incorporated into vertex with angulato-ovate inter-parietal; ascending processes of maxillary may extend posteriad to level of nasals and premaxillaries in juvenile specimens but are at about same level in mature specimens; posterior of palatine bones angulate; hamular process of pterygoid elongate (Fig. 5f) .... dwarf or diminutive form

Anterior of nasal bones straight or concave, extending forward laterally and with no inferior elliptical groove; parietals and inter-parietal excluded from vertex; posterior borders of ascending processes of maxillary, nasals and premaxillaries at about same level in both juvenile and mature specimens; posterior of palatine bones smoothly curving; hamular process of pterygoid bones stout (Omura, 1975; Fig. 5) .... dark shoulder form

ACKNOWLEDGEMENTS

We would like to thank the many volunteers who helped with the observations on and subsequent necropsy of the Hook Reef specimen, especially W.H.

Dawbin, W. Dowd, H. Goodall, V. Harriot, G. Kelly, R. Speares, T. Walker, L. Winsor, L. Zell and the pilots of Air Whitsunday. Information, often unpublished, on various forms of minke whales was provided by the late P. Aitken, J. Bannister, P. Best, M. Bryden, W.H. Dawbin, J. Dixon, D. Gaskin, W. Gladstone, H. Goodall, F. Kasamatsu, J. Ling, T. Miyashita, R. Molnar, G. Oke, M. Simmons, J. Stern, S. van Dyke, D. Wall and M. Waugh. We thank staff of the South Australian and Queensland Museums, especially S. van Dyke, for arranging to draw and or photograph skulls of minke whales in their collections. T. Kasuya and N. Miyazaki arranged for measurements of skulls to be taken at the National Science Museum, Tokyo by Marsh.

Field expenses incurred in the observation and necropsy of the Hook Reef specimen were partially covered by funds from the Great Barrier Reef Marine Park Authority to Marsh. We also thank the Great Barrier Reef Marine Park Authority for permission to publish several photographs taken by their staff.

We thank the James Cook University Photographic Section, and especially R. Yeldham and B. Pump, for efficient, speedy preparation of photographs used in the plates.

Finally we thank the two anonymous referees for their exceptionally careful reviews.

REFERENCES

Allen, G.M., 1916. The whalebone whales of New England. *Mem. Boston Soc. nat. Hist.*, 8: 107–322, 9 plates.

Anon., 1985. Report of the sub-committee on southern hemisphere minke whales. *Rep. int. Whal. Commn*, 35: 75–89.

Baker, A.N., 1983. *Whales and dolphins of New Zealand and Australia*. Victoria University Press. Wellington, N.Z. 133 pp.

Best, P.B., 1977. Two allopatric forms of Bryde's whales off South Africa. *Rep. int. Whal. Commn*, (special issue 1): 10–38.

Best, P.B., 1982. Seasonal abundance, feeding, reproduction, age and growth in minke whales off Durban (with incidental observations from the Antarctic). *Rep. int. Whal. Commn*, 32: 759–786.

Best, P.B., 1985. External characters of southern minke whales and the existence of a diminutive form. *Sci. Rep. Whales Res. Inst.*, 36: 1–33.

Brandon, D.E., 1973. Waters of the Great Barrier Reef Province. pp. 187–232. *In*: O. Jones and R. Endean (eds) *Biology and Geology of Coral Reefs*. Vol. 1. Academic Press, London.

Carte, A. and A. MacAlister, 1868. On the anatomy of *Balaenoptera rostrata*. *Phil. Trans. R. Soc. London*, 158: 201–261, 7 pl.

Cowan, I. McT., 1939. The sharp-headed finner whale of the eastern Pacific. *J. Mamm.*, 20: 215–225.

Davies, J.L. and E.R. Guiler, 1958. A newborn piked whale in Tasmania. *J. Mamm.*, 39: 593–594.

Deranyigala, P.E.P., 1948. Some Mystaceti (sic) whales from Ceylon. *Spolia Zeylanica*, 25: 61–63.

Deranyigala, P.E.P., 1960. Some southern temperate zone snakes, birds and whales that enter the Ceylon area. *Spolia Zeylanica*, 29: 79–85.

Deranyigala, P.E.P., 1963. Mass mortality of the new subspecies of little piked whale *Balaenoptera acutorostrata thalmaha* from Ceylon. *Spolia Zeylanica*, 30: 79–84, pl. 1.

Doroshenko, N.V., 1979. Populations of minke whales in the southern hemisphere. *Rep. int. Whal. Commn*, 29: 361–364.

FLOWER, W.H., 1864. Notes on the skeletons of whales in the principal museums of Holland and Belgium, with descriptions of two species apparently new to science. *Proc. zool. Soc. London*, 32: 384–420.

GASKIN, D.E., 1976. The evolution, zoogeography and ecology of Cetacea. *Oceanogr. Mar. Biol. Ann. Rev.*, 14: 247–346.

GLADSTONE, W., 1984. Meeting minke whales. *Geo*, 6: 80–81.

GUILER, E.R., 1978. Whale strandings in Tasmania since 1945 with notes on some seal reports. *Pap. Proc. R. Soc. Tasmania*, 112: 189–213.

HARRISON, J., 1974. *An introduction to mammals of Singapore and Malaya.* Malayan Nature Soc., Singapore Branch. xi + 430 pp.

HERRE, A.W., 1925. A Philippine rorqual. *Science*, 61: 541.

IVASHIN, M.V. and YU GOLUBOVSKY, 1978. On the cause of appearance of white scars on the body of whales. *Rep. int. Whal. Commn*, 28: 199.

JONES, E., 1971. *Isistius brasiliensis*, a squaloid shark, the probable cause of crater wounds on fishes and small cetaceans. *Fishery Bull.*, 69: 791–798.

JONSGÅRD, A., 1951. Studies on the little piked whale or minke whale. *Norsk Hvalfangst-Tidende*, 5: 209–230.

JUNGE, G.C.A., 1950. On a specimen of the rare fin whale *Balaenoptera edeni* Anderson, stranded on Pulu Sugi near Singapore. *Zool. verhand. Leiden*, 9: 1–26, 9 pl.

KASUYA, T., 1978. The life history of Dall's porpoise with special reference to the stocks off the Pacific coast of Japan. *Sci. Rep. Whales Res. Inst.*, 30: 1–64.

KASUYA, T. and T. ICHIHARA, 1965. Some information on minke whales from the Antarctic. *Sci. Rep. Whales Res. Inst.*, 19: 37–43.

LABOUTE, P. and Y. MAGNIER, 1979. *Underwater guide to New Caledonia.* Editions du Pacifique, Papeete. 160 pp.

LEATHERWOOD, S. and L. CORNELL, 1985. Birth of a dolphin. Success at Sea World. *Oceans*, 18: 46–49.

LEATHERWOOD, S., R. REEVES, W.F. PERRIN and W.E. EVANS, 1982. Whales, dolphins and porpoises of the eastern North Pacific and adjacent Arctic waters: a guide to their identification. *NOAA Tech. Rep. NMFC Circ.* 444. 244 pp.

LEKAGUL, B. and J.A. MCNEELY, 1977. *Mammals of Thailand.* Sahakarnbhat, Bangkok. li + 758 pp.

LILLIE, D.G., 1910. Cetacea. *Nat. Hist. Sci. Rep. Brit. Antarctic (Terra Nova) Exped., Zool.*, 1: 85–123.

LING, J.K. and P.F. AITKEN, 1981. *Marine mammals in South Australia.*(Extract from *South Australia Yearbook, 1981.* Adelaide. 10 pp.)

MARSH, H., 1985. Observations on the ovaries of an isolated minke whale: evidence for spontaneous sterile ovulation and structure of the resultant corpus. *Sci. Rep. Whales Res. Inst.*, 36: 35–39.

M'INTOSH, W.C., 1917. On the skeleton of an adult female small finner or piked whale (*Balaenoptera acutorostrata* Lacépède). *J. zool. Res.*, 2: 39–73, 5 pl.

MILLER, G.S., 1923. The telescoping of the cetacean skull. *Smithson. Misc. Coll.*, 76: 1–71.

MÖRZER-BRUYNS, W.F.J., 1971. *Field guide of whales and dolphins.* Uitgeverij tor/n.v. uitgeverij v/h c. a. mees, Amsterdam. 258 pp.

NORRIS, K., 1961. Standardized methods for measuring and recording data on the smaller cetaceans. *J. Mamm.*, 42: 471–476.

NORRIS, K. and J. PRESCOTT, 1961. Observations on Pacific cetaceans of Californian and Mexican waters. *Univ. Calif. Publ. Zool.*, 63: 291–402, pl. 27–41.

OHSUMI, MASAKI and KAWAMURA, 1970. Stock of the Antarctic minke whale. *Sci. Rep. Whales Res. Inst.*, 22: 45–62.

OMURA, H., 1957. Osteological study of the little piked whale from the coast of Japan. *Sci. Rep. Whales Res. Inst.*, 12: 1–21.

OMURA, H., 1975. Osteological study of the minke whale from the Antarctic. *Sci. Rep. Whales Res. Inst.*, 27: 1–36.

OMURA, H. and K. FUJINO, 1954. Sei whales in the adjacent waters of Japan. II. Further studies on the external characters. *Sci. Rep. Whales Res. Inst.*, 9: 89–103.

OMURA, H. and T. KASUYA, 1976. Additional information on skeleton of the minke whale from the Antarctic. *Sci. Rep. Whales Res. Inst.*, 28: 57–68.

OMURA, H. and H. SAKIURA, 1956. Studies on the little piked whale from the coast of Japan. *Sci. Rep. Whales Res. Inst.*, 11: 1–37.

ROBERTS, T.F., 1978. *Gazeteer of named reefs of the Great Barrier Reef.* Great Barrier Reef Committee, Brisbane. 18 pp.

ROBINEAU, D. and V. DE BUFFRENIL, 1985. Osteological and osteometric data on Commerson's dolphin, *Cephalorhynchus commersonii* (Lacépède 1804), with particular reference to those of the Kerguelin Islands. *Mammalia*, 49: 109–123 (in French).

ROCKMAN, I., 1986a. Diving with mincke (sic) whales. *Skin diving in Australia and the South Pacific*, 16: 64–67.

ROCKMAN, I., 1986b. Diving with mincke (sic) whales. *Habitat*, 14: 16–17.

SATAKE, Y. and H. OMURA, 1974. A taxonomic study of the minke whale in Antarctic by means of hyoid bone. *Sci. Rep. Whales Res. Inst.*, 26: 15–24.

SERGEANT, D.E., 1963. Minke whales, *Balaenoptera acutorostrata* Lacépède, of the western North Atlantic. *J. Fish. Res. Bd Canada*, 20: 1489–1504.

SHEVCHENKO, V.I., 1977. Application of white scars to the study of the location and migrations of sei whale populations in area III of the Antarctic. *Rep. int. Whal. Commn*, (special issue 1): 130–134.

SINGARAJAH, K.V., 1984. Observations on the occurrence and behaviour of minke whales off the coast of Brazil. *Sci. Rep. Whales Res. Inst.*, 35: 17–38.

STEARN, W., 1973. *Botanical Latin.* David and Charles. Newton Abbot. iv + 566 pp.

STEWART, B.S. and S. LEATHERWOOD, 1985. Minke whale. pp. 91–136. *In*: S. Ridgway and R. Harrison (eds). *Handbook of marine mammals. Vol. 3. Sirenians and baleen whales.* Academic Press, Sydney. 362 pp.

TAYLOR, R.J.F., 1957. An unusual record of three species of whale being restricted to pools in Antarctic sea-ice. *Proc. zool. Soc. London*, 129: 325–331, 7 pl.

TOMILIN, A.G., 1967. *Cetacea. Mammals of the U.S.S.R. and adjacent countries.* (Israel Program for Scientific Translation of 1957, *Zveri SSR i Prilezhaschohikh Stran*) 9: xxi + 717 pp.

TRUE, F.W., 1904. The whalebone whales of the western North Atlantic compared with those occurring in European waters, with some observations on the species of the north Pacific *Smithson. Contrib. Knowledge*, 33: 1–332.

TURNER, W., 1892. The lesser rorqual (*Balaenoptera rostrata*) in the Scottish seas, with observations on its anatomy. *Proc. R. Soc. Edinburgh*, 17: 36–75.

VAN BEEK, J.E. and J.B. VAN BIESEN, 1982. A review of the morphological and biochemical research on population identification of southern minke whales. *Rep. int. whal. Commn*, 32: 753–758.

WADA, S., 1983. Genetic structure and taxonomic status of minke whales in the coastal waters of Japan. *Rep. int. Whal. Commn*, 33: 361–363.

WADA, S. and K. NUMACHI, 1979. External and biochemical characters as an approach to stock identification for the Antarctic minke whale. *Rep. int. Whal. Commn*, 29: 421–432.

WAKEFIELD, N., 1967. Whales and dolphins recorded for Victoria. *Victorian Naturalist*, 84: 273–281.

WATSON, L., 1981. *Sea guide to whales of the world.* Hutchinson and Co. Publ., Sydney. 302 pp.

WILLIAMSON, G.R., 1973. Counting and measuring baleen and ventral grooves of whales. *Sci. Rep. Whales Res. Inst.*, 25: 279–292.

DENSITY DEPENDENT CHANGES IN GROWTH PARAMETERS OF THE SOUTHERN MINKE WHALE*

HIDEHIRO KATO**

ABSTRACT

Changes in growth parameters with time were examined for the southern hemisphere minke whales, using materials collected by Japanese Antarctic whaling expeditions in Areas III (0° ~ 70°E) and IV (70° ~ 130°E) during seasons from 1971/72 to 1982/83. Mean age at sexual maturity (50% maturation) for both sexes estimated from the transition phase in earplug declined from 12~13 years in the 1940s year-classes to 7~8 years in those of late 1960s to early 1970s, and the female trend agreed with the decline in mean age of females having a corpus luteum of first ovulation, but the mean body length of first ovulation remained constant around 27.5 ft (8.4 m) in all year-classes and in year of capture. Both analyses of growth curve and epiphyseal fusion of vertebrae suggested an increase in the growth rate and body length at attainment of physical maturity in recent year-classes, while it was not enough to examine changes in age at the attainment of physical maturity. These changes are thought to have resulted from the decline of possible competitative whale stocks such as blue and fin whales.

INTRODUCTION

Census data indicate that the populations of some penguins (Sladen, 1964) and pinnipeds (Laws, 1973; Payne, 1977) in the Antarctic had increased during 1940s to 1970s. Laws (1977a, b) considered these increases attributable to the decline of the populations of ecological competitors such as blue whale *Balaenoptera musculus* (Linnaeus, 1758), and fin whale, *B. physalus* (Linnaeus, 1758). The southern minke whales, *B. acutorostrata* (Lacèpéde, 1804), also share their habitat and food resources with the above whales, so they may have received same kind of similar or stronger influence from the changes.

Decline of minke whale age at sexual maturity from 14 years in the 1940s year-classes to 6 years in late 1960s year classes was suggested by the analysis of transition phase in earplugs (Masaki, 1979; Best, 1982; Kato, 1983a). And

---

* *An earlier version of this report was presented to the Scientific Committee of the International Whaling Commission in 1985 and 1986 as documents SC/37/Mi13 and SC/38/Mi15, respectively, and constitutes some sections of Ph D thesis submitted to Hokkaido University.*

** *Whales Research Institute, 3-32-11, Ohjima, Koto-ku, Tokyo 136, Japan.*

Sci. Rep. Whales Res. Inst.,
No. 38, 1987, 47–73

this was once considered indicating increase in minke whale population prior to the start of full exploitation in 1971/72 (International Whaling Commission (IWC), 1979).

Recently, however, Cooke and de la Mare (1983) expressed a doubt on the validity of transition phase analyses which had been adopted for several large whale stocks, and suggested that the apparent decline of age at sexual maturity could be the result of ageing errors and possible data handling biases such as truncated sampling problems. Since then, no general concensus has been obtained on this subject among the Scientific Committee of IWC in spite of many studies in this field (IWC, 1985).

Truncated samples will most seriously exaggerate the estimation of yearly trends of decline in age at sexual maturity (IWC, 1985). Kato (1983a) has solved this problem by excluding data possibly under the effect of the truncation bias. The present study compares annual changes in the age at sexual maturity suggested by his method with other changes in several parameters related to the growth of minke whales.

MATERIALS AND METHODS

Materials in this study were collected from minke whales taken by Japanese Antarctic whaling expeditions in 1971/72 to 1982/83 of austral summers in the waters south of 60°S to ice edge zone. To increase sample size, data from Areas III (0° to 70°E) and IV (70° to 130°E) were combined. Number of catches by the Japanese fleets by sex, whaling season and area is given in Table 1. Individual age was determined using growth layers in earplug, and assuming annual deposition of the layer (a pair of light and dark laminae to be formed annually--Best, 1982; Kato and Best, unpublished). Growth layers were counted with stereoscopic microscope ($6 \sim 10 \times$) by myself (for samples after 1978/79 season), or by Drs Yasuhiko Masaki and Seiji Ohsumi (before 1977/78 season). No systematic ageing error was detected among those three readers (IWC, 1984a).

Age and length at sexual maturity

Following parameters were calculated for each year-class group and year of capture using samples shown in Table 2.

L_{mov}: Mean body length of females soon after the attainment of sexual maturity (first ovulation), identified by the presence of a corpus luteum (CL) and no corpus albicans (CA) in the ovaries.

$L_{m50\%}$: Body length where 50% of females are sexually mature, using presence of corpus luteum or albicans in the ovaries as the indicator of sexual maturity. This length was calculated by fitting logtistic curve (weighted by sample size) to the proportion of sexually mature females at each length. If the Chi-square (goodness of fit) of the logistic curve to the observed values was low ($p > 0.95$), the $L_{m50\%}$ was not estimated. Although

TABLE 1. NUMBER OF CATCHES OF THE SOUTHERN MINKE WHALES BY THE JAPANESES FLEETS BY SEX, WHALING SEASON AREAS. DATA FROM INTERNATIONAL WHALING STATISTIS

Whaling season	Area III		Area IV		Whole Antactic*	
	Male	Female	Male	Female	Male	Female
1971/71	170	184	930	1,728	1,100	1,912
1972/73	–	–	1,116	975	1,116	975
1973/74	320	1,174	761	1,282	1,116	2,597
1974/75	554	805	430	410	1,247	2,252
1975/76	417	604	198	237	1,464	1,553
1976/77	446	939	521	429	1,678	2,272
1977/78	398	614	128	353	1,012	1,388
1978/79	642	958	386	573	1,097	1,635
1979/80	521	732	1,048	482	1,952	1,327
1980/81	327	292	529	664	1,472	1,647
1981/82	188	71	582	1,043	1,578	1,999
1982/83	–	–	530	490	1,083	2,140
Total	3,983	6,373	7,159	8,666	15,915	21,697

*) including Areas I (60°-120°W), II (60°W-0°), V (130°E-170°W) and IV (170°-120°W) as well as Areas III (0°-70°E) and IV (70°-130°E) where the present study has been done.

TABLE 2. NUMBER OF SAMPLES USED FOR ANALYSES OF AGE AND BODY LENGTH AT SEXUAL MATURITY

Parameter*	Data grouping	Number of samples examined		
		Male	Female	Total
L_{mov}	Year of capture	–	512	512
	Year-class	–	222	222
$L_{m50\%}$	Year of capture	–	12,332	12,332
t_{mov}	Year of capture	–	222	222
$t_{m50\%}$	Year of capture	–	6,872	6,872
	Year-class	–	6,872	6,872
t_{mp}	Year-class	1,121	1,721	2,842
	Year of maturation	1,538	2,272	3,810

*) L_{mov}, mean body length of females having CL of the first ovulation.
$L_{m50\%}$, body length at 50% sexual maturity.
t_{mov}, mean age of females having CL of the first ovulation.
$t_{m50\%}$, age at 50% sexual maturity.
t_{mp}, mean age at sexual maturity estimated from transition phase in earplug (both sexes).

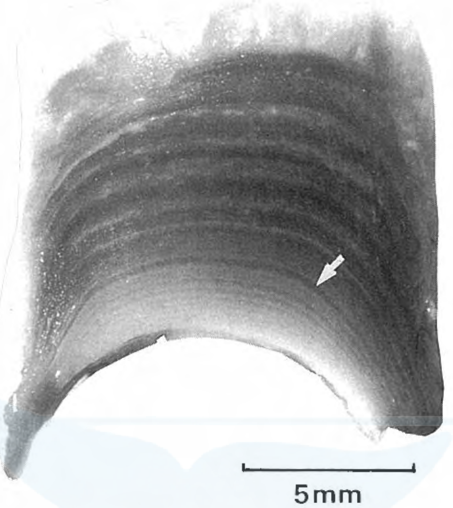


Fig. 1. Earplug core of southern minke whale, bisected to expose growth layers (a pair of light and dark laminae constitutes one growth layer). Arrow shows transition phase which is formed at the attainment of sexual maturity.

male minke whales in the Antarctic fishing ground are believed to mature at testis weight of 400g at heavier side (Ohsumi, Masaki and Kawamura, 1970; Ohsumi and Masaki, 1975; Masaki, 1979; Kato, 1982), this figure may underestimate mean testis weight at maturation for the population because mature males are more likely to come to the fishing ground than immature individuals of the same testis weight (Best, 1982; Kato, unpublished). Thus use of this maturity criterion will mislead the minke whale growth. Therefore this parameter was not estimated for males.

t_{mov}: Mean age of females having CL of the first ovulation, defined as item of L_{mov} above.

$t_{m50\%}$: Age where 50% of females are sexually mature defined as item of L_{mov} above.

t_{mp}: Mean age at sexual maturity estimated for both sexes using transition phase in the earplug (Fig. 1) as an indicator of sexual maturity (Lockyer, 1972; Kato, 1983b; Ohsumi, 1986a). In order to avoid trucated sampling problems, individuals of the following age ranges were selected for this analysis using criteria of Kato (1985), which principally selects ages (at capture) older than expected oldest immature individuals in each year-class.

Year-classes before 1951; used all individuals (> 20 years)
1951–1955 year-class; over 19 years old at capture
(caught in 1971/72–82/83 seasons)

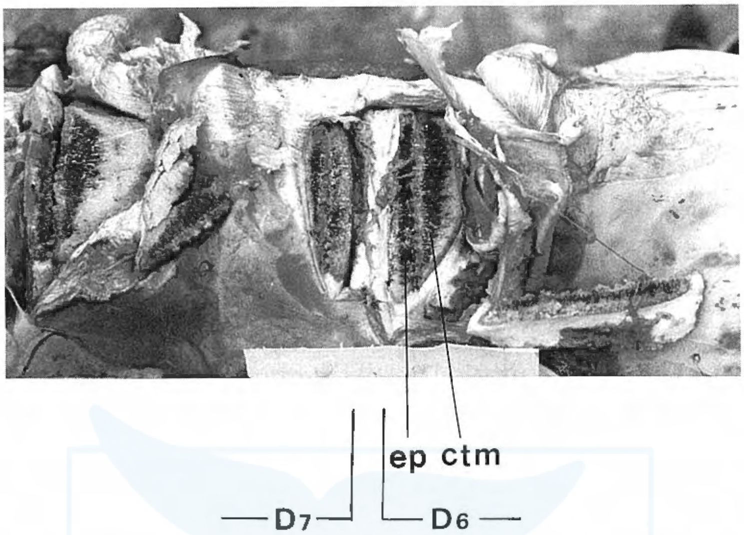


Fig. 2. The thoracic vertebrae of the southern minke whale, cut to expose boundary between the epiphysis (ep) and the centrum (ctm) at the 6th vertebra, ventral side.

1956–1960 year-class; over 15 years old at capture
(caught in 1972/73–82/83 seasons)
1961–1965 year-class; over 13 years old at capture
(caught in 1975/76–82/83 seasons)
1966–1970 year-class; over 12 years old at capture
(caught in 1979/80–82/83 seasons)

Growth curve

Apparent growth curves (mean body length on age at capture) were constructed for four year-class groups using each containing 10 year-classes. The total number of samples for this is 5,203 males and 6,998 females caught by Japanese fleets in 1971/72 to 1982/83 seasons.

Physical maturity

Materials were collected from 223 males and 356 females caught by Japanese whaling expeditions in 1978/79 and 1979/80 seasons. Only the 6th vertebral epiphyses and centrum of these individuals were cut with hand axe and observed with naked eyes for the presence of cartilage separating these bones (Fig. 2). The fusion of epiphyses to the centrum occurs lastly on the middle parts of thoratic (dorsal) vertebrae as in fin (Wheeler, 1930; Ohsumi, Nishiwaki and Hibiya, 1958) and minke whales (Kato, unpublished), and the southern minke whales have 11 to 12 thoracic vertebrae (Omura, 1975; Omura and Kasuya, 1976). The condition between epiphyses and centrum was initially classified into stages after Ohsumi, Nishiwaki and Hibiya (1958) and Laws (1961), then the absence of cartilage between the epiphyses and the centrum (stages *a* and *A* of Ohsumi *et al.* (1958) and *EJV* and *EJI* of Laws (1961)) was used as the indicator of physically mature individuals. Physically immature individuals of the present study therefore include stages *N* and *n* of Ohsumi *et al.* (1958) and *UTC* and *UFC* of Laws (1961). This study included data of limited number of whales examined by Dr P. B. Best (University of Pretoria, South Africa) on board *Nisshin Maru No. 3* in 1978/79 season.

Grouping of samples

Present analyses were done after grouping materials by year of capture, year-class, and year of maturation as defined below.

Year of capture: Used for L_{mov}, $L_{m50\%}$ and t_{mov}. Fishing season normally starts in November and closes in March of the next year.

Year-class (= year of birth): Year-classes were defined by;

Year-class = (starting year of the season) − (age at capture).

and used for L_{mov}, $t_{m50\%}$, t_{mp}, growth curve and physical maturity analyses. Both values of t_{mp} and $t_{m50\%}$ were calculated for each year-class, while L_{mov} and growth curve (as well as physical maturity) were analysed by combining year-classes of three and 10, respectively.

Year of maturation: Year of maturation of each individual was calculated as follows and used for t_{mp} analysis;

Year of maturation = (year of birth) + (age at transition phase)
= (starting year of the season) − (time after sexual maturity).

RESULTS

Age and body length at sexual maturity

1) Mean body length of females having CL of the first ovulation (L_{mov})

Since gestation of the minke whale lasts less than one year and the longevity of corpus luteum of ovulation must be shorter than this period (IWC, 1984b), females having a corpus luteum of pregnancy or ovulation (with no corpus albicans) were considered to have matured within one year.

Fig. 3 (left) shows body length distribution of recently matured females by year of capture. A mode existed at 27–28 ft (8.2–8.5 m), and L_{mov} ranged from 27.0 (8.2 m) to 28.0 ft (8.5 m) with no significant yearly trend ($0.1 < p < 0.2$, t-test of the regression coefficient of L_{mov} on year of capture).

Even when L_{mov} was analyzed by year-class group, the annual trend was also insignifiant ($0.2 < p < 0.3$; Fig. 3, right).

2) Body length at 50% sexual maturity ($L_{m50\%}$) for females

Fig. 4 shows $L_{m50\%}$ values as well as the relationships between sexual

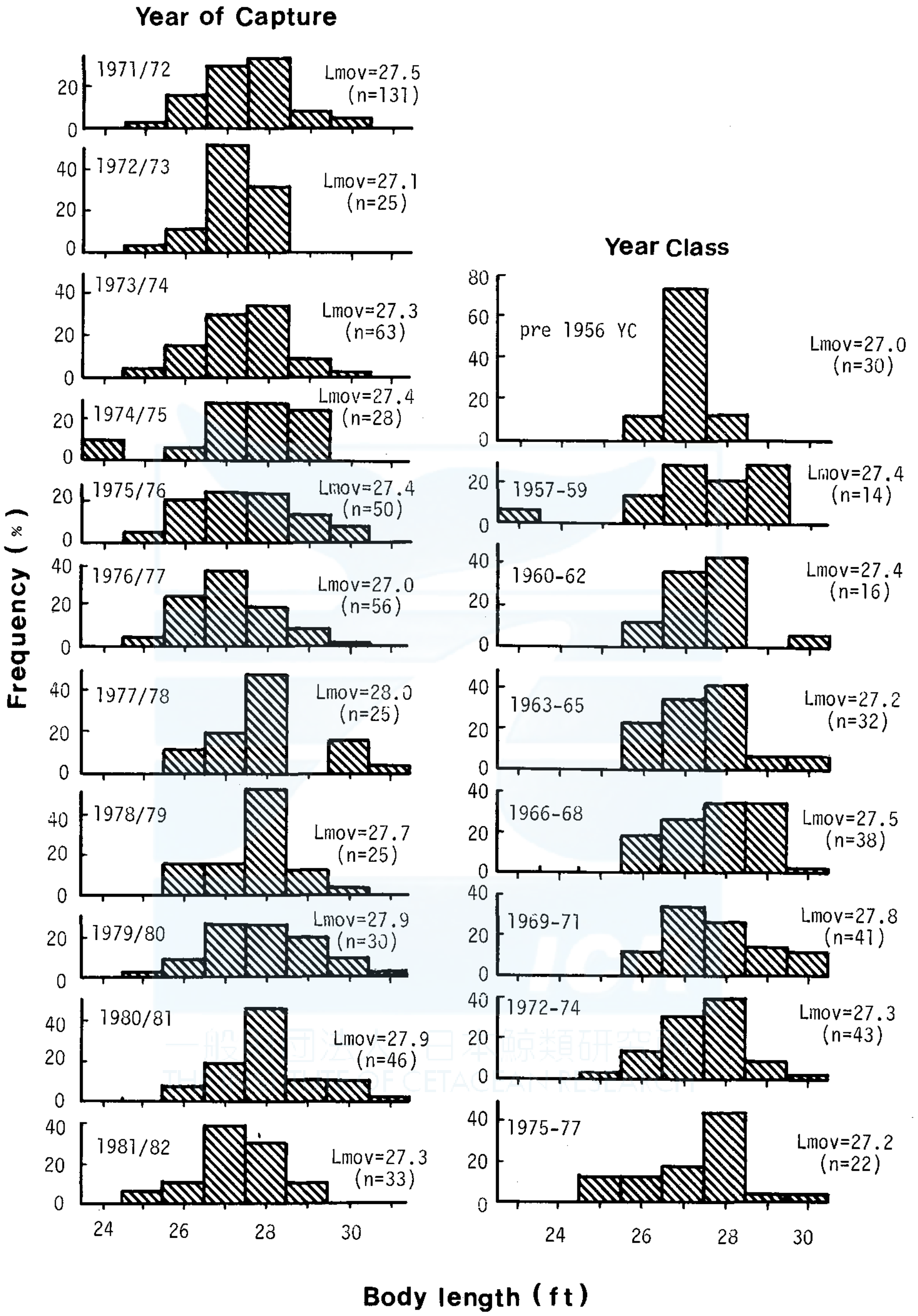


Fig. 3. Length distribution of females at the first ovulation having only one corpus letum and no corpora albicantia in the ovaries and *Lmov* for the southern minke whales in Areas III and IV. Grouped by year of capture (left) and year-class (right).

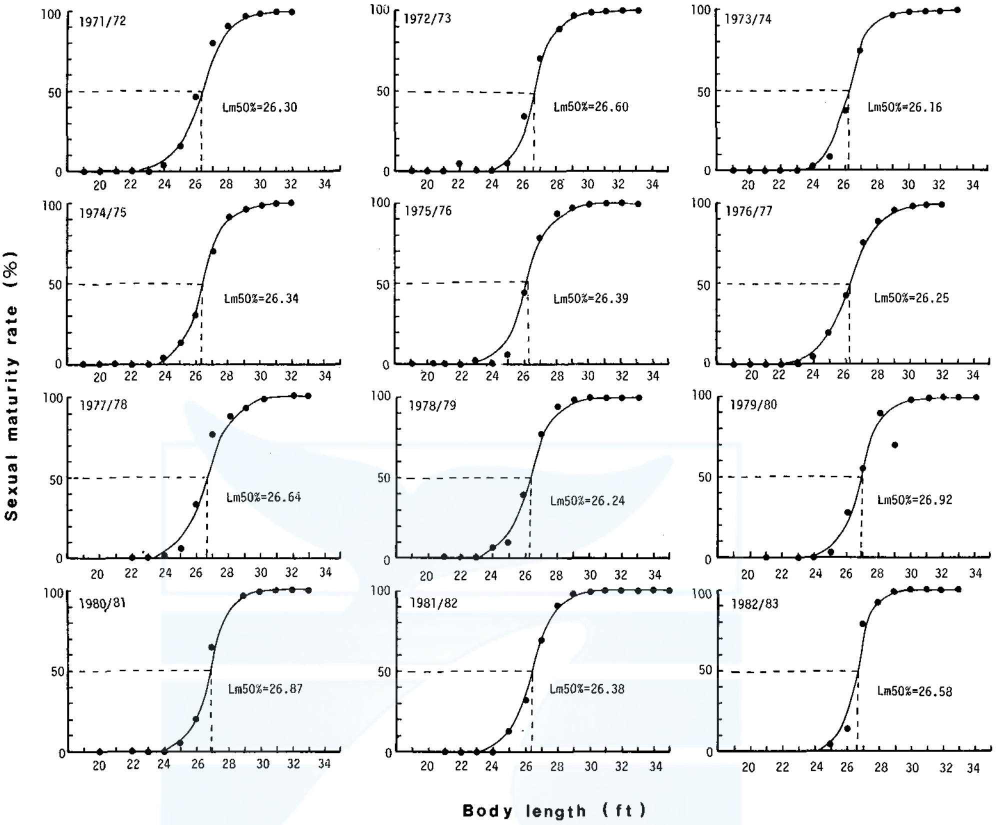


Fig. 4. Body length at 50% sexual maturity ($L_{m50\%}$) of the female southern minke whales collected in Areas III and IV, expressed for year of capture. Logistic curves are fitted by the least squares weighted by sample size.

maturity rate (proportion of sexually mature individuals in the sample) and body length analysed by the year of capture (1971/72 to 1982/83 seasons). The relationship was almost identical between seasons, and sexually mature individuals appeared at body length over 25 ft (7.6 m) and most of the individuals completed maturation below the length 28 ft (8.5m). $L_{m50\%}$ values were approximately at 26.5 ft (8.1 m), with no siginificant yearly trend ($0.1 < p < 0.2$, t-test of the regression coefficient of $L_{m50\%}$ on year of capture).

3) Mean age of females having CL of the first ovulation (t_{mov})

Fig. 5 shows distribution of age at the first ovulation (t_{mov}) by year of capture. The t_{mov} values have decreased from about 9 years in early 1970's

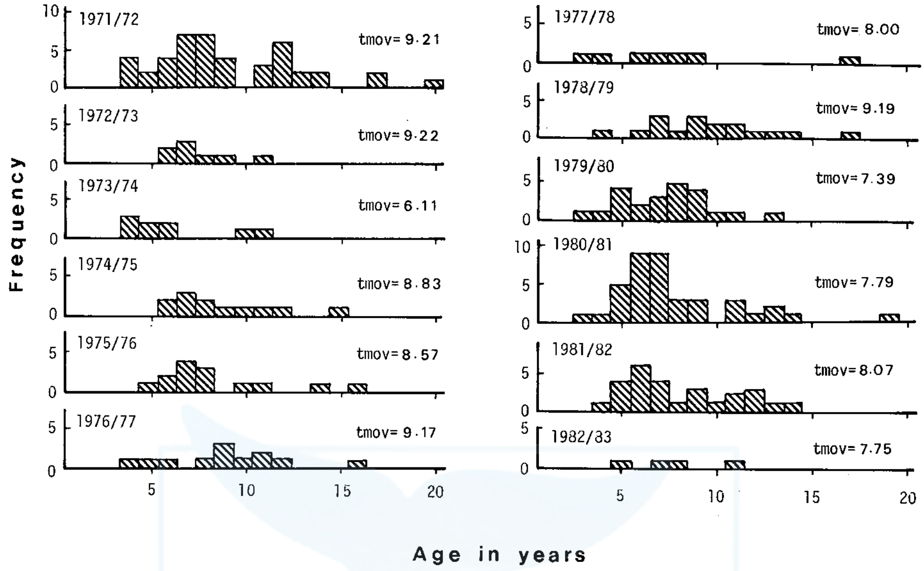


Fig. 5. Age distributions of females having only one corpus luteum and no CA in ovaries and t_{mov}, data from Areas III and IV.

to about 7 years in late 1970s and early 1980s. The trend was expressed by the following least square regression (t_{mov} on year of catch; weighted by sample size):

$$t_{mov} = 9.164 - 0.138t \quad \text{-------------------- Equation 1}$$

$$(r = -0.548,\ 1 < t < 12)$$

where, t is year of capture setting 0 for 1970/71.
Slope of the above regression was significantly different from zero (t-test, $p < 0.05$).

4) Age at 50% sexual maturity ($t_{m50\%}$) for female

Fig. 6 shows $t_{m50\%}$ values as well as the relationships between sexual maturity rate (proportion of sexually mature individuals) and age at capture for females. Except for the 1974/75 season when the value was apparently high (7.75 years), all the other figures of $t_{m50\%}$ ranged between 6 and 7 years with no specific annual trend. The regression coefficient of $t_{m50\%}$ on season was not significantly different from zero (t-test, $0.2 < p < 0.3$) as reported by Kato (1982).

Even if the relationship between sexual maturity rate and age is analysed by year-class using the same data set (Fig. 7), the $t_{m50\%}$ values were the same as above and showed no significant change among year-classes (t-test, $0.4 < p < 0.5$).

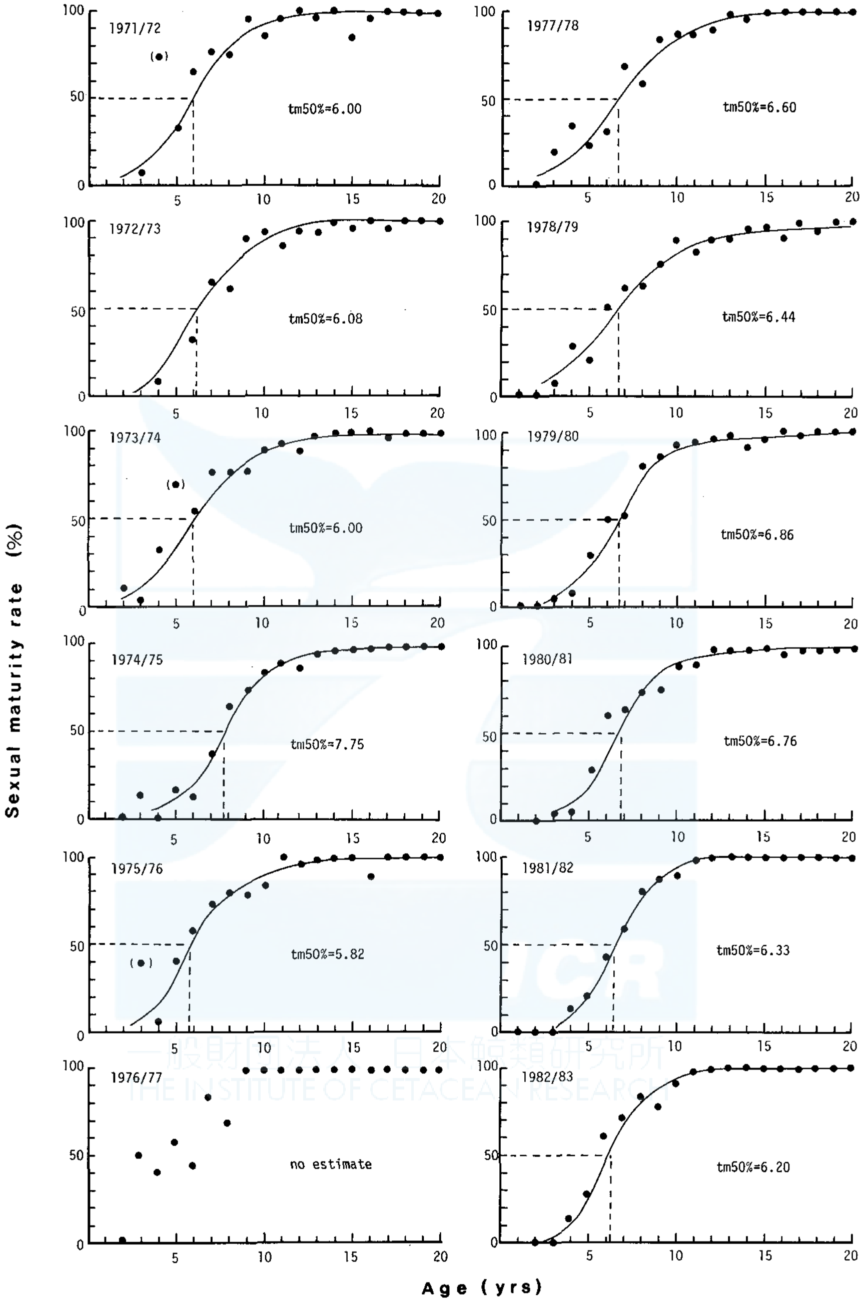


Fig. 6. Age at 50% sexual maturity ($t_{m50\%}$) of the female southern minke whales in Areas III and IV, expressed for each year of capture. Logistic curves are fitted by the least squares weighted by sample size (closed circles in parenthesis were not used for fitting logistic curve).

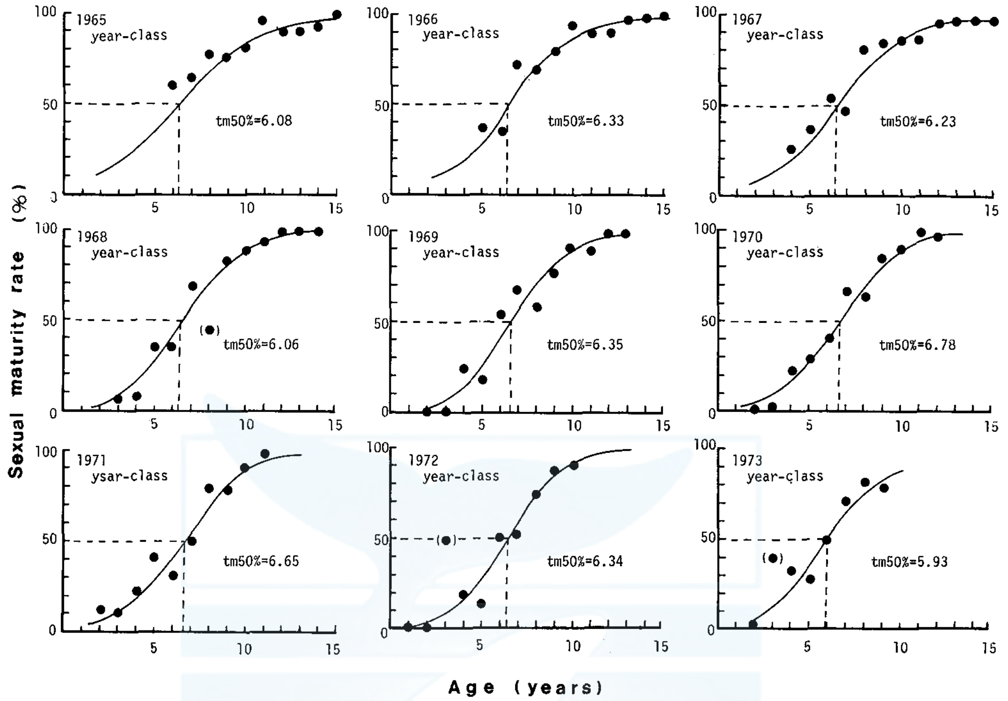


Fig. 7. Age at 50% sexual maturity ($t_{m50\%}$) of the female southern minke whales in Areas III and IV, expressed for each year-class. Logistic curves are fitted by the least squares weighted by sample size (closed circles in parenthesis were not used for fitting logistic curve).

5) Mean age at sexual maturity estimated from transition phase (t_{mp}) for both sexes

As indicated in Table 3 and Fig. 8 (left), the mean age at sexual maturity estimated from the transition phase in earplug (t_{mp}) seemed to be almost constant in both sexes in year-classes before 1940, but then it has declined from 12~13 years of year-classes in mid 1940s to 7~ 8 years of those in late 1960s. The regressions of t_{mp} for both sexes on year-class weighted by sample size are expressed by the following equations;

Male, $t_{mp} = 22.15 - 0.219k$ ($r = -0.971$, $45 \leq k \leq 70$) – Equation 2

Female, $t_{mp} = 21.64 - 0.206k$ ($r = -0.963$, $45 \leq k \leq 70$) – Equation 3

where, k is year-class setting 0 for 1900. Both of the slopes were significantly different from zero (t-test, $p < 0.001$).

The values of t_{mp} and its standard deviation for each year of maturation are given in Table 4, and are plotted in Fig. 8 (right). Due to the small sample size of the observed data, the values of t_{mp} and its standard deviation

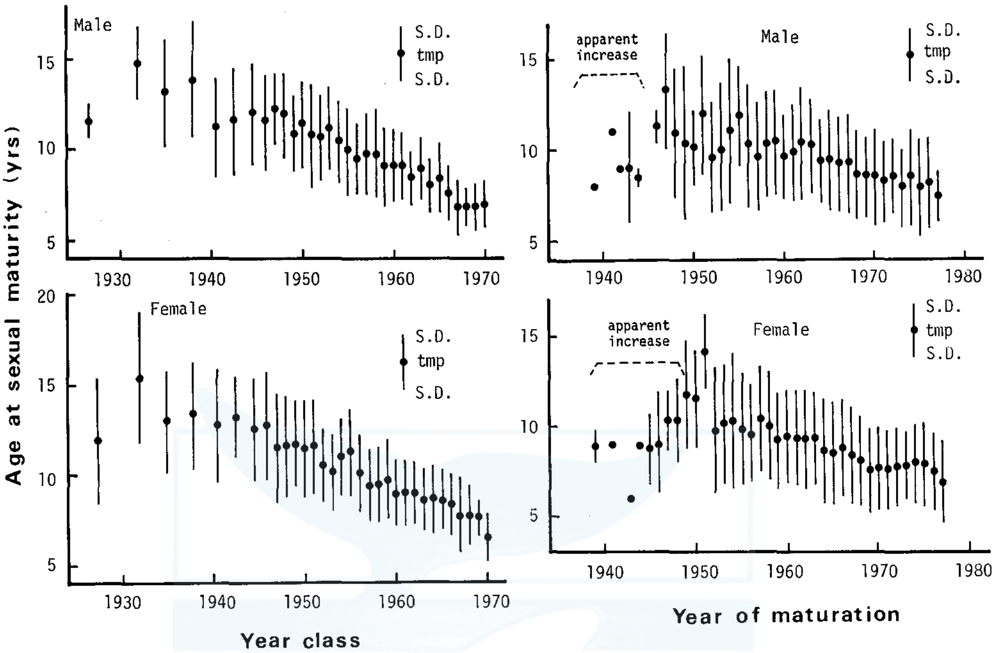


Fig. 8. Changes in age at sexual maturity deduced from transition phase in earplug for males (top) and females (bottom) of the southern minke whales. Range of one standard deviation (solid line) is expressed on each side of the mean age (*tmp*; closed circle). Samples are grouped by year-class (left) and year of maturation (right).

after 1978 were not examined for both sexes. Kato (1983a) pointed out the apparent increasing trends of *tmp* were to be produced by the procedure of converting data of year-class to year of maturation in the beginning several years of the time series of year of maturation, unless the time series of the data infinitely continued. Later this fact was identified again by the simulation study of Sakuramoto, Kato and Tanaka (1985). Therefore the apparent increasing trends of *tmp* values for both sexes before 1949 are artefact.

Then, only those trends from 1950 to 1977 have biological meaning. The *tmp* values declined from around 12 years in 1950s to 8 years in early 1970s. This is shown by the following least square regressions (*tmp* on year of maturation weighted by sample size):

Male, $tmp = 18.38 - 0.138t$ ($r = -0.921$, $50 \leq t \leq 77$ --- Equation 4

Female, $tmp = 19.59 - 0.152t$ ($r = -0.919$, $50 \leq t \leq 77$) --- Equation 5

where, t is year of maturation setting 0 for 1900. Both of the slopes were significantly different from zero (t-test $p < 0.001$).

TABLE 3. STANDARD DEVIATION (s.d.) AND THE MEAN (t_{mp}) OF AGE AT SEXUAL MATURITY ESTIMATED FROM TRANSITION PHASE IN EARPLUG FOR THE SOUTHERN MINKE WHALES COLLECTED IN AREAS III AND IV, 1971/72 TO 1982/83. YEAR-CLASS GROUPING

Year class	Male			Female		
	t_{mp}	s.d.	n	t_{mp}	s.d.	n
1924	13.00	–	1	18.00	–	1
1925	11.00	–	1	–	–	–
1926	–	–	–	–	–	–
1927	–	–	–	–	–	–
1928	–	–	–	11.00	–	1
1929	–	–	–	10.00	–	1
1930	13.00	–	1	9.00	–	1
1931	15.40	5.122	5	14.00	3.266	3
1932	15.33	0.471	3	22.00	–	1
1933	13.67	3.682	3	15.00	2.608	5
1934	13.67	3.682	3	14.20	1.720	5
1935	12.75	2.681	4	12.90	2.548	10
1936	12.75	2.681	4	12.67	3.300	9
1937	10.67	3.399	3	14.83	3.023	6
1938	16.25	2.385	4	12.25	3.269	8
1939	14.00	2.204	7	13.57	2.195	7
1940	11.50	2.617	10	11.40	3.231	10
1941	10.89	2.885	9	13.80	2.822	15
1942	9.16	2.115	6	13.47	2.329	17
1943	12.56	2.715	16	13.00	2.134	18
1944	11.09	2.503	11	13.04	2.091	24
1945	12.53	2.849	15	12.08	3.370	25
1946	11.54	2.664	26	12.78	3.071	27
1947	12.25	4.122	20	11.53	3.154	40
1948	11.94	2.488	31	11.68	2.823	56
1949	10.79	2.041	24	11.77	3.370	57
1950	11.38	2.518	39	11.45	2.745	76
1951	10.81	2.891	48	11.60	2.673	62
1952	10.49	2.493	59	10.55	2.033	69
1953	11.17	2.325	43	10.25	2.193	77
1954	10.43	2.330	44	11.04	2.172	53
1955	9.96	2.410	26	11.27	2.497	55
1956	9.45	1.958	58	10.11	2.168	129
1957	9.75	2.306	53	9.41	2.054	96
1958	9.72	2.420	46	9.48	2.103	80
1959	9.02	2.184	61	9.71	2.220	69
1960	9.09	2.032	44	8.97	1.865	69
1961	9.05	1.965	73	9.01	1.941	99
1962	8.46	1.562	63	8.99	1.742	90
1963	8.94	1.605	50	8.65	1.717	100
1964	8.00	1.469	38	8.67	2.030	60
1965	8.34	1.882	41	8.62	1.747	66
1966	7.49	1.517	39	7.86	1.398	37
1967	6.72	1.484	25	7.80	2.111	35
1968	6.85	1.079	27	7.81	1.704	16
1969	6.85	1.292	13	7.72	0.989	18
1970	6.95	1.356	19	6.50	1.402	14

Growth curve

The growth curves (mean body length plotted on age at capture) are shown in Fig. 9 and the corresponding body length values in Table 5. The mean body lengths of the recent year-classes came always above those for the same age in earlier year-classes, the difference was significant in 9 (female)

TABLE 4. STANDARD DEVIATION (s.d.) AND THE MEAN (t_{mp}) OF AGE AT SEXUAL MATURITY ESTIMATED FROM TRANSITION PHASE IN EARPLUG FOR THE SOUTHERN MINKE WHALES COLLECTED IN AREAS III AND IV COMBINED, 1971/72 TO 1982/83. YEAR OF MATURATION GROUPING

Year of maturation	Male			Female		
	tmp	s.d.	n	*tmp*	s.d.	n
1936	11.00	–	1	–	–	–
1937	13.00	–	1	–	–	–
1938	–	–	–	–	–	–
1939	8.00	–	1	10.00	0.816	3
1940	–	–	–	–	–	–
1941	11.00	–	1	10.00	–	1
1942	9.00	–	1	18.00	–	1
1943	9.00	3.000	2	7.00	–	1
1944	8.50	0.500	2	10.00	–	1
1945	–	–	–	9.33	2.115	6
1046	11.00	0.943	3	10.00	2.739	4
1947	13.40	3.250	5	11.33	1.700	3
1948	11.00	3.674	4	11.40	2.417	5
1949	10.40	4.224	5	12.73	0.119	9
1950	10.14	2.167	7	12.75	2.634	8
1951	12.08	3.430	13	15.17	2.115	6
1952	9.87	3.145	6	10.32	3.588	11
1953	10.80	3.682	10	11.16	3.498	19
1954	11.17	4.079	12	11.35	3.838	20
1955	12.00	2.852	15	10.90	3.161	20
1956	10.39	3.630	18	10.63	2.836	32
1957	9.70	3.035	20	11.33	3.107	42
1958	10.41	2.949	22	11.09	3.029	33
1959	10.51	2.943	39	10.27	2.585	49
1960	9.75	2.332	40	10.15	2.776	59
1961	9.69	2.681	47	10.43	2.775	125
1962	10.40	3.178	57	10.37	2.808	120
1963	10.01	2.651	59	10.43	2.775	125
1964	9.48	2.469	66	9.75	3.077	120
1965	9.50	2.898	80	9.64	2.906	119
1966	9.34	2.610	99	9.78	2.803	140
1967	9.37	2.849	105	9.43	2.650	175
1968	8.77	2.528	113	9.13	2.571	173
1969	8.62	2.326	104	8.56	2.476	187
1970	8.58	2.688	120	8.71	2.052	172
1971	8.41	2.350	103	8.81	2.189	137
1972	8.72	2.170	95	8.83	2.128	135
1973	8.01	2.239	67	8.87	2.041	110
1974	8.64	2.708	69	8.08	2.193	60
1975	7.96	2.724	62	8.90	2.414	31
1976	8.22	2.620	23	8.57	2.129	29
1977	7.57	1.450	14	7.89	2.315	27

and 10 (male) of the 15 pairwise comparison for each sex (t-test, $p<0.05$; Table 5). The magnitude of the difference of mean body length between pairs tended to be larger in younger age classes, but it should be noted that there are still statistically significant difference of mean body lengths between pairs which are age 25 years in males and ages 25 and 28 years in females (t-test, $p<0.05$; Table 5), which were close to or over the age at physical maturity (see below).

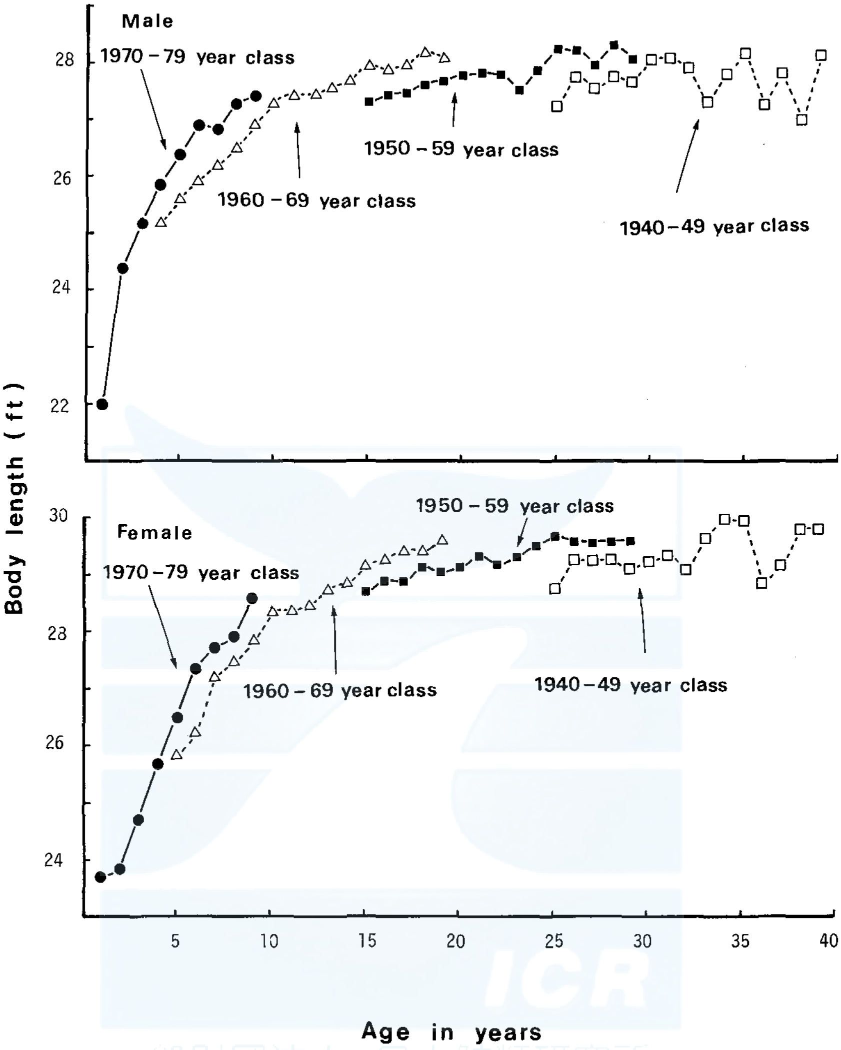


Fig. 9. Mean body length plotted on age at capture of the southern minke whales in each 10 year-class group. Data from Areas III and IV combined, 1971/72 to 1982/83.

TABLE 5. CHANGE IN MEAN BODY LENGTH (FT) AT AGE OF SOUTHERN MINKE WHALES INDICATEDS FOR FOUR YEAR-CLASS GROUPS (YCG). AREAS III AND IV

‹Male›

Age	1940 – 1950 YCG				1950 – 1959 YCG				1960 – 1969 YCG				1970 – 1979 YCG		
	Mean	s.d.	n	t(df)1)	Mean	s.d.	n	t(df)1)	Mean	s.d.	n	t(df)1)	Mean	s.d.	n
1	–	–	–	–	–	–	–	–	–	–	–	–	22.0	2.61	6
2	–	–	–	–	–	–	–	–	–	–	–	–	24.4	2.02	75
3	–	–	–	–	–	–	–	–	–	–	–	–	25.2	1.65	143
4	–	–	–	–	–	–	–	–	–	–	–	–	25.8	1.34	138
5	–	–	–	–	–	–	–	–	25.6	1.92	68	3.49(212)4)	26.4	1.39	146
6	–	–	–	–	–	–	–	–	25.9	1.93	66	4.28(207)4)	26.9	1.33	143
7	–	–	–	–	–	–	–	–	26.2	1.88	95	3.32(250)4)	26.8	1.26	157
8	–	–	–	–	–	–	–	–	26.5	1.40	114	4.87(282)4)	27.3	1.26	170
9	–	–	–	–	–	–	–	–	26.9	1.38	145	2.96(254)3)	27.4	1.21	111
10	–	–	–	–	–	–	–	–	27.3	1.42	172	–	–	–	–
11	–	–	–	–	–	–	–	–	27.4	1.40	225	–	–	–	–
12	–	–	–	–	–	–	–	–	27.4	1.25	288	–	–	–	–
13	–	–	–	–	–	–	–	–	27.5	1.27	247	–	–	–	–
14	–	–	–	–	–	–	–	–	27.6	1.31	249	–	–	–	–
15	–	–	–	–	27.3	1.21	81	3.38(289)4)	27.9	1.28	210	–	–	–	–
16	–	–	–	–	27.4	1.14	81	2.40(263)2)	27.8	1.29	184	–	–	–	–
17	–	–	–	–	27.5	1.07	82	2.94(253)3)	28.0	1.24	173	–	–	–	–
18	–	–	–	–	27.6	1.27	91	3.22(241)3)	28.2	1.22	152	–	–	–	–
19	–	–	–	–	27.9	1.29	102	0.84(252)	38.0	1.28	108	–	–	–	–
20	–	–	–	–	27.8	1.33	119	–	–	–	–	–	–	–	–
21	–	–	–	–	27.9	1.26	147	–	–	–	–	–	–	–	–
22	–	–	–	–	27.8	1.26	138	–	–	–	–	–	–	–	–
23	–	–	–	–	27.5	0.79	83	–	–	–	–	–	–	–	–
24	–	–	–	–	27.9	1.31	90	–	–	–	–	–	–	–	–
25	27.3	1.31	21	3.77(100)4)	28.3	0.98	81	–	–	–	–	–	–	–	–
26	27.9	1.11	28	1.54(82)	28.3	1.23	56	–	–	–	–	–	–	–	–
27	27.8	1.45	47	0.45(97)	27.7	1.15	52	–	–	–	–	–	–	–	–
28	27.9	1.27	27	1.27(61)	28.3	1.06	36	–	–	–	–	–	–	–	–
29	27.8	1.33	26	0.84(58)	28.1	0.95	34	–	–	–	–	–	–	–	–
30	28.2	1.23	36	–	–	–	–	–	–	–	–	–	–	–	–
31	28.1	1.13	28	–	–	–	–	–	–	–	–	–	–	–	–
32	28.0	0.88	33	–	–	–	–	–	–	–	–	–	–	–	–
33	27.4	1.19	23	–	–	–	–	–	–	–	–	–	–	–	–
34	27.9	1.32	27	–	–	–	–	–	–	–	–	–	–	–	–
35	28.2	0.98	11	–	–	–	–	–	–	–	–	–	–	–	–
36	27.3	0.91	14	–	–	–	–	–	–	–	–	–	–	–	–
37	27.8	1.03	12	–	–	–	–	–	–	–	–	–	–	–	–
38	27.0	1.41	2	–	–	–	–	–	–	–	–	–	–	–	–
39	28.2	1.48	10	–	–	–	–	–	–	–	–	–	–	–	–

TABLE 5. (Cont.)
‹Female›

Age	1940 – 1950 YCG				1950 – 1959 YCG				1960 – 1969 YCG				1970 – 1979 YCG		
	Mean	s.d.	n	t(df)[1]	Mean	s.d.	n	t(df)[1]	Mean	s.d.	n	t(df)[1]	Mean	s.d.	n
1	–	–	–	–	–	–	–	–	–	–	–	–	23.7	1.97	6
2	–	–	–	–	–	–	–	–	–	–	–	–	23.8	2.20	77
3	–	–	–	–	–	–	–	–	–	–	–	–	24.7	1.78	141
4	–	–	–	–	–	–	–	–	–	–	–	–	25.7	1.94	130
5	–	–	–	–	–	–	–	–	25.0	2.11	74	1.81(233)	26.5	1.64	161
6	–	–	–	–	–	–	–	–	26.3	1.95	89	4.47(244)[4]	27.3	1.70	157
7	–	–	–	–	–	–	–	–	27.2	1.71	131	2.17(273)[2]	27.7	1.71	144
8	–	–	–	–	–	–	–	–	27.5	1.62	158	2.29(308)[2]	27.9	1.52	152
9	–	–	–	–	–	–	–	–	27.9	1.56	222	4.17(336)[4]	28.6	1.26	116
10	–	–	–	–	–	–	–	–	28.4	1.50	245	–	–	–	–
11	–	–	–	–	–	–	–	–	28.3	1.48	329	–	–	–	–
12	–	–	–	–	–	–	–	–	28.5	1.95	351	–	–	–	–
13	–	–	–	–	–	–	–	–	28.8	1.36	326	–	–	–	–
14	–	–	–	–	–	–	–	–	28.9	1.40	279	–	–	–	–
15	–	–	–	–	28.9	1.43	90	1.53(350)	29.2	1.32	262	–	–	–	–
16	–	–	–	–	29.1	1.32	132	0.96(375)	29.3	1.37	245	–	–	–	–
17	–	–	–	–	29.0	1.27	133	3.20(346)[3]	29.4	1.27	215	–	–	–	–
18	–	–	–	–	29.3	1.56	145	2.06(338)[2]	29.3	1.35	195	–	–	–	–
19	–	–	–	–	29.1	1.30	186	3.63(304)[4]	29.6	1.12	118	–	–	–	–
20	–	–	–	–	29.2	1.34	225	–	–	–	–	–	–	–	–
21	–	–	–	–	29.4	1.17	210	–	–	–	–	–	–	–	–
22	–	–	–	–	29.2	1.29	208	–	–	–	–	–	–	–	–
23	–	–	–	–	29.3	1.28	201	–	–	–	–	–	–	–	–
24	–	–	–	–	29.5	1.23	156	–	–	–	–	–	–	–	–
25	28.8	1.28	41	4.07(169)[4]	29.7	1.21	130	–	–	–	–	–	–	–	–
26	29.7	2.17	51	0.61(147)	29.5	1.22	98	–	–	–	–	–	–	–	–
27	29.3	1.44	56	0.87(145)	29.5	1.18	91	–	–	–	–	–	–	–	–
28	29.5	1.35	47	0.44(104)	29.6	1.18	59	–	–	–	–	–	–	–	–
29	29.1	1.27	63	2.05(111)[2]	29.6	1.29	50	–	–	–	–	–	–	–	–
30	29.3	1.38	41	–	–	–	–	–	–	–	–	–	–	–	–
31	29.4	1.50	40	–	–	–	–	–	–	–	–	–	–	–	–
32	29.1	1.47	54	–	–	–	–	–	–	–	–	–	–	–	–
33	29.7	1.25	40	–	–	–	–	–	–	–	–	–	–	–	–
34	30.1	1.10	39	–	–	–	–	–	–	–	–	–	–	–	–
35	30.0	1.39	19	–	–	–	–	–	–	–	–	–	–	–	–
36	28.8	2.00	28	–	–	–	–	–	–	–	–	–	–	–	–
37	29.2	1.47	17	–	–	–	–	–	–	–	–	–	–	–	–
38	29.8	0.94	12	–	–	–	–	–	–	–	–	–	–	–	–
39	29.9	1.21	13	–	–	–	–	–	–	–	–	–	–	–	–

1) t-value and degree of freedom between nearest YCGs.
2) difference between adjacent YCG is statistically significant at $0.01 < p < 0.05$.
3) difference between adjacent YCG is significant at $0.001 < p < 0.01$.
4) difference between adjacent YCG is significant at $p < 0.001$.

TABLE 6. RELATIONSHIP BETWEEN BODY LENGTH AND PHYSICAL MATURITY IN THE SOUTHERN MINKE WHALES TAKEN IN 1978/79 AND 1979/80 IN AREAS III AND IV

Body length (ft)	Male				Female			
	Immat.	Mat.	To.	Mat.rate(%)	Immat.	Mat.	To.	Mat.rate(%)
18	–	–	–	–	1	0	1	0.00
19	–	–	–	–	–	–	–	–
20	–	–	–	–	–	–	–	–
21	–	–	–	–	–	–	–	–
22	5	0	5	0.00	4	0	4	0.00
23	–	–	–	–	12	0	12	0.00
24	5	0	5	0.00	10	0	10	0.00
25	16	2	18	11.11	10	0	10	0.00
26	33	6	39	15.38	19	0	19	0.00
27	37	14	51	27.45	42	7	49	16.67
28	43	21	64	32.81	53	11	64	17.19
29	15	13	28	46.42	56	22	78	28.21
30	5	6	11	54.54	47	27	74	36.48
31	1	1	2	50.00	18	14	32	43.75
32	–	–	–	–	0	1	1	100.00
33	–	–	–	–	0	2	2	100.00

TABLE 7. RELATIONSHIP BETWEEN AGE AND PHYSICAL MATURITY IN THE SOUTHERN MINKE WHALES TAKEN IN 1978/79 AND 1979/80 IN AREAS III AND IV

Age class (years)	Male				Female			
	Immat.	Mat.	To.	Mat.rate(%)	Immat.	Mat.	To.	Mat.rate(%)
1– 3	6	0	6	0.00	13	0	13	0.00
4– 6	13	0	13	0.00	23	0	23	0.00
7– 9	24	1	25	4.00	41	0	41	0.00
10–12	21	5	26	19.23	42	7	49	14.17
13–15	18	5	23	21.73	39	8	47	17.02
16–18	19	6	25	24.00	29	9	38	23.68
19–21	12	6	18	33.33	21	6	27	22.22
22–24	4	12	16	75.00	11	10	21	47.61
25–27	6	8	14	57.14	17	11	28	39.28
28–30	2	5	7	71.42	9	8	17	47.05
31–33	2	4	6	66.67	3	5	8	62.50
≧34	1	3	4	75.00	4	12	16	75.00

Physical maturity

Table 6 shows the relationships between physical maturity and body length. Physically mature animals appeared at the body lengths over 25 (7.6 m) and 27 ft (8.2 m) in males and females, respectively, and the proprtion of

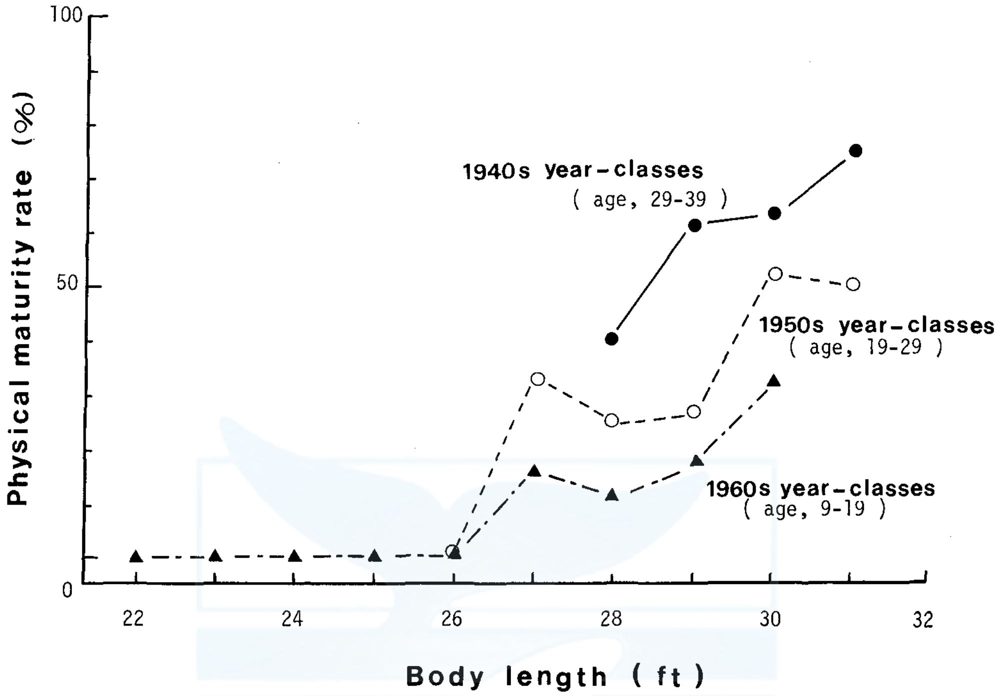


Fig. 10. Relationship between physical maturity rate and body length of female southern minke whales in Areas III and IV. The physical maturity is determined by the fusion of epiphysis with the centrum of the 6th theoracic vertebra.

physically mature individuals increased with increasing of body length.

When physical maturity is compared with age, the physically mature animals first appear at the age of 7~9 years and 10~12 years in males and females, respectively (Table 7). And the proportion of physically mature individuals increases slowly with increasing age in both sexes.

The physical maturity rate (proportion of physically mature individuals) and body length are compared in Fig. 10 between year-classes (10 year-classes combined) among females for which sample size was relatively large. Although the proportion of physically mature individuals increased with the increase of body length in all three year-class groups examined, it is always higher in the earlier year-classes of the same body length, which are older at capture. The proportion of physically mature individuals is statistically different between three year-class groups (1940~'49, 1950~'59, 1960~'69) and for the two length groups (28~29 ft, 30~31 ft) compared ($p < 0.001 \sim 0.05$, χ^2 – test; Table 8).

TABLE 8. COMPARISON OF PHYSICAL STATUS OF FEMALES BETWEEN YEAR-CLASS GROUPS (YCG) IN EACH BODY LENGTH CLASS

Body length Class (ft)	Physical status	Number of animals			Test
		1940s YCG	1950s YCG	1960s YCG	
28–29	Immature	8	23	58	$\chi^2 = 14.248$
	Mature	10	8	9	df=2, $p < 0.001$
30–31	Immature	5	19	27	$\chi^2 = 7.412$
	Mature	10	20	11	df=2, $p < 0.05$

The body lengths of females at 50% physical maturity are estimated to be approximately 28.4 ft (8.7 m) and 29.8 ft (9.1 m) for the 1940s and 1950s year-class groups, respectively. Less than 50% of individuals are physically mature in the 1960s year-class group in all length classes.

Any examination on the age at physical maturity for year-classes has not been made out due to the small sample size and too short time series of the data to be analyzed.

DISCUSSION

Age and body length at sexual maturity

Present study indicated for the southern minke whales that the mean body length of females at the first ovulation (L_{mov}) and the mean length where 50% of the females were sexually mature ($L_{m50\%}$) remained constant at about 27.5ft (8.4 m) and 26.5ft (8.1 m), respectively, during the seasons studied (1971/72 to 1982/83). The mean of 12 $L_{m50\%}$ values is 26.5 ft (8.1 m), and is close to the corresponding figures of 26 ft (7.9 m) estimated for samples in late 1960s to early 1970s (Ohsumi, Masaki and Kawamura, 1970; Ohsumi and Masaki, 1975) or 26.3 ft (8.0 m) estimated for 1971/72 to '76/77 samples (Masaki, 1979). But these values are lower than L_{mov} estimated in the present study by about 0.5~1.5ft (0.15~0.45m).

The present study estimated $L_{m50\%}$ by fitting logistic curve to sexual maturity rate. This procedure should give value which is substantially close to the mean body length at the first ovulation if there is no sample bias, because the curve is symmetric at the point of 50% maturity and the fitness of the present data is good. DeMaster (1984) indicated using artificial data set that different methods may produce different estimates of mean age (or length) at sexual maturity, and that the estimate obtained by least square method ($L_{m50\%}$ or $t_{m50\%}$) is always higher than the mean of the individual ages at maturation (L_{mov} or t_{mov}). This is totally reversed to the result of this study ($L_{m50\%} < L_{mov}$), and I suspect that there must be some biological bias in the present minke whale data.

Ohsumi and Masaki (1975), Masaki (1979) and Best (1982) pointed out, for the southern minke whale stocks, that sexually mature animals tend to segregate in the Antarctic whaling ground. This causes samples to overrepresent the proportion of sexually mature animals, and consequently underestimates the population mean of body length where 50% of individuals are sexually mature, even when $L_{m50\%}$ correctly represents the mean value for the population migrating into the whaling ground. On the other hand, L_{mov} is free from such segregation by maturity. This will be the reason of the discrepancy of 0.5 to 1.5ft (0.15–0.45m) observed between $L_{m50\%}$ and L_{mov}, and the latter will represent the mean body length of females at the attainment of sexual maturity in the southern minke whale population.

Fig. 11 compares t_{mov}, $t_{m50\%}$ and t_{mp} values obtained by two different data groupings, i.e. year-class and year of capture (equivalent to year of maturation). Estimate of t_{mp} covers longer period (28~40 years), while $t_{m50\%}$ and t_{mov} only nine and 11 years, respectively. In years when comparison is possible (1971~78) in the grouping year of capture the t_{mp} values agree with the t_{mov} values in both absolute figures and trend. However, $t_{m50\%}$ values are always about 0.5~2 years lower than t_{mov} or t_{mp} in both groupings (χ^2–test, $p < 0.05$), as pointed out by Cooke (1985). This discrepancy can be explained by the segregation of sexually mature animals in the Antarctic whaling ground, as considered above for body length at sexual maturity. This is supported by Best (1982). He estimated $t_{m50\%}$ of female minke whales to be about 8 years using samples collected off Durban during breeding season in the early 1970s, which is higher than $t_{m50\%}$ obtained from the Antarctic ground in the present study, but is very close to t_{mov} and t_{mp} of the present study. Thus the t_{mp} and t_{mov} are considered to be free from the segregation and give correct value for the population.

It is known that truncated sampling seriously biased t_{mp} value downward in recent year-classes (Free and Beddington, 1980; IWC, 1984a). However, the present study used only samples which are free from this bias. Another possible factor that may cause bias in the transition phase analysis is the ageing error. Cooke and de la Mare (1983) argued that an apparent decline of t_{mp} is produced by assuming a mean ageing error of 25~50% of the true age, even when true t_{mp} remained constant over the period. However, comparison of age readings between readers showed that ageing error of experienced readers is not proportional to the age of whales, but that it is always 2~4 layers (IWC, 1984a). Following this result Sakuramoto, Kato and Tanaka (1984) and Sakuramoto, Tanaka and Kato (1985) showed that the observed declining trend of t_{mp} is real based on a simulation under the assumption of ageing error of 2~4 layers (absolute values which is independent of the age of whales) for each of the transition phase age and age at capture.

While there is no independent parameter, such as t_{mov} of females, to confirm the male t_{mp} estimate, I consider the decline of male t_{mp} is also valid because the male trend is almost the same as that of females and the recent increase of

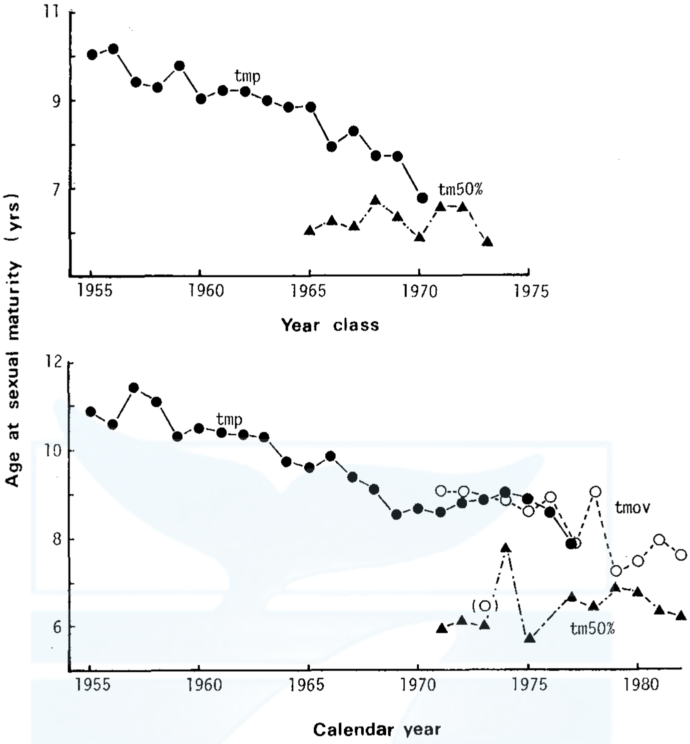


Fig. 11. Comparison of three kinds of estimates of age at sexual maturity for female southern minke whale (Areas III and IV). $t_{m50\%}$; age at 50% maturity rate, t_{mov}; mean age of females having corpus luteum of the first ovulation, t_{mp}; mean age of transition phase in earplug.

the growth rate has been identified in both sexes.

Thus I conclude that the age at sexual maturity of the southern minke whale declined from 12~13 to 7~8 years in the past 30 years, while female body length at sexual maturity remained unchanged at around 27.5 ft(8.4m) at least in the past 20 years. Similar finding has been made by Ohsumi (1986b) in the North Pacific fin whale stock. He found that the female age at sexual maturity ($t_{m50\%}$ and t_{mov}) delined from 12 years in the middle 1950s to 6 years in the middle 1970s, while body lengths at sexual maturity ($L_{m50\%}$) remained unchanged at around 57ft and 61ft in males and females, respectively.

Growth curve and physical maturity

The present study showed that recent year-classes attains larger body size than the previous ones of the same age and attaine larger size at ages close to the attainment of physical maturity. If the growth increase had appeared only in the young fast growing ages, it would be possible to attribute it to an artefact due to possibly intensified fishery selection for larger whales. However, the increase of the growth rate in older age classes strongly suggests that the recent increase in growth rate is real.

The analysis on epiphyseal fusion at the 6th thoracic vertebra showed physical maturity rate in recent year-classes is lower than that in earlier year-classes of the same body length. One possible explanation for this would attribute it to the fact that samples of earlier year-classes tend to include older individuals than those of recent year-classes, and reject the possibility that the body length at physical maturity have increased over the period. Other explanation will consider that the attainment of physical maturity is not dependent on age but on physiological factors which can be decided by some environmental factors such as nutrition, and that the recent increase in body length at physical maturity is real. However, due to short data series available, it is inconclusive which interpretation is more appropriate.

Possible factors causing changes in growth parameters

It is generally known on various mammal and fish populations that growth parameters, such as age at sexual maturity, change with the depletion of the stock or increase of food availability. As shown in Fig. 12, for the southern minke whale stocks, since changes in growth parameters were observed in the period prior to the start of full-exploitation of this stock, the reasons causing such changes will be required for another factors rather than stock depletion. Laws, Parker and Johnstone (1975) reported for the African elephant, *Loxodonta africana*, that the mean ages at sexual maturity differ between populations in different habitats, and attributed it to difference on food availability. Yamagishi (1977) made a detailed cohort analysis of human growth in comparison with the historical changes in food availability, and concluded that recent Japanese year-classes grew faster and to larger body size mainly by improved nutrition in the adolescent growth spurt stages.

From analogizing above studies, the decline in the age at sexual maturity and increases in growth rate (and presumably in body length at physical maturity) will be attributable to the increase of food availability of minke whales (*per capita*) in the Antarctic feeding ground, which is considered to have been produced by the depletion of whale stocks such as blue, fin and humpback whales which share an ecological niche with minke whales (Gambell, 1973, 1975; Laws, 1977a, 1977b).

Laws (1977a) estimated that extra food availability for krill-feeders brought from the depletion of large whale stocks due to the past Antarctic whaling will be about 147,000,000 tons/year during 1920s to 1970s. Additionally, Lockyer (1981) estimated through the analyses of energy cost and growth of the southern minke whale that females will require 3.5% of the additional food to attain sexual maturity one year earlier. In order to make rough examination if the above increase in food availability allows for minke whales

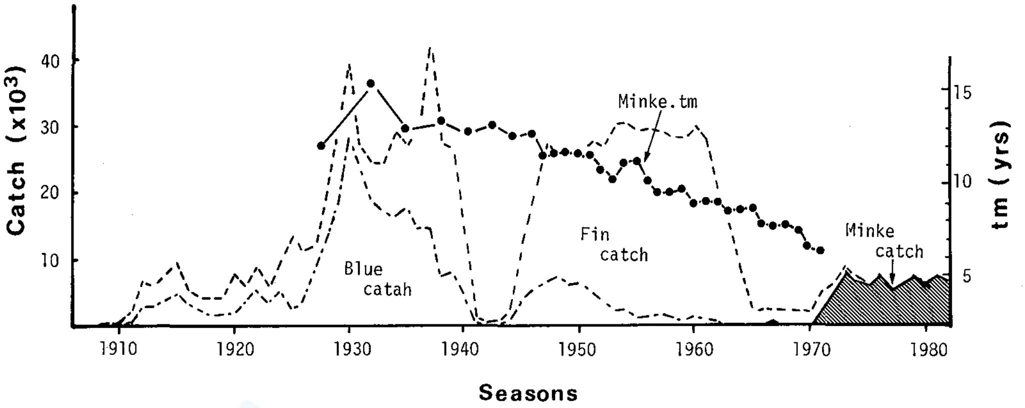


Fig. 12. Historical changes in mean age at sexual maturity of females (t_m, •—•) deduced from transition phase in earplug in the present study female by year-class and in the catch by the whole Antarctic (▨) for the southern minke whales, as well as blue (—·—) and blue + fin (———) whale catches. Catch data from International Whaling Statistics.

to decrease juvenile period from 12 years in middle 1940s to 7 years in early 1970s, I have made a calculation assuming;

(a) Mean food intake for both sexes in 1940s was 280kg/day whale (Ohsumi, 1979), which was constant within feeding season.

(b) Minke whales feed in the Antarctic for 135 days and feed nothing outside the Antarctic.

(c) Total minke whale population in 1940s was 382,074 as calculated from sighting surveys in late 1970s to early 1980s (IWC, 1985). (possible increase of the total population size from 1940s to 1970s suggested by the decline of age at sexual maturity was not incorporated)

These assumptions give total krill consumption by the southern minke whale population at the Antarctic as about 14,442,400 tons/year in 1940s. This has to be increased to 14,442,400 × $(1+0.035)^5$ in 1970s, or net increase of food intake of about 108,400 tons/year to allow the five year decrease of the prepubertal stage. This is only 1/1,356 of the food surplus estimated by Laws (1977a). And even under the extreme assumptions of two folds population size in 1940s and daily food consumption during the period, it is still only 1/352 of the food surplus produced by the depletion of the large whale stocks. Thus, there is still room to support the possible increase of other krill-feeder populations such as seabird and seals indicated by seveval authors (Sladen, 1964; Laws, 1973, 1977b; Payne, 1977). The total biomass of above competitors is estimated to be 3,561,000 tons, which is brought from 580,000 tons of seabirds (Group of specialist on living resources of the southern ocean, SCAR and SCOR, 1977) and 2,981,000 tons of seals, including all seal species which have the possibility to feed krill regardless of its amount, based on Øritsland (1977), Laws (1977a) and Gilbert and Erickson (1977), and is about 1.11 folds of the total minke whale biomass (382,074 × 7.0 tons (average body weight)). Furthermore, the biomass of several species of fishes and squids, which are yet other krill-feeders at the Antarctic, will not exceed 10 folds of the minke whale biomass (Mr Ichii, pers. comm.), though the practical estimation on the biomass of these fishes has not been done. Then, the total biomass of krill-feeders other than minke whales in the Antarctic is about 29,420,000 tons (about 11 folds of minke whale biomass). However, even when food requirement of those krill-feeders has historically increased, I consider that there has been an ample supply of krill to allow the changes in minke whale growth parameters in the present study judging from considerably small proportion of aditional food requirements for these changes to the food surplus brought from the stock depletion of the large whales.

ACKNOWLEDGEMENTS

My sincere thanks are due to Dr T. Kasuya, Far Seas Fisheries Research Laboraotry, for his critical and useful review of manuscript. I would like to also express my thanks to Dr S. Ohsumi of Far Seas Fisheries Research Laboratory who kindly and critically reviewed the eariler version and made valuable suggestions. Drs Peter B. Best, University of Pretoria, Republic of South Africa and Y. Masaki, South East Regional Fisheries Research Laboratory, kindly permitted to use their data for the present study. Dr H. Omura, director of my institute, kindly encouraged the present study. Drs S. Mishima, K. Amaoka and A. Kawamura, Faculty of Fisheries, Hokkaido University, kindly reviewed the earlier version of the present paper. Mr T. Ichii, Far Seas Fisheries Research Laboratory, provided some informations on the krill-feeder biomass. Ms T. Shirai of my Institute assisted making the manuscript of the present study. I am largely indebted to the staffs and crew of *Nisshin-maru #3*, especially Messrs K. Yamaguchi, M. Sato, S. Tabata and K. Maeda, and I would not be able to carry out several researches in the present study without their cooperations.

REFERENCES

Best, P.B., 1982. Seasonal abundance, feeding, reproduction, age and growth in minke whale off Durban (with incidental observations from the Antarctic). *Rep. int. Whal. Commn*, 32: 759–86.

Cooke, J.G., 1985. Has the age at sexual maturity of southern minke whales declined? *Rep. int. Whal. Commn*, 35: 335–40.

Cooke, J.G. and W.K. De La Mare, 1983. The effect of variability in age data on the estimation of biological parameters of minke whales (*Balaenoptera acutorostrata*). *Rep. int. Whal. Commn*, 33: 333–46.

Demaster, D.P., 1984. Review of techniques used to estimate the average age at attainment of sexual maturity in marine mammals. *Rep. int. Whal. Commn* (special issue 6): 175–79.

FREE, C.A. and J.R. BEDDINGTON, 1980. A technique for estimating mean and variance of age at sexual maturity for data obtained from the transition phase of ear plug laminae. *Rep. int. Whal. Commn,* 30: 375–377.

GAMBELL, R., 1973. Some effects of exploitation on reproduction in whales. *J. Reprod. Fert. Suppl.,* 19: 533–553.

GAMBELL, R., 1975. Variations in reproduction parameters associated with whale stock size. *Rep. int. Whal. Commn,* 25: 182–189.

Group of specialists on living resources of the southern ocean, SCAR and SCOR, 1977. Biological investigations of marine Antarctic systems and stocks (Biomass), 1: 1–79.

GILBERT, J.R. and A.W. ERICKSON, 1977. Distribution and abundance of seals in the pack ice of the Pacific sector of the Southern Ocean. pp. 703–748. *In*: G.A. Llano(ed.) *Adaptations within Antarctic Ecosystems*. Smithsonian Institution, Washington, D.C. 1252 pp.

International Whaling Commission, 1979. Report of the special meeting on southern minke whales, Seattle 1978. *Rep. int. Whal. Commn,* 29: 349–58.

International Whaling Commission, 1983. Report of the Scientific Committee. *Rep. int. Whal. Commn,* 33: 43–190.

International Whaling Commission, 1984a. Report of the minke whale ageing workshop. *Rep. int. Whal. Commn,* 34: 675–700.

International Whaling Commission, 1984b. Report of the workshop. *Rep. int. Whal. Commn* (special issue 6): 1–26.

International Whaling Commission, 1985. Report of the Scientific Committee. *Rep. int. Whal. Commn,* 35: 31–64.

KATO, H., 1982. Some biological parameters for the Antarctic minke whale. *Rep. int. Whal. Commn,* 32: 935–45.

KATO, H., 1983a. Some consideration on the decline in age at sexual maturity of the Antarctic minke whale. *Rep. int. Whal. Commn,* 33: 393–99.

KATO, H., 1983b. Relation of earplug growth and skull growth in the Antarctic minke whale. Paper SC/A83/AW5 submitted to minke whale ageing workshop of IWC. 6pp.

KATO, H., 1985. Further examination of the age at sexual maturity of the Antarctic minke whale as determined from earplug studies. *Rep. int. Whal. Commn,* 35: 273–81.

LAWS, R.M., 1961. Reproduction, growth and age of Southern Hemisphere fin whales. *Discovery Rep.* 31: 327–486.

LAWS, R.M., 1973. Population increases of fur seals at South Georgia. *Polar Record,* 16: 856–58.

LAWS, R.M., 1977a. Seals and whales of the Southern Ocean. *Phil. Trans. R. Soc. B.,* 279: 81–96.

LAWS, R.M., 1977b. The significance of vertebrates in the Antarctic marine ecosystem. pp. 411–38. *In*: G.A. Llano (ed.) *Adaptations within Antarctic Ecosystem.* Proc. 3rd SCAR Symp. on Antarctic Biology. Smithsonian Institution, Washington, D.C. XLIV 1252pp.

LAWS, R.M., I.S.C. PARKER and R.C.B. JOHNSTONE, 1975. *Elephants and their habitats. The ecology of elephants in North Bunyoro, Uganda.* Claren Don Press, Oxford. 366 pp.

LOCKYER, C., 1972. The age at sexual maturity of the southern fin whale (*Balaenoptera physalus*) using annual layer counts in the earplug. *J. Cons. int. Explor. Mer.,* 34(2): 276–94.

LOCKYER, C., 1981. Estimation of the energy costs of growth, maintenance and reproduction in the female minke whale, *Balaenoptera acutorostrata,* from the Southern Hemisphere. *Rep. int. Whal. Commn,* 31: 337–47.

MASAKI, Y., 1979. Yearly change of the biological parameters for the Antarctic minke whale. *Rep. int. Whal. Commn,* 29: 375–96.

OHSUMI, S., 1979. Feeding habits of the minke whale in the Antarctic. *Rep. int. Whal. Commn,* 29: 473–476.

OHSUMI, S., 1986a. Earplug transition phase as an indicator of sexual maturity in female Antarctic minke whales. *Sci. Rep. Whales Res. Inst.,* 37: 17–30.

OHSUMI, S., 1986b. Yearly change in age and body length at sexual maturity of a fin whale stock in the eastern North Pacific. *Sci. Rep. Whales Res. Inst.,* 37: 1–16.

OHSUMI, S. and Y. Masaki, 1975. Biological parameters of the Antarctic minke whales at the virginal population level. *J. Fish. Res. Board Can.*, 32(7): 995–1004.

OHSUMI, S. and Y. Masaki, 1977. Age-length keys and growth curves of the Southern Hemisphere sei whale. *Rep. int. Whal. Commn*, 28: 431–48.

OHSUMI, S., M. NISHIWAKI and T. HIBIYA, 1958. Growth of fin whale in the North Pacific. *Sci. Rep. Whales Res. Inst.*, 13: 97–133.

OHSUMI, S., Y. MASAKI and A. KAWAMURA, 1970. Stock of the Antarctic minke whale. *Sci. Rep. Whales Res. Inst.*, 22: 75–125.

OMURA, H., 1975. Osteological study of the minke whale from the Antarctic. *Sci. Rep. Whales Res. Inst.*, 27: 1–36.

OMURA, H. and T. KASUYA, 1976. Additional information on skeleton of the minke whale from the Antarctic. *Sci. Rep. Whales Res. Inst.*, 28: 57–68.

ØRITSLAND, T., 1977. Food consumption of seals in the Antarctic pack ice. pp. 749–768. *In*: G.A. Llano(ed.) *Adaptations within Antarctic Ecosystems*. Smithsonian Institution, Washington, D.C. 1252 pp.

PAYNE, R.M., 1977. Growth of fur seal population. *Phil. Trans. R. Soc. London Ser. B.*, 279: 67–79.

SAKURAMOTO, K., H. KATO and S. TANAKA, 1985. A simulation study about several factors influencing the estimates of a trend in age at sexual maturity of the Antarctic minke whale. *Rep. int. Whal. Commn*, 35: 285–90.

SAKURAMOTO, K., S. TANAKA and H. KATO, 1986. A simulation study evaluating the effects of ageing error on estimates of a trend of age at sexual maturity of the Antarctic minke whale. *Rep. int. Whal. Commn*, 36: 213–20.

SLADEN, W.J.L., 1964. The distribution of Adelie and chinstrap penguins. *In*: R. Carrick, *et al.* (eds), pp. 359–365. *Biologie antarctique*. Paris, Hermann.

WHEELER, J.F.C., 1930. The age of fin whales at physical maturity. *Discovery Rep.*, 2: 403–34.

YAMAGISHI, H., 1977. *Biology of growth*. Koodansya. Tokyo. 198 pp. (in Japanese).

一般財団法人　日本鯨類研究所
THE INSTITUTE OF CETACEAN RESEARCH

OBSERVATIONS ON THE OVARY OF THE SOUTHERN MINKE WHALE

CHRISTINA LOCKYER*

ABSTRACT

Ovaries of minke whales appear similar in shape, form and structure to those of related balaenopterid whales. However, the size and weight of the ovaries and their internal structures are smaller. In particular, the mean sizes of the active corpus luteum (CL) and regressed corpora albicantia (CA) are smaller. A high number of corpora appear to be present in the ovaries relative to age, consistent with a more frequent ovulation rate and/or shorter reproductive interval than observed in other balaenopterids. The types of corpora observed in the minke whale are similar to those reported for other whales, although the CA in minke are characteristically very yellow in colour. The CA appear to persist in the ovary despite considerable shrinkage and degeneration, thus forming a complete record of the individual's ovulation history. The cyclical changes in the ovary in relation to reproductive condition appear similar to those observed in other balaenopterids.

INTRODUCTION AND BACKGROUND

The minke whale, *Balaenoptera acutorostrata,* the smallest of the balaenopterid cetaceans, attaining a maximum size in the southern hemisphere of 10.7 m (Lockyer, 1984) and weight of about 13.87 t (Lockyer, 1976; Ohsumi, 1979), is found in all latitudes of the world's' oceans. Although the life history, longevity, pattern of feeding, growth and reproduction have many similarities with other balaenopterids, the duration of the reproductive cycle appears to differ, and in minke whales is closer to one year rather than two years as in the majority of this genus (Best, 1982; Christensen, 1974; Ivashin and Mikhalev, 1978; Jonsgård, 1951; Larsen and Kapel, 1983; Lockyer, 1981, 1984; Masaki, 1979; Mitchell and Kozicki, 1975; Williamson, 1975).

The most reliable estimate of reproductive cycle length is 14 months (IWC, 1979), comprising 10 months' gestation and 4 months' suckling of a single calf. The female appears to commence a subsequent pregnancy either during lactation or at weaning of the calf. The evidence for this is derived from ovulation rates calculated by plotting ovarian corpora numbers versus age, from foetal growth records and timing of parturition, and from propor-

---

* *Sea Mammal Research Unit (NERC), c/o British Antarctic Survey, Madingley Road, High Cross, Cambridge CB3 OET, England.*

Sci. Rep. Whales Res. Inst.,
No. 38, 1987, 75–89

tions of pregnant, lactating and anoestrous females in the mature portion of the commercial catches.

Studies of minke whale populations have been made in both hemispheres, and include polar waters of the Antarctic, off Norway and Greenland, and more temperate seas off South Africa, Canada, Japan and Korea, as well as equatorial waters off Brazil. The biology of the different populations has generally been comparable.

The subject of the present study is the Antarctic minke whale. The mature female usually conceives in August-September, and gives birth in May-June of the following year to a 2.8 m neonate (Ivashin and Mikhalev, 1978; Lockyer, 1984). The mean age at first ovulation and possibly conception, ranges between 6–14 years (Masaki, 1979; Kato, 1983, 1985) at an average body length of 8.0 m and weight of 6.05 t. In this study, a detailed account is presented of the macroscopic structure of the ovaries of the minke whale, and analyses of cyclical activity in relation to reproductive age and status.

MATERIAL AND METHODS

The study material comprised 67 pairs of ovaries, collected during the Japanese Antarctic minke whaling expedition December 1980–March 1981. The ovaries were removed intact from freshly killed carcases on board factory ships, were maintained frozen between −15°C and −20°C, and shipped back to Japan where, after initial palpation and examination at the Far Seas Fisheries Research Laboratory, Shimizu, they were fixed and preserved whole in neutral buffered 10% formalin (4% formaldehyde) and freighted to Cambridge. On arrival, the ovaries were in excellent anatomical and histological condition. Data on sexual status and condition, age, date of capture, body length, geographical position of capture and foetal length (if present), were provided. The classification of the reproductive status, e.g. pregnant, anoestrous, lactating, was determined on site when the whale was first dismembered after capture and the ovaries collected. This was done by careful macroscopic investigation of the uterus and mammary glands. Ages of individuals were determined by Dr H. Kato (Whales Research Institute, Tokyo).

After soaking/rinsing in running water for 24-hours, the individual ovaries were trimmed of adhering fallopean tube and connective tissue, weighed and examined for gross general appearance and presence of corpora lutea. These latter, if found, were detached, weighed, and cut vertically from the ovulatory scar along two planes at right angles to each other and to a third transverse plane of cut. The maximum diameters through these three planes were measured to give an average diameter of the corpus luteum (CL).

The ovaries were then sectioned at intervals of 2-3 mm, using a commercial meat slicing machine. During this procedure, slices were accumulated serially and examined for the presence of corpora albicantia (CA), follicles and various other ovarian structures, all of which were recorded and measured for mean maximum diameter in at least two planes. Unusual items, such as corpora atretica, were excised and put aside in 10% formalin for subsequent histological examination for confirmation of their identity.

The classification of ovarian bodies was made by reference to work of Laws(1961) and the International Whaling Commission report (IWC, 1984). The categorization of the CA into young, medium and old in terms of state of regression and resorption has been based on the terminology of Laws(1961).

RESULTS AND DISCUSSION

The ovarian structure is typically mammalian (Mossman and Duke, 1973), and generally conforms to the findings of Harrison (1969), Laws (1961) and Slijper (1966) for other cetaceans. In the following analyses, the ovaries were sorted by reproductive category of the female, as defined below:

Immature – where ovaries contain follicles but no evidence of ovulation;
Mature – where ovaries, of which at least one half of the pair, contain evidence of ovulation; there are sub-categories of maturity status:
a. Pregnant – where ovaries contain an active corpus luteum, and there is evidence of foetal development in the uterus;
b. Ovulating – where ovaries contain a large active corpus luteum, but there is no evidence of a foetus in the uterus; note however, that fertilisation may have occurred but not implantation;
c. Regressing CL – where ovaries contain a no longer active corpus luteum which is undergoing shrinkage and histological changes commensurate with becoming a corpus albicans (Marsh, 1985; Marsh and Kasuya, 1984);
d. Anoestrous – where ovaries contain no corpora lutea, active or regressing;
e. Lactating – where milk is present in the mammary glands, but the ovaries may contain a regressing CL, an active CL or no CL; ovulation and pregnancy may occur during lactation.

Gross appearance of the ovaries

1) Size

The elongate, slightly flattened ovaries are lobulate in mature and maturing females and smooth in juveniles. The overall external colour is a mixture of pink, white and grey. The hilus is long, similar to that in the fin whale, *B. physalus* (Laws, 1961). Corpora (both CL and CA) generally protrude from the surface, and are connected at the base by a thick "neck" to the main body of the ovary. The ovary surface is frequently criss-crossed by "tags" and adhesions such as observed for sei whales, *B. borealis* (Gambell, 1968 and

TABLE 1. OVARY WEIGHTS IN MINKE WHALES

Reproductive class and category		No individual ovaries	Mean ovary weight(g)±s.d.	
			Ovary without CL	Ovary with CL
Immature		22	50.4±37.92	
Mature				
Anoestrous	<10CA	10	77.75±31.72	
	11-24CA	12	167.50±45.40	
	>25CA	8	218.12±97.24	
	All groups	30	150.11±81.13	
Pregnant	All groups	36	161.14±68.62	339.17±113.16
Ovulating	(CL+19CA)*)	2	200	480
Regressing	CL (2-11CA)**)	6	78.17±5.01	131.67±16.07

*) corpora count of ovary pair,

**) range of corpora counts in the 3 ovary pairs.

personal observation); 18% of juveniles and 12.5% of mature females showing this feature. Sometimes mushroom-like appendages dangle from the main body of the ovary, but have no unusual internal structure. These have also been observed in fin whales (Laws, 1961).

The paired ovaries are usually of similar size and weight, except where a CL is present, when the CL-bearing ovary greatly exceeds the weight of the other.

2) Weight

The average weight of ovaries for different reproductive classes are shown in Table 1. The minke ovaries, by reproductive class, are almost one tenth the weight of those reported for the much larger fin (Laws, 1961) and sei whales (Gambell, 1968). As expected, the immature ovaries are lightest. In the mature ovary, weight increases significantly with the accumulation of CA, although the overall mean weight of the anoestrous ovary is similar to that of the non-CL-bearing ovary of the pregnant female. The combined effects of corpora number and stage of pregnancy have not been investigated, as sample size is inadequate. The CL-bearing ovary in both the fully pregnant and post-lactational phase (with regressing CL), is significantly heavier than its partner. This, as will be shown later, is almost certainly due to the additional weight of the CL. The single ovulating female in the sample, also demonstrates a weight assymetry with greater weight in the recently ovulated ovary.

Internal structure of the ovary

Internally, the encapsulating tunica albuginea in mature ovaries is between 0.83-2.99 mm in thickness with a modal range 1.25-1.50 mm. This is comparable to the 0.95-1.60 mm observed in fin whales (Laws, 1961). The

TABLE 2. MEAN DIAMETER OF THE LARGEST FOLLICLES IN MINKE WHALES

Reproductive class and category	No females	Mean diameter of the largest follicles (mm) ±s.d.
Immature	11	6.41±3.35
(age 2–7 years;		
length 6.2–8.6 m)		
Mature		
Anoestrous	17	9.29±4.90
Pregnant		
(foetus <30 cm)	8	9.87±5.92
(foetus 30–130 cm)	26	13.74±3.81
(foetus >130 cm)	2	13.00±0.07
Ovulating	1	14.00
Regressing CL (2–11CA)*)	3	3.50±2.18

*) range of corpora counts in the 3 females.

body of the ovary, particularly the medulla, is well supplied with blood vessels, and the cortex contains varying numbers of follicles of differing sizes with developing oocytes, the stage dependent on reproductive condition of the female, and products of ovulation, the CL and CA. In addition, various other bodies are found near the cortical surface, including different types of corpora atretica, cysts and cystic follicles. These ovarian bodies are described below.

1) Follicles

The dimensions and abundance of gel-filled Graafian follicles, found throughout the cortex of the ovary, vary in size with stage of maturity, and with stage of the reproductive cycle (Table 2). The immature ovaries of juveniles and animals approaching puberty have smaller follicles than those in most mature ovaries. In very young females, the follicles are not macroscopically visible.

Ovulating and mid- and late-term pregnant females have the largest follicles, whilst follicles in ovaries of anoestrous and early-term pregnant females are smaller. The smallest follicles, indicating little follicular activity, are seen in the ovaries of females with a regressing CL.

Follicular activity in terms of size, throughout the reproductive cycle in minke, is broadly similar to that of fin whales (Laws, 1961).

No mature ovaries were observed to lack follicles as has been reported by Marsh and Kasuya (1984) for older "post-reproductive" or senescent pilot whales (*Globicephala macrorhynchus*).

2) Corpus luteum

The active CL is similar in appearance to those described for fin (Laws,

TABLE 3. SIZE OF THE CORPUS LUTEUM IN MINKE WHALES

Reproductive class and category	Mean size of CL±s.d. (n=sample size) Diameter (mm)		Weight (g)	
Pregnant				
(foetus <30 cm)	62.68±8.78	(8)	137.25±45.27	(8)
(foetus 30–130 cm)	66.40±6.79	(26)	156.73±48.39	(26)
(foetus >130 cm)	70.58±12.94	(2)	202.50±137.89	(2)
Ovulating	75.70	(1)	180.00	(1)
Regressing CL	41.37±3.60	(3)	48.00±11.31	(3)

1961), sei (Gambell, 1968) and blue whales, *B. musculus* (Mackintosh and Wheeler, 1929); its form and structure is as described in the IWC report (IWC, 1984).

The CL of the ovulating female (determined as such from the absence of a foetus) was similar in appearance to those of the pregnant females, confirming the view (IWC, 1984; Marsh, 1985) that the CL of ovulation and pregnancy are not readily distinguishable, if at all. Of course, during the pre-implantation phase when the blastocyst is unattached, the reproductive status of the female is impossible to differentiate from that of the condition with a recent unfertilised ovum.

The stigma, site of the follicular rupture at ovulation, was usually clearly visible at the apex of the protruding CL, and was often surrounded by a slightly raised rim or corona. The colour of the CL was pinkish-grey to yellow. One unusual form of CL was found where a surrounding fold of tunica albuginea from the ovary had formed around the body, enfolding it like a cup around an acorn. Central vesicles within the CL were observed in 25% of early-pregnant (n=8; foetus length<30 cm) and 33.3% of mid-pregnant females (n=26; foetus length 30-130 cm), but none were observed in late-pregnant females (n=2; foetus>130 cm). There was no significant association with stage of pregnancy. Larsen (1984) reported an incidence of 13% of vesicular CL in pregnant minke whales, but no breakdown by stage of pregnancy was presented.

Variation in size of the CL throughout the reproductive cycle is shown in Table 3. Volume and weight appear to increase with advance of pregnancy. However, the differences in size are not significant with these small samples. The regressing CL, determined as such from shrinkage of the secretory lobules and commencement of fibrous replacement of the luteal tissue, appears very small in relation to the size at ovulation, and approaches the mean largest size of the youngest CA.

The additional weight of the CL explains the assymetry in the weight of ovaries from pregnant females (Table 1).

The size range of the minke CL (Table 3) is similar to that observed by Best (1982) for minke whales off South Africa, and by Larsen and Kapel

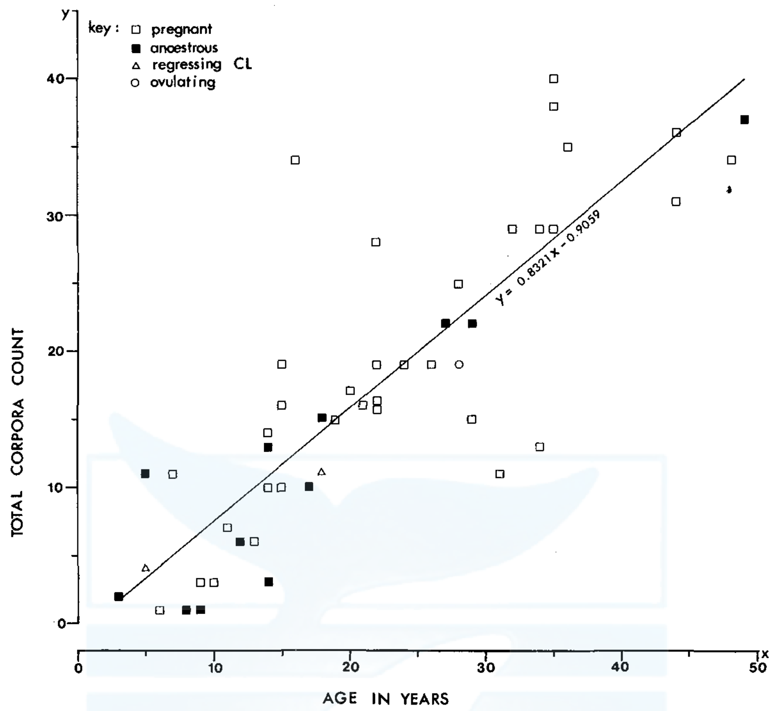


Fig. 1. Observed relation of ovarian corpora number with age from ear plug growth layers in minke whales.

(1983) for the minke whale off Greenland. Larsen (1984) gave a mean size of CL of pregnancy as 56.6±5.8(s.d.)mm for Greenland minke whales, rather smaller than the values for the southern hemisphere. He considered that the smaller size of the CL of the northern hemisphere animals might be due to their smaller body size. The size of the CL of ovulation observed here seems large by comparison with the data summarised by Lockyer (1984), approaching nearly twice the diameter given by Larsen (1984). However, no significance can be ascribed to this solitary observation. The mean sizes of the minke CL are smaller than those of all other baleen whales quoted by Lockyer (1984) for pregnant females, including:

blue, 136.5 mm (Mackintosh and Wheeler, 1929),
fin, 114.4 mm (Laws, 1961),
sei, 76-84mm (Gambell, 1968),
humpback, *Megaptera novaeangliae*, 106-123 mm (Matthews, 1937; Chittleborough, 1954),
Bryde's, *B. edeni*, 72-78 mm (Best, 1977), and gray, *Eschrichtius robustus*, 82-87 mm (Rice and Wolman, 1971).

In all these baleen species, the mean size of the CL of ovulation is smaller than that of pregnancy.

No examples of accessory CL, as described by Laws (1961) and IWC

(1984), were found. However, there is a possibility of their existence, particularly with reference to c. atretica described later, whose function and fate are unclear.

3) Corpora albicantia

All CA were classified into young, medium and old categories (Laws, 1961), and mean diameters measured. The first impression gained in examining the ovaries, was the high numbers of CA accumulated even in young females, so that it was not unusual to observe many females of age 15 years and over with as many corpora as years (Fig. 1). This suggests two points: 1) females probably ovulate at least annually, and may be poly-ovulating; 2) complete resorption even of old CA is unlikely, so that CA are permanent features of the ovary, even when greatly regressed in size.

The young CA, are in fact most usually highly pigmented and yellow-tan in colour, whereas fin or sei ovaries are usually pale greyish-brown (personal observation). In the minke whales, the medium and old CA generally become brown and greyish, but some CA are still well pigmented. The difference between a highly pigmented CA and a corpus aberrans (Laws, 1961) equivalent to a corpus atreticum type a (IWC, 1984) (see Plate la) is not immediately obvious, since the latter is often regularly shaped and bright yellow or orange-yellow in hue.

Fig. 2 shows the course of regression of the CA with time in different reproductive classes.

4) Young CA

The mean maximum diameter range of the young CA is 28.14-16.50mm, with pregnant and ovulating females tending to bear slightly larger and, in the former, more numerous young corpora than females in anoestrus and with regressing CL, despite similar total counts of all ages of corpora. This might suggest that hormones of pregnancy may temporarily allay degenerative processes and shrinkage of the CA. Such explanations have been proposed for fin whales where similar observations were made (Laws, 1961). Marsh and Kasuya (1984) found slower rate of shrinkage of CA in pregnant pilot whales. Larsen (1984) gave a mean diameter of young CA of 21.4±3.5(s.d.)mm for Greenland minke whales, within the range presented here.

Initially the CL shrinks rapidly to 40% of its original diameter (Larsen, 1984, gave a figure of 37.8%), and then continues to about 25% of original CL diameter (Fig. 2a).

5) Medium CA

The range of mean diameters of the medium CA is 19.17−10.00 mm, the smallest being about 15% of original CL diameter, and 40% of initial diameter of the youngest CA. The shrinkage of the CA in this medium phase is

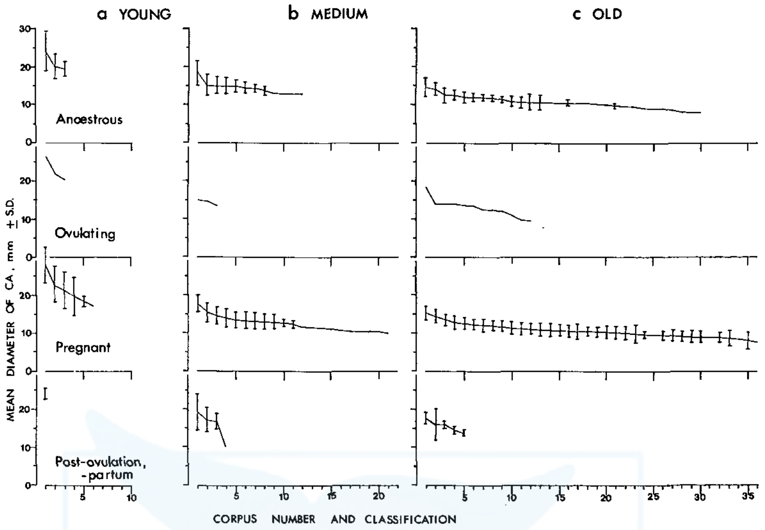


Fig. 2. Regression of accumulated corpora albicantia, measured by mean diameter, in decreasing order of c.albicans size, by different reproductive classes:
a. Young c.albicantia;
b. Medium c.albicantia;
c. Old c.albicantia.

slower (Fig. 2b), and there is considerable size overlap with the old CA category below (Fig. 2c). Larsen (1984) observed a shrinkage in diameter of medium CA in Greenland minke to 15.8±2.4(s.d.)mm, similar to results here, and 27.9% of original CL diameter.

6) Old CA

The range of mean diameters of the old CA is 18.5-7.5 mm. The shrinkage here is very slow (Fig. 2c), and not greatly different from that for medium CA. The similar size range with the medium CA, suggests not so much continued shrinkage, but a continued histological change in the structure. It seems unlikely that CA which have regressed to this third stage will regress or alter further; they become a permanent feature in the ovary. Examples of old CA are shown in Plates la and ld.

The general pattern of corpus regression in minke whales is similar to that in fin whales (Laws, 1961), but the sizes of minke CA in the different ovarian age categories are smaller. The ultimate regressed modal diameter (about 10 mm) of the old CA in minke being approximately half that for the fin whale (Laws, 1961). However, this body is still quite readily visible macroscopically. Larsen (1984) found a mean diameter of old CA of 10.0±2.4(s.d.)mm in Greenland minke, and shrinkage to about 17.7% of original CL diameter. The equivalent shrinkage here is 15.2% of CL size, close to the estimate of Best (1982) of 15.7%.

7) Corpora atretica, cystic follicles and cysts

Corpora atretica – type a: The corpus atreticum type a (IWC, 1984) identified here is equivalent to the corpus aberrans described by Laws (1961). These bodies exhibit follicular origins, there being evidence of apparent rupture or ovulation through presence of a stigma on the germinal epithelium overlying the body (Plate lb). However, they fail to luteinise fully and undergo instead a fatty degeneration over time (Plates lc and ld). These corpora often attain a moderate size, e.g. 23mm in diameter, and are very bright yellow in colour (Plate le). When recently formed they appear as lobules protruding from the mass of the ovary, and frequently a CA in form. The presence of older regressed or atrophied ones is often ascertained only after cutting into the ovary. A few maintain central vesicles (Plate lf).

No c.atretica a were found in the ovaries of the eleven juveniles, none in the ovaries of the ovulating female, or of the three females with a regressing CL. The anoestrous females (n=14) showed an incidence of 78.6%. Half of the anoestrous females had only a single c.atreticum a, while 7% had two, 14.3% had 3, and 14.3% had four. The mean diameter of the c.atreticum a was 10.82±4.50(s.d.)mm. Among pregnant females, the incidence of c.atretica a was 62.5% for those with a foetus <30 cm (n=8), 37.5% having a single body and 25.0% having two. The mean diameter was 10.08±3.78(s.d.)mm. The incidence in the group of foetal size 30–130 cm (n=26), was lower, at 26.9%, with 15.4% having a single body, 7.7% having two and 3.8% having three. The mean diameter was 10.50±5.4(s.d.)mm. The two females in late pregnancy had no c.atretica a. Sample size is too small in several categories for a valid χ^2-test, but restricting the test to incidences in anoestrous and pregnant females, $\chi^2=10.6751$ with d.f.=2, and is significant at $p<0.01$. It is therefore suggested that these bodies are directly associated with certain phases of the reproductive cycle, and by implication, certain hormone levels. Laws (1961) observed a decrease in incidence of c.aberrantia (c.atretica a) with advance of pregnancy in fin whales. In odontocetes, Best (1967) reported the highest incidence of c.atretica a in recently ovulated females, 45.5%, with lower levels of 4.6% in pregnant, 7.7% in lactating and 13.6% in anoestrous sperm whales, *Physeter macrocephalus*. Marsh and Kasuya (1984) found an apparent association of incidence of c.atreticum a with states of oestrus, ovulation and early pregnancy in pilot whales. The bodies appeared to degenerate post-partum and in anoestrus.

The fact that percentage occurrence varies so much between reproductive classes in minke whales also suggests that most c.atretica a degenerate completely, perhaps within a year, the usual reproductive interval. Laws (1961) held a similar view on the fate of c.aberrantia (c.atretica a) in the fin whale.

Of females with ovaries having a vesicular CL (n=11), 54.5% had a c.atreticum a, compared with 24.0% of those females with ovaries having a non-vesicular CL (n=25). The difference, however, was insignificant with $p>0.05$ using a χ^2test.

Corpora atretica – type b: This category corresponds with the definition of c.atreticum used by Laws (1961) and with the c.atreticum type b (IWC, 1984). These bodies are usually smaller than the c.atreticum a, and, unlike the frequently regular internal shape of the latter, are usually stellate or amoeboid in shape and deep yellow-orange or tan in colour. They never protrude from the ovary surface, and none examined exhibited a stigma. Usually, these c.atretica b lay deeper in the cortex than the c.atretica a.

No c.atretica b were observed in females with immature ovaries (n=11), and none were observed in the ovulating ovary or in the three pairs of ovaries with regressing CL. The incidence in anoestrous females (n=14) was 35.7%, with 14.3% having one, 7.1% having two, and 14.3% having seven c.atretica b. The maximum diameter of the c.atreticum b was 8.3mm, but many were much smaller. Among pregnant females, the early pregnant (n=8) group had an incidence of 12.5% with two c.atretica b, and very small diameter, <5 mm, while mid-pregnant females (n=26) had an incidence of 34.6%, with 19.2% having one and 15.4% having two c.atretica b. The maximum diameter observed was about 7 mm. Marsh and Kasuya (1984) observed no c.atretica b in immature pilot whales, but found 75% of all mature ovaries bore these bodies. Best (1967) found an average incidence of 50% in all reproductive classes of sperm whales.

Using similar criteria as above for the c.atreticum a data, a χ^2-test showed no significant differences between reproductive states, excluding juveniles. A similar finding was obtained in fin whales (Laws, 1961), and also in pilot whales (Marsh and Kasuya, 1984) and sperm whales (Best, 1967).

The persistence of these bodies is uncertain, particularly because of their small irregular form which may mean that some are inevitably overlooked in a macroscopic examination of the ovaries. Marsh and Kasuya (1984) suggest that these bodies do not persist. Total resorption is a possibility. Also, the overall incidence of c.atretica b are lower than for c.atretica a.

8) Cysts

Follicular, gel-filled cysts: In the present sample of ovaries, this type of cyst appears to occur exclusively in ovaries of pregnant females, with an incidence of 12.5% and a mean diameter of 31.7 mm in females in early pregnancy (n=8), and 3.8% and a mean diameter of 40 mm in females in mid pregnancy (n=26). No other examples of cystic follicles were observed. These cysts were often multichambered, resembling a thin-walled honeycomb filled with mucous gel. The ultimate fate of such cysts is not known, but presumably they regress, because they are not observed in other reproductive groups. Should some luteinisation or hyalisation occur, they may regress to a form of yellow body such as c.atreticum b, but this is speculative.

Cornified solid cysts: Only one example of a solid cyst was observed, and this was present in the cortex of a female in early pregnancy, in the form of a small whitish and homogeneous sphere, with a fibrous collagen-type of texture. The origin of this body was unknown.

Differential activity in the ovary pairs

The side of the whale from which the ovary was collected was not generally known or identifiable. The possibility of bi-lateral activity could thus not be evaluated as to preferential left or right activity. However, a simple analysis was performed to identify whether or not one ovary, regardless of side, might be more active than the other.

The pairs of ovaries with a total corpora count of 2 or more (52 pairs) were arranged in ascending order of corpora count. The individual ovary corpora counts of each pair were compared and the difference between them (d) was squared (d^2) and divided by the total corpora count (N). A plot of d^2/N on N revealed no pattern of increasing variability with corpora count, and insignificant correlation of $p>0.05$ with $r=-0.127$, d.f.$=50$. We may therefore conclude that there is no indication of differential activity between halves of ovary pairs.

Both Slijper (1949) and Laws (1961) found a tendency for the right ovary to be more active in fin and blue whales. Larsen (1984), examining left and right ovaries for a small sample of Greenland minke, found no significant bi-lateral ovarian activity.

ACKNOWLEDGEMENTS

The assistance from and collaboration with staff of the Far Seas Fisheries Research Laboratory, Shimizu, are gratefully acknowledged; their provision of the material and associated data have enabled this study to be carried out. Dr Seiji Ohsumi is especially thanked for his help. The advice and criticism from Dr John Harwood, Dr Richard M. Laws and Dr Helene Marsh in the analysis and preparation of the paper have been useful, and they are thanked for their help. The advice of Dr Hidehiro Kato and anonymous referees was of great assistance.

REFERENCES

Best, P.B., 1967. The sperm whale (*Physeter catodon*) off the west coast of South Africa. 1.Ovarian changes and their significance. *Div. Sea Fish. Investl Rep.,* 61: 1–17.

Best, P.B., 1977. Two allopatric forms of Bryde's whale off South Africa. *Rep. int. Whal. Commn* (special issue 1): 10–34.

Best, P.B., 1982. Seasonal abundance, feeding, reproduction, age and growth in minke whales off Durban (with incidental observations from the Antarctic). *Rep. int. Whal. Commn,* 32: 759–786.

Chittleborough, R.G., 1954. Studies on the ovaries of the humpback whale, *Megaptera nodosa* (Bonnaterre), on the western Australian coast. *Aust. J. Mar. Freshw. Res.,* 5(1): 35–63.

Christensen, I., 1974. Minke whale investigations in the Barents Sea and off East and West Greenland in 1973. *Fiskets Gang.,* 14: 278–286.

Gambell, R.G., 1968. Seasonal cycles and reproduction in sei whales of the Southern Hemisphere. *Discovery Rep.,* 35: 31–134.

Harrison, R.J., 1969. Reproduction and reproductive organs. pp. 253–348. *In*: H.T. Andersen (ed.) *The biology of marine mammals.* Academic Press, New York and London. 511 pp.

International Whaling Commission, 1979. Report of the special meeting on Southern Hemisphere minke whales, Seattle, May 1978. *Rep. int. Whal. Commn,* 29: 349–358.

International Whaling Commission, 1984. Report of the workshop on reproduction in whales, dolphins and porpoises. *Rep. int. Whal. Commn* (special issue 6): 2–24.

Ivashin, M.V. and Yu.A. Mikhalev, 1978. To the problem of the prenatal growth of minke whales, *Balaenoptera acutorostrata* of the Southern Hemisphere and of the biology of their reproduction. *Rep. int. Whal. Commn,* 28: 201–205.

Jonsgård, A., 1951. Studies on the little piked whale or minke whale (*Balaenoptera acuto-rostrata* Lacépède). Report on Norwegian investigations carried out in the years 1943–1950. *Norsk Hvalfangsttid,* 40(5): 5–54.

Kato, H., 1983. Some considerations on the decline in age at sexual maturity of the Antarctic minke whale. *Rep. int. Whal. Commn,* 33: 393–399.

Kato, H., 1985. Further examination of the age at sexual maturity of the Antarctic minke whale as determined from ear plug studies. *Rep. int. Whal. Commn,* 35: 273–278.

Larsen, F., 1984. Reproductive parameters of the minke whale, *Balaenoptera acutorostrata*, at West Greenland. *Rep. int. Whal. Commn* (special issue 6): 233–236.

Larsen, F. and F.O. Kapel, 1983. Further biological studies of the west Greenland minke whale. *Rep. int. Whal. Commn,* 33: 329–332.

Laws, R.M., 1961. Southern fin whales. *Discovery Rep.,* 31: 327–486.

Lockyer, C., 1976. Body weights of some species of large whales. *J. Cons. int. Explor. mer,* 36(3): 259–273.

Lockyer, C., 1981. Estimation of the energy costs of growth, maintenance and reproduction in the female minke whale, (*Balaenoptera acutorostrata*), from the Southern Hemisphere. *Rep. int. Whal. Commn,* 31: 337–343.

Lockyer, C., 1984. Review of baleen whale (Mysticeti) reproduction and implications for management. *Rep. int. Whal. Commn* (special issue 6): 27–50.

Mackintosh, N.A. and J.F.G. Wheeler, 1929. Southern blue and fin whales. *Discovery Rep.,* 1: 257–540.

Marsh, H., 1985. Observations on the ovaries of an isolated minke whale: evidence for spontaneous sterile ovulation and structure of the resultant corpus. *Sci. Rep. Whales Res. Inst.,* 36: 35–39.

Marsh, H. and T. Kasuya, 1984. Changes in the ovaries of the short-finned pilot whale, *Globicephala macrorhynchus*, off the Pacific coast of Japan. *Rep. int. Whal. Commn* (special issue 6): 311–341.

Masaki, Y., 1979. Yearly change of the biological parameters for the Antarctic minke whale. *Rep. int. Whal. Commn,* 29: 375–396.

Matthews, L.H., 1937. The humpback whale, *Megaptera nodosa. Discovery Rep.,* 17: 7–92.

Mitchell, E. and V.M. Kozicki, 1975. Supplementary information on minke whale, (*Balaenoptera acutorostrata*) from Newfoundland fishery. *J. Fish. Res. Bd Can.,* 32(7): 985–994.

MOSSMAN, H.W. and K.L. DUKE, 1973. *Comparative morphology of the mammalian ovary*. University of Wisconsin Press. 461 pp.

OHSUMI, S., 1979. Feeding habits of the minke whale in the Antarctic. *Rep. int. Whal. Commn*, 29: 473–476.

RICE, D.W. and A.A. WOLMAN, 1971. *The life history and ecology of the gray whale* (*Eschrichtius robustus*). (Special Publication 3). The American Society of Mammalogists, Washington. 142 pp.

SLIJPER, E.J., 1949. On some phenomena concerning pregnancy and parturition of the Cetacea. *Bijd. Dierk.*, 28: 416.

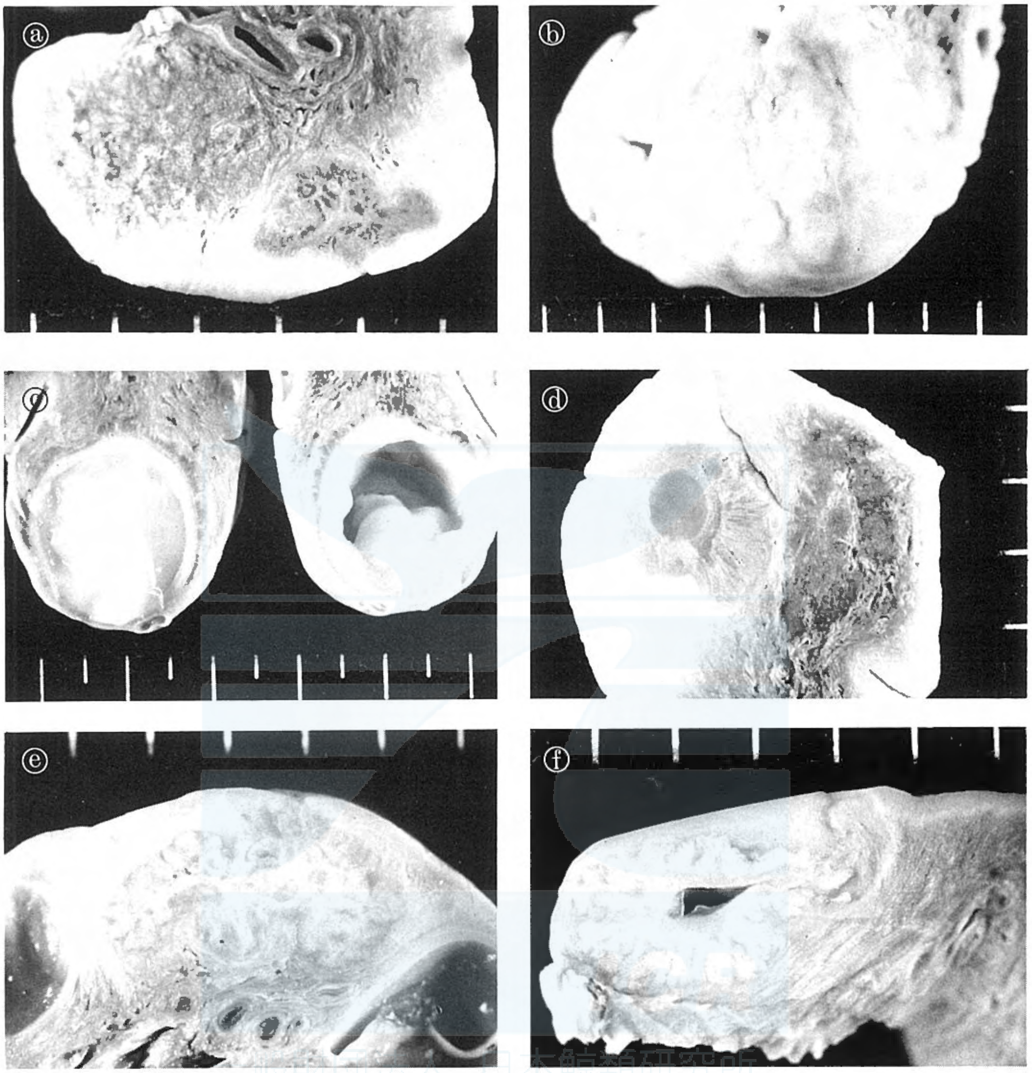
SLIJPER, E.J., 1966. Functional morphology of the reproductive system in Cetacea. pp. 277–319. *In*: K.S. NORRIS (ed.) *Whales, dolphins and porpoises*. University of California Press, Berkeley and Los Angeles. 789 pp.

WILLIAMSON, G.R., 1975. Minke whales off Brazil. *Sci. Rep. Whales Res. Inst.*, 27: 37–59.

EXPLANATION OF PLATE

PLATE I

a. Old corpus albicans (on right) and corpus atreticum type a (on left) showing pigmentation.
b. External appearance of a recent corpus atreticum type a, showing the stigma (site of rupture).
c. Internal appearance of recently ruputured follicle above (Plate 1b) showing commencement of luteinisation.
d. Uneven luteinisation of corpus atreticum type a, with a fibrin-filled vesicle (on left), showing the stigma and adjacent old c. albicans (on right).
e. Corpus atreticum type a (centre) showing yellow pigmentation and the stigma (point of follicular rupture), and adjacent follicles.
f. Corpus atreticum type a with a central vesicle.



一般財団法人　日本鯨類研究所
THE INSTITUTE OF CETACEAN RESEARCH

A STRANDING OF *MESOPLODON STEJNEGERI* IN THE MAIZURU BAY, SEA OF JAPAN*

NOBUYUKI MIYAZAKI**, IZUMI NAKAMURA***, SHINSUKE TANABE****, AND RYO TATSUKAWA****

ABSTRACT

On 13 June 1984 a Stejneger's beaked whale, *Mesoplodon stejnegeri*, was found to have stranded on the beach of Maizuru Bay (35° 31′N,135° 24′E), the Sea of Japan. This whale was probably one of two unidentified whales occasionally sighted in the bay since eight months before the stranding. The animal was a juvenile male having testes of 34 g and measuring 396.5 cm in body length. It had 44 vertebrae, composed of 7 cervical (first three cervical bones were fused into one unit), 9 dorsal, 11 lumbar and 17 caudal vertebrae. Only vertebral epiphyses of the 3rd–7th cervicals and the 16–17th caudals were fused with the centrum. The external, cranial and vertebral measurements, and organ weights were presented. The PCBs and *p,p*'-DDE levels in blubber were 7.0 and 44 μg/g on wet weight basis, respectively. The distribution of the five species of *Mesoplodon* known from the North Pacific Ocean was discussed.

INTRODUCTION

In the Sea of Japan, there have been reported four *Mesoplodon stejnegeri* True, 1885 and one *Mesoplodon ginkgodens* Nishiwaki and Kamiya, 1958. A stranding of *Mesoplodon bowdoini* (Andrews, 1908) reported by Nishiwaki (1962b) was reidentified by Moore (1963) as *M. stejnegeri*. This was the first record of the species in the Sea of Japan. Later, Nishimura and Nishiwaki (1964) reported two additional specimens of *M. stejnegeri* incidentally taken by the salmon drift gill net fishery in the Sea of Japan. They were a 520 cm male taken in 39°32′N, 137°03′E on 23 April 1963 and a 238 cm female taken in 39°08′N, 135°16′E on 10 May 1963. The species was identified based on the external characters, and the skulls were later lost by an earthquake in the Niigata area on 16 June 1964. The fourth specimen was a male (body length: 490 cm) found on the beach of Niigata Prefecture on 10 May 1984 (Ikehara, Shimizu, Hiyama, Ito,

---

* *This work was partly supported by the Grant-in-Aid for Scientific Research from the Ministry of Education, Japan (grant no. 61560224).*

** *Department of Zoology, National Science Museum, 3-23-1 Shinjuku-ku, Tokyo, 160 Japan.*

*** *Fisheries Research Station, Kyoto University, Nagahama, Maizuru-shi, Kyoto, 625 Japan.*

**** *Department of Environment Conservation, Ehime University, 3-5-7 Matsuyama, Ehime, 790 Japan.*

Sci. Rep. Whales Res. Inst.,
No. 38, 1987, 91–105

Ogawa and Kamiya, 1985). Only record of *M. ginkgodens* is a juvenile female of 344 cm in body length. It was captured in a set net off Hiyoriyama in the Sea of Japan on 16 March 1984 (Hiyoriyama Aquarium, 1984) and was identified to the species by Dr T. Tobayama (T. Tobayama, pers. comm.). These five records (*M. stejnegeri* and *M. ginkgodens*) were obtained during March to June when the oceanographic condition changes from the winter type to the summer.

Present study is to describe the *M. stejnegeri* found on the beach of Maizuru Bay on 13 June 1984, and to describe the ontogenetic change of cranium, the sexual dimorphism and the level of organochlorine pollutant. The distribution of the species is briefly discussed in comparison with other species of *Mesoplodon* in the North Pacific.

MATERIAL AND METHODS

On 13 June 1984, a male beaked whale of 396.5 cm in body length was found on the beach of Taira (35°31′N, 135°24′E), coast of the Maizuru Bay, Sea of Japan. The first observer told to one of the authors (Nakamura) that the animal had been already dead at his first sighting. After identifying the specimen as *Mesoplodon* on 15 June, Nakamura transported it to the Fisheries Research Station of Kyoto University for further examination. In the station, Nakamura recorded the pigmentation, dissected the specimen and weighed the organs with cooperation of Messrs H. Tanaka and Y. Yamamoto of Ehime University. The measurements of external proportion and photographs were also taken. The cranial and vertebral bones were measured by Miyazaki after cleaning and deposited at the Fisheries Research Station, Kyoto University (FAKU M851). Other bones were lost during preparation. As the major portion of the teeth of the specimen were embedded in the alveoli, only right tooth was removed from the alveolus for examination after cutting a part of the right mandible.

PCBs and *p,p*'-DDE were extracted using the alkaline alcohol digestion method of Wakimoto, Tatsukawa and Ogawa (1971). The organochlorines in the final extracts were quantified by a gas chromatograph with electron capture detection (Tanabe, Tatsukawa, Tanaka, Maruyama, Miyazaki and Fujiyama, 1981). Values of *p,p*'-DDE reported here also include those of *p,p*'-DDT, because *p,p*'-DDT is converted to *p,p*'-DDE during alkaline alcohol digestion.

RESULTS

External morphology

The body shape was typical of beaked whales, characterized by a relatively large thorax and small head, flippers and tail (Plate I). The body proportion of the specimen is shown in Table 1. The dorsal fin was placed well posterior

TABLE 1. EXTERNAL MEASUREMENTS OF *MESOPLODON STEJNEGERI* STRANDED ON THE BEACH OF MAIZURU BAY KYOTO, 1984

Measurments*	cm	%
1. Body length	396.5	100
2. Tip of rostrum to apex of melon	13.0	3.3
3. Tip of rostrum to angle of gape	19.5	4.9
4. Tip of rostrum to blowhole	33.0	8.3
5. Tip of rostrum to center of eye	35.0	8.8
6. Tip of rostrm to ear	45.0	11.3
7. Tip of rostrum to anterior insertion of flipper	78.0	19.7
8. Tip of rostrum to anterior insertion of dorsal fin	244.0	61.5
9. Tip of rostrum to umbilicus	188.0	47.4
10. Tip of rostrum to center of genital aperture	249.0	62.8
11. Tip of rostrum to anus	290.0	73.1
12. Width of flipper at the base	18.5	4.7
13. Anterior insertion of flipper to tip	41.0	10.3
14. Posterior insertion of flipper to tip	25.5	6.4
15. Basal length of dorsal fin	37.5	9.5
16. Anterior insertion of dorsal fin to tip	33.0	8.3
17. Posterior insertion of dorsal fin to tip	18.5	4.7
18. Height of dorsal fin	8.8	2.2
19. Width of tail flukes	94.0	23.7
20. Anterior insertion of fluke to tip (left)	54.5	13.7
21. Anterior insertion of fluke to notch (left)	34.0	8.6
22. Center of flukes to tip (left)	48.5	12.2

* Measurements parallel to the body axis.

to the middle of body (tip of rostrum to anterior insertion of dorsal fin : 61.5% of body length) and nearly at the level of genital aperture (tip of rostrum to genital aperture : 62.8%). The length of visceral cavity represented by the proportion of anterior insertion of flipper to anus (55.4%) was longer than the head (tip of snout to ear : 11.3%), the tail (anus to the center of posterior margin of tail flukes : 26.9%) or the remaining portion (ear to anterior insertion of flipper : 8.4%). The height of dorsal fin (2.2%) and the flipper length (anterior insertion of flipper to the tip: 10.3%) were relatively small. Other characteristic features of the specimen were long and narrow snout, forehead smoothly tapering to the rostrum, absence of demarcation between the melon and the rostrum, a pair of prominent throat grooves (left: 24.5 cm in length, right: 26.0 cm), and absence of a median notch on the posterior margin of tail flukes (Plate I).

The color of the animal was black on the dorsal side and lighter on the mandible and the ventral side of the body. The flippers and tail flukes were pigmented black on both sides. In the adult male of *Mesoplodon carlhubbsi*, the rostrum and anterior portion of the mandible back to the posterior edge of the tooth are a brilliant white (Orr, 1953; Mead, Walker and Houck, 1982). This pigmentation was absent on the present specimen of *M. stejnegeri*.

TABLE 2. BODY AND ORGAN WEIGHT OF *MESOPLODON STEJNEGERI* STRANDED ON THE BEACH OF MAIZURU BAY, KYOTO, 1984

Measurments		g	%
Body weight		544,973	100
Brain		783	0.14
Muscle		343,780	63.1
Blubber		112,659	20.7
Bone		50,934	9.35
Viscera		35,258	6.47
Others		1,559	0.29
Internal organs (included in viscera)			
Heart		2,530	0.46
Lungs		6,480	1.19
Liver		5,100	0.94
Diaphragm		2,730	0.50
Pancreas		255	0.05
Kidney	(left)	1,200	0.22
	(right)	1,480	0.27
Spleen		76	0.01
Testis	(left)	15	
	(right)	19	

Body and organ weights

Body weight of the animal was calculated at 544.973 kg as the total of the weights of muscle, blubber, bone, viscera, brain and other miscellaneous tissues. This value seemed to be underestimation of the true body weight because some of the blood and body fluid were not included. This will cause some inaccuracy in the proportional weights of organs and tissues in Table 2. Brain weight was 0.14% of the body weight, which was smaller than those of seven delphinid species, ranging from 0.53% in *Stenella coeruleoalba* to 1.48% in *Delphinus delphis* (Bryden, 1972; Miyazaki, Fujise and Fujiyama, 1981). Muscle (63.1% of body weight) was the largest and followed by blubber (20.7%), bone (9.3%) and viscera (6.5%). Among internal organs, lungs (1.2%) were the heaviest organ, and followed by liver (0.94%), diaphragm (0.50%), kidneys (0.49%), heart (0.45%), pancreas (0.05%) and spleen (0.01%). Testis weight was 15 g in the left and 19 g in the right.

Osteology

The cranial and vertebral measurements are shown in Appendix Tables 1 and 2, respectively. It is noted that this specimen had a pair of antorbital notches, but no prominental notches which are characteristics for *M. carlhubbsi* (Plate II).

This specimen had the following characters of *M. stejnegeri* described by Moore (1963): (1) Each antorbital notch opened with an obtuse angle of more than 90°. (2) The profile of the premaxillary crest above the superior nares showed an abrupt turn forward, forming about 90° turn in dorsoanterior face of each premaxillary. (3) In the anterior view, this 90° turn showed a deep crease across the premaxillary on the portion of its greatest width and descended laterally about 20° below the horizontal. (4) Both the dorsal and ventral profiles of beak were virtually straight. These points are characteristic to *M. stejnegeri* (Moore, 1963). The alveolus of the mandible was entirely posterior to the symphysis. This separates *M. stejnegeri* from *M. carlhubbsi* having alveolus overlapped with the symphysis. The tooth was a triangular shape and was laterally compressed. The ratio of the greatest thickness to the greatest antero-posterior width of the right tooth was 0.15 in the present specimen and was within the range (0.13–0.20) of *M. stejnegeri* (Moore, 1963).

The mesirostral canal was not filled with bone. The anterior margin of the tooth was not of a straight line and the apex of the tooth was not found to lie on that line (Plate III). Apex of the teeth was not worn because the teeth were not erupted. The pulp cavity was widely open. These characters were virtually different from those of adult male of the species described by Moore (1963). The thyrohyals were not fused with the basihyal. Vertebral formula was C:7+D:9+L:11+Ca:17=44. The first to third cervicals were fused on both neural arches and centra, and formed one unit. Only posterior epiphysis of the third cervical and all epiphyses of the 4–7th cervicals were fused with their centrum as well as those of the 16th and 17th caudal vertebrae. These indicate that this animal is juvenile and physically immature.

Organochlorine residues

Concentrations of PCBs and *p, p*'-DDE in some organs and tissues were shown in Table 3. Among the tissues, the concentration was highest in the blubber on wet weight basis. This is because the blubber contains larger quantity of fat and these pollutants have high lipophilicity. The *p, p*'-DDE concentration was higher than that of PCBs in all parts of the body analyzed. *M. stejnegeri* showed higher burdens of both PCBs and *p, p*'-DDE in blubber than other tissues as seen in other marine mammals (dolphin and seal) having higher fat content in the blubber (Tanabe *et al.*, 1981; Hidaka, Tanabe and Tatsukawa, 1983).

DISCUSSION

Since October 1983, several staffs of the Fisheries Research Station of Kyoto University sometimes observed a pair of medium-sized whales during their own investigations in the Maizuru Bay, but they were not able to identify the species because the whales were very shy against the vessel and didn't come within about 100 m of the R/V *Ryouyomaru* (9.8 tons) of the station or didn't jump from the surface. Then in February 1984, a 4–5 m whale was stranded in the Maizuru Bay at the almost same position as that of the present strand-

TABLE 3. CONCENTRATIONS OF PCBS AND *p,p'*-DDE IN THE TISSUES AND ORGANS OF *MESOPLODON STEJNEGERI* STRANDED ON THE BEACH OF MAIZURU BAY, KYOTO, 1984

Tissue and organ	Fat content (%)	Wet weight basis (μg/g)		Fat weight basis (μg/g)		Burden (mg)	
		PCB	*p,p'*-DDE*	PCB	*p,p'*-DDE*	PCB	*p,p'*-DDE*
Blubber	90	7.0	44	7.8	49	790	4900
Muscle	1.2	0.048	0.21	4.0	17	16	72
Liver	8.9	0.29	0.82	3.2	9.1	1.5	4.2
Kidneys	3.6	0.086	0.31	2.4	8.7	0.14	0.52

* *p,p'*-DDE includes *p,p'*-DDT (See text).

ing. This animal was buried under the ground without scientific examination. Since there were no sightings of whales in the Maizuru Bay after these two strandings, there is a high possibility that the present specimen is one of the pair of the medium-sized whales sighted since October 1983.

The detailed cranial measurements of the present specimen are shown in Appendix Table 1, and selected measurements of five available *M. stejnegeri* specimens in Table 4. The proportion of rostrum length (measurement no. 2) to skull length (no. 1) is higher in the larger individuals in both sexes. The same tendency is observed in the following four measurements (measurement nos 3, 5, 6 and 8) related with rostrum length.

The relative and absolute sizes of tooth (nos 56, 57 and 59) and the length of alveolus (no. 53), are obviously larger in adult males than adult females as described by Moore (1963). The ratio of the skull width (nos 17, 18 and 19) to skull length (no. 1) is larger in males than females. The same tendency is observed in the ratio of the premaxillary width at midlength of rostrum (no. 32), the span of premaxillary crests (no. 29) and the nasal breadth on vertex (no. 26) to skull length. The absolute values of both superior nares width (no. 39) and inferior nares width (no. 40) are larger in males than females as well as their proportional values to skull length. The ratios of occipital condyle measurements (nos 21, 22 and 23) to skull length, are larger in males than females as well as that of breadth of foramen magnum (no. 24).

Fig. 1 shows the reported positions of the catches or strandings of the five species of *Mesoplodon* (*M. stejnegeri*, *M. carlhubbsi*, *M. ginkgodens*, *M. densirostris* and *M. hectori*) from the Sea of Japan, the Bering Sea and the North Pacific Ocean (Ogawa, 1938; Jellison, 1953; Nishiwaki and Kamiya, 1958, 1959; Nishiwaki, 1962a, 1962b; Moore, 1963; Galbreath, 1963; Yang, 1964; Nishimura and Nishiwaki, 1964; Fiscus, Rice and Johnson, 1969; Kasuya and Nishiwaki, 1971; Nishiwaki, Kasuya, Kureha and Oguro, 1972; Mead, 1981; Mead, *et al.*, 1982; Loughlin, Fiscus, Johnson and Rugh, 1982; Leatherwood, Reeves, Perrin and Evans, 1982; Nakajima, 1984). Present record extends the range of *M. stejnegeri* in the Sea of Japan to the south by about 1.5 degree in

TABLE 4. COMPARISON OF SKULL MEASUREMENTS (mm) OF 6 SPECIMENS OF *MESOPLODON STEJNEGERI**

Measurements	Present specimen (juv. ♂)	Nushagak** (ad. ♂)	Akita*** (ad. ♂)	Kasilof** (im. ♀)	Tofino** (ad. ♀)	Cedros Is.** (im. no sex)
1. Condylobasal length	612 (100)	686 (100)	682 (100)	708 (100)	782 (100)	631 (100)
2. Rostrum length	327 (53.4)	–	403 (59.1)	405 (57.2)	474 (60.6)	323 (51.2)
3. Rostrum tip to post. margin of pterygoid	446 (72.9)	–	560 (82.1)	540 (76.3)	625 (79.9)	–
4. Rostrum tip to post. ext. of pterygoid wing	270 (44.1)	335 (48.8)	–	313 (44.1)	395 (50.5)	277 (43.9)
6. Rostrum tip to post. ext. of max. on palate	351 (57.4)	426 (62.1)	429 (62.9)	412 (58.2)	500 (63.9)	368 (58.3)
8. Rostrum tip to ant. margin of sup. nares	404 (66.0)	480 (70.0)	502 (73.6)	482 (68.1)	572 (73.1)	422 (66.9)
17. Breadth across frontals	302 (49.8)	–	346 (50.7)	336 (47.5)	355 (45.4)	–
18. Breadth across zygomatic proc.	289 (47.2)	–	333+(48.8+)	323 (45.6)	337 (43.1)	277+(43.9+)
19. Breadth across orbits	289 (47.2)	–	340 (49.9)	323 (45.6)	335 (42.8)	277 (43.9)
21. Span of occipital condyles	95 (15.5)	115 (16.8)	118 (17.3)	108 (15.3)	111 (14.2)	103 (16.3)
22. Width of occipital condyles	36 (5.9)	42 (6.1)	–	39 (5.5)	42 (5.4)	40 (6.3)
23. Length of occipital condyle	63 (10.3)	72 (10.5)	80 (11.7)	63 (8.9)	70 (9.0)	62 (9.8)
26. Breadth across exoccipitals	252 (41.2)	–	–	270 (38.1)	278 (35.5)	247 (39.1)
29. Pmx. crest to right nasal	26 (12.7)	–	–	42 (5.9)	30 (3.8)	36 (5.7)
32. Pmx. width at mid-rostrum	30 (4.9)	–	41 (6.0)	29 (4.1)	26 (3.3)	31 (4.9)
39. Width of sup. nares	49 (8.0)	55 (8.0)	52 (7.6)	53 (7.5)	55 (7.0)	52 (8.2)
40. Width of inf. nares	101 (16.5)	94 (13.7)	116 (17.0)	87 (12.3)	88 (11.3)	85 (13.5)
53. Alveolus length	20 (3.3)	119 (17.3)	121 (17.7)	30 (4.2)	26 (3.3)	–
56. Mandibular tip to alveolus	147 (24.0)	145 (21.1)	149 (21.8)	165 (23.3)	211 (27.0)	–
57. Length of tooth	51 (8.3)	153 (22.3)	164 (24.0)	56 (7.9)	61 (7.8)	–
59. Thickness of tooth	8 (1.3)	18 (2.6)	24 (3.5)	9 (1.3)	9 (1.3)	–

* Figures in parentheses indicate the percentage to the condylobasal length. For details of measurements see Appendix Table 1.

** Measurements from Moore (1963).

*** Measurements from Nishiwaki (1962a).

latitude, but does not require to alter the current knowledge of the distribution that it is distributed in the colder waters of the North Pacific Ocean, the Sea of Japan, and deep waters of the southwest Bering Sea (Tomilin, 1967; Leatherwood and Reeves, 1983; Loughlin and Perez, 1985). Comparison of the sightings among the five species of *Mesoplodon* in the North Pacific indicates that *M. stejnegeri* was found in the coldest waters and *M. densirostris* in the warmest waters. *M. carlhubbsi* was found in the colder waters than *M. ginkgodens* and *M. hectori*.

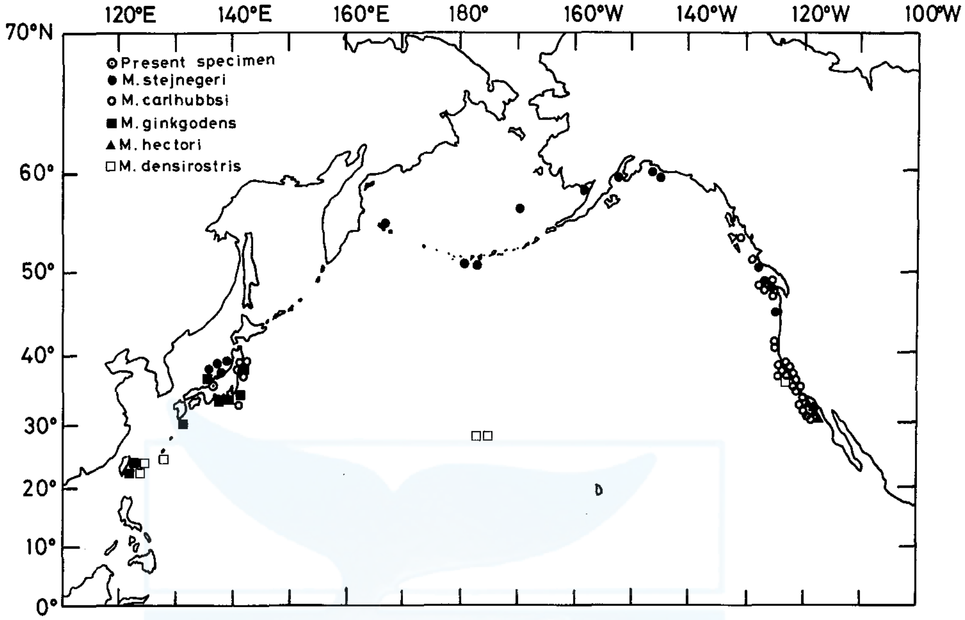


Fig. 1. Locations of the present specimen and the five species of *Mesoplodon* that have been reported from the North Pacific and adjacent seas.

The organochlorine concentrations in the present specimen (7.0 μg/g of PCBs and 44 μg/g of *p, p*'-DDE in wet blubber) are within the range of the concentrations represented by two males *M. densirostris* (PCBs: 14 and 29 μg/g, DDT: 38 and 65 μg/g) from northwestern Atlantic (Taruski, Olney and Winn, 1975), a female *M. densirostris* (PCBs: 4.8 μg/g, DDT: 11 μg/g) from Mediterranian Sea (Aguilar, Jover and Nadal, 1982), and one female and three males of *Ziphius cavirostris* (PCBs: 7.9 to 12 μg/g, DDT: 12 to 45 μg/g) from Bermuda (Knap and Jickells, 1983).

ACKNOWLEDGEMENTS

I wish to thank Mr M. Ueno of Kyoto University, and Messrs H. Tanaka, K. Yamamoto and S. Watanabe of Ehime University for their invaluable assistance in the examination of this study. Mr K. Kameda of the Fishermen's Cooperative Union of Kyoto Prefecture helpfully gave us the stranding information of the present Stejneger's beaked whale. Dr T. Tobayama of the Kamogawa Sea World kindly permitted us to use the stranding record of *M. ginkgodens* as his personal information. Drs Toshio Kasuya of Far Seas Fisheries Research Laboratory, Japan and James Mead of Smithsonian Institution, U.S.A. reviewed the manuscript and made helpful suggestions.

REFERENCES

AGUILAR, A., L. JOVER and J. NADAL, 1982. A note on the organochlorine contamination in a Blainville's beaked whale, *Mesoplodon densirostris* (de Blainville, 1817) from the Mediterranian Sea. *P. Dept. Zool. Barcelonas*, 7: 85–90.

BRYDEN, M.M., 1972. Growth and development of marine mammals. pp. 1–79. *In*: R.J. Harrison (ed.) *Functional anatomy of marine mammals Vol. 1.* Academic Press, London and New York. 451 pp.

FISCUS, C.H., D.W. RICE and A.M. JOHNSON, 1969. New records of *Mesoplodon stejnegeri* and *Ziphius cavirostris* from Alaska. *J. Mamm.*, 50:127.

GALBREATH, E.C., 1963. Three beaked whales stranded on the Midway Islands, Central Pacific Ocean. *J. Mamm.*, 44: 422–423.

HIDAKA, H., S. TANABE and R. TATSUKAWA, 1983. DDT compounds and PCB isomers and congeners in Weddell seals and their fate in the Antarctic marine ecosystem. *Agric. Biol. Chem.*, 47(9): 2009–2017.

HIYORIYAMA AQUARIUM, 1984. *Annual report of the Japanese zoo and aquarium society* (in Japanese). No. 3.

IKEHARA, H., E. SHIMIZU, Y. HIYAMA, T. ITO, T. OGAWA and T. KAMIYA, 1984. On *Mesoplodon* stranded on the beach of Niigata (in Japanese). Abstract of Spring Annual Meeting of the Society of Japanese Fisheries. No. 404.

JELLISON, W.L., 1953. A beaked whale, *Mesoplodon* sp., from the Pribilofs. *J. Mamm.*, 34: 249–251.

KASUYA, T. and M. NISHIWAKI, 1971. First record of *Mesoplodon densirostris* from Formosa. *Sci. Rep. Whales Res. Inst.*, 23: 129–137.

KNAP, A.H. and T.D. JICKELLS, 1983. Trace metals and organochlorines in the goosebeaked whale. *Mar. Pollut. Bull.*, 14(7): 271–274.

LEATHERWOOD, J.S. and R.R. REEVES, 1983. *Whales and dolphins.* Sierra Club Books, San Francisco. 302pp.

LEATHERWOOD, J.S., R.R. REEVES, W.F. PERRIN and W.E. EVANS, 1982. Whales, dolphins, and porpoises of the eastern North Pacific and adjacent arctic waters. *National Marine Fisheries Service Circular* 444. 245pp.

LOUGHLIN, T.R. and M. PEREZ, 1985. *Mesoplodon stejnegeri. Mammalian Species*, 250: 1–6.

LOUGHLIN, T.R., C.H. FISCUS, A.M. JOHNSON and D.J. RUGH, 1982. Observations of *Mesoplodon stejnegeri* (Ziphiidae) in the central Aleutian Islands, Alaska. *J. Mamm.*, 63: 697–700.

MCCANN, C., 1964. A coincidental distribution pattern of some of the larger marine animals. *Tuatara*, 12: 119–124.

MEAD, J.G., 1981. First records of *Mesoplodon hectori* (Cetacea, Ziphiidae) from the northern Hemisphere and a description of the adult male. *J. Mamm.*, 62(2): 430–432.

MEAD, J.G., W.A. WALKER and W.J. HOUCK, 1982. Biological observations on *Mesoplodon carlhubbsi* (Cetacea: Ziphiidae). *Smithsonian Contributions to Zoology*, 344: 1–25.

MIYAZAKI, N., Y. FUJISE and T. FUJIYAMA, 1981. Body and organ weight of striped and spotted dolphins off the Pacific coast of Japan. *Sci. Rep. Whales Res. Inst.*, 33: 27–67.

MOORE, J.C., 1963. Recognizing certain species of beaked whales of the Pacific Ocean. *American Midland Naturalist*, 70: 396–428.

NAKAJIMA, M., 1984. *Mesoplodon* drifting in the sea. *Geikentsushin*, 356: 94–100 (in Japanese).

NISHIMURA, S. and M. NISHIWAKI, 1964. Records of the beaked whales *Mesoplodon* from the Japan Sea. *Publ. Seto Mar. Biol. Lab.*, 12: 323–334.

NISHIWAKI, M., 1962a. *Mesoplodon bowdoini* stranded at Akita beach, Sea of Japan. *Sci. Rep. Whales Res. Inst.*, 16: 61–77.

NISHIWAKI, M., 1962b. Observation on two mandibles of *Mesoplodon. Sci. Rep. Whales Res. Inst.*, 16: 79–82.

NISHIWAKI, M. and T. KAMIYA, 1958. A beaked whale *Mesoplodon* stranded on Oiso beach, Japan. *Sci. Rep. Whales Res. Inst.*, 13: 53–83.

NISHIWAKI, M. and T. KAMIYA, 1959. *Mesoplodon stejnegeri* from the coast of Japan. *Sci. Rep. Whales Res. Inst.*, 14: 35–48.

NISHIWAKI, M., T. KASUYA, K. KUREHA and N. OGURO, 1972. Further comments on *Mesoplodon ginkgodens*. *Sci. Rep. Whales Res. Inst.*, 24: 43–56.

OGAWA, T., 1938. Studien uber die Zahnwhale in Japan, insbesondere uber die vier bei uns bisher unbekannten Gattungen *Tursiops, Steno, Pseudorca* and *Mesoplodon*. *Arb. Anat. Inst., Kaiserl. Japan. Univ. Sendai.*, 21: 173–218.

ORR, R.T., 1953. Beaked whale (*Mesoplodon*) from California, with comments on taxonomy. *J. Mamm.*, 34(2): 239–249.

TANABE, S., R. TATSUKAWA, H. TANAKA, K. MARUYAMA, N. MIYAZAKI and T. FUJIYAMA, 1981. Distribution and total burdens of chlorinated hydrocarbons in bodies of striped dolphins (*Stenella coeruleoalba*). *Agric. Biol. Chem.*, 45(11): 2569–2578.

TARUSKI, A.G., C.E. OLNEY and H.E. WINN, 1975. Chlorinated hydrocarbons in cetaceans. *J. Fish. Res. Board Can.*, 32(11): 2205–2209.

TOMILIN, A.G., 1967. *Mammals of the U.S.S.R. and adjacent countries, Vol. IX. Cetacea.* (Translated from Russian). The Israel Program for scientific translations, Jerusalem. 717pp.

WAKIMOTO, T., R. TATSUKAWA and T. OGAWA, 1971. Analytical method of PCBs. *J. Environ. Pollut. Control*, 7: 517–522 (in Japanese).

YANG, H.C., 1964. Whaling and Whales of Taiwan. *Geikentsushin*, 157: 5–122 (in Japanese).

EXPLANATIONS OF PLATES

PLATE I

External features of the present *Mesoplodon stejnegeri* found on the beach of Maizuru Bay (35°31′N, 135°24′E) on 13 June 1984. The male, 396.5 cm in body length (Photographs by H. Tanaka).

Fig. 1. Lateral view of head.
Fig. 2. Dorsal fin.
Fig. 3. Left flipper.
Fig. 4. Throat region of head.
Fig. 5. Ventral view.
Fig. 6. Dorsal view of tail flukes (dorsal).

PLATE II

Skull of the present specimen, *M. stejnegeri.*

Fig. 1. Dorsal view.
Fig. 2. Ventral view.
Fig. 3. Lateral view.

PLATE III

Skull and skeleton of the present specimen, *M. stejnegeri.*

Fig. 1. Lingual aspect of the right tooth.
Fig. 2. Buccal aspect of the right tooth.
Fig. 3. Mesial aspect of the right mandible.
Fig. 4. Mesial aspect of the mandibles.
Fig. 5. Hyoid bones.
Fig. 6. Dorsal view of the cervical vertebrae.
Fig. 7. Lateral view of the cervical vertebrae.
Fig. 8. Lateral view of the dorsal vertebrae. The eight and 9th dorsal vertebrae have been used for pollutant analysis, and are missing from the figure.
Fig. 9. Lateral view of the lumbar vertebrae.
Fig. 10. Lateral view of the anterior segment of caudal vertebrae.
Fig. 11. Lateral view of the posterior segment of caudal vertebrae.

PLATE I

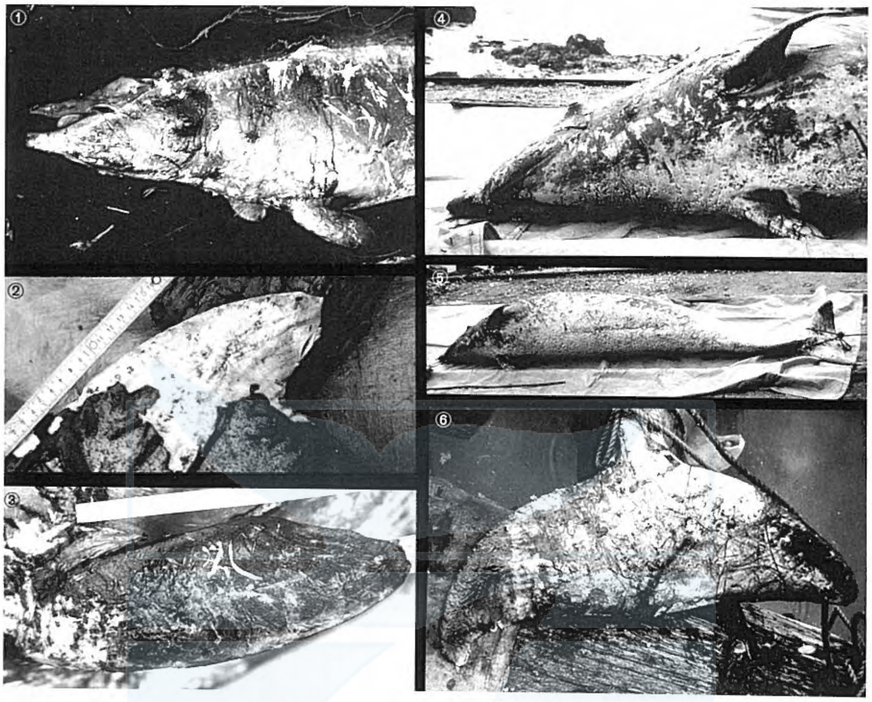


PLATE II

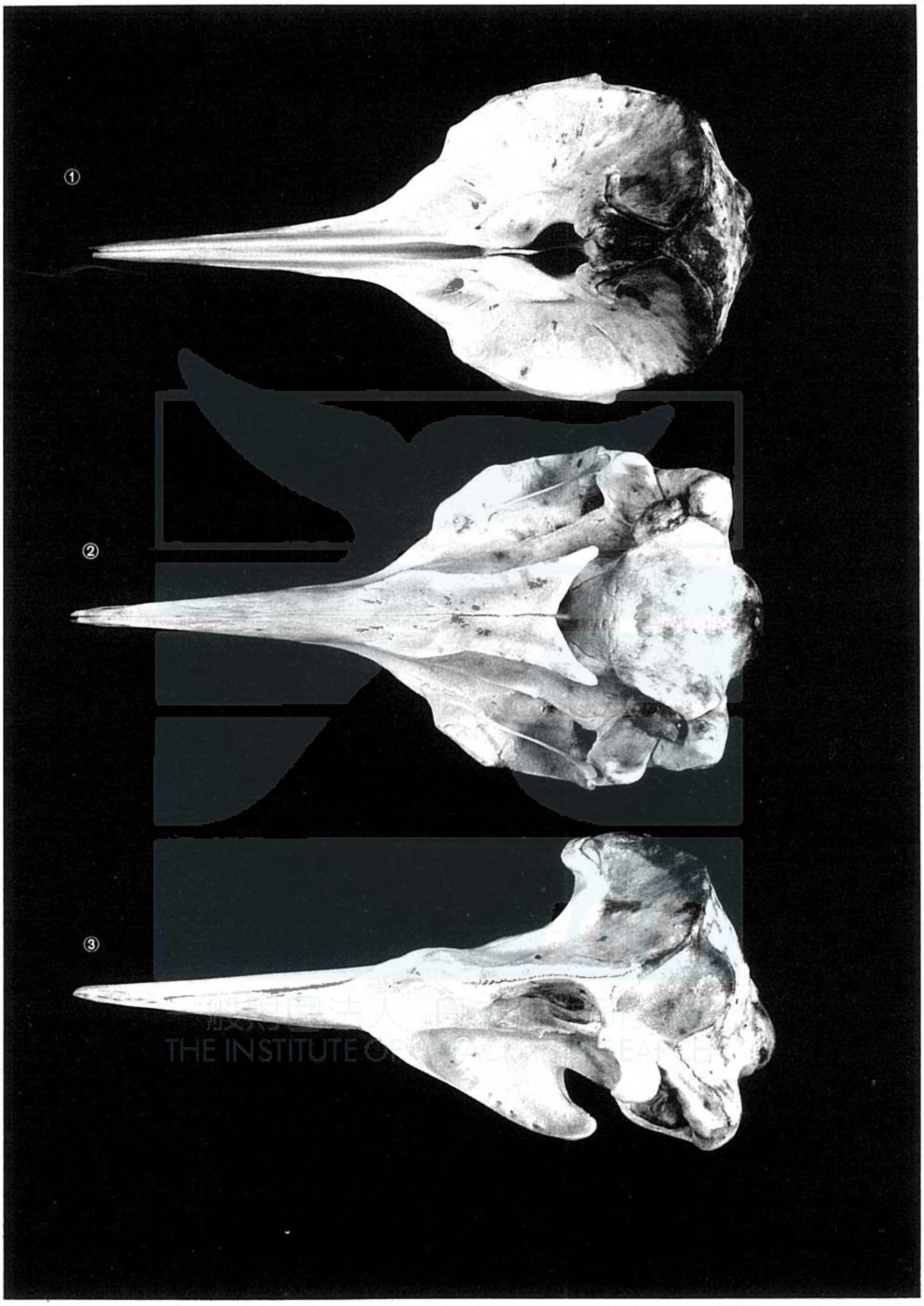
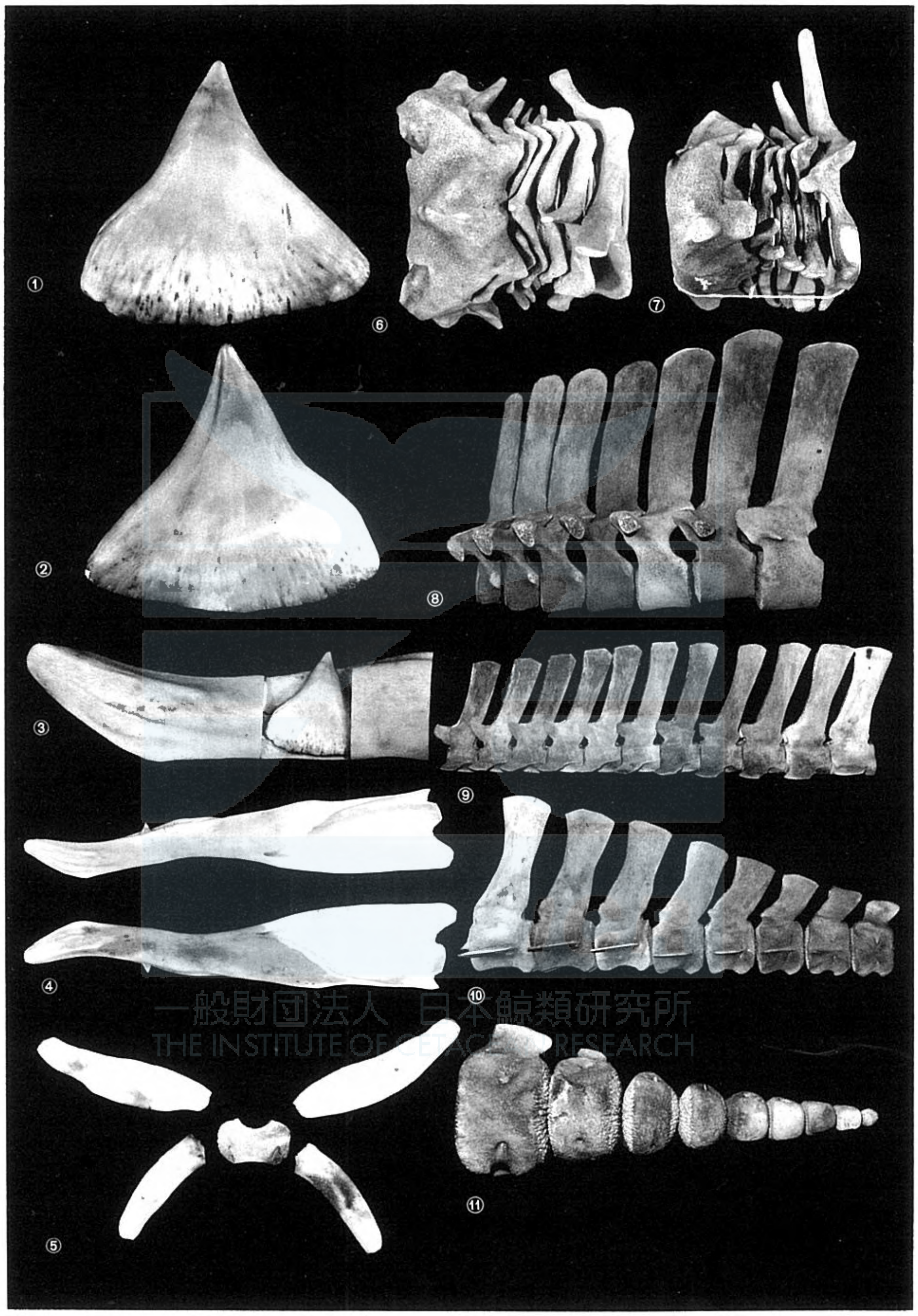


PLATE III



APPENDIX TABLE 1. SKULL MEASUREMENTS OF THE PRESENT SPECIMEN OF *MESOPLODON STEJNEGERI*

Measurements	mm	%
1. Condylobasal length*	612	100
2. Rostrum length*	327	53.4
3. Tip of rostrum to posterior margin of pterygoid nearest mid-sagittal plane*	446	72.9
4. Tip of rostrum to most posterior extension of wing of pterygoid (L)	472	77.1
5. Tip of rostrum to most anterior extension of pterygoid (L)	270	44.1
6. Tip of rostrum to most posterior extension of maxillaries between the pterygoids on the palate*	351	57.4
7. Tip of rostrum to most posterior extension of maxillary plate (L)	557	91.0
8. Tip of rostrum to anterior margin of superior nares*	404	66.0
9. Tip of rostrum to most anterior point of premaxillary crest	436	71.2
10. Tip of rostrum to most posterior extension of temporal fossa (L)	574	93.8
11. Tip of rostrum to most posterior extension of lateral tip of premaxillary crest (L)	469	76.6
12. Tip of rostrum to most anterior extension of pterygoid sinus (L)	311	50.8
13. Greatest length of temporal fossa (L)	101	16.5
14. Greatest length of orbit (L)	89	14.5
15. Greatest length of right nasal on vertex of skull	41	6.7
16. Length of nasal suture	42	6.9
17. Greatest breadth of skull across postorbital process of frontals	302	49.8
18. Greatest breadth of skull across zygomatic processes of squamosals	289	47.2
19. Greatest breadth of skull across centers of orbits	289	47.2
20. Least breadth of skull across posterior margins of temporal fossae	199	32.5
21. Greatest span of occipital condyles	95	15.5
22. Greatest width of occipital condyle (L)	36	5.9
23. Greatest length of occipital condyle (L)	63	10.3
24. Greatest breadth of foramen magnum	40	6.5
25. Greatest height of foramen magnum	42	6.9
26. Greatest breadth of skull across exoccipitals	252	41.2
27. Greatest breadth of nasals on vertex	37	6.0
28. Least distance between premaxillary crests	21	3.4
29. Distance from anterior process of premaxillary crest to posterior to right nasal on vertex	26	12.7
30. Greatest span of premaxillary crests	116	19.0
31. Width of rostrum at midrostral length	39	6.4
32. Width of premaxillae at midlength of rostrum	30	4.9
33. Width of rostrum at 1/4 rostral length from the tip	24	3.9
34. Width of premaxillae at 1/4 rostral length from the tip	24	3.9
35. Width of rostrum at 3/4 rostral length from the tip	48	7.8
36. Width of premaxillae at 3/4 rostral length from the tip	32	5.2
37. Greatest depth of rostrum at midrostral length	38	6.2
38. Width of rostrum in apices of antorbital notches	156	25.5
39. Greatest width of superior nares	49	8.0
40. Greatest width of inferior nares, at apices of pterygoid notches, on the pterygoids	101	16.5
41. Height of skull, distance between vertex of skull and most ventral point on pterygoids	214	35.0
42. Greatest width of temporal fossa approximately at right angles to greatest length (L)	60	9.8
43. Least distance between maxillary foramina	63	10.3
44. Least distance between premaxillary foramina	36	5.9
45. Greatest length of vomer visible on palate	65	10.6
46. Greatest condylar length of mandibular ramus (L)	518	84.6
47. Greatest length of mandibular symphysis	94	15.4
48. Greatest height of mandible at coronoid process (L)	105	17.2
49. Height of mandible at midlength of alveolus (measured from lingual margin of alveolus) (L)	46	7.5
50. Height of mandible at midlength of alveolus (measured from buccal margin of alveolus) (L)	45	7.4
51. Length from most posterior extension of mandibular symphysis to most posterior extention of condyle (L)	426	69.6
52. Length from posterior margin of alveolus to condyle (L)	365	59.6
53. Length of alveolus (L)	20	3.3
54. Width of alveolus (L)	9	1.5
55. Tip of mandible to anterior margin of alveolus (L)	136	22.2
56. Tip of mandible to center of alveolus (L)	147	24.0
57. Greatest length of tooth (R)	51	8.3
58. Greatest antero-posterior width of tooth at approximately right angles to long axis of tooth (R)	55	9.0
59. Greatest thickness of tooth (R)	8	1.3

* These characters were measured parallel to the condylobasal length while the others by distance between points. L and R indicate left and right, respectively.

APPENDIX TABLE 2. MEASUREMENTS OF VERTEBRAE (mm) OF *MESOPLODON STEJNEGERI* STRANDED ON THE BEACH OF MAIZURU BAY, KYOTO, 1984

Serial no.	Segment no.	Greatest B	Greatest H	Centrum B	Centrum H	Centrum L	Neural canal B	Neural canal H	Fusion of epiphyses
1	C1	14.3	13.0	–	–	–	5.1	3.7	yes
2	2	13.9	13.0	–	–	–	–	–	yes
3	3	11.8	12.1	5.9	4.1	–	4.4	–	yes
4	4	10.1	10.7	5.6	3.8	1.1	4.2	4.0	yes
5	5	9.1	10.5	5.4	4.1	1.0	4.3	4.2	yes
6	6	8.6	14.5	5.4	4.3	1.2	4.6	4.5	yes
7	7	12.8	19.4	6.0	4.3	1.5	5.1	4.8	yes
8	D1	15.2	22.5	5.3	4.3	2.3	5.2	5.0	no
9	2	15.2	24.5	5.4	4.3	3.5	5.0	5.1	no
10	3	15.0	24.9	5.5	4.2	4.4	4.7	5.3	no
11	4	14.8	25.7	5.4	4.1	5.0	4.4	5.5	no
12	5	14.8	26.7	5.7	4.3	5.6	4.2	5.6	no
13	6	14.9	27.4	5.9	4.5	6.3	4.0	5.6	no
14	7	11.6	27.5	6.2	4.7	6.7	3.7	5.5	no
15	8*	–	–	–	–	–	–	–	
16	9*	–	–	–	–	–	–	–	
17	L1	27.1	30.7	7.4	5.5	8.4	3.4	5.4	no
18	2	27.5	31.9	7.7	5.9	8.8	3.1	5.3	no
19	3	27.8	32.8	7.9	6.2	9.3	3.0	5.2	no
20	4	28.2	34.3	8.1	6.3	9.4	3.0	5.1	no
21	5	27.7	35.0	8.3	6.7	9.7	3.0	5.0	no
22	6	27.8	35.3	8.4	6.9	10.1	3.2	5.1	no
23	7	27.7	35.1	8.6	7.4	10.5	2.9	4.6	no
24	8	27.8	34.4	9.0	7.6	11.1	2.9	4.2	no
25	9	27.9	35.2	9.2	7.8	11.2	2.5	3.6	no
26	10	27.2	34.2	9.4	8.0	11.7	2.3	3.2	no
27	11	26.4	33.7	9.4	8.2	11.6	2.2	2.4	no
28	Ca1	24.9	33.2	9.7	8.4	11.5	1.8	2.6	no
29	2	22.4	30.8	9.8	8.6	11.0	1.6	2.3	no
30	3	20.1	28.3	9.5	8.6	10.4	1.4	1.9	no
31	4	17.9	24.6	9.4	8.5	9.7	1.4	1.8	no
32	5	15.4	21.6	9.6	8.7	9.2	1.4	1.6	no
33	6	12.5	18.7	9.6	9.1	8.9	1.4	1.2	no
34	7	10.1	16.3	9.9	9.1	8.2	1.3	1.0	no
35	8	8.7	14.2	8.7	9.0	7.4	0.9	1.0	no
36	9	7.7	11.8	7.7	8.8	6.6	0.8	0.7	no
37	10	7.2	9.1	7.2	7.7	5.3	0.6	0.5	no
38	11	6.7	6.5	6.7	6.4	4.0	–	–	no
39	12	5.8	5.1	5.8	5.0	3.6	–	–	no
40	13	5.1	4.0	5.1	3.8	3.3	–	–	no
41	14	4.6	3.5	4.6	3.3	2.9	–	–	no
42	15	4.0	2.8	4.0	2.7	2.6	–	–	no
43	16	3.3	2.0	3.3	2.0	2.0	–	–	yes
44	17	2.1	1.4	2.1	1.4	1.3	–	–	yes

* These two vertebral bones were used for analysis of organochlorine compounds without making measurement.

B: breadth, H: height, L: length.


ICR
一般財団法人 日本鯨類研究所
THE INSTITUTE OF CETACEAN RESEARCH

STRANDING OF A SPECIMEN OF GRAY'S BEAKED WHALE AT PUERTO PIRAMIDES (CHUBUT, ARGENTINA) AND ITS GONADAL APPRAISAL

GUSTAVO A. DELHON*, ENRIQUE A. CRESPO**,
AND GUSTAVO PAGNONI**

ABSTRACT

A single specimen of *Mesoplodon grayi* was stranded at Puerto Pirámides (42°35'S, 64°53'W), on the Patagonian coast (Chubut, Argentina). Some external body measurements were taken in situ and the skull was preserved. A list of skull measurements is given. Histological study of the testes showed the specimen to be sexually mature. Noteworthy was the presence of adipocytes in the interstitial tissue, which can be easily confused with Leydig's cells. Age could not be determined since the lower jaws were missing and the teeth could not be recovered.

INTRODUCTION

Previous records of Gray's whale have been summarized by Goodall (1978), Lichter and Hooper (1983) and Lichter (in press), for the Argentine coast, including two specimens near the site of the present stranding of Península Valdés (True, 1910; Mermóz, 1979) (Fig. 1).

Other species of Ziphiidae have also been found in this area, such as a Tasman whale (*Tasmacetus shepherdi*) reported by Mead and Payne (1975).

The present paper presents external and skull measurements and a histological study of the testes.

MATERIAL AND METHODS

Features of the stranding

We were informed of the stranding by the Gamekeeper of the Sealion Reserve at Punta Pirámides, Chubut, Argentina. A medium-sized cetacean, which was later determined as a Gray's beaked whale *Mesoplodon grayi*,

---

* *Cátedra de Histología, Facultad de Ciencias Veterinarias, Universidad de Buenos Aires, Chorroarín 280 (1427), Buenos Aires, República Argentina.*

** *Centro Necional Patagónico, C.O.N.I.C.E.T., 28 de Julio 28, 9120 Puerto Madryn, Chubut, República Argentina.*

Sci. Rep. Whales Res. Inst.,
No. 38, 1987, 107–115

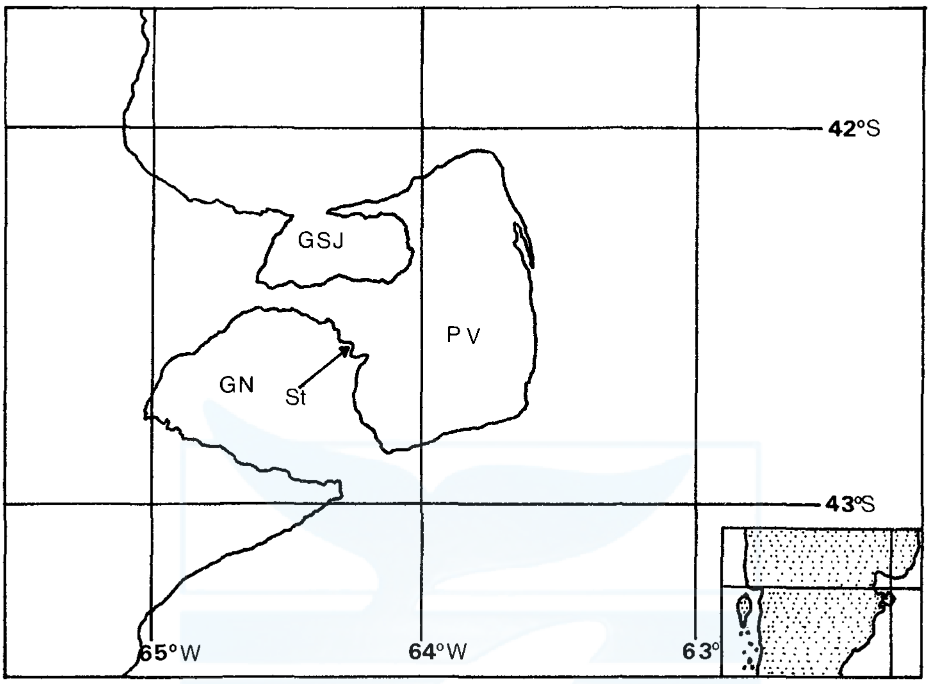


Fig. 1. Location of the stranding. PV: Península Valdés, GN: Golfo Nuevo, GSJ: Golfo San José, St: Stranding.

stranded on June 28, 1983. It was in good condition, except that the body had ulcerations made by sea-birds (gulls and petrels), there were wounds and scars of unknown origin in the skin, the beak was broken, and the lower jaws had been sectioned, possibly by fishermen.

Identification of the species

The species was identified in the field as *Mesoplodon grayi*, by means of the color pattern, presence of seven maxillary teeth and descriptions given by Ross (1979) and Lichter and Hooper (1983) "body elongate, compressed laterally to some degree, bulgy melon, long and slender beak, small dorsal fin inserted at about two-thirds of body length from the anterior, small flippers and flukes lacking of caudal notch". Subsequently study of the skull confirmed the species determination. The cranial rostrum is "slender, elongate, narrow at its base, with a straight dorsal margin in profile view, without prominential notches in dorsal view" (Ross, 1979).

Biological data and samples

Standard external measurements (Norris, 1961) were taken to the nearest

TABLE 1. EXTERNAL BODY MEASUREMENTS OF THE PRESENT SPECIMEN (MEASURED AFTER NORRIS, 1961)

Measurements	cm
1. Total length, from tip of upper jaw to middle of the posterior margin of tail flukes	452.5
2. Tip of upper jaw to anterior insertion of flipper	120
3. Tip of upper jaw to anterior insertion of dorsal fin	340
4. Tip of upper jaw to midpoint of genital aperture	300
5. Tip of upper jaw to centre of anus	343
6. Tip of upper jaw to centre of blowhole	60
7. Tip of upper jaw to angle of gape	37.5
8. Tip of upper jaw to centre of eye	63.5
9. Girth on a transverse plane intersecting axilla	186
10. Girth, maximum	206
11. Girth on a transverse plane intersecting anus	148
12. Length of the flipper, anterior insertion to tip	55
13. Length of the flipper, axilla to tip	46
14. Maximum width of flipper	18
15. Length of dorsal fin base	31
16. Height of dorsal fin	19
17. Width of flukes tip to tip	117
18. Distance from nearest point on anterior border of flukes to notch	35

5 mm with a tape measure and are listed in Table 1. Skull measurements were taken with a caliper and a metal ruler to the nearest 1 mm, following the methods of Ross (1979) (Table 2). Color pattern was recorded in the field and vertebral count was made directly on the cleaned skeleton.

The gonads were fixed in 10% formalin, embedded in paraffin, cut into 7 μm thick sections and stained with Hematoxylin-Eosine, Masson's Trichrome and Periodic Acid Schiff-Hematoxylin. Frozen pieces were cut in a criostate and stained with Sudan for lipid detection. Sub-capsular, perimediastinic, and intermediate zones of the entire glands were studied in this evaluation.

RESULTS

The specimen was a 452 cm adult male. Other external body measurements are listed in Table 1.

The dorsal surface of the body was black, gradually becoming grayish laterally. The ventral surface was black with unpigmented patches (5 to 30 mm in diameter). The dorsal fin, flippers and flukes were black. As is usual in the Ziphiidae, the specimen had two ventral throat grooves.

Four different positions of the skull can be seen in Fig. 2. Seven small maxillary teeth were observed in the stranded specimen, but these were lost during the cleaning of the skull.

The vertebral formula was C7, T10, L11, C18+ = 46+.

TABLE 2. SKULL MEASUREMENTS OF THE PRESENT SPECIMEN IN MILLIMETER (MEASURED AFTER ROSS, 1979)

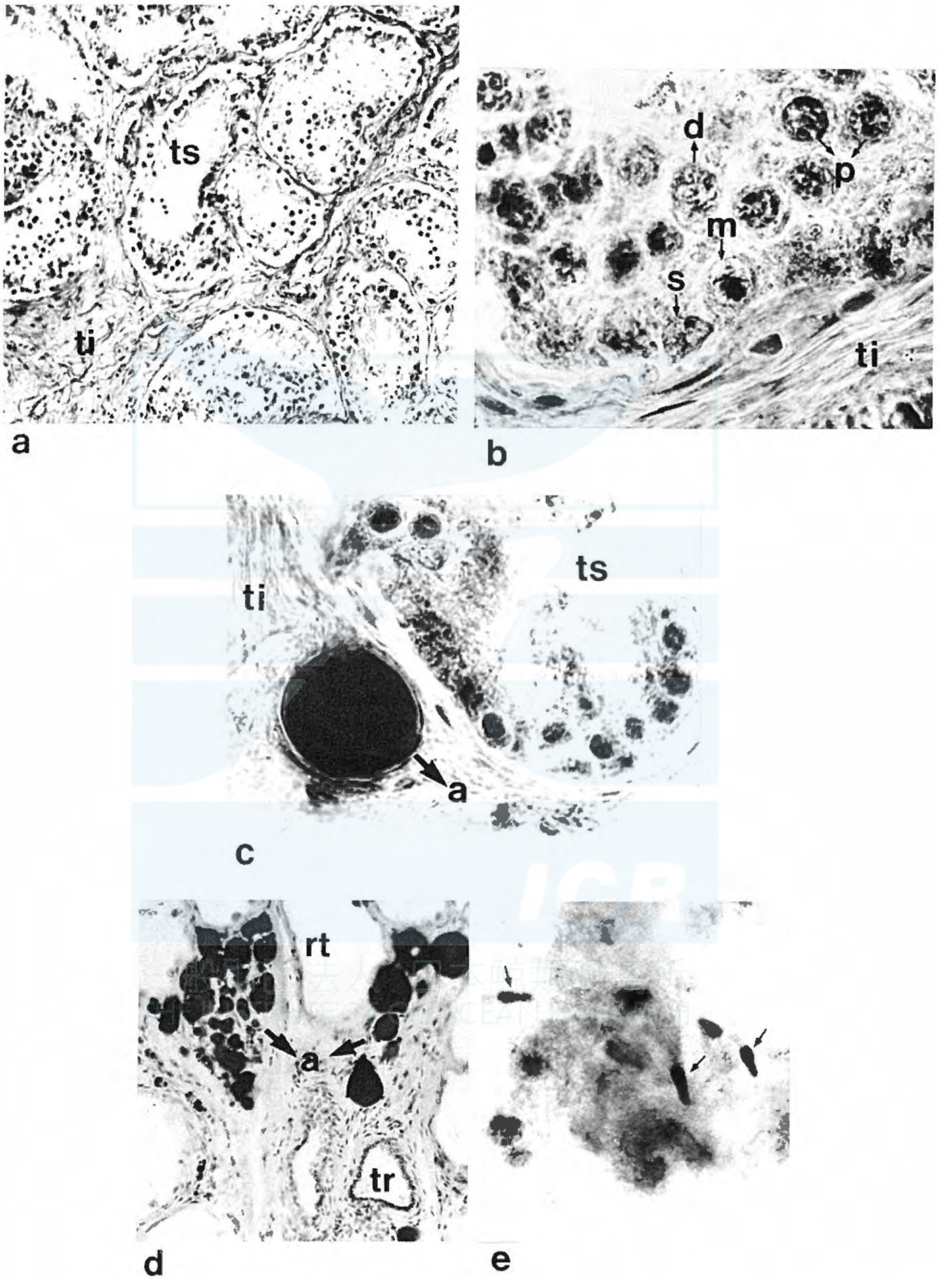
	Measurements	mm
1.	Condylobasal length	810
2.	Length of rostrum, tip of beak to line connecting apices of antorbital notches	535
3.	Tip of rostrum to most anterior extension of pterigoid	465
4.	Tip of rostrum to most posterior extension of maxillaries between pterygoids	510
5.	Tip of rostrum to most posterior extension of maxillary plate	720
6.	Tip of rostrum to anterior margin of superior nares	595
7.	Tip of rostrum to most anterior point on premaxillary crest	620
8.	Tip of rostrum to most posterior extension of temporal fossa	760
9.	Tip of rostrum to most posterior extension of lateral tip of premaxillary crest	650
10.	Tip of rostrum to most anterior extension of pterygoid sinus	500
11.	Length of temporal fossa	90
12.	Length of orbit	90
13.	Length of right nasal on vertex of skull	55
14.	Length of nasal suture	35
15.	Breadth of skull across postorbital process of frontals	298
16.	Breadth of skull across zygomatic processes of squamosales	288
17.	Breadth of skull across centers of orbits	285
18.	Least breadth of skull across posterior margins of temporal fossae	190
19.	Greatest span of occipital condyles	109
20.	Greatest width of an occipital condyle (right)	45
21.	Greatest length of an occipital condyle (right)	68
22.	Greatest breadth of foramen magnum	50
23.	Breadth of skull across exoccipitals	235
24.	Breadth of nasals on vertex	31
25.	Least distance between premaxillary crests	17
26.	Greatest span of premaxillary crests	127
27.	Least width (strictly transverse) of premaxillae where they narrow opposite superior rares	100
28.	Greatest width of premaxillae anterior to place of measurement No. 27	111
29.	Width of premaxillae at midlength of rostrum	31
30.	Width of rostrum in apices of antorbital notches	180
31.	Width of rostrum in apices of prominential notches	97
32.	Greatest width of rostrum at midlength of rostrum	45
33.	Greatest depth of rostrum at midlength of forstrum	46
34.	Greatest transverse width of superior nares	48
35.	Greatest width of temporal Fossa approximately at right angles to greatest length (right)	65
36.	Least distance between (anterior) maxillary foramina	65
37.	Least distance between premaxillary foramina	34
38.	Distance from posterior margin of left maxillary foramen to most anterior extension of left maxillary prominence	35
39.	Length of tympanic bulla, left	48
40.	Length of tympanic bulla, right	53
41.	Height of mandible at coronoid process	115

Histological study of the testes and related organs

Before fixing, testes weight and measurements were taken as follows:

	left	right
weight (g)	86.5	112
measurements (mm)	90×45×50	120×50×50

Fig. 2. Skull of the specimen stranded.
a. Lateral view
b. Dorsal view
c. Ventral view
d. Posterior view
Scale indicates 10 cm.


ts
ti
a
d
p
m
s
ti
b
ti
ts
a
c
rt
a
tr
d
e

Seminiferous tubules: All zones observed possesed typical functional mature tubules (Fig. 3a) with an average diameter of 195.31 μm (S.D. ± 22.5). Despite postmortem changes it was possible to distinguish the different stages of the spermatogenic cycle. Qualitative and quantitative analyses of the seminal epithelium showed spermatogonial mitotic divisions (Fig. 3b), as well as complete spermatocytogenesis and spermiogenesis. All of the tubules counted (300 tubules × three zones) showed spermatogenic activity.

The tubuli recti and rete testis structure of the intratesticular seminal pathways, confirmed the sexual maturity of this individual. Both the tubules and the rete had terminal states of differentiation at epithelial and stromatal levels but no spermatozoa were observed in the lumen.

The interstitial space of *Mesoplodon* testes follows the general delphinid pattern of organization (Harrison, 1969). Interstitial cells are relatively unconspicuous, hard to distinguish in routine preparations and occur isolated in an abundant regular connective tissue stroma. Large and small blood vessels are distributed randomly in the stroma, but no apparent relation exists between these vessels and the interstitial cells. The lymphatic vessels could not be seen because we could not perform the intravascular perfusion of the gland (Harrison, 1969; Fawcet, Neaves and Flores, 1973; Sergeant, 1962).

An interesting feature of the interstitial space is the presence of adipocytes. These appear isolated in the interstitium or form masses of closely compacted cells (Figs 3c and 3d). Adipocytes with few intracytoplasmic lipid droplets can be easily confused with interstitial cells. In mammalian testis literature, no reports concerning these cells (in physiological or pathological conditions) appeared (Courot, Hochereau and Ortavant, 1970; Setchell, 1978). Such adipocytes in a normal functional gland are remarkable; further observations are needed to confirm the *Mesoplodon* interstitium histology (Roosen-Runge, 1962, 1969).

Fig. 3. Histology of the testes of the present specimen.

a. Subcapsular zone. Seminiferous tubule (ts) and intertubular space (ti). (Masson's Trichromic Staining, original magnification 100 ×).

b. Subcapsular zone. Seminiferous tubule epithelium. s: Sertoli cell nuclei, m: gonial mitosis, p: pachitene primary spermatocytes, d: diplotene primary spermatocytes, ti: interstitial tissue showing abundant fibrilar material. (Pas-Hematoxylin Staining, 630 original magnification 630 ×).

c. Subcapsular zone. Intertubular space (ti) showing and isolated adipose cell (a) resting on the lamina propia of the seminiferous tubule (ts). (Sudan-Hematoxylin Staining, original magnification 400 ×).

d. Mediastinum testes showing adipocytes clusters (a) between the tubuli recti (tr) and rete channels (rt). (Sudan-Hematoxylin Staining, original magnification 100 ×).

e. Spermatozoa in the epididymal duct. See the lateral view of the heads (arrows) with the typical flat anterior segment. (Hematoxylin-Eosin Staining, original magnification 100 ×).

Epididymis and ductus deferens: These extragonadal tubular structures are lined by a single or pseudostratified columnar epithelium. Despite the intense desquamation, it was possible to find a great number of spermatozoa. The flat anterior segment of the sperm head observed in other cetaceans was evident in profile views (Fig. 3e).

DISCUSSION

Mesoplodon grayi has a circumpolar distribution in the southern hemisphere between 30°S and 45°S (Ross, 1979). More southern records of this species are listed for Tierra del Fuego (54°S), including one nearly complete skeleton, three crania and one group of thoracic vertebrae (Goodall, 1978). Few strandings along the Argentine coast have been reported in several papers, and reviewed by Lichter and Hooper (1983).

The present paper include measurement data and original considerations about the sexual maturity.

There is little information on lengths of specimens of this species. Ross (1979) gave total lengths of four adult males as follows: 1) 4.72 m, 2) 4.27 m, 3) 5.64 m, 4) 4.53 m ($\bar{x} = 4.79$ m, s.d. $-1 = 0.59$). The specimen from Puerto Pirámides measured 4.52 m, falling within this range. The condylobasal length of Ross's specimen No. 1 was 802 mm, and expressed as percentages of body length was 16.99%. The present specimen's CBL was 810 mm, being the 17.92% of the body length.

The vertebral formula of the present individual agrees with that of six specimens discussed by Ross (1979), but individual variation can be seen in the number of thoracic vertebrae (range from 9 to 11), lumbar vertebrae (range from 10 to 12), caudal vertebrae (range from 16 to 20), and the total number of vertebrae (range from 46+ to 49).

Unfortunately, age determination could not be performed because the lower jaws had been cut off and the teeth were lacking, but the histological appraisement of the specimen testes, epididymis, and ductus deferens, enable us to determinate that the animal was sexually mature and in an active state of spermatogenesis.

ACKNOWLEDGEMENTS

The authors are indebted to Mr Mariano Van Gelderen, and J.C. López and J.M. Musmeci (Dirección de Conservación del Patrimonio Turístico), who helped with the specimen in the field, to Dr Guillermo Harris for valuable information, to Dr Atila Gozstonyi (Centro Nacional Patagónico), who corrected the English manuscript, to Lic. Hugo P. Castello (Mus. Arg. Ciencias Naturales "Bern. Riv.") and Mrs Nathalie Goodall who read critically the manuscript and Dr Toshio Kasuya (Far Seas Fish. Res. Lab.) who read an early draft of the histological study.

REFERENCES

COUROT, M.,T. HOCHEREAU and R. ORTAVANT, 1970. Spermatogenesis. pp. 339–432. *In:* A.D. JOHNSON, W.R. GOMES and N.L. VAN DEMARK (eds) *The Testis*. Academic Press, N.Y. 649 pp.

FAWCET, D.W., W.B. NEAVES and M.N. FLORES, 1973. Comparative observations on intertubular limphatics and the organization of the interstitial tissue of the mammalian testis. *Biol. of Rep.*, 9: 500–532.

GOODALL, R.N.P., 1978. Report on the small Cetaceans stranded on the coast of Tierra del Fuego. *Sci. Rep. Whales Res. Inst.*, 30: 197–230.

HARRISON, R.J., 1969. Reproduction and reproductive organs. pp. 253–348. *In:* T.H. ANDERSEN (ed.) *The biology of Marine Mammals*. Academic Press, N.Y. and London. 511 pp.

LICHTER, A. and A. HOOPER, 1983. *Guía para el reconocimiento de cetáceos del Mar Argentino.* Fundación Vida Silvestre Argentina, Buenos Aires. 96 pp.

LICHTER, A., 1986. Record of Beaked whale (Ziphiidae) from the Western South Atlantic. *Sci. Rep. Whales Res. Inst.*, 37: 109–127.

MEAD, J.G. and R.S. PAYNE, 1975. A specimen of the Tasman Beaked Whale *Tasmacetus shepherdi*, from Argentina. *J. Mamm.*, 56: 213–218.

MERMÓZ, J.F., 1979, Hallazgo de una ballena picuda de Gray, *Mesoplodon grayi*, en el Golfo San José, (Chubut, Argentina). *Rev. Mus. Arg. Cienc. Nat. Bern. Riv.*, 12 (10): 137–142.

NORRIS, K.S., 1961. Standarized methods for measuring and recording data on smaller cetaceans. *J. Mamm.*, 42 (4): 471–476.

ROOSEN-RUNGE, E.C., 1962. The process of spermatogenesis in Mammals. *Biol. Rev.*, 37: 343–377.

ROOSEN-RUNGE, E.C., 1969. Comparative aspects of spermatogenesis. *Biol. Repord. Suppl.*, 1: 24–39.

ROSS, G.J.B., 1779. The smaller cetaceans of the south east coast of Southern Africa. *PhD. Thesis Univ. of Port Elizabeth.* 415 pp.

SERGEANT, D.E., 1962. The biology of the pilot or pothead whale *Globicephala melaena* (Traill) in Newfoundland waters. *Bull. Fish. Res. Board Can.*, 132: 84.

SETCHELL, B.P., 1978. Chap. I and VII. *In:* C.A. Finn (ed.) *The Mammalian Testis.* Cornell Univ. Press. Ithaca, N.Y. 450 pp.

TRUE, F.W., 1910. An account on the beaked whales of the family Ziphiidae in the collection of the U.S. Nat. Mus. with remarks on some other specimens in other Museums. *Bull. U.S. Nat. Mus.*, 73: 1–89.

一般財団法人　日本鯨類研究所
THE INSTITUTE OF CETACEAN RESEARCH

ON THREE ODONTOCETE SKULLS FROM HEARD ISLAND

ERIC R. GUILER*, HARRY R. BURTON**,
AND NICHOLAS J. GALES**

ABSTRACT

Two crania and a rostrum were recovered from Heard Island by the 1985 Australian National Antarctic Expedition to that island. The specimens were assigned to three species, two of which, *Globicephala melaena* and *Mesoplodon layardi*, are confirmed other than by sighting reports as occurring in Antarctic Seas. The third species, *Phocaena spinipinnis*, of which cranial measurements are given, was previously known only from coastal South American waters and is shown to have a much wider distribution than hitherto suspected.

INTRODUCTION

Heard Island (Lat. 53°S, Long. 73° 30′E) is infrequently visited but served as a base for an Australian National Antarctic Expedition which camped on the island from October to November, 1985. Three cetacean skulls were brought back from the island by the party and these were the first collection, albeit small, of whale material from the island.

THE SPECIMENS

Pilot whale, Globicephala melaena (L.)

A complete cranium with some minor damage to the ventral surface was recovered from an entire skeleton stranded on the northern face of the Spit on the eastern extremity of the island. The carcase was estimated to have been stranded for less than a year. Another skeleton, possibly of the same species, was stranded 500 metres distant on the same beach but the skull was missing. Both carcases had been exposed for an apparently similar period and much of the external covering remained. The cranium was full of brain tissue when collected. The baso-condylar length was 62.7 cm.

The cranium was identified from photographs in the collection of one of us (E.R.G.) which had previously been assigned to this species by Dr P.H. van Bree.

---

* *Zoology Department, The University of Tasmania, Hobart, Tasmania, Australia 7001.*
** *Antarctic Division, Department of Science, Kingston, Tasmania, Australia* 7150.

According to Watson (1981) pilot whales have been sighted by whaling expeditions as far south as the Antarctic Convergence but they were not listed by Parker (1978) or Brownell (1974) as occurring in Antarctic Seas. However, *Globicephala* has been sighted at sea in these waters, a school of at least 6 individuals being sighted by one of us (E.R.G.) in Lat. 60° 08′S, Long. 90° 10′E on 23 Jan. 1980 and a large group of 75 individuals was sighted in 60° 44′S, 55° 51′W by the "Polar Star" (Hanson and Erickson, 1985). These two authors quote a personal communication from P. Best to the effect that over 1750 of these whales were sighted south of 60°S by five I.W.C. cruises. All of these reports are to the south of Heard Island.

Mercer (1975) noted that the northern form of *Globicephala melaena* penetrated into Arctic waters during the summer period in pursuit of squid and it would seem likely that a similar seasonal migration into Antarctic waters takes place.

The record from Heard Island represents the first confirmation by skeletal evidence that pilot whales occur south of the Antarctic Convergence.

The cranium has been lodged in the Tasmanian Museum, Reg. No. A1409.

Strap-toothed Whale, Mesoplodon layardi (Gray)

The material consisted only of the rostrum of which about 1 cm was missing from the distal end (Fig. 1). The right maxilla was intact but the left was broken on both the posterior and post-lateral borders. The internal nares were intact but all of the posterior cranium, including the vertex, was missing. The ventral surface of the posterior rostrum was extensively damaged with all of the ventral bones either absent or reduced by erosion. No mandibles, teeth, jugal arch or otic bones were found.

The rostrum was dry and clearly had been ashore for many years.

The asymmetry of the nasals clearly assigned the rostrum to the Fam. Ziphiidae and the arrangement of the antorbital notch, maxillary tubercle and the premaxillary and maxillary foramina indicated that the specimen could be assigned to *Mesoplodon layardi*. The steps in this identification are intended to be published elsewhere by the senior author.

The firm sutures indicated that the specimen was derived from an adult whale.

The bones of the beak were strongly sutured with no space between the dorsal surfaces of the premaxillaries and the maxillaries. The mesorostral groove was filled by osseus material which was believed to be a feature of the male (Besharse, 1971). However, Moore (1960) had earlier noted that the groove filled more slowly in females than in males and he suggested that this was also an age related factor. To some extent this view was supported by the findings of McCann (1965) who observed that the groove was filled with replacing bone formed by the transformation of the mesethmoid cartilage, commencing at the proximal end. He found that there was some sexual dimorphism in that the groove in females often is irregular and not completely

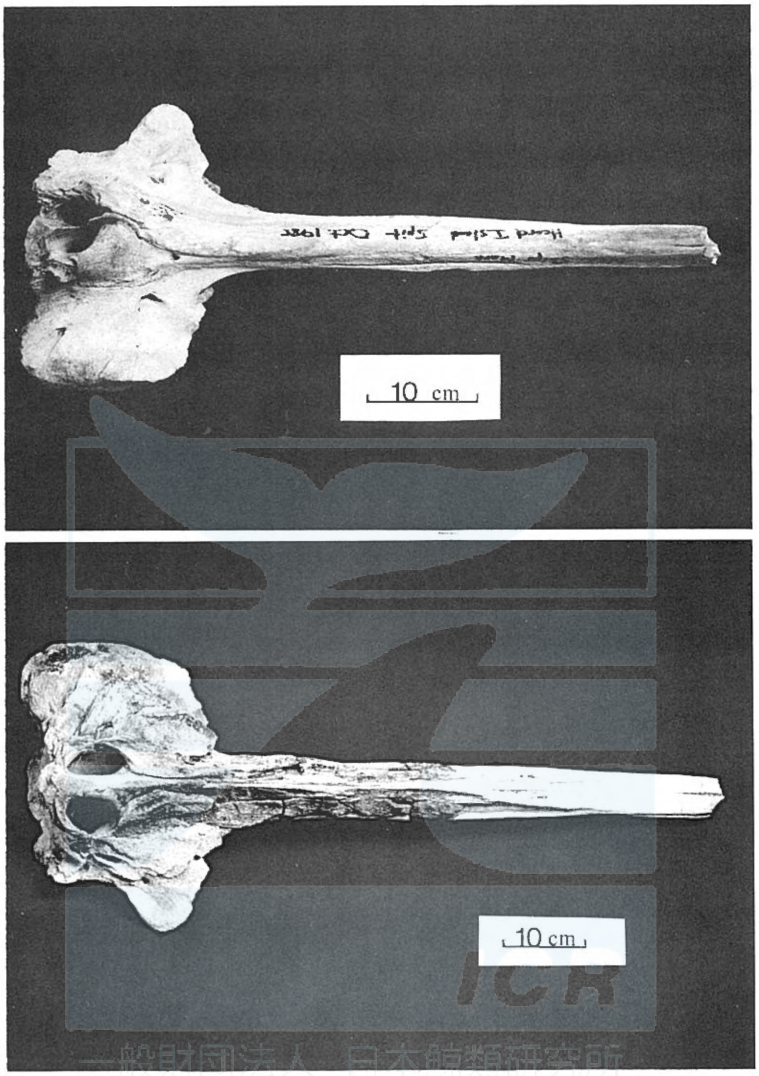


Fig. 1. Dorsal (top) and ventral (bottom) views of the skull of *Mesoplodon layardi* from Heard Is., 1985.

filled whereas in the male the filling is of a highly compacted, ivory-like bone often rising above the dorsal surface of the premaxillae.

It would appear that the skull from Heard Is. is that of a male.

DISTRIBUTION OF *MESOPLODON LAYARDI*

This species has a wide southern hemisphere cool temperate distribution being known from circumpolar regions including South America and the

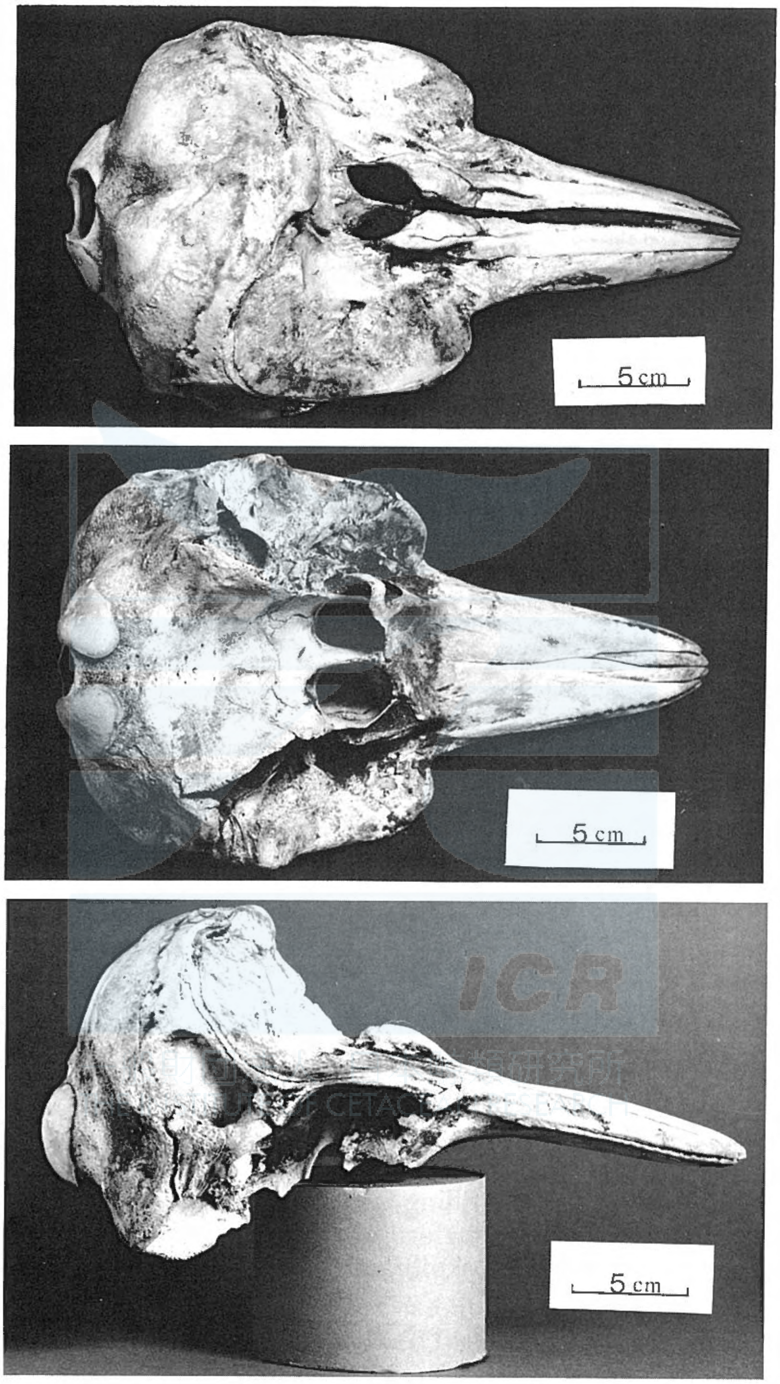


Fig. 2. Dorsal (top), ventral (middle) and lateral (bottom) views of the skull of *Phocaena spinipinnis*, Heard Is., 1985.

Falkland Is (Bruyns, 1971; Rice, 1977) and Tierra del Fuego (Goodall, 1978). It is relatively common in New Zealand (Gaskin, 1972). The Australian records were reviewed by Dixon (1980) and a breeding population occurs in or close to Tasmanian waters (Guiler, 1984). The species has been sighted by whaling fleets as far south as the Antarctic Convergence (Watson, 1981), but it was not listed as living in Antarctic Seas by Brownell (1974), nor do there appear to be any records of this whale from the Antarctic Peninsula or the associated islands.

The present record from Heard Is. is the first report of this species from south of the Antarctic Convergence and also is the first time that the genus *Mesoplodon* has been recorded from Antarctic Seas.

The specimen has been deposited in the Tasmanian Museum, Reg. No. A1410.

Burmeister's porpoise, Phocaena spinipinnis Burmeister

The genus *Phocaena* until recently was represented in southern waters by two species, *P. spinipinnis* (Burmeister) and *P. dioptrica* Lahille. The latter species has recently been moved into the new genus *Australophocaena*

TABLE 1. CERTAIN SKULL MEASUREMENTS OF *AUSTRALOPHOCAENA DIOPTRICA*, *P. SPINIPINNIS* AND THE SKULL FROM HEARD ISLAND

	A. dioptrica (Baker, 1977)	*P. spinipinnis* Norris and Macfarland, 1958	Heard Is. skull
Cranio-basal length	310	273	303
Max. height	155	–	163
Pre-orbital width	162		164
Zygomatic width	180	168	169
Max. width	180	–	169
Parietal width	157	–	156
Rostral length	117	152	162
width at base	84	83	82
middle	51		51
$\frac{3}{4}$length	51		38
height at middle	15		24
Width premax. at middle	29		31
Height premax. at middle	3.5		5
Length of fused premax.	open	open	open
to ant. margin of nares	165		159
to vertex of nasals	221		235
of temporal fossa	61		42
Height of temporal fossa	58		39
Length of upper l. toothrow	81	79	71
upper r. toothrow	82		79
Ratio width to length of rostrum	0.727	0.517	0.513
width of skull to length		0.560	0.550

(Barnes, 1985). A good comparison of these two species is given by Norris and McFarland (1958) together with details of two northern hemisphere species, *P. sinus* Norris and McFarland and *P. phocaena* (L.).

The specimen was relatively fresh and in our opinion the porpoise had been stranded within the prior 12 months.

The skull was complete except for the absence of teeth and mandibles and some minor damage in the palatine and otic regions. The jugal arches were absent.

The skull is identified as belonging to *Phocaena spinipinnis* Burmeister. This identification is based on a comparison of the specimen with photographs in Norris and McFarland (1958) which showed good agreement in the features of the skull and the arrangement of the sutures (Fig. 2).

The measurements of the skull show that this was a large individual (Table 1) and this fact, combined with the complete closure of all the sutures, indicates that the animal was an adult.

Although the skull was larger than that described by Norris and McFarland, the ratio of rostral width : rostral length (0.513) is similar to that found by those two authors (0.517) as is the ratio of skull length : skull width (0.55 compared to 0.560). These ratios are different from those found for *P. sinus* (0.630 and 0.637 respectively) and for *P. phocaena* (0.470 and 0.537). The rostral proportions for *A. dioptrica* are 0.737.

The number of alveoli in the upper jaw of the Heard Is. specimen was 14 on the left side and 13 on the right which is similar to that for *P. spinipinnis* whereas *A. dioptrica* and *P. sinus* have a total of 45 and 46 alveoli respectively.

DISTRIBUTION OF BURMEISTER'S PORPOISE

Burmeister's Porpoise has hitherto been known only from the southern Atlantic and Pacific coasts of South America (Praderi, 1971), extending as far as Uruguay (Pilleri and Gihr, 1972, 1975). The presence of the cold waters on the western side of the continent enables the species to range as far as Peru where one was found in a fish market at Chimbote (Clarke, 1962). Watson (1981) believed it possible that substantial numbers of this so-called rare porpoise were sold every year in the 100,000 kg or more of dolphin meat which passes annually through the fish markets.

No records have come to our attention of the presence of this species around the Antarctic Peninsula.

This record is evidence of a wider distribution of this species than its previously known limits. The porpoise must be able to undertake oceanic trips and it must be able to make penetrations into Antarctic waters, at least to the extent of crossing the Antarctic Convergence.

This is not the only South American "coastal" porpoise which has been found on Antarctic or Sub-Antarctic islands. The spectacled porpoise, *Australophocaena dioptrica* (Lahille), has been discovered in comparatively recent years to occur in the Auckland Islands (Baker, 1977) and at Macquarie Island (Fordyce, Mattlin and Dixon, 1984). Neither of these localities are south of the Convergence. This species may have been seen at sea near New Zealand (Cawthorn, 1977) as well as at the Kerguelen Islands (Frost and Best, 1976).

We suggest that a similar distribution could eventually be found for *Phocaena spinipinnis*.

The cranium has been lodged in the Tasmanian Museum, Reg. No. A1411.

ACKNOWLEDGEMENTS

Thanks are given to all members of the 1985 A.N.A.R.E. to Heard Island whose field support made this collection possible. We also wish to thank the staff of the Photographic Section, Antarctic Division for the photographs of the specimens.

REFERENCES

BAKER, A.N., 1977. Spectacled porpoise, *Phocaena dioptrica*, new to the Subantarctic Pacific Ocean. *N.Z.J. Mar. Freshw. Res.*, 11: 401–6.

BARNES, L.G., 1985. Evolution, taxonomy and antitropical distributions of the porpoises (Phocaenidae, Mammalia). *Mar. Mammal. Sci.*, 1: 149–65.

BESHARSE, J.C., 1971. Maturity and sexual dimorphism in the skull, mandible and teeth of the beaked whale *Mesoplodon densirostris*. *J. Mammal.*, 52: 297–315.

BROWNELL, R.L., 1974. Small Odontocetes of the Antarctic. *American Geographical Society Antarctic Map Folio Series*. Folio 18.

BRUYNS, W.F.J.M., 1971. *Field Guide to the Whales and Dolphins*. Amsterdam. 258pp.

CAWTHORN, M., 1977. *Whale Identification. Field Guide for New Zealand Whales*. Mimeo. (quoted by Fordyce *et al.*, 1984).

CLARKE, R., 1962. Whale observations and whale marking off the coast of Chile. *Norsk Hvalfangst-Tid.*, 51: 265–87.

DIXON, J. M., 1980. A recent stranding of the Strap-toothed whale, *Mesoplodon layardi* (Gray) (Ziphiidae) from Victoria and a review of Australian records for the species. *Vict. Nat.*, 97(1): 34–41.

FORDYCE, R.E., R.H. MATTLIN and J. M. DIXON, 1984. Second record of spectacled porpoise from Subantarctic southwest Pacific. *Sci. Rep. Whales Res. Inst.*, 35: 159–64.

FROST, P.G.M. and P.B. BEST, 1976. Design and application of a coded format for recording observations of cetaceans at sea. *S. Afr. J. Antarct. Res.*, 6: 9–14.

GASKIN, D.E., 1972. *Whales, Dolphins and Seals.* Heinemann, Auckland. 200pp.

GOODALL, R. N.P., 1978. Report on the small cetaceans stranded on the coasts of Tierra del Fuego. *Sci. Rep. Whales Res. Inst.*, 30: 197–230.

GUILER, E.R., 1984. A young Strap-toothed whale in Tasmanian waters. *Pap. Proc. R. Soc. Tasm.*, 118: 65–8.

HANSON, M.B. and A.W. ERICKSON, 1985. Sightings of toothed whales along the Antarctic coast and in the South Atlantic Ocean. *Antarctic Journal of the United States*, 20(2): 16–19.

MERCER, M.C., 1975. Modified Leslie-Delury population models of the long-finned pilot whale (*Globicephala melaena*) and an annual production of the short-finned squid (*Illex cerebrosus*) based on their interaction at Newfoundland. *J. Fish. Res. Bd. Can.*, 32(7): 1145–54.

McCANN, C., 1965. The mesorostral groove in Ziphiidae, with special reference to its closure by ossification in *Mesoplodon* – Cetacea. *Rec. Dom. Mus.*, 5: 83–8.

Moore, J.C., 1960. New records of the Gulf Stream Whale, *Mesoplodon gervaisi,* and some taxonomic considerations. *Amer. Mus. Novitat.,* 1993: 1–34.

Norris, K.S. and W.N. MacFarland, 1958. A new Harbor Porpoise of the genus *Phocaena* from the Gulf of California. *J. Mammal.,* 39: 22–39.

Parker, D.A.A., 1978. Observations of whales on ANARE voyages between Australia and Antarctica. *Aust. Wildl. Res.,* 5: 25–39.

Pilleri, G. and M. Gihr, 1972. Burmeister's Porpoise, *Phocaena spinipinnis* Burmeister, 1865 off the Punta del Diablo, Uruguay. *Investigations on Cetacea,* 4: 171–81.

Pilleri, G. and M. Gihr, 1975. Second record of Burmeister's Porpoise, *Phocaena spinipinnis,* off Los Cerres, Uruguay. *Investigations on Cetacea,* 5: 151–3.

Praderi, R., 1971. Contribucion al conocimiento de Genero *Phocaena* (Cetacea: Phocaenidae). *Rev. Mus. Argent. Cienc. nat. Bernardino Rivadavia Inst. nac. Inv. Sci. nat.* (*Zool.*), 7: 251–66.

Rice, D.W., 1977. A list of the marine mammals of the world. *NOAA Tech. Rep. NMFS SSRF,* 711: 1–15.

Watson, L., 1981. *Sea Guide to Whales of the World.* Hutchinson, London. 302pp.

DISTRIBUTION OF MOTHER-CALF DALL'S PORPOISE PAIRS AS AN INDICATION OF CALVING GROUNDS AND STOCK IDENTITY

TOSHIO KASUYA* AND HARUO OGI**

ABSTRACT

Eighty nine mother-calf Dall's porpoise pairs were sighted in August and September 1982, 1983 and 1985 in the Bering Sea and the western North Pacific (outside the principal range of the *truei*-type population). These sightings were analyzed with an attempt to determine the range of the calving ground and the identity of the stocks. Three discrete concentrations of such pairs were found in the study area, two in the Pacific area north of 45°N and another in the central Bering Sea. The *dalli*-type Dall's porpoises in the surveyed area represent at least two local stocks each breeding to the north and south of the western Aleutian Islands. In addition to these, there is probably another stock which calves off the east coasts of the northern Kuril Islands, although its relationship with the Sea of Japan-Okhotsk Sea stock needs additional examination.

INTRODUCTION

Using sightings data of Dall's porpoise, *Phocoenoides dalli* (True, 1885), from the western North Pacific south of the Aleutian Islands obtained between August and September 1982 (which corresponds to the mating season after the parturition peak of the species (Newby, 1982)), Kasuya and Jones (1984) indicated that mother-calf pairs occurred north of the Subarctic Convergence. They also noted the dominance of weaned juveniles and presumably of males in the Subarctic Convergence zone, and their behavior of approaching vessels. Ogi and Fujise (1984) conducted a cruise during the same season in 1983 and recorded similar geographical behavior differences (Kasuya and Shiraga, 1985).

Miyazaki and Fujise (1985) reported the results of a similar cruise in May and June 1984, south of the western Aleutian Islands. Although their sightings of mother-calf Dall's porpoise pairs were limited due to the period before the parturition peak, their data indicated the presence of latitudinal difference of catchability of the species which probably reflected the difference in the bow riding behavior. This suggests that the Dall's porpoise segregates by growth stages, sex and reproductive status even prior to the parturition peak.

---

* *Far Seas Fisheries Research Laboratory, 5-7-1, Orido, Shimizu-shi, Shizuoka-ken, 424 Japan*

** *Faculty of Fisheries, Hokkaido University, 6-1-1, Minatomachi, Hakodate-shi, Hokkaido, 041 Japan*

Sci. Rep. Whales Res. Inst.,
No. 38, 1987, 125–140

The above studies brought to question if such segregation within the species, especially that of the calving individuals extends further north into the Bering Sea. In order to resolve this question, Japan Fisheries Agency conducted in 1985 a 47 days cruise of the *Hoyomaru No. 12* in the Bering Sea for sighting and collecting biological sample from the species by harpooning (Ogi, Tanaka, Kuramochi and Yamamoto, 1986).

Using data obtained during these three cruises conducted after the parturition peak for Dall's porpoises, the present study analyzes segregation of their breeding population, and attempts to identify the local stocks of the species in the western North Pacific and Bering Sea.

MATERIALS AND METHODS

Materials used are sighting records of Dall's porpoises obtained during three cruises (17 August to 17 September 1982, 10 August to 16 September 1983, and 6 August to 17 September 1985) of the *Hoyomaru No. 12*. This vessel was chartered by the Japan Fisheries Agency for the purpose of studying the biology of the Dall's porpoise incidentally taken in the Japanese salmon gillnet fishery. During these cruises sightings were conducted in the same way as those described by Kasuya and Jones (1984). Most of the Dall's porpoise schools were chased for possible harpooning, although the length and method of the chase were not the same between the cruises and the proportion of passed schools (schools neither chased or closed for harpooning or for further observation) were significantly higher in the 1985 cruise as mentioned below. In the following section the former survey mode (i.e., research vessel stops ordinary sightings activity and to approach the porpoise schools for observation or harpooning) is expressed as closing mode, and the latter (i.e., the vessel continues sighting on the prefixed track line even after finding a school) as passing mode.

Biologists on board the 1982 cruise were Y. Fujise, T. Kasuya and C. Thomson. Outline of the cruise track line and proportion of individuals constituting mother-calf pairs in the daily sightings of the Dall's porpoise are given in Fig. 1 and Appendix Table 1. Further details of the cruise and sightings are in Kasuya and Jones (1984).

Y. Fujise, H. Ogi and S. Shiraga were on board of the 1983 cruise, except for the two days period (14 August and 8 September) when it cruised within fishery conservation zone (FCZ) of the Union of Soviet Socialist Republics (USSR), the survey was conducted in the Pacific area south of the FCZ of the United States of America (USA) and all Dall's porpoise schools encountered were chased. Sightings were discontinued on 2 days of rough weather, but continued on days of poor visibility. Results of the sightings and the cruise track line are given in Fig. 2 and Appendix Table 2.

The 1985 cruise was conducted with four biologists on board, H. Ogi, H. Tanaka, T. Kuramochi and Y. Yamamoto. Most of the period of the north bound cruise and days spent in the northern Bering Sea the vessel cruised the FCZ of the USA or the USSR, and the chasing or harpooning was not conducted (8–12 August, 16–21 August, 5–6 September, 11–12 September). Sightings were discontinued in rough weather (27 August), but continued on some days of poor visibility (7 to 11, and 25 August). The sighting track line and sightings of Dall's porpoises are shown in Fig. 3 and Appendix Table 3.

RESULTS

Density distribution

Kasuya and Ogi (1986) analyzed segregation between the two color types of Dall's porpoise (*dalli*-type and *truei*-type, terminology after Kasuya (1978)), using data which became available after Kasuya (1978), i.e. Kasuya and Jones (1984), Miyazaki, Jones and Beach (1984), Miyazaki, Fujise, Komuro and Taketomi (1984), Ogi and Fujise (1984) and Ogi *et al.* (1986). Recently Miyashita and Kasuya (1987) made similar analysis using additional data obtained during several whale sighting cruises, and indicated that although the ranges of the two color types overlap the *truei*-type predominates in the summer season in the Pacific area between 40°N and 45°N latitude and between 145°E and 155°E longitude and that the northern boundary does not change significantly during May to September when the Japanese coastal Pacific is predominated by *dalli*-types from the Sea of Japan-Okhotsk Sea Stock.

Our survey data do not show clear density change in the northern boundary area of *truei*-types (Appendix Tables 1 to 3). Additionally, distribution of the Dall's porpoise in the surveyed area did not show clear density gap which may correspond to the stock boundary deduced in the present study, although there were detected some apparently high density areas, i.e. around the western Aleutian Islands (Appendix Table 3) and in the Pacific area at around 45°N latitude and 160° to 165°E longitude (Appendix Tables 1 and 2; Kasuya and Jones, 1984). The density was low in the northern Bering Sea north of 59°N latitude (Appendix Table 3).

Dall's porpoises are reported to be uncommon to the north of the cape Navarin (Anon., 1986) and on the continental shelf in the eastern and northeastern Bering Sea (Anon., 1985). Our survey in 1985 confirmed this (Appendix Table 3).

Mother-calf pairs in the western North Pacific

In the 1982 cruise there were 39 sightings of mother-calf pairs in the waters predominated by the *dalli*-type and three of unidentified type in the *truei*-type area (Kasuya and Jones, 1984). None of the former sightings was identified as the *truei*-type. The majority of them (36 pairs) were concentrated in a small area between 165°E and 174°E (eastern end of the research area) longitude and north of 45°N latitude (Fig. 1). The remaining three pairs were

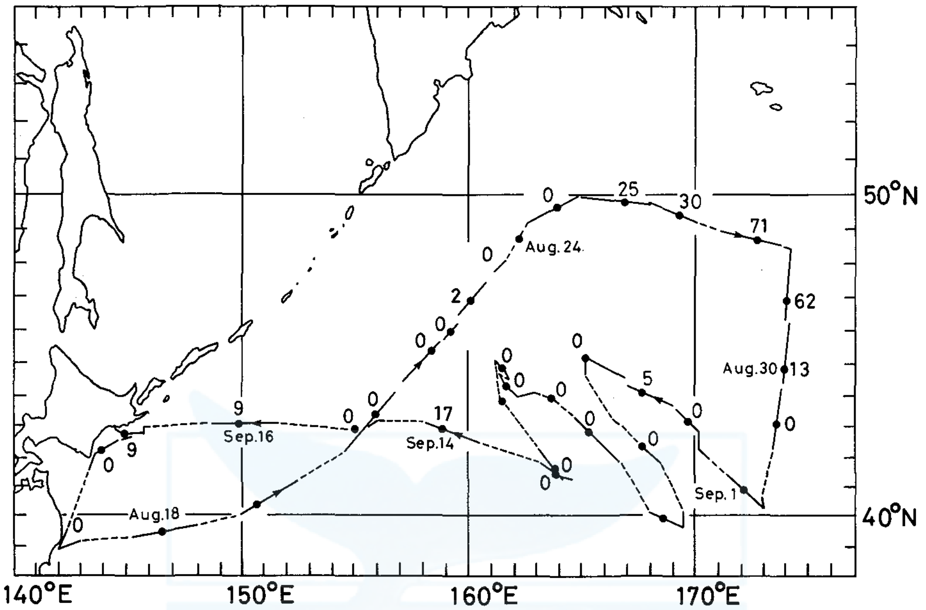


Fig. 1. Distribution of mother-calf pairs of the Dall's porpoise indicated by the percentage of individuals constituting such pairs in the daily number of individuals sighted. *Hoyomaru No. 12* Cruise, 17 August to 17 September, 1982. Solid line indicates track line surveyed, dotted line track line not surveyed, and closed circle noon position. No mother-calf pairs of the *truei*-type were identified during the cruise.

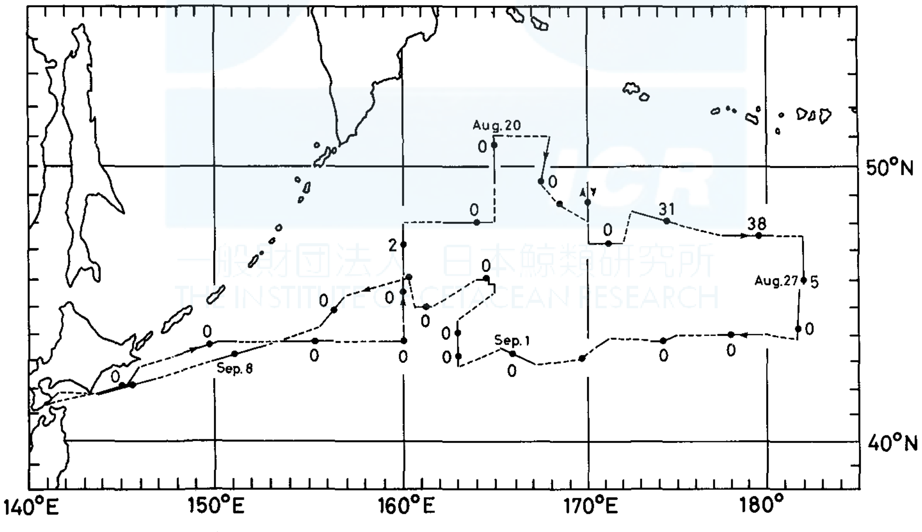


Fig. 2. Distribution of mother-calf pairs of the Dall's porpoise indicated by the percentage of individuals constituting such pairs in the daily number of individuals sighted. *Hoyomaru No. 12* cruise, 10 August to 16 September, 1983. Solid line indicates track line surveyed, dotted line track line not surveyed, and closed circle noon position. No mother-calf pairs of the *truei*-type were identified during the cruise.

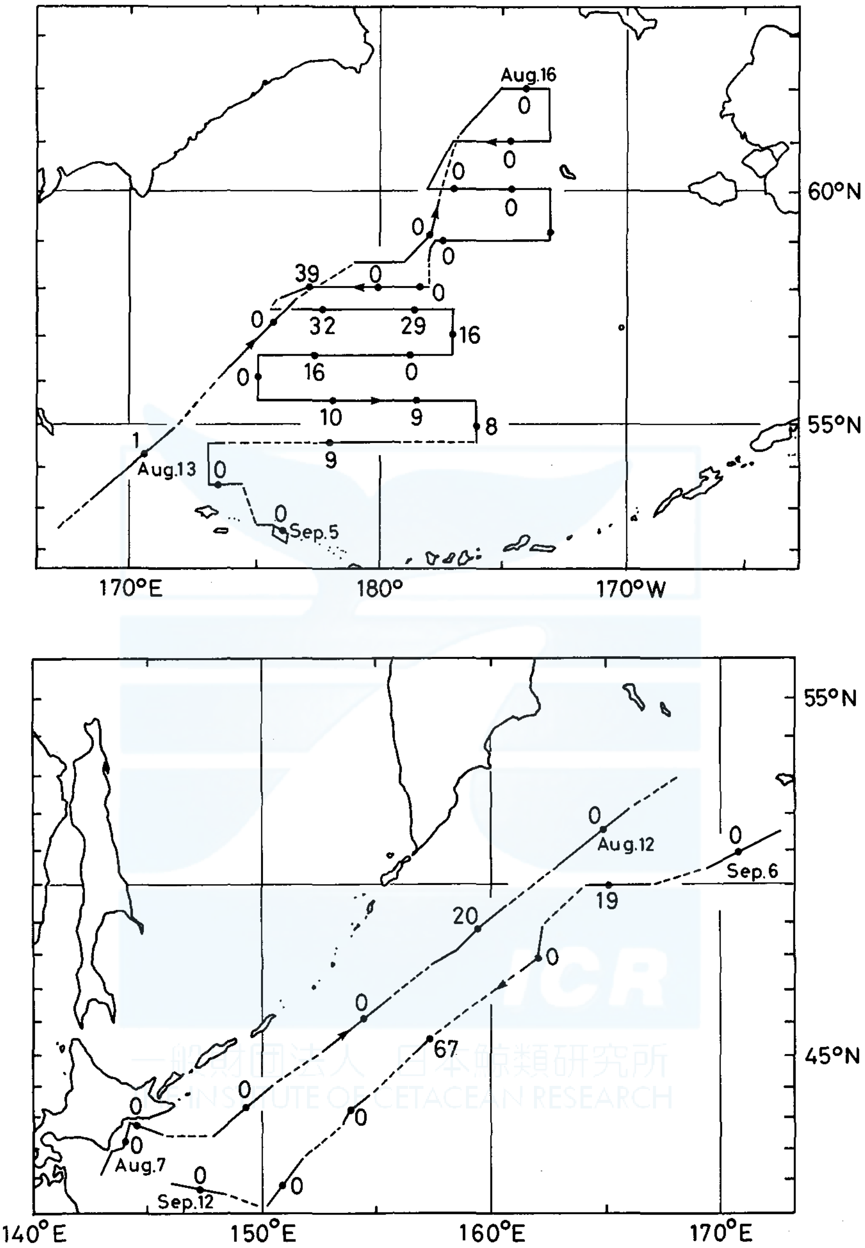


Fig. 3. Distribution of mother-calf pairs of the Dall's porpoise indicated by the percentage of individuals constituting such pairs in the daily number of individuals sighted. *Hoyomaru No. 12* cruise, 7 August to 17 September, 1985. Solid line indicates track line surveyed, dotted line track line not surveyed, and closed circle noon position. No mother-calf pairs of the *truei*-type were identified during the cruise.

sighted in the *dalli*-type area but occurred in the three isolated positions, i.e. approximately in 47°N, 160°E; 44°N, 168°E; 43°N, 159°E.

The 16 mother-calf pairs recorded during the 1983 cruise in the Pacific area occurred in the *dalli*-type area and none were identified as the *truei*-type. One of them was sighted on 18 August in 47°N and 160°E, which was about 500 nautical miles (nm) west of the western limit of the rest of the pairs (Fig. 2), but it was close to the position of one of the three isolated records of mother-calf pair in the 1982 cruise (see above). The remaining 15 pairs were sighted in the Pacific area east of 172°30′E and north of 45°N. The western boundary of this range is located about 300 nm east of the possibly corresponding calving area identified in the previous year (east of 165°E and north of 45°N, see Fig. 1) and these two identified ranges overlapped only in the area east of 172°E.

Of the 34 mother-calf pairs identified in the 1985 cruise, 12 pairs were sighted in the Pacific area (6 pairs on 11 August, 5 pairs on 7 September, and one pair on 9 September, see Appendix Table 3). They were found north of the major range of the *truei*-type distribution (Fig. 3), and none of them were identified as the *truei*-type. The positions of the 5 pairs encountered on 7 September (50°N, 165°E) were situated on the western limit of the aggregation of 36 mother and calf pairs encountered during the 1982 cruise (see above), but the remaining 7 pairs (11 August and 9 September) situated west of 160°E longitude and were close to the position of two isolated western records in 1982 and 1983 cruises.

We conclude from the above data that the distribution of mother-calf pairs suggests the presence of two discrete calving areas for *dalli*-type Dall's porpoise in the western North Pacific. One is found approximately between 45° and 49°N latitude and west of 160°E longitude. This was deduced from only 9 sightings and additional data are still needed to confirm the range and magnitude of this area. However, we consider the presence of this calving area to be reliable because it was confirmed during the three survey cruises. The other is the area east of 165°E longitude and north of 45°N latitude. This calving area extended at least to 178°W longitude, but the eastern limit is not known because of the limitation of survey area. The identified western range of this calving area was variable. In 1982 it was situated at 165°E longitude, possibly as in the case of 1985 season when only western portion of the range was surveyed. The apparent eastern shift of this area in 1983 was possibly due to the northward shift of the area into the USA FCZ (see Discussion). We do not consider that two mother-calf pairs sighted in isolated locations south of 44°N and east of 159°E on 3 and 14 September (Fig. 1 and Appendix Table 1) represent another breeding area, because it has not been confirmed by subsequent cruises in the area (Appendix Tables 2 and 3, Figs 2 and 3).

The two calving areas in the western North Pacific described above are separated by about 5 degree in longitude or about 250 nm in the minimum linear distance (distance between the sightings on 11 August 1985 (48°16′N, 158°32′E) and that on 7 September (49°59′N, 164°10′E)). They were further separated in 1982 and 1983. This indicates the discontinuity of these two calving grounds.*

Mother-calf pairs in the Bering Sea

The Bering Sea was surveyed in 1985, and there were sightings of 22 mother-calf pairs. None of these pairs were identified as *truei*-type. The southern most sighting of a mother-calf pair in the Bering Sea occurred on 13 August in 54°27′N and 170°04′E, or just on the southern boundary of the Bering Sea. The other 21 pairs were sighted in the central portion of the Bering Sea. No mother-calf pairs were sighted in the northern Bering Sea (north of the 59°N) in spite of the sightings of 82 Dall's porpoises in this area (Fig. 3).

The proportion of mother-calf pairs in the Bering Sea declined toward the Aleutian Islands (Fig. 3), from the highest figure of over 39% in the middle part of the Bering Sea at 58°N latitude (24 August) to 8% at 55°N latitude (2 September). During this time the survey method was the closing mode. During the five day period in the FCZs of USA and USSR around the Aleutian Islands (12–13 August and 4–6 September), the passing mode was used and only one mother-calf pair (mentioned above) was identified among 396 Dall's porpoises. This apparently low proportion of mother-calf pairs in the Aleutian Islands area can not be fully explained by the difference of detectability between the two survey methods.

On the other hand, mother-calf pairs of Dall's porpoise were identified even on the days of passing mode survey when no porpoise schools were closed or chased (nine mother-calf pairs in the total of 322 individuals sighted on 11 and 13 August, and 3 and 9 September 1985, see Fig. 3), but no mother-calf pairs were sighted on some of the subsequent days of closing mode (six days of 14, 15, and 23 August, and 10 and 12 September 1985, when total of the 134 Dall's porpoises were sighted). Therefore, not denying the possibility that more mother-calf pairs might have been identified if we had used the closing mode in the Aleutian Islands area, we believe that the apparently low abundance of mother-calf pairs in the area reflects the geographically biased distribution of calving individuals, and that the calving ground in the Bering Sea is discrete from those in the Pacific Ocean.

---

*: *After this manuscript was sent to printer, Yoshioka, Ogura and Shikano (1987) completed a transpacific research cruise on board of the* Hoyomaru No. 12 *in August through October 1986 for sightings of Dall's porpoises. They confirmed calving grounds off the east coast of northern Kuril Islands (represented by four mother-calf pairs in 43° to 46°N latitude and 155° to 165°E longitude) and south of the Aleutian Islands (seven mother-calf pairs in 47° to 49°N latitude and 180° to 165°W longitude), and found the third calving ground in the Gulf of Alaska east of 153°W (eight mother-calf pairs). Although the ranges of the two western calving grounds were located considerably to the east of the ranges indicated by the present study, they were apart for over 500 nm and the boundaries were distinct. Thus the cruise of Yoshioka* et al., *(1987) provided an additional support to our conclusion on the presence of two calving grounds of the* dalli-*type Dall's porpoise in the northwestern North Pacific.*

DISCUSSION

Dall's porpoises in the calving ground tended to avoid vessels and were difficult to harpoon (Kasuya and Jones, 1984). This was supported by later cruises in the western North Pacific with similar purpose (see above). However, the survey of closing mode in the central Bering Sea in 1985 showed that the number of Dall's porpoises that rode the ship's bow wave ranged from 0 to 69% (mean was 21%) of the total number of individuals sighted daily. This was apparently higher than the figures below 30% in 1982 (Appendix Table 1) and in 1983 (Appendix Table 2) cruises recorded in the same season for the calving ground in the south of the western Aleutian Islands. This can be attributable to two reasons. The first is that the segregation of breeding population may not have been so distinct in the Bering Sea as in the western North Pacific reported by Kasuya and Jones (1984). This was deduced from the fact that the proportion of mother-calf pairs declined from the highest value at 58°N latitude to the lowest near the USA FCZ (55°N) (and then to almost zero of the passing mode survey in USA FCZ, 49° to 54°N). The second reason can be a possible higher intensity of chasing schools during the 1985 Bering Sea cruise. Few members of a school could have approached the vessel and eventually been harpooned after a long intense chase. During the 14 day cruise of closing mode in the central Bering Sea, they caught only 12 Dall's porpoises (0.86 individuals/day). This is considerably lower than the total catch made during about one month cruises in the Pacific area including both calving grounds and other areas, i.e. 72 individuals in the 32 days cruise in 1982 (Kasuya and Jones, 1984), 95 in the 38 days cruise in 1983 (Kasuya and Shiraga, 1985), and 187 in the 43 days cruise in 1984 (Miyazaki and Fujise, 1985). Therefore, it will be accepted, in general, that the central Bering Sea area is one of the calving grounds for Dall's porpoises and the individuals in the area tended to avoid vessels.

Using the incidental take rate from 1981 to 1984 salmon gillnet fishing seasons (June and July) as an index of abundance, Ferrero and Jones (1986) analyzed distribution of Dall's porpoises by sex and maturity in the western Aleutian Islands area of the USA FCZ which was bounded by 168°E and 175°E longitude and 49°N and 55°N latitude. This area is between the two major calving areas in the Bering Sea and western North Pacific identified above, and partially overlaps with the latter. Their data indicate that (1) the density of immature individuals was higher in the northern latitude in all years/months and in both sexes, (2) adult female density in July was higher in the southern latitude except for the opposite trend in July 1983 (the density was low and had less distinct latitudinal change in June of these years), and (3) the density of the adult males was always lower than that of the adult females and the latitudinal trend was indistinct. The first two of these features can be explained by assuming that the segregation by sex and growth stages of the Dall's porpoise occurs parallelly in the Bering Sea as in the western

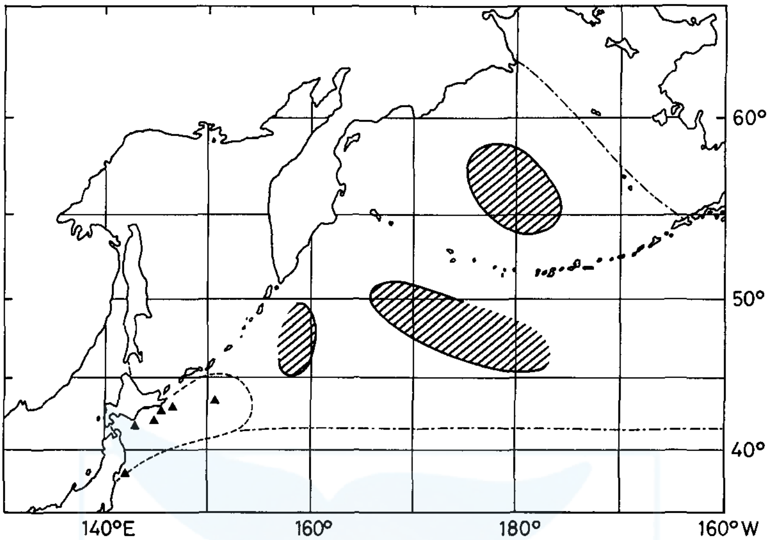


Fig. 4. Calving grounds of the *dalli*-type Dall's porpoise identified in the present study (shaded areas). Chain indicates ordinary summer range of the species where *dalli*-type predominates, and dotted line that of *truei*-type predominance. Triangles indicate three mother-calf pairs of *truei*-type sighted in July 1984 (*Toshimaru No. 25* cruise, Kasuya unpublished) and three mother-calf pairs of unidentified type sighted in the *truei*-type area in September (*Hoyomaru No. 12* cruise in 1982, Appendix Table 1). Information is not available on breeding ground of the Dall's porpoise in the Okhotsk Sea. Some *dalli*-types from the Sea of Japan-Okhotsk Sea stock summer in the southwestern coastal portion of the *truei*-type range (Miyashita and Kasuya, 1987)

North Pacific, and that the northern range of the Pacific stock (inhabited by the calving population) overlaps partially with the southern range of the Bering Sea stock (predominated by immature individuals). Therefore, we consider that the two independent calving grounds of Dall's porpoises are utilized by two isolated local stocks of the species. The adult males of the stocks probably live further north and south of the study area of Ferrero and Jones (1986).

The 1983 season was characterized by both the unusual distribution of adult female density (Ferrero and Jones, 1986) and the apparent eastern shift of the range of the calving area observed outside the USA FCZ south of the western Aleutian Islands (present data). These can be explained by assuming that the western portion of the calving ground of the western North Pacific stock was located further north during the 1983 season than other seasons.

The apparent overlap of the range of the two local stocks will offer only a limited chance of interbreeding because the breeding populations of the two stocks do not usually meet in an area (Fig. 4). The similar, but less influential, effect is also expected in the possible earlier occurrence of the mating season in the western North Pacific stock. Among 29 adult *dalli*-type Dall's porpoise females taken during the 1982 and 1983 cruises in the south of the western Aleutian Islands, five were pregnant (with fetal body lengths 0.32 to 13.1 cm and the mean of 4.0 cm), eight had embryonic membrane containing no identifiable embryo, and 16 females had only corpus luteum of ovulation (Kasuya, unpublished). However, among nine adult females in the Bering Sea collected in the same season and by the same method, seven had corpus luteum of ovulation and no fetus or embryonic membrane. The remaining two adult females had no corpus luteum (Yoshioka, 1986). Therefore, it is probable that the mating peak occurs late in the Bering Sea.

There are no direct data on migration of adult individuals between calving grounds in successive years, but we consider it uncommon from the regularity of reproduction of the species, i.e. narrow and successive parturition and mating seasons and one year cycle of female reproduction (Newby, 1982). Support for this was found for the *dalli*-type Dall's porpoise in the Bering Sea and western North Pacific in the concentration of heavy metals and organochlorines, and in the parasite load. Walker (1987) compared the occurrence of cestode, *Phyllobothrium* sp., and nematode, *Crassicauda* sp., between the Dall's porpoises of the same growth stage taken in the western North Pacific and the Bering Sea, and found significant difference of the infectation rates between the two areas. Subramanian, Tanabe, Fujise and Tatsukawa (1986) found geographical difference in the PCB and DDE concentrations and their ratios between individuals taken during the summer in the Bering Sea and northwestern North Pacific, and concluded that those individuals used different feeding grounds although two individuals from the western Aleutian Islands had intermediate values. Tatsukawa, Fujise, Honda and Mishima (in prep.) discovered higher cadmium concentrations and lower mercury concentrations in individuals from the Bering Sea and opposite ratios from individuals south of the western Aleutian Islands, and arrived at a conclusion which was similar to that of Subramanian *et al.* (in press). They also suggested the Aleutian Islands as an intermingling area. Their results agreed with the possible distribution of two stocks in the Aleutian Islands area deduced in the present study.

Our study indicated that *dalli*-type Dall's porpoises also calves in an area of the Pacific west of the major calving ground south of the western Aleutian Islands which was discussed above (Fig. 4). The two calving grounds in the western North Pacific did not merge each other, although the ranges probably fluctuated annually. This suggests that these calving grounds are used by two different populations of the *dalli*-type Dall's porpoise. Further study is needed on the extent of this calving ground along the east coast of the northern Kuril Islands and southern Kamchatka Peninsula. Additional research is also needed on how the Dall's porpoises in this calving ground are related to the Sea of Japan-Okhotsk Sea stock proposed by Kasuya (1978), because there remains a possibility of a local intrusion of the Sea of Japan-Okhotsk Sea stock as well as the possibility of existence of a local stock.

We found substantial agreement between the major ocean current systems and the calving grounds of the presently accepted stocks of Dall's porpoise. The majority of the Sea of Japan-Okhotsk Sea stock (*dalli*-types) seem to stay in the Okhotsk Sea Gyre during the breeding season, although some individuals of unknown reproductive status from the stock might summer off the Pacific coast of southern Hokkaido (Kasuya, 1978; Miyazaki and Fujise, 1985; Miyashita and Kasuya, 1987; Subramanian *et al.*, 1986). Distribution of the stock off the Pacific coast of Japan is limited to the waters under the influence of the Oyashio Current, with the Kuroshio and Tsugaru Currents as the southern and western boundaries, respectively. We are still unclear if this stock is composed entirely of the *truei*-type individuals (i.e. all the *dalli*-types found in the area are migrant from other stock), or a small proportion of *dalli*-type individuals are contained in it. We found that the breeding ground of the Bering Sea stock (*dalli*-types) is limited to the Bering Sea Gyre, and its breeding population does not intrude into the Western Subarctic Gyre south of the Aleutian Islands, which is inhabited during the summer breeding season by the breeding population of another stock of the *dalli*-type Dall's porpoises (western North Pacific stock). The non-breeding member of this western North Pacific stock is known to segregate in the Subarctic Convergence Zone south of the breeding ground (Kasuya and Jones, 1984).

Not denying the possibility of some additional local stocks or small scale intermingling across the current system as suggested by the breeding ground in the East Kamchatka Current area, we consider the above correspondence is important and presume that the eastern boundary of the calving ground of the western North Pacific stock will not extend into the Alaskan Gyre. The ranges of the Western Subarctic Gyre and Alaskan Gyre extends at least approximately to 160°W and 180° longitude, respectively (Favorite, Dodimead and Nasu, 1976). Therefore the eastern boundary of the western North Pacific stock (which breeds in the area east of 165° E) seems to be located somewhere between these longitudes. Recently the breeding ground of this western North Pacific stock has been confirmed to extend to 165°W (Yoshioka *et al.*, 1987) rather than 178°W (confirmed in the present study).

Available records of mother-calf pairs in *truei*-type area are scanty. Three (*truei*-types) were sighted by myself during the cruise of the *Toshimaru No. 25* in July 1984 (southern three records in Fig. 4), which scanned the major range of the *truei*-types outside the USSR FCZ (Kasuya, 1986). Other three sightings of mother-calf pairs of unknown type occurred during the 1982 cruise of this study off the east coast of Hokkaido at about 43°N (Fig. 4).

ACKNOWLEDGEMENTS

All the biologists on board of the *Hoyomaru No. 12* cruises cooperated in collecting sightings data while many of them were conducting their own biological tasks. Captain F. Ito and his crew supported every research activity on the vessel. The principal planning and organization of the cruise were done by Drs S. Odate, K. Takagi, J. Ito and M. Kato of the Salmon Division of the Far Seas Fisheries Research Laboratory. Dr R.L. Brownell and Mr W.A. Walker critically read the draft and corrected English.

REFERENCES

ANON., 1985. Survey of fur seal stocks and ocean environment in the Bering Sea in 1984. Far Seas Fish. Res. Lab., Shimizu (Japan). 71pp. (in Japanese).

ANON., 1986. Draft environmental impact statement and economic impact analysis on the incidental take of Dall's porpoise in the Japanese salmon fishery. Nat. Mar. Fish. Ser. (USA). 240pp.

FAVORITE, F., A.J. DODIMEAD and K. NASU, 1976. Oceanography of the Subarctic Pacific region 1960–71. *Bull. Int. North Pac. Fish. Comm.*, 33: 1–187.

FERRENO, R.C. and L.L. JONES, 1986. Distribution and movement patterns of Dall's porpoise (*Phocoenoides dalli*) in the western North Pacific Ocean during June and July 1981–1984. Document submitted to the Scientific Subcommittee, Ad Hoc Committee on Marine Mammals, International North Pacific Fisheries Commission, Tokyo. 24pp.

KASUYA, T., 1978. The life history of Dall's porpoise with special reference to the stock off the Pacific coast of Japan. *Sci. Rep. Whales Res. Inst.*, 30: 1–63.

KASUYA, T., 1986. Distribution and behavior of Baird's beaked whales off the Pacific coast of Japan. *Sci. Rep. Whales Res. Inst.*, 37: 61–83.

KASUYA, T. and L.L. JONES, 1984. Behavior and segregation of the Dall's porpoise in the northwestern North Pacific Ocean. *Sci. Rep. Whales Res. Inst.*, 35: 107–128.

KASUYA, T. and H. OGI, 1986. Segregation of Dall's porpoise in the Bering Sea and western North Pacific by color type and reproductive status. Document submitted to the meeting of the Scientific Committee, Ad Hoc Committee on Marine Mammals, International North Pacific Fisheries Commission, Tokyo. 11pp.

KASUYA, T. and S. SHIRAGA, 1985. Growth of Dall's porpoise in the western North Pacific and suggested geographical growth differentiation. *Sci. Rep. Whales Res. Inst.*, 36: 139–152.

MIYASHITA, T. and T. KASUYA, 1987. Distribution of Dall's porpoises off Japan. Document submitted to the meeting of the Scientific Committee of Ad Hoc Committee on Marine Mammals, International North Pacific Fisheries Commission, Tokyo, March 10–14, 1987. 24pp.

MIYAZAKI, N. and Y. FUJISE, 1985. Report of the survey by the dedicated vessel, *Hoyomaru No. 53*, in 1984. Document submitted to the meeting of the Scientific Subcommittee, Ad Hoc Committee on Marine Mammals, International North Pacific Fisheries Commission, Tokyo. 25pp.

MIYAZAKI, N., Y. FUJISE, T. KOMURO and H. TAKETOMI, 1984. Outline of the survey of the porpoises in the northern North Pacific by the *Hoyomaru No. 53* dedicated for the study of Dall's porpoise (10 May to 20 June 1984). Far Seas Fis. Res. Lab., Shimizu. 47pp.

MIYAZAKI, N., L.L. JONES and R. BEACH, 1984. Some observations on the schools of *dalli*- and *truei*-type Dall's porpoises in the northwestern Pacific. *Sci. Rep. Whales Res. Inst.*, 35: 93–105.

NEWBY, T.C., 1982. Life history of Dall porpoise (*Phocoenoides dalli*, True 1885) incidentally taken by the Japanese high seas salmon mothership fishery in the northwestern North Pacific and western Bering Sea, 1978 and 1980. Doctoral thesis submitted to University of Washington. 155pp.

OGI, H. and Y. FUJISE, 1984. Outline of the research on marine mammals by the *Hoyomaru No. 12* in 1983 (August 10 to September 11). Document submitted to the meeting of the Scientific Subcommittee, Ad Hoc Committee on Marine Mammals, International North Pacific Fisheries Commission, Tokyo. 14pp.

OGI, H., H. TANAKA, T. KURAMOCHI and Y. YAMAMOTO, 1986. Outline of the research on Dall's porpoise by the *Hoyomaru No. 12* in 1985. Document submitted to the meeting of the Scientific Subcommittee, Ad Hoc Committee on Marine Mammals, International North Pacific Fisheries Commission, Tokyo. 20pp.

SUBRAMANIAN, A., S. TANABE, Y. FUJISE and Y. TATSUKAWA, 1986. Organochlorine residues in Dall's and True's porpoises collected from northwestern Pacific and adjacent waters. *Mem. Natl Inst. Polar Res., Spec. Issue*, 44: 167–173.

WALKER, W.A., 1987. Geographical variation of the parasites *Crassicauda* (nematoda) and *Phyllobothrium* (cestoda) in *Phocoenoides dalli* in the northern North Pacific and Bering Sea. Document submitted to the meeting of the Scientific Committee of the Ad Hoc Committee on Marine Mammals, International North Pacific Fisheries Commission, Tokyo, March 10–14, 1987. 17pp.

YOSHIOKA, M., 1986. Report on biological studies of Dall's porpoise taken by the dedicated vessel, *Hoyomaru No. 12*, cruise in 1985. Document submitted to the Scientific Subcommittee, Ad Hoc Committee on Marine Mammals, International North Pacific Fisheries Commission, Tokyo. 12pp.

YOSHIOKA, M., M. Ogura and C. Shikano, 1987. Results of the transpacific Dall's porpoise research cruise by the *Hoyomaru No. 12* in 1986. Document submitted to the meeting of the Scientific Committee, Ad Hoc Committee on Marine Mammals, International North Pacific Fisheries Commission, Tokyo. 22pp.

APPENDIX TABLE 1. SIGHTINGS OF DALL'S PORPOISES DURING THE CRUISE ABOARD *HOYOMARU NO. 12* IN 1982 5)

Date		Noon position	No of individuals 6)			Mother-calf pairs	Rode ship's 1) wave (%)	Surface temperature (°C) 4)
mo.	day		T	D	U			
8.	17	Lv. Kesennuma	0	0	0	0	–	20.8–23.4
8.	18	39°27′N, 146°30′E	0	0	0	0	–	20.9–22.6
8.	19	40°36′N, 151°31′E	0	0	0	0	–	20.2–23.7
8.	20	43°32′N, 155°54′E	4	0	0	0	50	18.5–19.6
8.	21	45°17′N, 158°21′E	1	27	0	0	82	17.5–18.7
8.	22	45°59′N, 159°15′E	0	23	33	0	32	16.6–17.8
8.	23	46°49′N, 160°00′E	0	43	41	1	87	12.5–16.6
8.	24	48°37′N, 162°22′E	0	24	8	0	63	11.8–12.5
8.	25	49°41′N, 163°58′E	0	10	28	0	5	9.8–10.2
8.	26	49°46′N, 166°55′E	0	12	12	3	4	9.1– 9.5
8.	27	49°13′N, 169°22′E	0	15	12	4	7	9.2– 9.9
8.	28	48°38′N, 172°41′E	0	22	34	20	0	9.5–10.0
8.	29	46°58′N, 174°02′E	0	15	11	8	0	9.7–11.1
8.	30	44°55′N, 173°47′E	0	13	3	1	6	11.6–12.8
8.	31	43°08′N, 173°31′E	0	7	0	0	71	12.1–16.7
9.	01	40°59′N, 172°01′E	0	0	0	0	–	16.0–18.0
9.	02	43°09′N, 169°37′E	0	17	2	0	100	13.7–17.6
9.	03	44°05′N, 167°44′E	0	31	7	1	45	13.1–14.0
9.	04	45°10′N, 165°13′E	0	7	2	0	22	13.7–14.1
9.	05	42°20′N, 167°48′E	0	1	0	0	100	15.0–18.9
9.	06	40°00′N, 168°49′E	0	0	0	0	–	19.4–19.8
9.	07	42°48′N, 165°23′E	0	4	0	0	100	15.8–18.4
9.	08	43°58′N, 163°37′E	0	2 3)	0	0	100	14.4–15.4
9.	09	44°14′N, 161°41′E	1	23	2	0	85	14.6–17.1
9.	10	44°50′N, 161°27′E	1	59	25	0	76	14.8–16.8
9.	11	43°52′N, 161°30′E	No sighting surveys conducted					14.1–16.8
9.	12	41°29′N, 163°54′E	0	2	2	0	50	16.7–18.2
9.	13	41°31′N, 163°50′E	0	0	2	0	0	18.0–20.6
9.	14	42°50′N, 158°52′E	0	7	5	1	58	14.4–18.3
9.	15	42°56′N, 155°03′E	0	0	0	0	–	16.0–17.6
9.	16 2)	43°02′N, 149°51′E	5	1	17	1	22	13.8–17.6
9.	17	42°46′N, 144°52′E	12	15	16	2	63	14.1–18.0
9.	18	42°14′N, 143°53′E	31	0	13	0	30	15.0–18.5
9.	19	Ar. Kesennuma	0	0	0	0	–	19.1–20.1
	Total		55	380	275	42	46	

1) Porpoise came to the ship's wave, either at bow or side.
2) No porpoises were chased or caught by the vessel.
3) Porpoises were sighted on bow, but sighting survey was not conducted due to rough weather.
4) Temperature ranges during sighting surveys, or during the day if surveys were not conducted.
5) Reproduced from Kasuya and Jones (1984).
6) T, *truei*-type. D, *dalli*-type. U, Dall's porpoise of unknown type.

APPENDIX TABLE 2. SIGHTINGS OF DALL'S PORPOISES DURING THE CRUISE ABOARD *HOYOMARU NO. 12* IN 1983[1]

Date		Noon position		Distance surveyed (nm)	No. of individuals[2]				Mother /calf pairs	Porpoises rode bow wave	Surface water[3] temperature (C°)
mo.	day				T	D	U	sum			
8.	12	Hakodate Port		28	0	0	0	0	0	0	19.2–22.8
8.	13	42°11′N,	145°00′E	124	12	5	6	23	0	10	12.5–19.9
8.	14	43°43′N,	149°40′E	149	18	1	0	19	0	3	13.3–16.2
8.	15	43°47′N,	155°14′E	169	3	59	16	78	0	12	11.5–15.0
8.	16	43°49′N,	160°00′E	121	0	23[4]	0	23	0	16	13.0–18.4
8.	17	45°29′N,	160°04′E	84	0	56	38	94	0	19	11.7–12.6
8.	18	47°12′N,	159°52′E	97	0	35	54	89	1	3	10.5–12.0
8.	19	47°55′N,	164°01′E	119	0	29	11	40	0	1	10.0–10.9
8.	20	50°39′N,	165°00′E	120	0	1	7	8	0	0	9.9–10.9
8.	21	49°28′N,	167°28′E	89	1	4	0	5	0	0	9.4–10.3
8.	22	48°39′N,	168°34′E	0	0	0	0	0	0	0	no survey
8.	23	48°39′N,	170°10′E	84	0	0	0	0	0	0	9.2–9.7
8.	24	47°12′N,	171°08′E	126	0	4	3	7	0	1	9.6–9.9
8.	25	48°07′N,	174°28′E	112	0	34	18	52	8	10	9.8–10.8
8.	26	47°31′N,	179°33′E	111	0	13	19	32	6	0	10.9–11.5
8.	27	45°57′N,	178°05′W	103	0	21	17	38	1	17	11.6–13.2
8.	28	44°12′N,	178°13′W	80	0	2	2	4	0	0	13.3–16.2
8.	29	44°01′N,	177°53′E	113	0	3	3	6	0	3	13.1–14.9
8.	30	43°37′N,	174°04′E	62	0	4	0	4	0	0	13.9–15.9
8.	31	43°08′N,	169°38′E	30	0	0	0	0	0	0	13.9–14.5
9.	1	43°17′N,	165°46′E	94	0	49	7	56	0	8	12.4–13.0
9.	2	43°16′N,	163°04′E	43	2	83[5]	60	147	0	63	13.3–13.8
9.	3	44°04′N,	163°07′E	70	0	96	34	130	0	47	12.6–13.8
9.	4	46°00′N,	164°33′E	63	1	65	60	126	0	35	11.6–12.7
9.	5	45°06′N,	161°26′E	38	0	20	5	25	0	40	13.3–16.2
9.	6	46°05′N,	160°21′E	0	0	0	0	0	0	0	no survey
9.	7	44°54′N,	156°11′E	84	0	45	36	81	0	31	11.8–13.8
9.	8	43°17′N,	151°01′E	141	0	0	0	0	0	0	12.1–17.3
9.	9	42°11′N,	145°22′E	130	0	0	0	0	0	0	15.2–20.0
9.	10	Hakodate Port		31	0	0	0	0	0	0	

1) Includes secondary sightings. All the sightings were chased.
2) T, *truei*-type. D, *dalli*-type. U, Dall's porpoise of unknown type.
3) Surface water temperature range during sighting survey.
4) Includes one black type.
5) Includes two black types.

APPENDIX TABLE 3. SIGHTINGS OF DALL'S PORPOISES DURING THE CRUISE ABOARD *HOYOMARU NO. 12* IN 1985[1]

Date mo.	Date day	Noon position		Distance surveyed (nm)	No. of individuals[2] T	D	U	sum	Mother /calf pairs	Porpoises chased	Porpoises rode bow wave	Surface water[3] temperature (C°)
8.	7	42°12′N,	144°02′E	131.4	3	5	1	9	0	0	1	14.0–21.0
8.	8	42°52′N,	144°25′E	68.5	0	5	8	13	0	0	0	14.0–19.3
8.	9	43°21′N,	149°22′E	160.0	4	10	3	17	0	0	5	10.9–13.0
8.	10	46°02′N,	154°21′E	160.1	0	10	13	23	0	0	4	7.5–10.1
8.	11	48°46′N,	159°24′E	167.2	0	6	53	59	6	0	0	9.8–10.9
8.	12	51°30′N,	164°44′E	166.9	0	3	40	43	0	0	3	8.7–9.1
8.	13	54°11′N,	170°20′E	167.0	1	52	185	238	1	0	28	8.8–9.4
8.	14	57°13′N,	175°32′E	156.2	0	16	11	27	0	24	1	8.7–9.4
8.	15	59°02′N,	177°58′W	149.3	0	15	13	28	0	10	1	8.7–9.5
8.	16	62°00′N,	174°00′W	150.1	0	7	0	7	0	0	2	8.0–9.0
8.	17	61°00′N,	174°46′W	159.2	0	0	3	3	0	0	0	8.2–8.9
8.	18	60°00′N,	177°00′W	164.5	0	11	9	20	0	0	5	8.2–9.0
8.	19	60°02′N,	174°30′W	26.9	0	1	0	1	0	0	1	8.4–8.6
8.	20	59°09′N,	173°00′W	144.5	0	0	0	0	0	0	0	8.0–9.1
8.	21	58°59′N,	177°27′W	154.5	0	11	12	23	0	0	8	8.6–9.0
8.	22	58°00′N,	178°20′W	30.6	0	1	0	1	0	0	0	9.0–9.2
8.	23	58°00′N,	179°58′W	57.2	0	14	1	15	0	14	7	8.6–9.1
8.	24	57°59′N,	177°07′E	115.0	0	8	18	26	5	21	4	8.6–8.9
8.	25	57°30′N,	177°27′E	108.2	0	15	10	25	4	23	5	8.4–9.0
8.	26	57°30′N,	178°50′W	97.0	0	11	24	35	5	35	9	8.8–9.1
8.	27	57°01′N,	176°57′W	69.7	0	0	12	12	1	12	0	8.7–9.1
8.	28	56°30′N,	178°44′W	99.2	0	0	4	4	0	2	0	8.5–8.8
8.	29	56°30′N,	177°14′E	115.1	0	17	8	25	2	23	6	8.5–8.9
8.	30	56°01′N,	175°00′E	127.4	0	12	15	27	0	14	4	8.3–9.1
8.	31	55°30′N,	178°00′E	124.8	0	3	17	20	1	3	2	8.3–9.1
9.	1	55°30′N,	178°34′W	122.9	0	14	8	22	1	22	9	8.6–9.0
9.	2	55°00′N,	175°58′W	166.4	0	8	17	25	1	4	0	8.6–8.8
9.	3	54°30′N,	178°00′E	111.9	0	5	17	22	1	0	1	8.6–9.1
9.	4	53°28′N,	173°17′E	132.9	0	15	44	59	0	0	2	9.2–9.7
9.	5	52°22′N,	176°10′E	124.2	0	16	19	35	0	0	0	5.9–8.8
9.	6	50°51′N,	170°24′E	135.6	0	5	16	21	0	0	0	9.5–10.2
9.	7	49°57′N,	164°54′E	111.8	0	14	40	54	5	41	13	10.2–10.3
9.	8	47°59′N,	160°53′E	109.6	0	10	15	25	0	15	5	9.6–10.6
9.	9	45°31′N,	157°11′E	45.0	0	2	1	3	1	0	0	11.5–12.1
9.	10	45°13′N,	153°50′E	89.5	1	24	12	37	0	37	11	15.7–17.7
9.	11	40°46′N,	150°45′E	119.1	2	0	0	2	0	0	0	17.1–21.0
9.	12	40°40′N,	147°11′E	110.0	19	2	6	27	0	26	11	16.1–19.9

1) Includes secondary sightings of 27 individuals in six schools.
2) T, *truei*-type. D, *dalli*-type. U, Dall's porpoise of unknown type.
3) Surface water temperature range during the sighting survey.

GENETIC VARIABILITY AND DIFFERENTIATION IN THE TOOTHED WHALES

ETSUKO SHIMURA* AND KEN-ICHI NUMACHI*

ABSTRACT

Genetic variability and differentiation of three families containing 12 species of toothed whales mainly from the sea around Japan have been examined by starch-gel electrophoresis at 19 genetic loci encoding enzymes. The amount of genic variations presented by proportion of polymorphic loci and average heterozygosity of whole species studied were 0.207±0.151 and 0.063±0.051, respectively, and were found to be similar to the average of other vertebrates. The genetic distances and genetic identities among the species, genera and families of the toothed whales studied were discussed, and the degree of genetic divergence of given taxonomic levels were shown to be low in comparison with corresponding taxa of other organisms. The phylogenetic relationships among the species studied were estimated by the dendrogram of genetic distances.

INTRODUCTION

Electrophoretic data consisting of allele frequencies have been widely accumulated in a large variety of organisms, to estimate the amount of genetic variation in natural populations and the degree of genetic differentiation at various levels of taxonomic groups. In general, vertebrates including mammals are known to have lower levels of genetic variability than invertebrates. Selander and Kaufman (1973) and Valentine (1976) supposed that large, mobile animals, especially vertebrates had lower levels of variability than small, relatively immobile animals of most invertebrates from the viewpoint of adaptive strategy.

The cetacean is an unique group of mammals distinctly different from the other mammals in many aspects of their biology by perfectly adapting to an aquatic form of life, and is possibly a representative of large, active vertebrates. However, electrophoretic survey of protein molecules in the cetaceans is relatively few. It is probably because of some difficulties in sample collection. Several preliminary studies of electrophoretic examination of proteins have dealt with hemoglobin (Horvath, Chiodi, Ridgeway and Azar, Jr., 1968; Baluda, Kulu and Sparkes, 1972; Border, 1975), some blood proteins (Sharp, 1981) and lactate dehydrogenase (Numachi, 1970). Recently, studies of en-

---

* *Ocean Research Institute, University of Tokyo, Minamidai, Nakano-ku, Tokyo, 164, Japan*

TABLE 1. MATERIALS USED IN THIS STUDY

Name of species	Locality	No. of samples Liver	 Muscle
Ziphiidae			
North pacific giant bottlenose whale (*Berardius bairdii*)	Wadaura, Bōsō Pen.	9	12
Delphinidae			
Short-finned pilot whale (*Globicephala macrorhynchus*)	Taiji, Kii Pen.	39	39
Many-toothed blackfish (*Peponocephala electra*)	Taiji	6	1
False killer whale (*Pseudorca crassidens*)	Iki Island	31	31
Striped dolphin (*Stenella coeruleoalba*)	Kawana, Izu Pen.	370	204
Bridled dolphin (*Stenella attenuata*)	Kawana	183	90
Bottlenose dolphin (*Tursiops truncatus*)	Iki Island	35	35
Pacific whiteside dolphin (*Lagenorhynchus obliquidens*)	Iki Island	30	27
Routh-toothed dolphin (*Steno bredanensis*)	Taiji	10	29
Phocoenidae			
Harbor porpoise (*Phocoena phocoena*)	The east coast of Hokkaido	3	3
Finless porpoise (*Neophocaena phocaenoides*)	The coast of Kii Pen.	3	5
Dall porpoise (*Phocoenoides dalli dalli*-type)	North Pacific & the east coast of Hokkaido	483	61
(*P. dalli truei*-type)	Off Sanriku region	54	400

zyme polymorphisms and genetic structure of population in the species of cetacean were made by several authors (Wada and Numachi, 1979; Simonsen, Kapel and Larsen, 1982; Wada, 1982, 1983a, 1983b, 1984, 1986; Numachi and Shimura, 1984; Winans and Jones, 1986). Nevertheless, genetic variability and the degree of genetic differentiation in the cetaceans are still unclear.

In the present study, we examine enzyme polymorphism in 12 species of toothed whales mainly found off the coast of Japan. On the basis of the data obtained for 19 genetic loci encoding 12 enzymes, estimates of the proportion of polymorphic loci, average heterozygosity, genetic identity and distance among the various taxa of different taxonomic levels are presented. These values obtained here are discussed in comparison with those in other organisms. The dendrogram of genetic distance are presented, and the genetic relationships and the time of divergence of the species are discussed.

MATERIALS AND METHODS

Liver and/or skeletal muscle were obtained from the specimens caught either by harpoon, gill net or drive during the course of commercial fishing or research expedition off the coast of Japan and the North Pacific, between winter 1978 and autumn 1981. Twelve species, sampling locations and number of samples are shown in Table 1. The locations are also shown in Fig. 1.

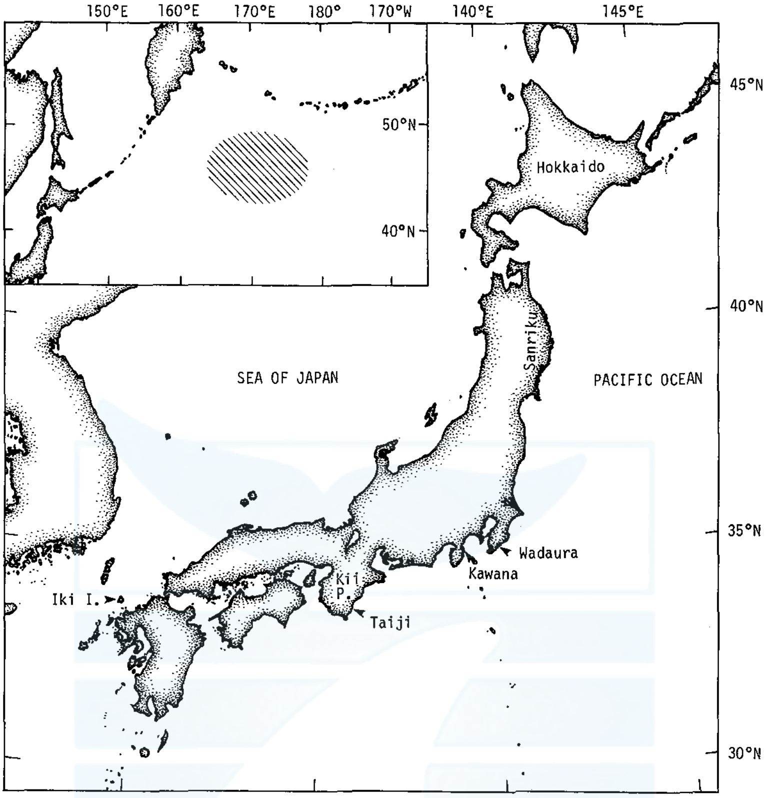


Fig. 1. Map showing the positions of collection. Shaded area represents the range of catch of *Phocoenoides dalli* (*dalli*-type) in the North Pacific.

Tissue samples were frozen in a container with dry ice, or in a freezing room on board immediately after the catch and thereafter stored below −20°C until use. For the electrophoretic run, after thawing tissues, cell lysates were collected by soaking with a small piece of filter paper, and then the filter paper was inserted in 12.5% starch gel (Electrostarch; Electrostarch Inc., Madison, Wisconsin, U.S.A.).

Electrophoresis was conducted horizontally at a high voltage of a 20 V/cm and stopped when the marker of Amide black 10B migrated 7 cm from the origin. During the electrophoresis, gels were set at 5°C and a glass-plate pan filled with ice water was placed on it for cooling the gel. Following two buffer systems were used by modifying the method of Clayton and Tretiak (1972): (1) C-AEA, pH 7.0 consisting of gel buffer, 2 mM citric acid adjusted to pH 7.0 with N-(3-aminopropyl)-diethanolamine (AEA), and electrode buffer of 40 mM citric acid adjusted to pH 7.0 with the same amine, and (2) C-T, pH 8.0 consisting gel buffer 3 mM citric acid-10 mM Tris, and electrode buffer of 16 mM citric acid-62 mM Tris. $MgCl_2$ (10 mM) was added to all the gels.

TABLE 2. LIST OF ENZYME AND LOCI EXAMINED AND TISSUE AND BUFFER USED FOR ELECTROPHORESIS

Enzyme	Loci encoding	Tissue used	Buffer
Sorbitol dehydrogenase (SDH)	*Sdh*	liver	C–T
Lactate dehydrogenase (LDH)	*Ldh–1*	liver, muscle	C–AEA
	Ldh–2	liver, muscle	C–AEA
Malate dehydrogenase (MDH)	*Mdh–1*	liver, muscle	C–AEA
	Mdh–2	liver, muscle	C–AEA
Malic enzyme (ME)	*Me*	liver, muscle	C–AEA
Isocitrate dehydrogenase (IDH)	*Idh–1*	liver, muscle	C–AEA
	Idh–2	liver, muscle	C–AEA
6-Phosphogluconate dehydrogenase (6-PGD)	*6–Pgd*	liver, muscle	C–AEA
Superoxide dismutase (SOD)	*Sod*	liver, muscle	C–T
Esterase	*Est–1*	liver	C–AEA
	Est–2	liver	C–AEA
Glutamate oxaloacetate transaminase (GOT)	*Got–1*	liver, muscle	C–T
	Got–2	liver, muscle	C–T
Phosphoglucomutase (PGM)	*Pgm–1*	liver, muscle	C–AEA
	Pgm–2	liver	C–AEA
	Pgm–3	liver	C–AEA
Mannose phosphate isomerase (MPI)	*Mpi*	liver, muscle	C–AEA
Phosphohexose isomerase (PHI)	*Phi*	liver	C–AEA

The buffer systems and tissues used for detecting each enzyme are shown in Table 2. For IDH, ME and 6-PGD, 30 mM NADP was added to the gel and cathodal electrode buffer, and for SDH 30 mM NAD to the both of them.

Details of reaction mixture for staining enzymes are; (1) SDH: 500 mg sorbitol, 50 mg sodium pyruvate, 20 mg NAD, 20 mg nitro blue tetrazolium (NBT), 5 mg phenazine methosulphate (PMS) or 1-methoxy-PMS, in 100 ml 0.1 M Tris-HCl buffer, pH 8.0, (2) LDH: 0.625 ml sodium lactate (50%), 20 mg NAD, 20 mg NBT, 5 mg PMS or 1-methoxy-PMS, in 100 ml 0.1 M Tris-HCl buffer, pH 8.7, (3) MDH: 250 mg sodium malate in the same buffer and reagent mixture as (2), (4) ME: 250 mg sodium malate, 1 ml 1M $MgCl_2$, 20 mg NADP, 20 mg NBT, 5 mg PMS or 1-methoxy-PMS, in 100 ml 0.1 M Tris-HCl buffer, pH 8.0, (5) IDH: 37 mg isocitric acid as substrate in the same mixture as (4), (6) 6-PGD: 100 mg 6-phosphogluconic acid in the same mixture, (7) SOD: 400 mg EDTA·2Na, 2 g β-D-glucose, 40 mg NBT, 50 mg PMS, in 100 ml 0.1 M Tris-HCl buffer, pH 9.5, (8) Esterase: detected by negative staining method of Harris and Hopkinson (1976), (9) GOT: 15 ml of L-aspartic acid solution (2.7 g / 100 ml D.W.) and 15 ml of 2-oxoglutaric acid solution (1.5 g / 100 ml D.W.), both adjusted pH 7.5 with 2 M KOH, 500 mg Fast blue BB, in 70 ml 0.2 M phosphate buffer, pH 7.5, (10) PGM: 150 mg D-glucose-1-phosphate containing D-glucose-1,6-diphosphate, 80 unit glucose-6-phosphate dehydrogenase (G-6-PDH), 1 ml 1 M $MgCl_2$, 20 mg NADP, 20 mg NBT, 5 mg PMS, in 100 ml 0.1 M Tris-HCl buffer, pH 8.0,

(11) MPI: 25 mg D-mannose-6-phosphate, 50 unit glucose phosphate isomerase, 80 unit G-6-PDH, 1 ml 1 M $MgCl_2$, 20 mg NADP, 20 mg NBT, 10 mg PMS, in 100 ml 0.1 M Tris-HCl buffer, pH 8.0, (12) PHI: 150 mg fructose-6-phosphate, 80 unit G-6-PDH, 20 mg NADP, 20 mg NBT, 5 mg PMS, in 100 ml 0.1 M Tris-HCl buffer, pH 8.0.

All the gels after electrophoresis and the staining were dried (Numachi, 1981) and then preserved for the future analysis of isozyme pattern.

RESULTS

Genetic variability in the toothed whales

A total of 19 genetic loci encoding 12 enzymes was surveyed in 12 species of toothed whales. Electrophoretic patterns of enzymes, the number of isozymes and tissue distribution showed that all the 12 species essentially have the same isozyme systems, each under the control of corresponding locus which is homologous phylogenetically throughout all the species studied. Electrophoretic patterns and schematic drawings of each enzyme assayed are shown in Plates I-VI. Alleles at the 19 loci are listed in Table 3. The frequencies of phenotypes on electrophoretic patterns were in good agreement with the Hardy-Weinberg proportion, except for two cases of *Idh-1* locus in *Pseudorca crassidens* ($\chi^2=6.758$, $0.01>p>0.005$, d.f.=1) and of the *Sdh* locus in *truei*-type of *Phocoenoides dalli* ($\chi^2=7.746$, $0.01>p>0.005$, d.f.=1). In both cases, the deviation was observed in heterozygotes excess.

The incidence of polymorphic loci (P) and average heterozygosity (H) is summarized in Table 4. P and H values of 12 species of the toothed whales showed a wide range of 0-0.474, and 0-0.154, respectively. In the two types of *P. dalli*, the highest values of P and H were obtained. By average of all the 12 species, proportion of polymorphic loci (P) in the definition of 5% level was 20.7%, and 16.4% excluding *P. dalli*. The average heterozygosity (H) was 0.063 in average of the 12 species, and 0.047 excluding *P. dalli*. Recently, Wada (1983b, 1986) showed that the proportion of polymorphic loci and/or the average heterozygosity were $P=0.13$ and $H=0.021$ in the striped dolphin, and $H=0.008$ in the short-finned pilot whale. Winans and Jones (1986) also showed that the average heterozygosity of *P. dalli* is 0.058. These values were something different from those obtained here, probably caused by the difference in the sample size and choice of loci examined. However, all the values obtained by other authors should be considered to be in the range of the values shown in Table 4.

Genetic differentiation between taxa

Genetic identity and genetic distance by Nei (1972) were calculated from the data in Table 3. Genetic distance (D) and genetic identity (I) between the populations, X and Y, are given by

TABLE 3. ALLELE FREQUENCIES AT THE 19 HOMOLOGOUS LOCI IN THE
ALPHABETICALLY FROM THE ANODAL SIDE BY THE MOBILIT
THE ALLELES. FREQUENCIES AT THE LOCI EXHIBITIN

	Ldh–1	*Ldh–2*	*Mdh–1*	*Mdh–2*	*Idh–1*	*Idh–2*	*Me*	*Sdh*	*6–Pgd*	*Got–1*	*Got–2*
1. *Berardius bairdii*	c	a	a	b	b	b	c	b	j	c	c
2. *Globicephala macrorhynchus*	a(.051) d(.949)	a	a(.990) b(.010)	b	c	b	b	b	b(.013) f(.013) g(.974)	b	b
3. *Peponocephala electra*	d	a	a	b	c	b(.750) d(.250)	b	b	g	b	b
4. *Pseudorca crassidens*	d	a	a	c	b(.100) c(.900)	b	b	b	g	b	b
5. *Stenella coeruleoalba*	d	a	a	b(.948) d(.052)	c	b	b	b	c(.013) g(.972) k(.015)	a(.020) b(.980)	b
6. *Stenella attenuata*	d	a	a	a(.022) b(.978)	c	b	b	b	f(.010) g(.990)	b	b
7. *Tursiops truncatus*	d	a	a	b	c	b	b	b	g	b	b
8. *Lagenorhynchus obliquidens*	d	a	a	b	a(.036) c(.946) e(.018)	b	b	b	g	b	a(.075) b(.925)
9. *Steno bredanensis*	d	a	a	b	b	b	c	b	e(.020) h(.980)	b	a(.050) b(.950)
10. *Phocoena phocoena*	e	a	a	b	d	a	a	c	i	c	c
11. *Phocoenoides dalli* (*dalli*-type)	e	a	a(.987) b(.013)	b(.983) e(.017)	b(.305) d(.695)	a(.906) c(.094)	a(.074) c(.916) d(.010)	a(.475) c(.525)	a(.967) b(.010) i(.023)	b(.013) c(.987)	b(.025) c(.975)
12. *Phocoenoides dalli* (*truei*-type)	b(.011) e(.989)	a	a(.987) b(.013)	b(.979) e(.021)	b(.280) d(.720)	a(.904) c(.096)	a(.083) c(.903) d(.014)	a(.441) c(.559)	a(.965) d(.016) i(.019)	b(.075) c(.925)	c
13. *Neophocaena phocaenoides*	e	b	a	b	d	a	c	c	i	c	c

PECIES OF TOOTHED WHALES. ALLELES AT EACH LOCUS WERE DESIGNATED
F HOMOPOLYMER CONSTITUTION OF THE PRODUCTS OF
OLYMORPHISMS ARE ALSO SHOWN IN PARENTHESES

Sod	*Mpi*	*Phi*	*Pgm-1*	*Pgm-2*	*Pgm-3*	*Est-1*	*Est-2*
e	f(.830) g(.170)	d	a	c	c	b	not assayed
a(.850) b(.150)	a	b	b	e(.750) f(.250)	f	a(.050) b(.950)	b(.075) c(.925)
	a	c	b	e	f	b	a(.170) b(.830)
a(.048) b(.952)	a	b(.975) e(.025)	a(.025) b(.975)	c(.025) e(.800) f(.175)	f(.950) g(.050)	a(.100) b(.900)	b
b	d(.030) f(.050) e(.030) g(.890)	d(.970) f(.030)	a(.023) b(.977)	d(.105) f(.711) e(.131) h(.053)	f(.974) i(.026)	a(.050) b(.925) e(.025)	a(.132) c(.210) b(.632) d(.026)
b(.920) c(.080)	d(.025) e(.025) g(.950)	d(.975) f(.025)	b	b(.025) f(.400) e(.550) g(.025)	c(.025) f(.975)	b(.425) c(.550) f(.025)	b(.075) c(.875) d(.050)
b	d(.275) g(.725)	d	b	e(.825) f(.175)	f	b	a(.974) b(.026)
b(.480) c(.520)	b(.525) g(.475)	b	b	e(.325) f(.675)	h	a(.050) b(.950)	a
d	a	b	b	e	f	b	c
a	f(.830) h(.170)	b	b(.830) d(.170)	c	c	b(.170) d(.830)	not assayed
a	f(.725) i(.275)	a(.025) b(.975)	a(.025) b(.975)	a(.025) d(.100) c(.800) f(.075)	a(.075) d(.100) b(.700) e(.075) c(.025) f(.025)	a(.050) b(.950)	e(.029) f(.971)
a	c(.025) f(.775) d(.025) i(.175)	a(.025) b(.975)	b(.977) c(.023)	b(.175) c(.725) f(.100)	b(.850) d(.025) c(.100) e(.025)	b	e(.050) f(.950)
a	f	b	b	c	b	b	not assayed

$$D = -\log_e I,$$

$$I = J_{XY}/\sqrt{J_X \cdot J_Y}$$

J_{XY}, J_X and J_Y are defined as

$$J_X = \sum_j \sum_i (x_{ij})^2/r$$

$$J_Y = \sum_j \sum_i (y_{ij})^2/r$$

$$J_{XY} = \sum_j \sum_i x_{ij} \cdot y_{ij}/r$$

(r: number of examined loci)

where x_{ij} and y_{ij} are the frequencies of the i^{th} allele at the j^{th} locus in X and Y populations. When X and Y populations share the same allele frequencies at all loci, genetic distance and identity are given by $D = 0$ and $I = 1$. Conversely when they do not share the common allele over all loci, the values become $D = \infty$ and $I = 0$. Estimates of D and I values among 12 species of the toothed whales based on allele frequencies at 18 loci are shown in Table 5. Allele frequencies of *Est-2* were excluded in calculation because of insufficiency of data. The frequency distribution of genetic identity was obtained in

TABLE 4. SUMMARY OF GENETIC VARIABILITY IN THE TOOTHED WHALES

Species	No. of loci	Proportion of polymorphic loci (P^*)	Average heterozygosity (H^{**} ± S.E.)
1. *Berardius bairdii*	18	0.056	0.016 ± 0.069
2. *Globicephala macrorhynchus*	19	0.263	0.054 ± 0.106
3. *Peponocephala electra*	19	0.105	0.035 ± 0.108
4. *Pseudorca crassidens*	19	0.211	0.051 ± 0.092
5. *Stenella coeruleoalba*	19	0.263	0.089 ± 0.160
6. *S. attenuata*	19	0.263	0.089 ± 0.170
7. *Tursiops truncatus*	19	0.105	0.039 ± 0.113
8. *Lagenorhynchus obliquidens*	19	0.316	0.093 ± 0.182
9. *Steno bredanensis*	19	0.053	0.007 ± 0.024
10. *Phocoena phocoena*	18	0.167	0.047 ± 0.111
11. *Phocoenoides dalli* (*dalli*-type)	19	0.421	0.154 ± 0.184
12. *P. dalli* (*truei*-type)	19	0.474	0.147 ± 0.170
13. *Neophocaena phocaenoides*	18	0.000	0.000
Average(1)***		0.207 ± 0.151	0.063 ± 0.051
Average(2)***		0.164 ± 0.112	0.047 ± 0.035

* P values were calculated in the level which included the loci where frequencies of variant alleles were found at more than 5%.

** H is calculated by averaging the value of heterozygosity of each locus (h) over all loci. The heterozygosity (h) is defined as $1 - \sum_{i=1}^{n} x_i^2$, where x_i is the frequency of the i th allele and n is the number of alleles at the locus.

*** Average(1) means all the 12 species, and (2) excluding values of 2 types of *P. dalli*.

TABLE 5. COEFFICIENTS OF GENETIC IDENTITY (ABOVE THE DIAGONAL) AND GENETIC DISTANCE (BELOW THE DIAGONAL) BETWEEN SPECIES OF THE TOOTHED WHALES

Species	1	2	3	4	5	6	7	8	9	10	11	12	13
1. *Berardius bairdii*		.341	.325	.291	.409	.383	.407	.356	.450	.451	.522	.519	.438
2. *Globicephala macrorhynchus*	1.075		.893	.902	.829	.827	.853	.851	.777	.340	.419	.421	.330
3. *Peponocephala electra*	1.123	.113		.879	.851	.854	.892	.791	.716	.230	.304	.306	.225
4. *Pseudorca crassidens*	1.235	.103	.129		.812	.808	.837	.807	.725	.235	.307	.308	.224
5. *Stenella coeruleoalba*	.895	.188	.162	.208		.974	.974	.850	.627	.233	.308	.310	.224
6. *S. attenuata*	.959	.190	.157	.213	.026		.974	.832	.633	.232	.279	.281	.197
7. *Tursiops truncatus*	.900	.159	.115	.178	.026	.026		.837	.670	.232	.307	.310	.227
8. *Lagenorhychus obliquidens*	1.034	.162	.235	.214	.162	.184	.178		.655	.299	.377	.382	.290
9. *Steno bredanensis*	.799	.252	.335	.321	.466	.458	.401	.423		.286	.435	.434	.335
10. *Phocoena phocoena*	.797	1.078	1.469	1.450	1.457	1.462	1.461	1.207	1.253		.778	.777	.787
11. *Phocoenoides dalli* (*dalli*-type)	.649	.869	1.192	1.182	1.178	1.275	1.180	.975	.832	.252		.996	.856
12. *P. dalli* (*truei*-type)	.656	.865	1.185	1.176	1.171	1.270	1.172	.964	.835	.252	.004		.861
13. *Neophocaena phocaenoides*	.825	1.109	1.494	1.496	1.496	1.624	1.485	1.239	1.095	.239	.156	.150	

all possible pairwise comparisons at every locus between species, genera and families (Fig. 2).

P. dalli consisted of two types, *dalli*-type and *truei*-type. These two were recently considered as the geographic variation of the color patterns of the single species (Houck, 1976; Kasuya, 1978, 1982). These two types were highly polymorphic, but alleles at these loci were common between them. In terms of genetic identity, almost 100% of the loci were very same ($I > 0.95$). Genetic identity and genetic distance between the two types were 0.996 and 0.004, respectively.

Stenella coeruleoalba and *S. attenuata* were compared for genetic divergency at specific level. Between the two species, eight of the 19 genetic loci were monomorphic for the same genes, and common or some species specific genes were shared at the other 11 polymorphic loci. Thus, about 90% of the loci were nearly identical ($I > 0.95$), as shown in Fig. 2a. Genetic identity and genetic distance between the two species were 0.974 and 0.026, respectively.

The 12 species of toothed whales examined here represent 11 genera. More than 70% of loci were nearly identical ($I > 0.95$) between these genera (Fig. 2b), but 15% of them were quite different ($I < 0.05$). Mean genetic identity and distance between the genera were 0.812 and 0.213, respectively.

The 12 species of toothed whales belong to three families; Ziphiidae (*Berardius*), Delphinidae (*Globicephala*, *Peponocephala*, *Pseudorca*, *Stenella*, *Tursiops*, *Lagenorhynchus* and *Steno*), and Phocoenidae (*Phocoena*, *Phocoenoides* and *Neophocaena*). Levels of genetic identity between the families covered a broad range, and the distribution of the values had a strong U-shaped pattern (Fig. 2c). The identical loci ($I > 0.95$) in genic compositions were only 30%, and 65% of loci were replaced by different genes. The frequency distribution of genetic distance (D) ranged widely from 0.6 to 1.65 (Fig. 3). The genetic

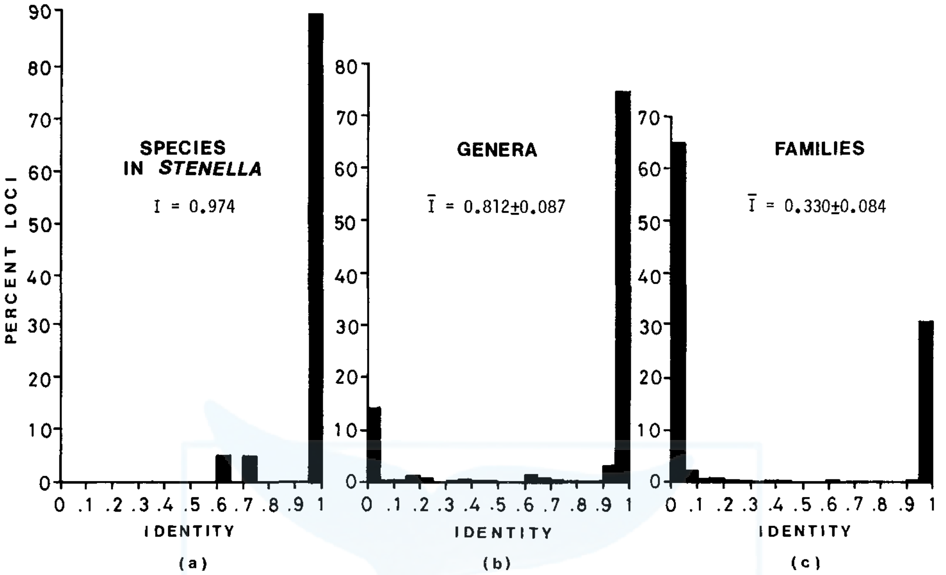


Fig. 2. Frequency distribution of loci with respect to genetic identity when comparing the different species of the same genus (a), between the different genera (b) and between the families (c). $\bar{I}$ is the mean genetic identity with its standard error.

distances between the families were much larger than those between the genera. Mean values of the genetic identity and distance between the families were 0.330 and 1.140, respectively.

Table 6 shows the values of mean genetic distance (D) of 4 taxonomic levels of the toothed whales and other animals. Higher D values were obtained in the higher taxonomic levels, but D values showed a wide range of variation among the taxa. D values of the toothed whales were generally small, and thus the degree of genetic divergency of the toothed whales seemed to be lower than the other animals. D value of the toothed whales at the family level was similar to those of *Drosophila* at the specific level ($D=1.056$) and of sunfish and salamanders at the generic level ($D=1.170-1.340$), indicating lower genetic divergency between the toothed whale families.

Genetic relationships of the toothed whales

Unweighted pair-group method of cluster analysis (Sokal and Sneath, 1963) were applied to the matrix of genetic distance (Table 5), to elucidate genetic relationships among the species studied. The dendrogram is shown in Fig. 4. In general, the dendrogram agreed with currently accepted opinions on phylogenetic relationship in toothed whales deduced from morphology (kasuya, 1973; Mead, 1975; Gaskin, 1982).

A crude estimate of divergence time (t) can be obtained by an equation, $t = 5 \times 10^6 D$, provided by Nei (1975). The time scale of divergence was also

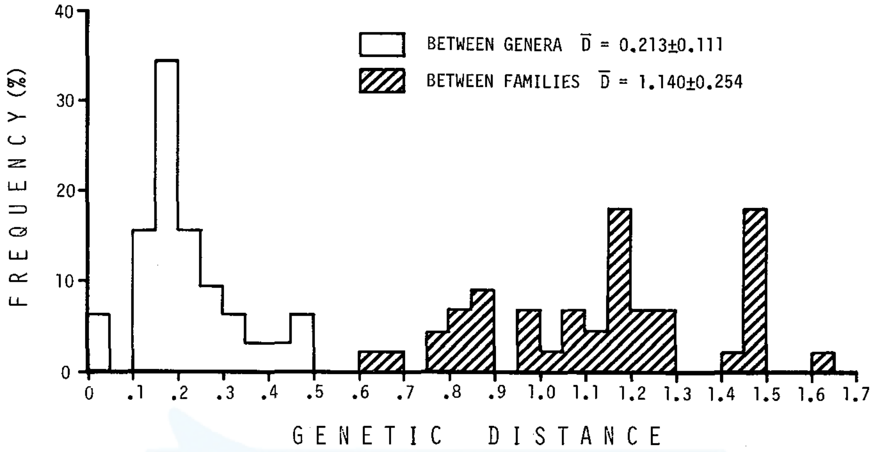


Fig. 3. Distribution of genetic distances among toothed whales between species in different genera and families. Mean distance and its standard error are indicated in each case.

shown in Fig. 4. The result represented that the families diverged 3.5–5.5 million years ago, and that speciation of the species within the same family occurred two million years ago.

DISCUSSION

Selander and Kaufman (1973), Powell (1975), Selander (1976) and Nevo (1978) made reviews of allozymic variations in natural populations of plants and animals so far studied. In three major taxa (plants, invertebrates and vertebrates), both *P* and *H* values increased in the following order: vertebrates, plants and invertebrates. Within vertebrates consisting of following five groups, fishes, amphibians, reptiles, birds and mammals, no significant difference was found (Nevo, 1978). Nevo (1978) reported $P=0.173 \pm 0.119$ (in 5% level) and $H=0.0494 \pm 0.0365$ for 135 species of vertebrates, and $P=0.147 \pm 0.098$ and $H=0.0359 \pm 0.0245$ for 46 species of mammals. *P* and *H* values of the toothed whales in the present study were $P=0.207$ and $H=0.047$. These values were slightly larger than those of mammals but similar to those of the vertebrates. Accordingly, the genetic variation level of the toothed whales is considered to be in the range of vertebrates in spite of their ecological specialization.

The values of the mean genetic distances of the toothed whales at the four taxonomic levels (Table 6) were distinctly smaller than those of other animals except the birds. The distribution patterns of the genetic identity as shown in Fig. 2 were also shown in *Drosophila* (Ayala, Tracey, Barr, McDonald and Pérez-sales, 1974), sunfish (Avise and Smith, 1977) and rodents (Zimmerman, Kilpatrick and Hart, 1978). Compared with these patterns, the genetic

TABLE 6. MEAN GENETIC DISTANCES (NEI'S *D*) AT FOUR TAXONOMIC LEVELS

Taxa	Local Populations	Species	Genera	Families	References
Drosophila	0.028	1.056	-------	-------	Ayala, 1975
Sunfish	0.024	0.626	1.340	-------	Avise & Smith, 1977
Salamanders	0.051	0.462	1.170	-------	Hedgecock & Ayala, 1974
Rodents	0.030	0.323	-------	-------	Zimmerman *et al.*, 1978
Birds					
Passerines	0.003	0.100	0.214	-------	Barrowclough *et al.*, 1981
Procellariiformes	-------	-------	0.435	0.683	Barrowclough *et al.*, 1981
Parulidae	-------	0.100	0.179	-------	Barrowclough & Corbin, 1978
Toothed whales	(0.004)*	0.026	0.213	1.140	Present study

* Two types of *Phocoenoides dalli*

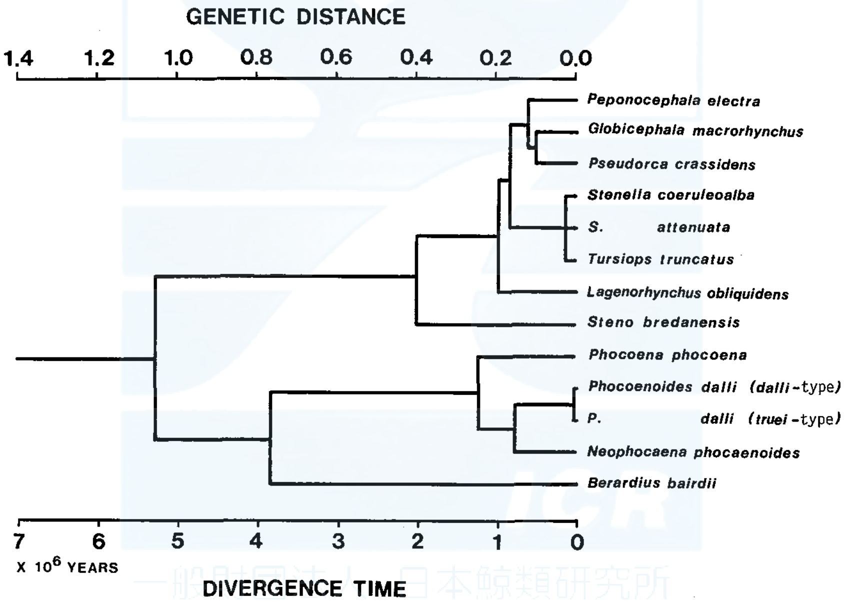


Fig. 4. Biochemical similarity dendrogram of toothed whales based on genetic distance. Divergence time by calibration of Nei (1975) is also shown.

divergence of the toothed whales was much smaller than those of the other species. The pattern obtained for the species of the toothed whales (Fig. 2a) was the very same as the populations of the other organisms, and the genus level (Fig. 2b) was much similar to the species level of the other organisms.

Most of cetologists have considered that Phocoenidae is fully distinguished from Delphinidae. However, Rice (1977) classified true porpoises into Delphinidae. Our result showed that *D* value between Phocoenidae and

Delphinidae were considerably high (D=1.051). Therefore, Phocoenidae and Delphinidae may be differentiated in the family level judging from the allozymic comparison.

The dendrogram showed that three species of globicephalids were not so different from other delphinids genetically. The D value btween *Steno* and other species of Delphinidae was slightly large compared with other genera, but considerably small when compared at the family level of Phocoenidae and Delphinidae. Therefore, the genetic difference of *Steno* is considered to be at the generic level in Delphinidae. In regard to the genetic relationship of Delphinidae, the dendrogram seems to be in good agreement with morphological relationships among the groups in this family.

Berardius bairdii is a species in a well-distinguished family, Ziphiidae. Gaskin (1982) suggested that Ziphiidae diverged from other families of Odontoceti in early evolutionary time deduced from the karyological characteristic of Ziphiids species. Based on our electrophoretic study, the relationship between Ziphiidae and Phocoenidae was relatively closer than that between Delphinidae and Phocoenidae.

Time of divergence was estimated from D values using the equation of Nei (1975). Our estimation of divergence time is different from that shown by the geological study. It is supposed that the major families of the toothed whales were established in Miocene (ca. 10–25 million years ago) (Kellog, 1928), and that morphologically "modern" delphinids became abundant in the following Pliocene (ca. 1–10 million years ago) (Gaskin, 1982). Our result by Nei's conversion represented that three families diverged 3.5–5.5 million years ago, and that the speciation within Delphinidae started from two million years ago. Accordingly, the time of divergence based on these calculation was much shorter than that of geological one. Possible reasons for the differences may be (1) the rate of genetic changes presumed by Nei may not fit to that of the toothed whales, and (2) the time of divergence tends to give underestimate when D is larger than 1 (Nei, 1975). Carlson, Wilson and Maxon (1978) found that 1 albumin immunological distance (*AID*) unit was equivalent to 0.54 million years (r=0.97) through the comparison between paleontological records and *AID*. Further, Wyles and Gorman (1980) reported a D of 1.0 corresponded to 35.6 *AID* units on the average. Thus, a D of 1.0 represents about 19 million years of continuous separation (Grant, Teel, Kobayashi and Schmitt, 1984). We estimated the time of divergence of toothed whale families using this method as about 13.3–20.0 million years, and for genera in Delphinidae 7.6 million years. These estimates properly agree with the paleontological time of divergence.

ACKNOWLEDGEMENTS

We are grateful to Dr T. Kasuya of the Far Seas Fisheries Research Laboratory, for his kindly supplying the specimens for this study and reviewing the manuscript. We wish to thank Dr T. Okazaki of the Far Seas Fisheries Research Laboratory, for checking the calculation and critically reading the manuscript. Dr N. Miyazaki of the National Science Museum, kindly provided many samples from the specimens associated with his own field work. We are indebted to Dr J. G. Mead of the Smithsonian Insitution, for giving us valuable suggestions.

REFERENCES

AVISE, J.C. and M.H. SMITH, 1977. Gene frequency comparisons between sunfish (Centrarchidae) populations at various stages of evolutionary divergence. *Syst. Zool.*, 26: 319–335.

AYALA, F.J., 1975. Genetic differentiation during the speciation process. *Evol. Biol.*, 8: 1–78.

AYALA, F.J., M.L. TRACEY, L.G. BARR, J.F. MCDONALD and S. PÉREZ-SALAS, 1974. Genetic variation in natural populations of five *Drosophila* species and the hypothesis of the selective neutrality of protein polymorphisms. *Genetics*, 77: 343–384.

BALUDA, M.C., D.D. KULU and R.S. SPARKES, 1972. Cetacean hemoglobins: electrophoretic findings in nine species. *Comp. Biochem. Physiol.*, 41B: 647–653.

BARROWCLOUGH, G.F. and K.W. CORBIN, 1978. Genetic variation and differentiation in the Parulidae. *Auk*, 95: 691–702.

BARROWCLOUGH, G.F., K.W. CORBIN and R.M. ZINK, 1981. Genetic differentiation in the Procellariformes. *Comp. Biochem. Physiol.*, 69B: 629–632.

BORDER, S.N., 1975. Electrophoretic analysis of the hemoglobin of four cetacean species. *Comp. Biochem. Physiol.*, 51B: 209–211.

CARLSON, S.S., A.C. WILSON and R.D. MAXON, 1978. Do albumin clocks run on time? A reply. *Science*, 200: 1183–1185.

CLAYTON, J.W. and D.N. TRETIAK, 1972. Amine-citrate buffers for pH control in starch gel electrophoresis. *J. Fish. Res. Bd. Can.*, 29: 1169–1172.

GASKIN, D.E., 1982. *The Ecology of Whales and Dolphins.* Heinemann, London. 459 pp.

GRANT, W.S., D.J. TEEL, T. KOBAYASHI and C. SCHMITT, 1984. Biochemical population genetics of Pacific halibat (*Hippoglossus stenolepis*) and comparison with Atlantic halibat (*H. hippoglossus*). *Can. J. Fish. Aquat. Sci.*, 41: 1083–1088.

HARRIS, H. and D.A. HOPKINSON, 1976. *Handbook of enzyme electrophoresis in human genetics.* North-Holland, Amsterdam.

HEDGECOCK, D. and F.J. AYALA, 1974. Evolutionary divergence in the genus *Taricha* (Salamandridae). *Copeia*, 1974: 738–747.

HORVATH, S.M., H. CHIODI, S.H. RIDGEWAY and S. AZAR, Jr., 1968. Respiratory and electrophoretic characteristics of hemoglobin of porpoises and sea lion. *Comp. Biochem. Physiol.,* 24: 1027–1033.

HOUCK, W.J., 1976. The taxonomic status of the porpoise genus *Phocoenoides.* Paper ACMRR/MM/SC/114, FAO Scientific Consultation on Marine Mammals, Bergen.

KASUYA, T., 1973. Systematic consideration of recent toothed whales based on the morphology of tympano-periotic bone. *Sci. Rep. Whales Res. Inst.,* 25: 1–103.

KASUYA, T., 1978. The life history of Dall's porpoise with special reference to the stock off the Pacific coast of Japan. *Sci. Rep. Whales Res. Inst.,* 30: 1–63.

KASUYA T., 1982. Preliminary report of the biology, catch and populations of *Phocoenoides* in the western North Pacific. *FAO Fish. Ser.* (5) (Mammals in the seas) 4: 3–19.

KELLOG, R., 1928. The history of whales-Their adaptation to the life in the water. *Quarterly Rev. of Biology,* 3: 29–76, 174–397.

MEAD, J.G., 1975. Anatomy of the external nasal passages and facial complex in the Delphinidae. *Smithsonian Contrib. Zool.,* 207: 1–72.

NEI, M., 1972. Genetic distance between populations. *Amer. Nat.*, 106: 283–292.

NEI, M., 1975. *Molecular population genetics and evolution.* North-Holland, Amsterdam. 288 pp.

NEVO, E.,1978. Genetic variation in natural populations: patterns and theory. *Theor. Pop. Biol.*, 13: 121–177.

NUMACHI, K., 1970. Lactate and malate dehydrogenase isozyme patterns in fish and marine mammals. *Bull. Jap. Soc. Sci. Fish.*, 36: 1067–1077.

NUMACHI, K., 1981. A simple method for preservation and scanning of starch gels. *Biochem. Genet.*, 19: 233–236.

NUMACHI, K. and E. SHIMURA, 1984. Biological genetic study on population structure in Dall's porpoise (*Phocoenoides dalli*). I. Population study based on the analysis of the allelic variations of enzymes. Document submitted to the meeting of the Scientific Subcommittee on Marine Mammals, International North Pacific Fisheries Commission, Tokyo, February, 1984. 8 pp.

POWELL, J.R., 1975. Protein variation in natural population of animals. pp. 79–119. *In*: T. Dobzhansky, M.K. Hecht and W.C. Steere (eds) *Evolutionary Biology*. Plenum Press, New York. 396 pp.

RICE, D.W., 1977. A list of the marine mammals of the world. (Third ed.) NOAA Technical Report NMSF-711. 15 pp.

SELANDER, R.K., 1976. Genic variation in natural populations. pp. 21–45. *In*: F.J. Ayala (ed.) *Molecular Evolution*. Sinauer associates, Sunderland, Massachusetts. 277 pp.

SELANDER, R.K. and D.W. KAUFMAN, 1973. Genic variability and strategies of adaptation in animals. *Proc. Nat. Acad. Sci.*, 70: 1875–1877.

SHARP, G.D., 1981. Biochemical genetic studies, their value and limitations in stock identification and discrimination of pelagic mammal species. *Mammals in the Sea*. Vol. II, pp. 131–136, FAO, Rome.

SIMONSEN, V., F. KAPEL and F. LARSEN, 1982. Electrophoretic variation in the minke whale, *Balaenoptera acutorostrata* Lecépède. *Rep. int. Whal. Commn*, 32: 275–278.

SOKAL, R.R. and P.H.A. SNEATH, 1963. *Principles of Numerical Taxonomy*. Freeman, San Francisco, 359 pp.

VALENTINE, J.W., 1976. Genetic strategies of adaptation. *In:* F.J. Ayala (ed.) *Molecular Evolution*. Sinauer associates, Sunderland, Massachusetts. 277 pp.

WADA, S., 1982. Gene frequency analysis on the Antarctic minke whale. IWC/SC/34/Mi13.

WADA, S., 1983a. Genetic structure and taxonomic status of minke whales in the coastal waters of Japan. *Rep. int. Whal. Commn*, 33: 361–363.

WADA, S., 1983b. Genetic heterozygosity in the striped dolphin off Japan. *Rep. int. Whal. Commn*, 33: 617–619.

WADA, S., 1984. A note on the gene frequency differences between minke whales from Korean and Japanese coastal waters. *Rep. int. Whal. Commn*, 34: 345–347.

WADA, S., 1986. Genetic differentiation in the two types of *Globicephala macrorhynchus* off the coast of Japan. Proceedings of the annual meeting of the Japan. Soc. Sci. Fish., Tokyo, April, 1986. (Abstract) p. 29. (In Japanese)

WADA, S. and K. NUMACHI, 1979. External and biochemical characters as an approach to stock identification for the Antarctic minke whale. *Rep. int. Whal. Commn*, 29: 421–432.

WINANS, G.A. and L.L. JONES, 1986. Electrophoretic variability in the Dall's porpoise (*Phocoenoides dalli*) in the North Pacific Ocean and Bering Sea. Document submitted to the meeting of the Scientific Subcommittee on Marine Mammals, International North Pacific Fisheries Commission, Tokyo, March, 1986. 20 pp.

WYLES, J. and G.C. GORMAN, 1980. The albumin immunological and Nei electrophoretic distance correlation: a calibration for the saurian genus *Anolis* (Iguanidae). *Copeia*, 1980: 66–71.

ZIMMERMAN, E.G., C.W. KILPATRICK and B.J. HART, 1978. The genetics of speciation in the rodent genus *Peromyscus*. *Evolution*, 32: 565–579.

EXPLANATION OF PLATES

PLATE I

Figs 1a and 1b. Electrophoretic patterns of tetrameric SDH isozymes from liver extracts in *Phocoenoides dalli* (*dalli*-type) (1a). Intraspecific variations appeared on the zymogram. Schematic drawings show the patterns detected through the species studied (1b). Designations of alleles (*a, b,* etc.) correspond to those of Table 3. Genotypes postulated and positions of homopolymeric isozymes of subunits produced by each allele are shown on the schematic drawings.

Figs 2a to 2d. Electrophoretic patterns of MDH and ME isozymes from muscle extracts in *Phocoenoides dalli* (*dalli*-type) (2a). Dimeric MDH isozymes appeared on both sides of the gel, and tetrameric ME isozymes only anodal side. Three schematic drawings show the patterns detected in each isozyme system through the species studied (2b, 2c and 2d). For designation see Plate I, Fig. 1.

PLATE II

Figs 1a and 1b. Electrophoretic patterns of LDH isozymes from liver extracts of all the species studied (1a). The numbers correspond to those of the species in Table 3. The positions of homopolymeric isozymes of subunits produced by each allele of two LDH loci are shown on the patterns. *Neophocaena phocaenoides* (no. 13) had specific variation in LDH-2. For LDH-1, three variations corresponded to the interfamilial differences. Schematic drawings (1b) show the patterns of LDH-1 detected through the species studied. Rare variations (*ad* and *be*) were observed in *Globicephala macrorhynchus* and *Phocoenoides dalli* (*truei*-type).

Fisg 2a to 2c. Electrophoretic patterns of dimeric IDH isozymes from liver extracts in *Phocoenoides dalli* (dalli-type) (2a). IDH-1 and -2 appeared separately on both sides of the gel. One or two conformeric bands appeared on the anodal side of the major bands of IDH-2. Two schematic drawings show the patterns detected in each isozyme system through the species studied (2b and 2c). For designation see Plate I, Fig. 1.

PLATE III

Figs 1a to 1c. Electrophoretic patterns of 6-PGD isozymes from liver extracts of all the species studied (1a). The numbers correspond to those of species in Table 3. Black points indicate the differences of the mobility of the patterns. Each band shows the most common one of each species. Electrophoretic patterns of *Stenella coeruleoalba* are also shown (1b). Two dimeric variations appeared. Schematic drawings show the patterns detected through the species studied (1c). For designation see Plate I, Fig. 1.

Figs 2a and 2b. Electrophoretic patterns of dimeric SOD isozymes from muscle extracts in *Phocoenoides dalli* (*dalli*-type) (2a). SOD isozymes appeared on the anodal side of the gel. Very rare variation in this species was detected here. Schematic drawings (2b) show the patterns detected through the species studied. For designation see Plate I, Fig. 1.

PLATE IV

Figs 1a and 1c. Electrophoretic patterns of Esterase isozymes from liver extracts in *Stenella coeruleoalba* (1a). Two Esterases appeared on the anodal side of the gel. Esterase-1 had dimeric isozymes and Esterase-2 monomeric. Two schematic drawings show the patterns detected in each isozyme system through the species studied (1b and 1c). For designation see Plate I, Fig. 1.

Figs 2a and 2b. Electrophoretic patterns of dimeric GOT isozymes from muscle extracts in *Phocoenoides dalli* (*dalli*-type) (2a). GOT-1 and -2 appeared separately on both sides of the gel. In GOT-1 patterns, three individuals were heterozygous. Schematic drawings (2b) show the patterns detected both in GOT-1 and -2 isozyme systems through the species studied. For designation see Plate I, Fig. 1.

PLATE V

Figs a to d. Electrophoretic patterns of monomeric PGM isozymes from liver extracts in *Phocoenoides dalli* (*truei*-type) (a). Heavily stained PGM-1 isozymes moved to cathodal side of the gel, and other two PGM appeared on anodal side. Three schematic drawings for each PGM isozyme system show the patterns detected through the species studied (b, c and d). For designation see Plate I, Fig. 1.

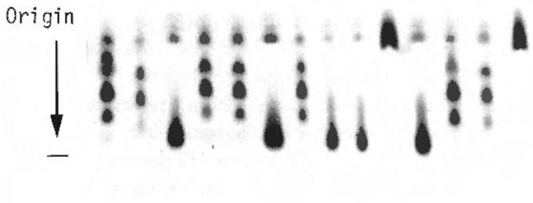
PLATE VI

Figs 1a and 1b. Electrophoretic patterns of monomeric MPI isozymes from muscle extracts in *Phocoenoides dalli* (*truei*-type) (1a). MPI was highly polymorphic in this species. Postulated genotypes of homozygotes in this zymogram are *cc* and *ff*, and heterozygotes *cf*, *df* and *fi* as shown in schematic drawings (1b). Arrow indicates a heterozygote of predominant allele *f* and a rare allele which is not named in this study. The schematic drawings show the patterns detected through the species studied. For designation see Plate I, Fig. 1.

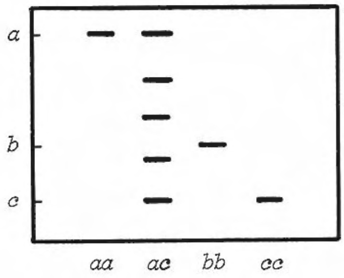
Figs 2a and 2b. Electrophoretic patterns of dimeric PHI isozymes from liver extracts in *Phocoenoides dalli* (*dalli*-type) (2a). A heterozygote appeared. Schematic drawings (2b) show the patterns detected through the species studied. For designation see Plate I, Fig. 1.

PLATE I

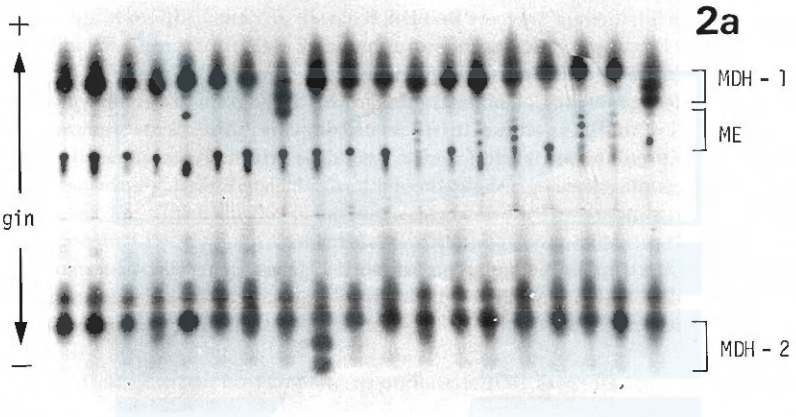
1a



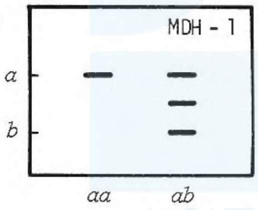
1b



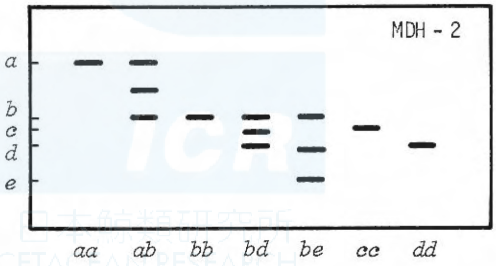
2a



2b



2c



2d

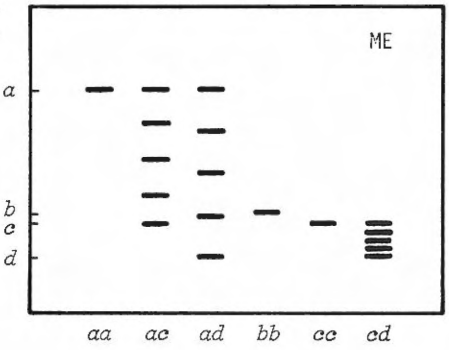
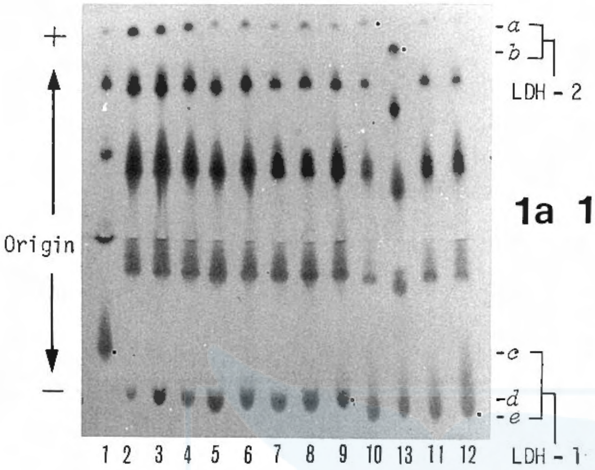
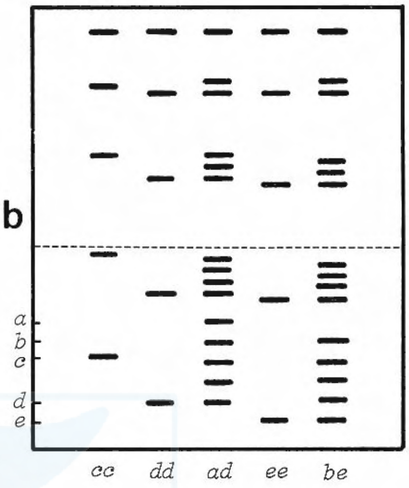


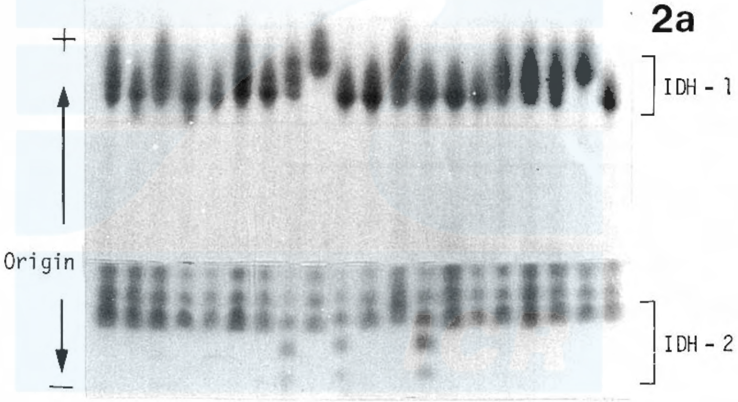
PLATE II



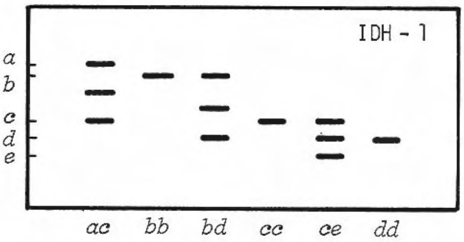
1a **1b**



2a



2b



2c

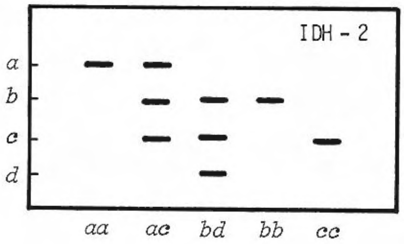
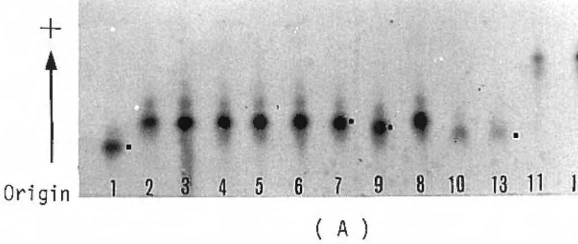
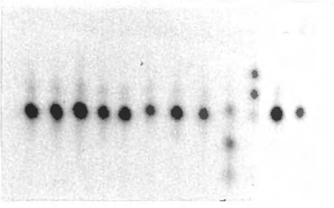


PLATE III

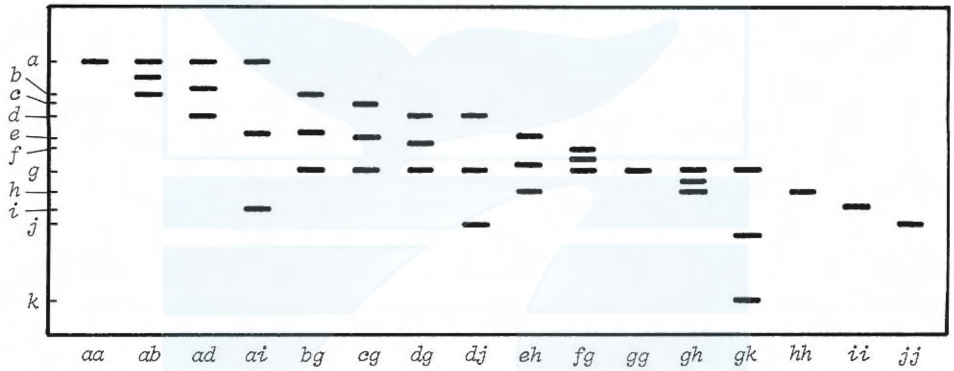


1a

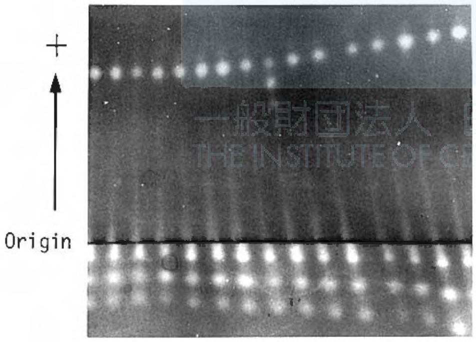


1b

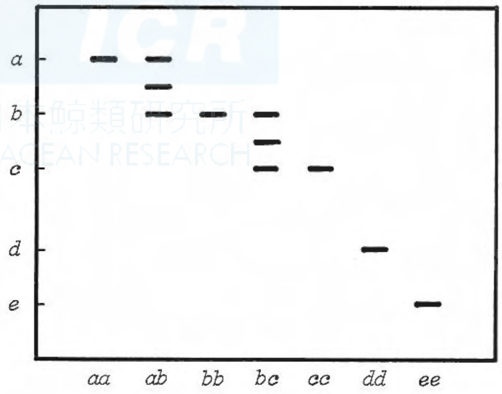
1c



2a

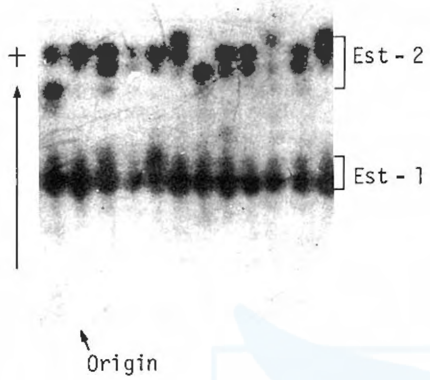


2b

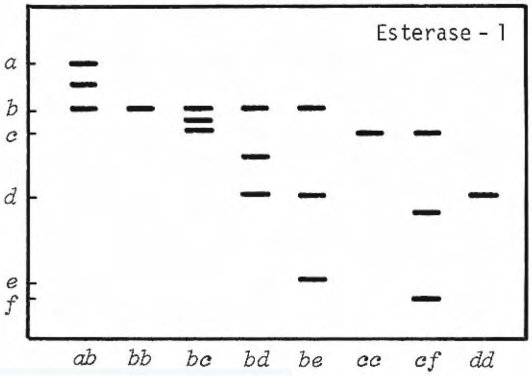


PLLATE IV

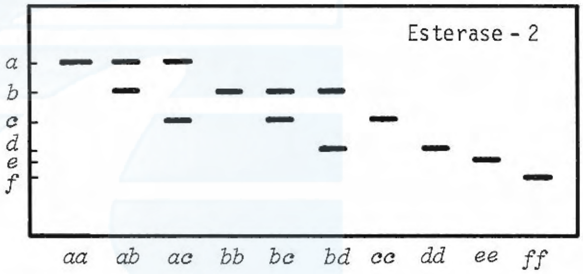
1a



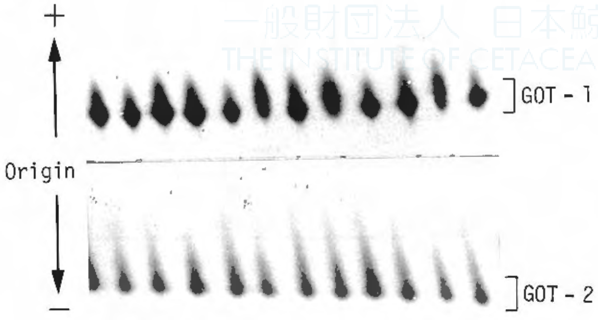
1b



1c



2a



2b

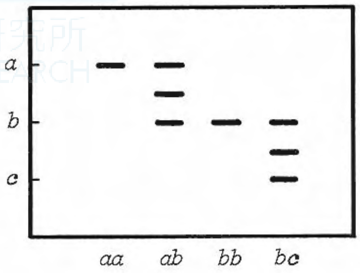


PLATE V

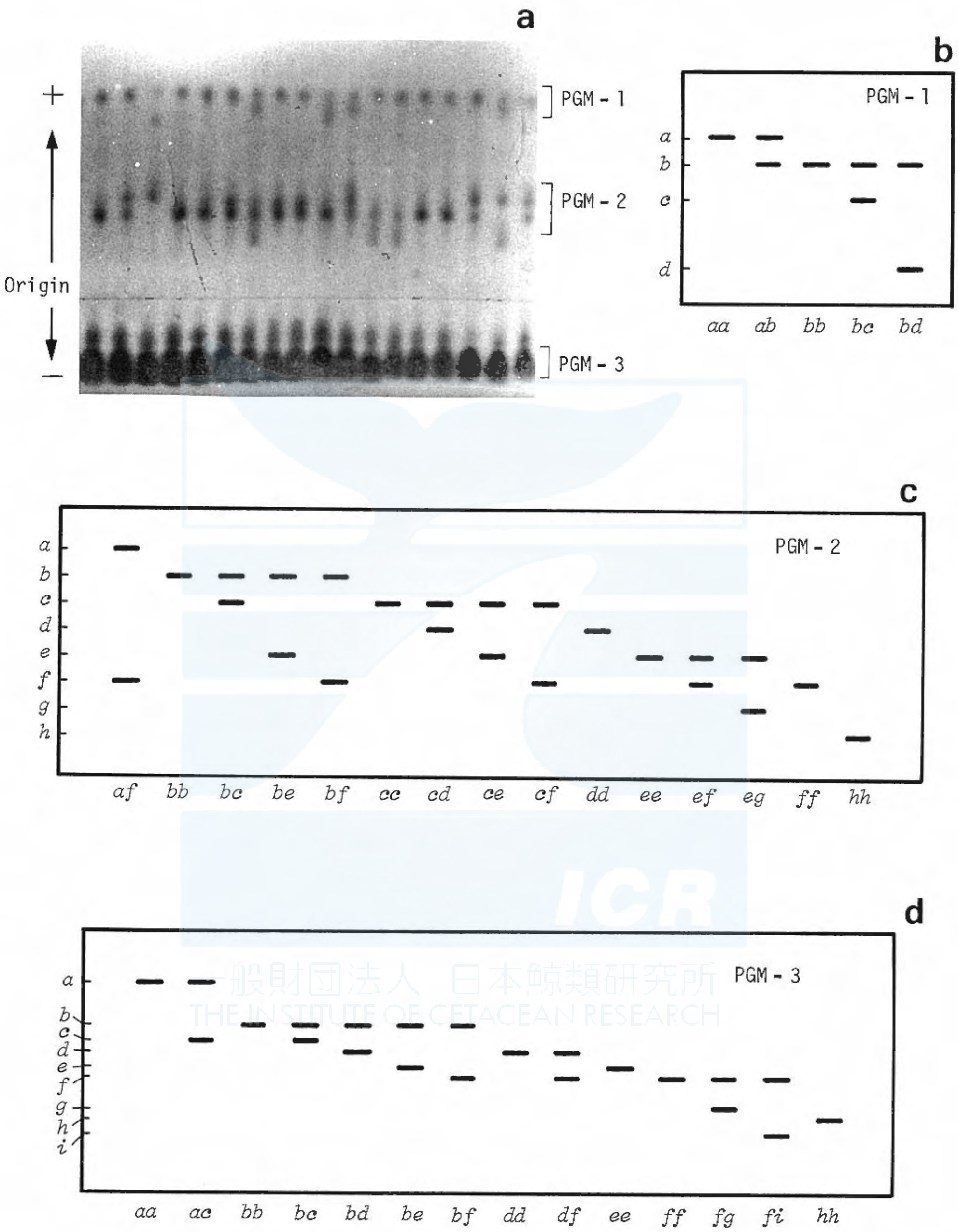
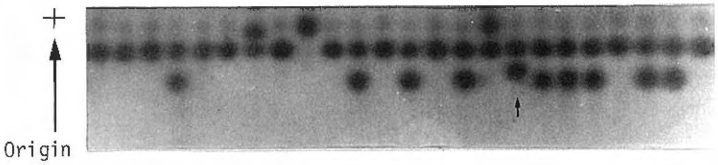
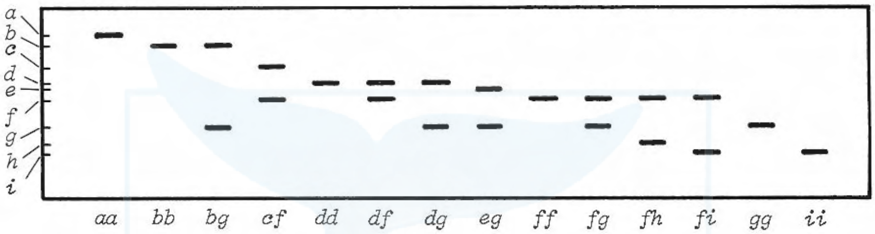

a
+
Origin
−
PGM - 1
PGM - 2
PGM - 3
b
PGM - 1
a
b
c
d
aa ab bb bc bd
c
PGM - 2
a
b
c
d
e
f
g
h
af bb bc be bf cc cd ce cf dd ee ef eg ff hh
d
PGM - 3
a
b
c
d
e
f
g
h
i
aa ac bb bc bd be bf dd df ee ff fg fi hh

PLATE VI



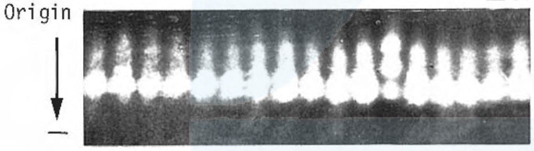
1a

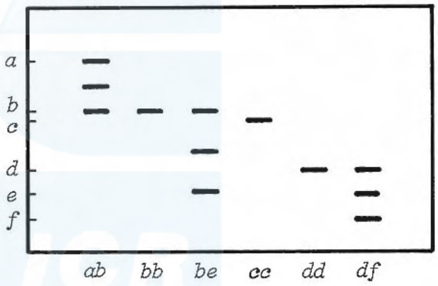
1b



2b

2a






ICR
一般財団法人　日本鯨類研究所
THE INSTITUTE OF CETACEAN RESEARCH

SIAMESE TWINS OF MINKE WHALES OF THE SOUTHERN HEMISPHERE

VALERYI L. ZINCHENKO*
AND
MIKHAIL V. IVASHIN**

Several authors have examined the whales which were raised on board more attentively and with more interest during the past southern ocean whaling expeditions. It gave the opportunity to reveal rare cases of atavism (Ogawa and Kamiya, 1957; Nemoto, 1963; Ohsumi, 1965; Zemsky and Berzin, 1961). Various cases of abnormalities in the development of foetus stage (Nishiwaki, 1957; Ohsumi, 1959; Ivashin, 1960, 1977) and cases of foetus mortality and extrauterine pregnancy (Ivashin, 1960, 1963, 1977; Ichihara, 1962; Kamiya and Miyazaki, 1974) were recorded.

Formation of conjoint pair of foetus is a pathological case, such cases are rare among marine mammals. Kawamura (1969) was the first to describe Siamese twins of Cetaceans. Zemsky and Budylenko (1970) examined female humpback whale of the southern hemisphere (body length – 12.7 m), in the uterine horn of which Siamese twins were found. Japanese scientists registered a blue-white dolphin with abnormal twins, which was collected in coastal water of Japan (Kawamura and Kashita, 1971; Kamiya, Miyazaki and Shiraga, 1981).

On 4 January, 1981, one female minke whale (body length–9.0m) with a pair of Siamese twins was caught, and such twins are for the first time recorded. It was taken at 64° 35′S, 81° 05′E. In the left uterus horn there were two females of 50.5 and 49.0 cm in total length, conjointing in abdominal and partly in lateral areas of the body. Their dorsal and abdominal sides could be distinguished (Figs 1 and 2). This case can be considered as ventropagus (Patten, 1959).

The foetuses were connected at the tip of the mouth to the umbilicus, the connected area was about 20.5 cm, that is 40.6% of the total length. The following parts were separate: upper jaws at the tip of the mouth, partly lower jaws, caudal peduncles, (which dranched only at the umbilicus level, where two umbilical cords came together, connected by a mesentery). The distance between both rostrums was 3.6 cm. The right foetus (with the body length – 120 cm) had harelip on the lower jaw (Fig. 3), as in the case with

---

* *Odessa Branch, 53 Mechnikov, GSP-983, Odessa, 270020, USSR*

** *VNIRO, 17, V. Krasnosel'skaya, Moscow, B-140, 107140, USSR*

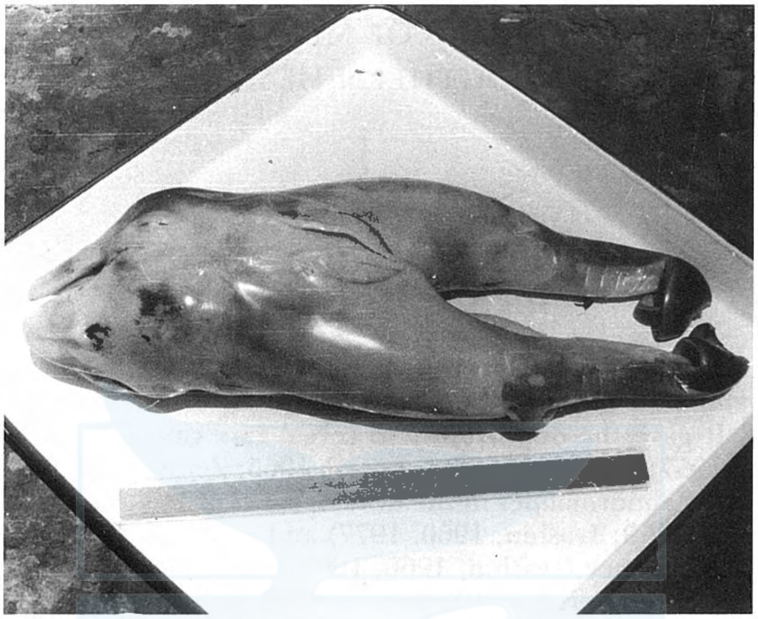


Fig. 1. Minke whale Siamese twins (dorsal side).

Fig. 2. Minke whale Siamese twins (abdominal side).

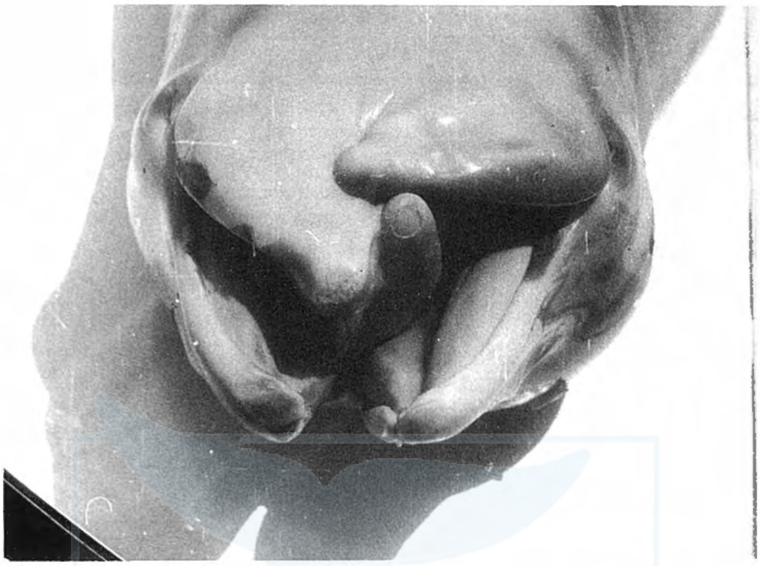


Fig. 3. Head of minke whale Siamese twins (from the abdominal side). The cleft lower jaw can be seen.

humpback whale described by Zemsky and Budylenko (1970). Data on the twins measurements are given in Table 1. The twins considered had clearly manifested asymmetric disposition of the eyes, pectoral fins and mouths. On the dorsal side the tip of the mouth common for the two foetuses was shifted more forward than on the abdominal side; pectoral fins were displaced in the caudal direction. On the connected side, the eye of each foetus was shifted in the direction of the rostrum. The distance between the eyes on the connected side was 1.8 cm, on the opposite side 11.5 cm (Figs 1 and 2). The distance between genital openings was 5 cm. Vibrissae on the foetuses heads were distributed unevenly (Table 2). Abdominal strips were not seen. The combined weight of the twins was 3,200 g.

The left ovary collected from the calf having the twins weighed 445 g and was 14 × 7.5 × 3 cm in size. Only one functioning corpus letum was observed and was 7.5 cm in diameter and six corpora albicans were found on it. This fact indicates the twins were identical ones, coming from one follicle. The right ovary was 15.5 × 7.0 × 3.5 cm in size, its weight was 285 g. At least thirteen growth layers were recognised on the earplug though it was slightly hard to read.

TABLE 1. MORPHOLOGICAL DATA OF SIAMESE TWINS OF MINKE WHALES

Measurements	Left foetus		Right foetus	
	cm	%	cm	%
	Left/Right side side	Left/Right side side	Left/Right side side	Left/Right side side
1. Total length	50.5	100	49.0	100
2. Tip of the snout to the middle of blowholes	7.3	14.5	6.8	13.9
3. Tip of the snout to mouth angle	12.5/8.4	24.8/16.6	8.4/12.3	17.1/25.1
4. End of the snout to eye centre	11.6/10.7	23.0/21.2	12.5/10.7	25.5/21.8
5. Eye centre to the centre of the ear	–/5.5	–/10.9	4.9/–	10.0/–
6. Tail fork to the notch of the caudal fin	14.0	27.7	12.0	24.5
7. Width of the tail flukes	4.3/4.3	8.5/8.5	4.5/4.5	9.2/9.2
8. Tail fork to umbilicus	24.0	47.5	23.5	48.0
9. Tail fork to anus	15.7	31.1	15.7	32.0
10. Anus to genital opening (Center to center)	1.3	2.6	1.2	2.4
11. Height of the dorsal fin	2.0	4.0	2.0	4.1
12. Length of the dorsal fin base	3.5	6.9	3.3	6.7
13. Length of the pectoral fin from the end to the pit	6.8/6.4	13.5/12.7	6.8/5.7	13.9/11.6
14. Length of the pectoral fin on the external edge	8.4/8.0	16.6/15.8	7.9/7.9	16.1/16.1
15. Pectoral fin curve length	7.5/7.5	14.9/14.9	7.5/7.5	15.3/15.3
16. Maximum length of the pectoral fin	2.3/2.3	4.6/4.6	2.3/2.3	4.7/4.7
17. Length of the head (from snout to ear)	–/16.5	–/32.7	16.7/–	34.1/–
18. Breadth of the head	9.3	18.4	9.5	19.4
19. Height of caudal peduncle of the dorsal fin	5.3	10.5	5.3	10.8
20. Length of flukes from the fork to the end	5.8/5.8	11.5/11.5	5.8/5.8	11.8/11.8
21. Span of flukes	11.3	22.4	11.2	22.9
22. From the end of the upper jaw to the end of the lawer jaw	3.5	6.9	5.7/7.0	11.6/14.3
23. Length of the blowhole	1.3	2.6	1.1	2.2
24. From the snout to the beginning of the pectoral fin	17.0/21.5	33.7/42.6	20.5/18.0	41.8/36.7
25. Width of the body at the umbilicus level	7.3	14.5	7.6	15.5
26. The distance between pectoral fins	9.5	18.8	9.3	19.0

TABLE 2. NUMBER OF VIBRISSAE OF SIAMESE TWINS OF MINKE WHALES

Location	Left foetus		Right foetus	
	Left	Right	Left	Right
Blowhole	3	1	3	2
Upper jaw	2	2	2	2
Lower jaw	3	2	2	1
Lower jaw protuberance	9	7	6	7

REFERENCES

IVASHIN, M.V., 1960. On multifetation, abnormalities in the development and embryonic mortality among whales. *Zool. zh.*, 39(5): 755–758.

IVASHIN, M.V., 1963. The case of extrauterine pregnancy in sei whale (*Balaenoptera borealis* Lesson). *Zool. zh.*, 42(8): 1275–1277.

IVASHIN, M.V., 1977. Cases of pathological embryogenesis of minke whales, *Balaenoptera acutorostrata* (Cetacea, Balaenopteridae) of the Antarctic part of the Indian Ocean. *Zool. zh.*, 56(11): 1736–1739.

ZEMSKY, V.A and A.A. BERZIN, 1961. On rare example of atavism in sperm whales. *Higher School Scientific papers, Biological Sciences*: 56–60.

ZEMSKY, V.A. and G.A. BUDYLENKO, 1970. Siamese twins in humpback whales. Whales of the Southern Hemisphere. *Trudy AtlantNIRO*, 29: 225–230.

PATTEN, B.M., 1959. *Embryology of a man.* Medgize, USSR. 768pp.

ICHIHARA, T., 1962. Prenatal dead foetus of baleen whales. *Sci. Rep. whales Res. Inst.*, 16: 47–60.

KAMIYA, T. and N. MIYAZAKI, 1974. A malformed embryo of *Stenella caeruleoalba. Sci. Rep. whales Res. Inst.*, 26: 259–263.

KAMIYA, T., N. MIYAZAKI and S. SHIRAGA, 1981. First case of dicephaly in Odontocety. *Sci. Rep. whales Res. Inst.*, 33: 127–129.

KAWAMURA, A., 1969. Siamese twins in the sei whale *Balaenoptera borealis* Lesson. *Nature*, 221(5179): 490–491.

KAWAMURA, A. and K. KASHITA, 1971. A rare double monster of dolphin *Stenella caeruleoalba. Sci. Rep. whales Res. Inst.*, 24: 139–140.

NEMOTO, T., 1963. New record of sperm whales with protruded rudimentary hind limbs. *Sci. Rep. whales Res. Inst*, 17: 79–81.

NISHIWAKI, M., 1957. One-eyed monster of fin whale. *Sci. Rep. whales Res. Inst.*, 12: 193–195.

OHSUMI, S., 1959. A deformed fin whale foetus. *Sci. Rep. whales Res. Inst.*, 14: 145–147.

OHSUMI, S., 1965. A dolphin (*Stenella caeruleoalba*) with protruded rudimentary hind limbs. *Sci. Rep. whales Res. Inst.*, 19: 135–136.

OGAWA, M. and T. KAMIYA, 1957. A case of the cachalot with protruded rudimentary hind limbs. *Sci. Rep. whales Res. Inst.*, 12: 197–208.

一般財団法人　日本鯨類研究所
THE INSTITUTE OF CETACEAN RESEARCH

FIRST RECORD OF A DWARF SPERM WHALE FROM SOUTHWEST ATLANTIC, WITH REFERENCE TO OSTEOLOGY, FOOD HABITS AND REPRODUCTION

MARIA C. PINEDO*

ABSTRACT

A female dwarf sperm whale, *Kogia simus*, 2,490 mm long with a 260 mm female foetus was found stranded on July, 1983 at Rio Grande do Sul coast, southern Brazil (32°05′S, 52°01′W). The species was identified based on external and cranial characters. The condylobasal length was 283 mm and the vertebral formula was C7 + D13 + L10 + Ca25 = 55, with 14 chevron bones. The first nine pairs of ribs were double headed. The complete skeleton and foetus were placed in the cetacean collection of the Museu Oceanografico do Rio Grande (MORG 495). Nematode parasites, shrimp remains and 78 cephalopod beaks were found in the stomach content. Of the identified cephalopod beaks, 55% belonged to Histioteuthidae, 14.1% to Chiroteuthidae and the remainder to other five families. A review of foetal records suggests that birth and copulation occur in summer.

INTRODUCTION

On July 5, 1983, a decomposed odontocete carcass was found 10 km north of the entrance to the Patos lagoon, Rio Grande do Sul (32° 05′S, 52° 01′W). It was a 2,490 mm female dwarf sperm whale, containing a 260 mm female foetus. The specimen was measured, photographed and the stomach collected. The complete skeleton was recovered and, along with the formolized foetus, placed in the marine mammals collection of Museu Oceanografico do Rio Grande (MORG 495).

The external measurements of both specimens were taken according to Leatherwood, Reeves, Perrin and Evans (1982) and are shown in Table 1. The skull was measured according to Ross (1979) and rest of the skeleton according to Nishiwaki, Kasuya, Kureha and Oguro (1972), Pinedo and Castello (1980) and Omura, Shirakihara and Ito (1984). The present study reports the external morphology, osteology, stomach contents of this specimen, together with the review of presently available fetal records of the species.

---

* *Departamento de Oceanografia, FURG, 96200 Rio Grande, RS Brazil.*

Sci. Rep. Whales Res. Inst.,
No. 38, 1987, 171–186

TABLE 1. EXTERNAL MEASUREMENTS OF A FEMALE *KOGIA SIMUS* (A) AND FOETUS (B) STRANDED AT RIO GRANDE DO SUL COAST, BRAZIL

	Measurements	A		B	
		in mm	% of total length	in mm	% of total length
1.	Tip of upper jaw to deepest part of fluke notch	2,490	100.0	260	100.0
2.	Tip of upper jaw to center of anus	1,770	71.1	195	75.0
3.	Tip of upper jaw to center of genital slit	1,715	68.9	195	75.0
4.	Tip of lower jaw to center of umbilicus	1,500	60.2	140	53.8
5.	Tip of upper jaw to top of dorsal fin	1,470	59.0	185	71.6
6.	Tip of upper jaw to leading edge of dorsal fin	1,170	46.9	160	61.5
7.	Tip of upper jaw to anterior insertion of flipper (left)	540	21.7	80	30.8
8.	Tip of upper jaw to center of blowhole	190	7.6	22	8.5
9.	Tip of upper jaw to anterior edge of blowhole	230	9.2	23	8.8
10.	Tip of upper jaw to auditory meatus, right			55	21.2
	left			55	21.2
11.	Tip of upper jaw to center of eye, right			44	16.9
	left			44	16.9
12.	Tip of upper jaw to angle of gape	235	9.4	34	13.1
13.	Center of eye to center of eye	505	20.3	52	20.0
14.	Height of eye, right	12	0.5	2	0.8
	left			1	0.4
15.	Length of eye, right	35	1.4	6	2.3
	left			6	2.3
16.	Center of eye to angle of gape, right	195	7.8	28	10.8
	left			30	11.5
17.	Center of eye to external auditory meatus, right	80	3.2	14	5.4
	left			13	5.0
18.	Center of eye to center of blowhole, right	320	12.9	42	16.2
	left	250	10.0	34	13.1
19.	Blowhole length	70	2.1	12	4.6
20.	Flipper width, right	130	5.2	15	5.8
21.	left	125	5.0	16	6.2
22.	Flipper length-tip to anterior insertion, right	330	13.3	39	15.0
	left	320	12.9	39	15.0
23.	Flipper length-tip to axilla, right	230	9.2	26	10.0
	left	220	8.8	27	10.4
24.	Dorsal fin height	155	6.2	9	3.5
25.	Dorsal fin base	305	12.3	27	10.4
26.	Fluke span	620	24.9	59	22.7
27.	Fluke width	180	7.2	20	7.7
28.	Fluke depth of notch	10	0.4	1	0.4
29.	Notch of flukes to center of anus	805	32.3	83	31.9
30.	Notch of flukes to center of genital aperture	855	34.3	86	33.1
31.	Notch of flukes to umbilicus	1,070	43.0	144	55.4
32.	Notch of flukes to nearest point on leading edge	170	6.8	19	7.3
33.	Girth at anus	1,040	41.8	100	38.5

TABLE 1. (Cont.)

34. Girth at axilla	1,360	54.6	175	67.3
35. Girth at eye			180	69.2
36. Blubber thickness (lateral)	25	1.0		
37. Mammary slit length, right	50	2.0		
left	45	1.8		
38. Genital slit length	50	2.0		

RESULTS

External morphology

The specimen was identified as a dwarf sperm whale, *Kogia simus* (Owen, 1866) (Fig. 1a) based upon the following external characteristics: height of dorsal fin equivalent to 6.2% of total body length (over 5% in *K. simus* according to Ross (1979)) and positioned in the midback; 10 teeth in each side of the lower jaw, which is in the ranges of the value for the species given by Handley (1966); the size of 8 lower teeth (15.5 to 20.5 mm) agrees with the values given by Ross (1979). Teeth were present on the upper jaws.

Due to decomposition, the colour pattern, throat grooves and the bracket mark behind the eye could not be observed (Fig. 1b). The bracket mark seems to be characteristic of the genus (Ross, 1979), whereas the throat grooves are present in *K. simus* and absent in *K. breviceps* (Leatherwood *et al.*, 1982). The blowhole was positioned to the front and directed to the left in an oblique way (Fig. 1c). It was an adult specimen, since a 260 mm foetus was found in it. The foetus was a female (Fig. 1d) which presented 5 vibrissae in each side of the maxilla (Fig. 1e) and two throat grooves.

Osteological characteristics

The specific cranial characteristics mentioned by Handley (1966) and Ross (1979) were observed on this specimen, especially the condylobasal length, the shape of the dorsal fossae, the width of the dorsal sagittal septum and the length and shape of the mandibular symphysis. These characteristics are shown in Fig. 2. The anterior part of the mesethmoid was not ossified (Fig. 2) and the skull sutures of the frontal in the vertex, the parieto-occipital and the maxillary were visible. The rami of the mandible were not fused together. Among a total of 8 teeth examined, two had the closed pulp cavity and the remainder were in process of closure. Skull measurements are listed in Table 2.

The vertebral formula was C7 + D13 + L10 + Ca25, with total of 55 vertebrae. The vertebral groups are presented in Fig. 3, and measurements of vertebrae in Table 3. Bones of axial skeleton, as well as the skull, were light and porous.

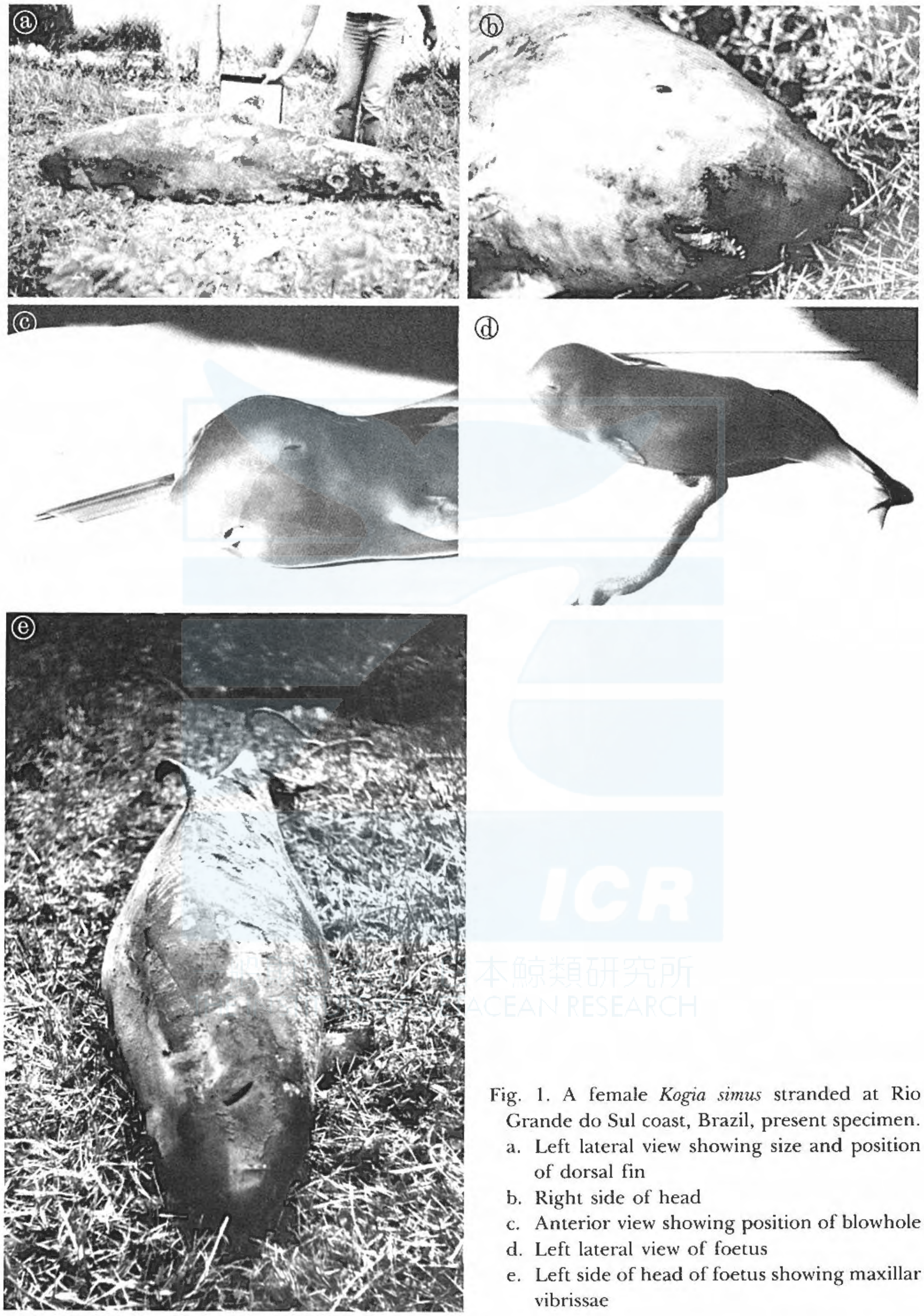


Fig. 1. A female *Kogia simus* stranded at Rio Grande do Sul coast, Brazil, present specimen.
a. Left lateral view showing size and position of dorsal fin
b. Right side of head
c. Anterior view showing position of blowhole
d. Left lateral view of foetus
e. Left side of head of foetus showing maxillar vibrissae

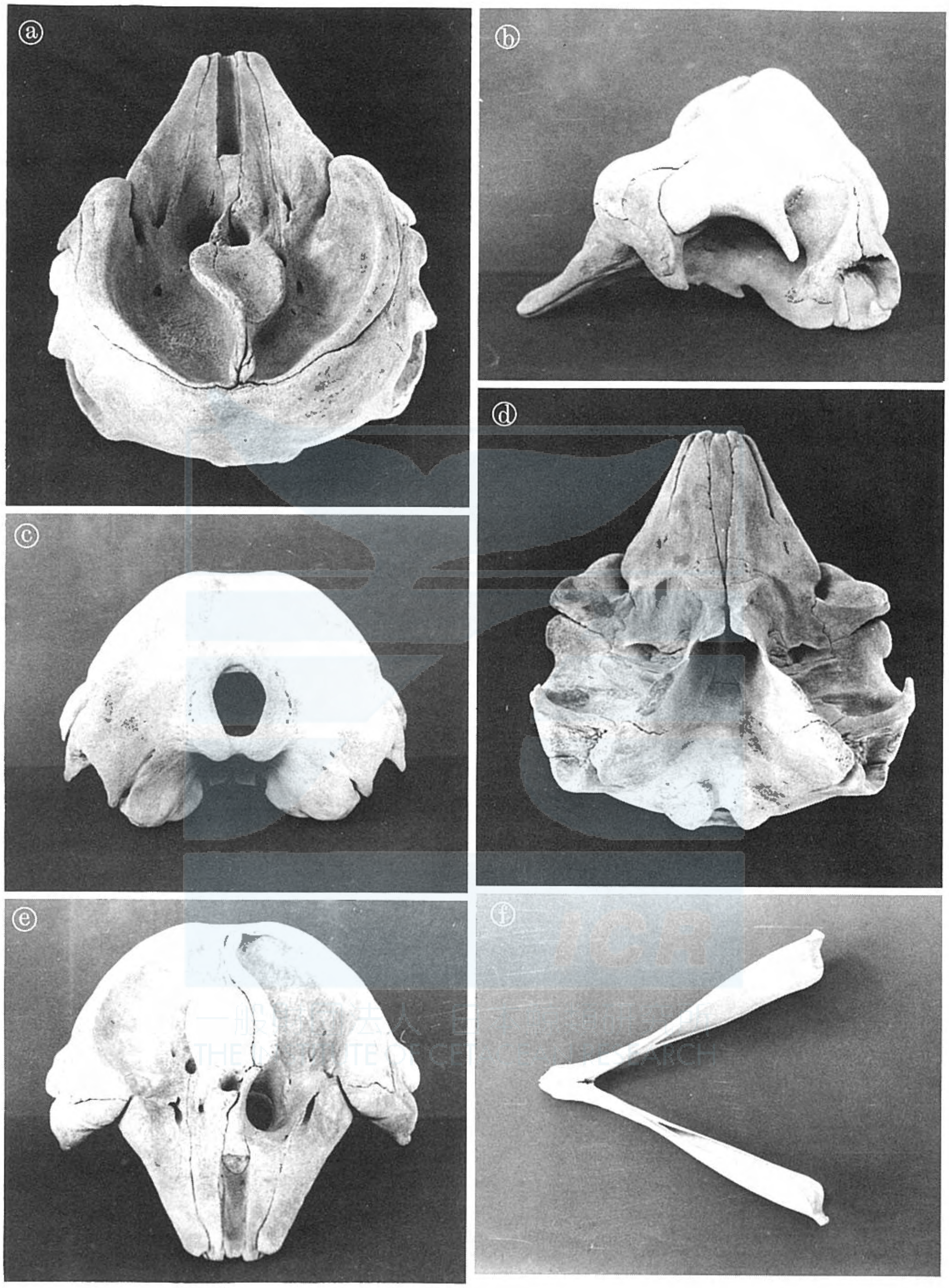


Fig. 2. Skull and mandibles of the present specimen
a. Dorsal view b. Lateral view c. Posterior
d. Ventral view e. Anterior view f. Mandible

The seven cervical vertebrae are fused into a single unit, where posterior three of them could be individualized. Most of the vertebral epyphyses, 60, were free from the centrum. The neural arch was closed up to the 13th caudal vertebra. The transverse and spinous apophyses attained their maximum sizes in the 5th lumbar vertebra. The last lumbar vertebra was distinguished from the 1st caudal by the absence of chevron bone in its ventral posterior portion. The 25th caudal vertebra showed a straightening, which confers it a triangular shape, in dorsal view. There were 14 chevron bones, and the first one was not fused bilaterally (Fig. 4). The measurements of these bones are provided in Table 4.

There were 12 ribs in the right side and 13 in the left; the last one was rudimentary for its small size (Fig. 5). The first nine pairs presented double articulation. Measurements of the ribs are shown in Table 5.

The sternum consisted of two bony sections both presenting a longitudinal rift in the ventral portion, evidencing the bilateral origin already mentioned

TABLE 2. CRANIAL AND MANDIBULAR MEASUREMENTS OF A FEMALE *KOGIA SIMUS* STRANDED AT RIO GRANDE DO SUL COAST, BRAZIL

Measurements	in mm	% of total length
1. Total condylobasal length	283	100.0
2. Rostrum length*	123	43.4
3. Rostrum, basal width*	146	51.5
4. Rostrum, width at its middle*	101	35.6
5. Breadth across pre-orbital angles of supra-orbital processes	241	85.1
6. Breadth across post-orbital processes	263	92.9
7. Zigomatic width	253	89.3
8. Height to vertex	185	65.3
9. Width of vertex	16	5.6
10. Width of supra-occipital at narrowest part between posterior margins of temporal fossae	190	67.1
11. Tip of rostrum to left naris	112	39.5
12. Height of ventral border of foramen magnum	65	22.9
13. Length of maxillary tooth groove – right	68	24.0
14. Length of maxillary tooth groove – left	65	22.9
15. Width between outer margins occipital condyles	80	28.2
16. Tip of rostrum to hind margin of pterygoids	160	56.5
17. Length of mandible	243	85.8
18. Height of mandible at coronoid	82	28.9
19. Length of mandibular symphysis	40	14.1
20. Length of lower toothrow – left	87	30.7
21. Length of lower toothrow – right	88	31.0
22. Height from dorsal border of foramen magnum to vertex	95	33.5

* Measured ventrally

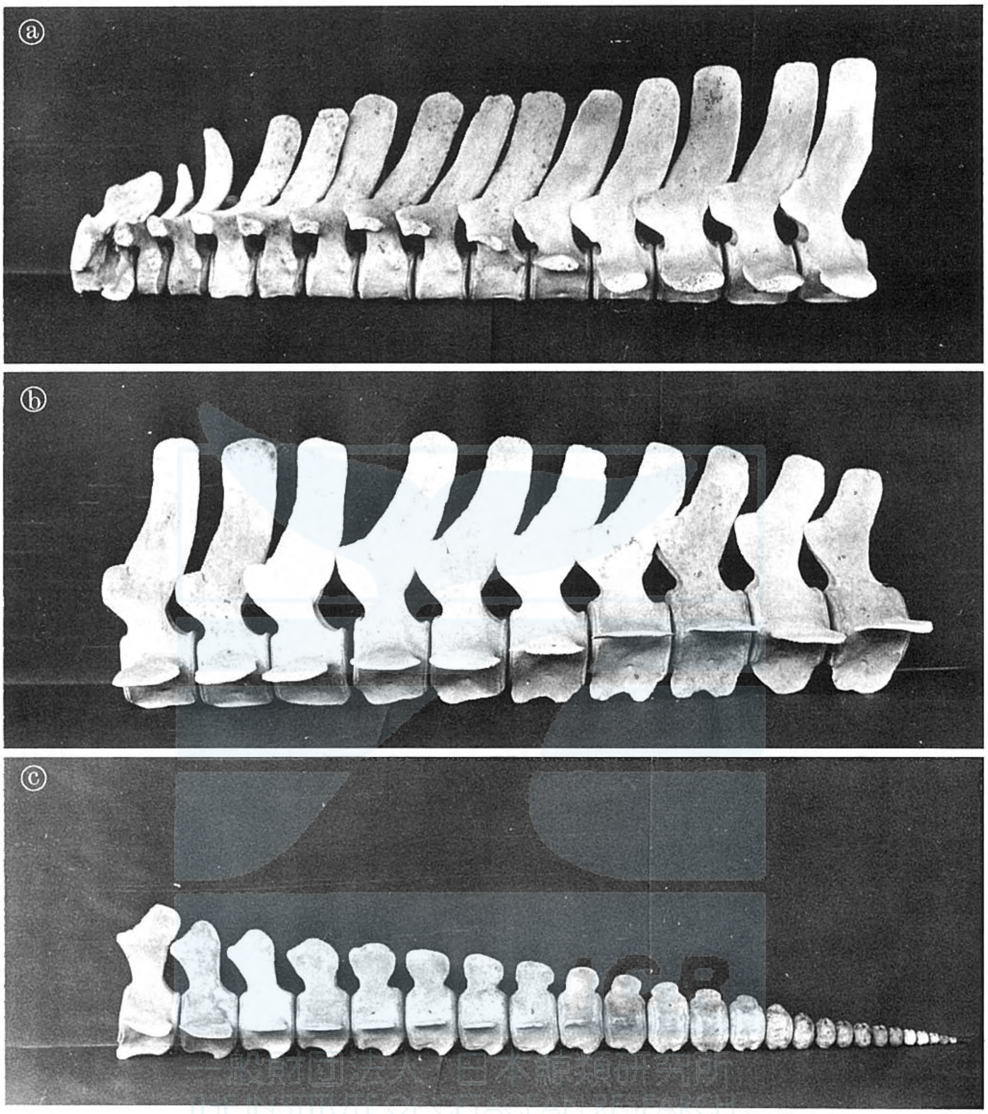


Fig. 3. Vertebrae of the present specimen

a. 1-7 cervical vertebrae (fused) and 1-13 dorsal vertebrae
b. 1-10 lumbar vertebrae
c. 1-25 caudal vertebrae

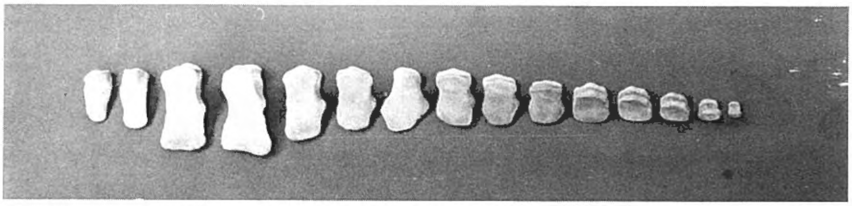


Fig. 4. 1-14 chevron bones of the present specimen showing isolated laminae of the first chevron.

TABLE 3. VERTEBRAL MEASUREMENTS OF A FEMALE *KOGIA SIMUS* STRANDED AT RIO GRANDE DO SUL COAST, BRAZIL (IN MM)

Serial No.	Vertebral No.	Greatest breadth	Greatest height	Centrum			Note
				Breadth	Height	Length*	
1	C 1						
2	2						
3	3						
4	4	127	99	45 (posterior)	36	38 (inferior)	all fused but posterior epiphysis of No. 7 is not fused to its centrum
5	5						
6	6						
7	7						
8	D 1	104	98	42 (anterior)	37	20	epiphysis fused only at upper part
9	2	99	120	39	35	29	epiphysis free until eigth caudal vertebra
10	3	100	138	36	33	32	
11	4	97	145	36	33	33	
12	5	97	148	36	31	36	
13	6	92	155	40	33	39	
14	7	93	154	38	32	38	
15	8	97	155	40	34	39	
16	9	108	156	43	36	42	
17	10	118	163	45	37	42	
18	11	132	168	45	40	44	
19	12	140	173	48	42	45	
20	13	168	172	50	43	46	
21	L 1	179	181	53	49	49	
22	2	176	181	51	46	48	
23	3	180	180	53	45	49	
24	4	183	186	56	56	50	
25	5	182	183	56	57	50	
26	6	177	178	54	61	51	
27	7	175	176	56	65	53	
28	8	168	172	56	71	53	
29	9	164	162	55	71	51	
30	10	162	152	54	67	50	

TABLE 3. (Cont.)

31	Ca 1	154	141	54		64	50	
32	2	144	122	55		54	49	
33	3	136	115	52		49	48	
34	4	125	107	52		48	47	
35	5	107	100	50		48	46	
36	6	91	95	51		49	45	
37	7	78	90	50		48	43	
38	8	66	84	52		47	42	
39	9	55	77	49		46	39	
40	10	49	70	45		48	39	
41	11	—	62	45		44	36	
42	12	—	57	42		42	34	
43	13	—	50	39		39	32	
44	14	—	41	37		33	25	
45	15	—	32	33		28	20	
46	16	—	27	31		23	18	
47	17	—	23	29		22	17	
48	18	—	21	27		20	17	
49	19	—	—	25		19	15	
50	20	—	—	23		16	14	
51	21	—	—	21		14	12	
52	22	—	—	19		13	11	
53	23	—	—	16		11	10	
54	24	—	—	13		8	9	
55	25	—	—	9		6	7	triangular shape, posterior epiphysis missing

* Measured with epiphysis

for *K. breviceps* by Carvalho (1966) and Vaz-Ferreira and Praderi (1973). Fig. 5 shows the way sternum measurements were taken, and the measurements are provided in Table 6. The sternal ribs were not found, demonstrating the attachments of ribs to the sternum only through cartilage, which agrees with Carvalho (1966) for *K. breviceps*.

Photographs of the hyoid arch and scapulae and the way measurements were taken are shown in Fig. 6. Tables 7 and 8 show the measurements of hyoid arch and scapulae, respectively.

The proximal and distal epiphyses of the right and left humerus were fused, as well as the proximal epiphyses of radius and ulna. The distal epiphyses of the latter were not fused. Measurements of humerus, radius and ulna are provided in Table 9. The phalangeal bones could not be counted. The pelvic bone was not found.

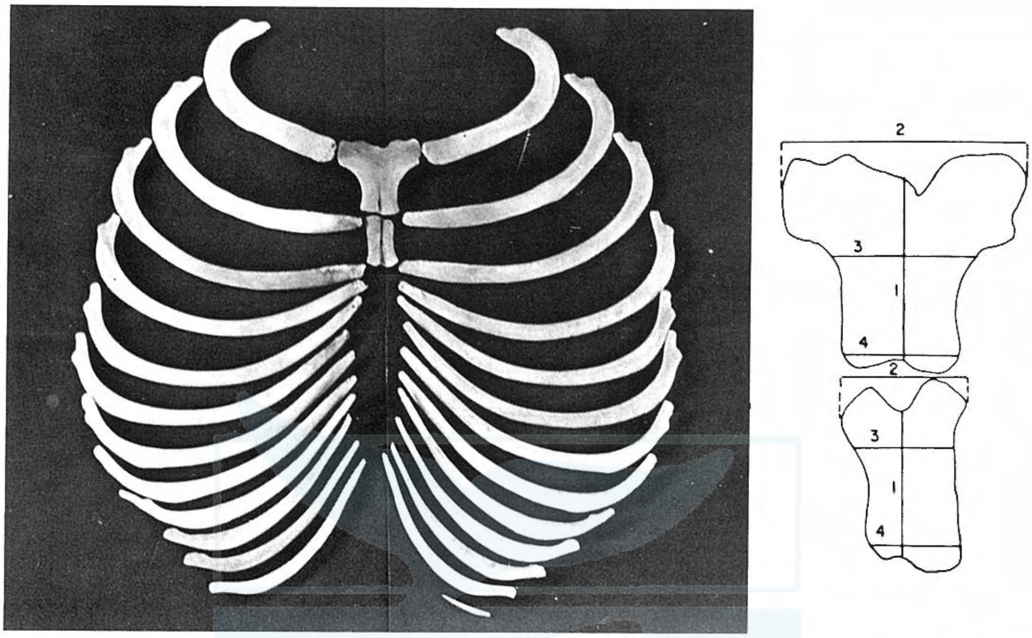


Fig. 5. Ribs and sternal bones of the present specimen (left), and illustration showing sternal measurements in Table 6 (right).

TABLE 4. MEASUREMENTS OF CHEVRON BONES OF A FEMALE *KOGIA SIMUS* STRANDED AT RIO GRANDE DO SUL COAST, BRAZIL (IN MM)

No.		Length*	Height*	No.	Length*	Height*
1	Right	19	37	8	26	35
	Left	20	43	9	26	30
2		29	63	10	26	27
3		27	63	11	24	24
4		29	53	12	21	19
5		27	45	13	16	13
6		30	46	14	10	9
7		27	39			

* Measured at midpoint

TABLE 5. STRAIGHT LENGTH OF RIBS OF A FEMALE *KOGIA SIMUS* STRANDED AT RIO GRANDE DO SUL COAST, BRAZIL (IN MM)

No.	Right	Left	No.	Right	Left
1	232	229	8	345	341
2	312	313	9	323	311
3	352	357	10	280	276
4	360	360	11	264	252
5	352	353	12	252	242
6	355	354	13	0	64
7	352	356			

TABLE 6. MEASUREMENTS OF THE STERNAL BONES OF A FEMALE *KOGIA SIMUS* STRANDED AT RIO GRANDE DO SUL COAST, BRAZIL (IN MM)

No.	Manubrium	Sternebrae
1. Length at medium	90	61
2. Maximum breadth	110	41
3. Anterior breadth	62	34
4. Posterior breadth	51	37

TABLE 7. MEASUREMENTS OF THE HYOID BONES OF A FEMALE *KOGIA SIMUS* STRANDED AT RIO GRANDE DO SUL COAST, BRAZIL (IN MM)

No.		Right	Left
1. Baiyhyal height at medium	54		
2. Maximum basihyal height	65		
3. Maximum basihyal breadth	77		
4. Thyrohyal length		83	81
5. Thyrohyal breadth		64	65
6. Straight line thyrohyal*	174		
7. Stylohyal length		74	86
8. Stylohyal height at medium		15	9

* Measured approximately – not fused with basihyal

Stomach content and parasites

The stomach contained 78 cephalopod beaks (38 upper and 40 lower) and gladius remains. Beaks were identified by M. J. Imber, Wildlife Service, Wellington, New Zealand and results are shown in Table 10. Fifty-five percent of the beaks belonged to the oceanic family Histioteuthidae and the remainder were assigned to six other families. Two beaks could not be identified due to their small size. Remains of shrimp carapaces were also found but identification was not possible due to wear. The presence of cephalopods and crustacean in the *K. simus* stomachs and the predominance of the former were previously observed by Fitch and Brownell (1968), Ross (1979), Jones (1981), Maigret

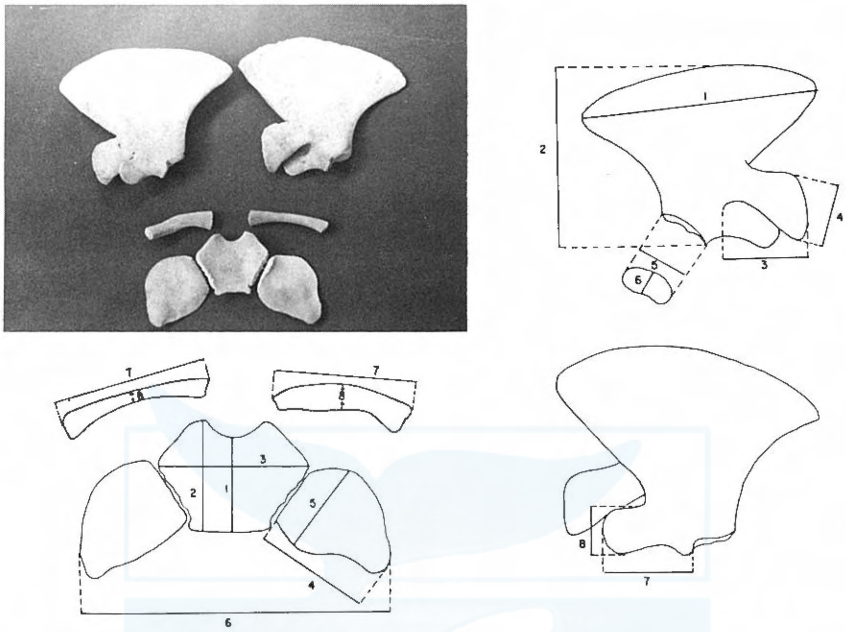


Fig. 6. Scapulae (right and left) and hyoid bones of the present specimen, and illustrations showing measurements in Tables 7 and 8.

TABLE 8. MEASUREMENTS OF THE SCAPULA OF A FEMALE *KOGIA SIMUS* STRANDED AT RIO GRANDE DO SUL COAST, BRAZIL (IN MM)

No.	Right	Left
1. Maximum length	187	183
2. Maximum height	151	149
3. Coracoid length	54	55
4. Coracoid maximum breadth	41	52
5. Glenoid fossa length	35	37
6. Glenoid fossa breadth	26	26
7. Acromium length	53	52
8. Acromium maximum breadth	26	23

TABLE 9. MEASUREMENTS OF HUMERUS, RADIUS AND ULNA OF A FEMALE *KOGIA SIMUS* STRANDED AT RIO GRANDE DO SUL COAST, BRAZIL (IN MM)

	Humerus		Radius		Ulna	
	Right	Left	Right	Left	Right	Left
Length*	87	87	57	56	55	55
Breadth*	37	38	31	30	28	26

* Measured at midpoint

TABLE 10. NUMBER OF CEPHALOPOD BEAKS FROM A STOMACH OF *KOGIA SIMUS* FROM SOUTHERN BRAZIL

Cephalopods	Upper	Lower	Total number	% of total	No of squids	Family % of total
Histioteuthidae						
Histioteuthis atlantica	4	4	8	10.3	4	55.1
Histioteuthis macrohista	16	17	33	42.3	17	
Histioteuthis sp. (*corpuscula*?)	1	1	2	2.6	1	
Lycoteuthidae						
Lycoteuthis diadema (= Oregoniateuthis longimanus)	3	4	7	9.0	4	9.0
Cranchiidae						
Megalocranchia maxima	2	2	4	5.1	2	7.7
Teuthowenia impennis	1	1	2	2.6	1	
Mastigoteuthidae						
Mastigoteuthis sp.	1	1	2	2.6	1	2.6
Chiroteuthidae						
Chiroteuthis capensis	6	5	11	14.1	6	14.1
Brachioteuthidae						
Brachioteuthis sp.	2	1	3	3.8	2	3.8
Sepiolidae						
Rossia sp.?	1	3	4	5.1	3	5.1
Unidentified	1	1	2	2.6	1	
Total	38	40	78		42	

and Robineau (1981), Nagorsen and Stewart (1983) and Ross (1984). Nevertheless, in most of the stomachs analyzed fish otoliths were also found. Nematode parasites were present in great number.

Most of the beaks found in the present specimen belonged to species *Histioteuthis atlantica* and *H. macrohista*, coinciding with what was observed for a *K. simus* specimen from New Zealand (Imber, pers. com.).

Fetal length

Body length at birth is not known for *Kogia simus*, but it is suggested to be around 1 m by comparison with *K. breviceps* (Ross, 1979). Known records of fetal and juvenile *K. simus* are cited in Table 11 and the Southern Hemisphere

TABLE 11. RECORDS OF *KOGIA SIMUS* OF CALVES AND FEMALES WITH FOETUS OR CALF.

Cat. N°	Total length (mm)	Length of foetus (mm)	Sex of foetus	Length of calf (mm)	Sex of calf	Date	Region	Source
MCZ 4038	2,210	c.300	–	c.1,500	male	21/ 4/39[a]	U.S.A.	Allen (1941) Barbour (1950)
PEM 1515/50	2,310+	?	–	1,520	–	28/ 4/70	South Africa	Ross (1979)
PEM 1515/53	2,305	–	–	1,525	–	Apr/May 1970	South Africa	Ross (1979)
PEM 1516/50	c.2,440	–	–	1,360	female	24/ 3/71	South Africa	Ross (1979)
PEM 1516/97	2,350	72	female	1,525	female	15/ 4/71	South Africa	Ross (1979)
PEM 1518/02	2,400	c.200–250	–	c.1,000–1,300[b]	–	23/ 8/72	South Africa	Ross (1979)
–	–	–	–	1,220	female	10/73	U.S.A.	Gunter and Overstreet (1974)
PEM 1519/72	2,240	325	female	1,610	female	17/ 9/75	South Africa	Ross (1979)
ELM 935	2,500	960	–	–	–	21/12/76	South Africa	Ross (1984)
PEM 1520/66	2,200	–	–	1,470	female	30/ 7/77	South Africa	Ross (1984)
PEM N678[c]	2,410	–	–	1,035	male	3/ 3/81	South Africa	Ross (pers. com.)
PEM N830	2,380[d]	–	–	1,030	female	31/ 3/82	South Africa	Ross (pers. com.)
MORG 495	2,490	260	female	–	–	5/ 7/83	Brazil	Present study
–	2,270	591	female	–	–	19/10/83	Mexico	Fleischer *et al.* (1984)
PEM N1132[c]	–	–	–	1,275	female	17/ 1/85	South Africa	Ross (pers. com.)

a. Although Allen (1941) mentions that this record was found on 21/4/39, Barbour (1950) wrote it was found during Autumn of 1939.
b. Due to the great range of the estimated length this calf is not present in Figure 7.
c. Lactating female (PEM N678). Stranded near Gaimtoos River Mouth, Eastern Cape.
d. Lactating and calf stranded alive, Coega River Mouth, Algoa Bay.
e. Stranded 300m from an adult male, Cape Receife, Port Elizabeth. Preserved whole, stomach not examined.

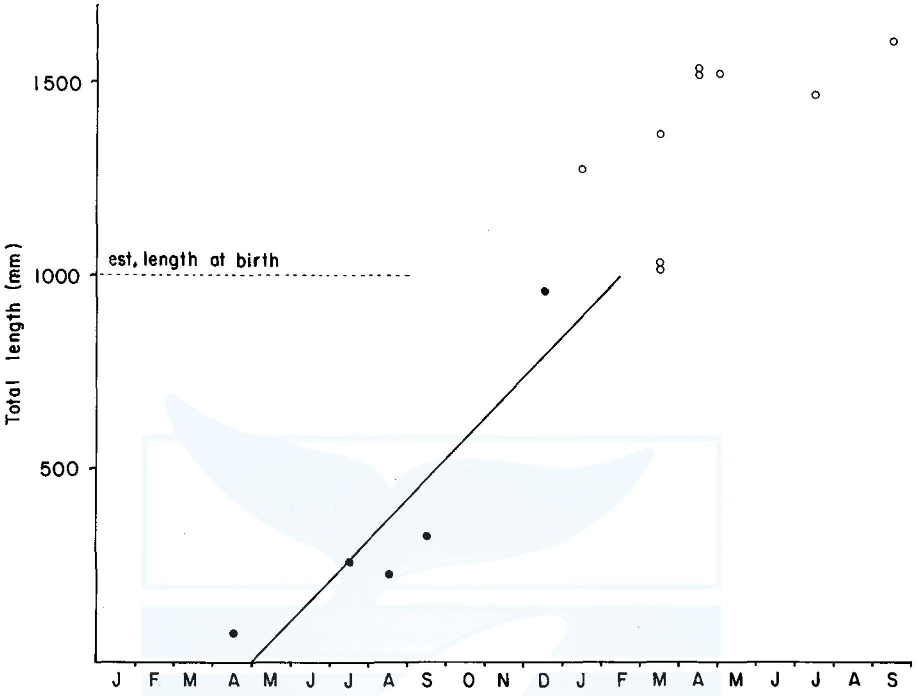


Fig. 7. Lengths of foetuses (●) and calves (○) of *K. simus* plotted against month of occurrence in the Southern Hemisphere.

records of the body length are plotted against the date in Fig. 7. The occurrence of small foetuses in April and of large foetus and new born calves in November to February suggests the matings in summer and births in early summer. The gestation period is possibly about 9.5 months and the length at birth around 1 m, agreeing with those suggested by Ross (1979).

ACKNOWLEDGEMENTS

I wish to thank Dr G.J.B. Ross and Mr V.G. Cockcroft, Port Elizabeth Museum, South Africa, for their generous provision of foetuses and calves unpublished records on *Kogia simus* from South Africa; Mr M. Imber, Wildlife Service, Wellington, New Zealand, for identification of cephalopod beaks and Dr G.J.B. Ross for his valuable comments on the manuscript.

REFERENCES

ALLEN, G.M., 1941. Pygmy sperm whale in the Atlantic. *Zool. Series, Field Mus. Nat. Hist.* (Chicago), 27: 17–36, figs 1–4.

BARBOUR, T., 1950. *Naturalist at large*. pp206–207. Robert Hale, London. 258 pp.

CARVALHO, C.T. DE, 1966. Notas sobre *Kogia breviceps* (Cetacea, Physeteridae). *Rev. Biol. Trop.*, 14(2): 169–181.

FITCH, J.E. and R.L. BROWNELL, JR., 1968. Fish otoliths in cetacean stomachs and their importance in interpreting feeding habits. *J. Fish. Res. Bd. Can.*, 25(12): 2561–2574.

FLEISCHER, L.A., F. CERVANTES, R. FUENTES and G.E. MICHEL, 1984. New records of whales strandings at the Bay of La Paz, Baja California Sur, Mexico. Presented at IX International Reunion of the Mexican Society for the Study of Marine Mammals, La Paz, B.C.S., Mexico, 29–31 March.

GUNTER, G. and R. OVERSTREET, 1974. Cetacean notes. I. Sei and rorqual whales on the Mississippi coast, a correction. II. A dwarf sperm whale in Mississippi Sound and its helminth parasites. *Gulf Res. Repts.*, 4(3): 479–481.

HANDLEY, C.O., 1966. A synopsis of the genus *Kogia* (pigmy sperm whale). pp. 62–69. *In*: K.S. Norris (ed.) *Whales, dolphins and porpoises.* Univ. California Press, Berkeley and Los Angeles. 789pp.

JONES, R.E., 1981. Food habits of smaller marine mammals from northern California. *Proc. Calif. Acad. Sci.*, 42: 409–433.

LEATHERWOOD, S., R.R. REEVES, W.F. PERRIN and W.E. EVANS, 1982. Whales, dolphins and porpoises of the eastern North Pacific and adjacent Arctic waters. A guide to their identification. *NOAA Technical Report NMFS Circular 444*. 245pp.

MAIGRET, J. and D. ROBINEAU, 1981. Le genre *Kogia* (Cetacea, Physeteridae) sur les cotes du Senegal. *Mammalia*, 45(2): 199–204.

NAGORSEN, D.W. and G.E. STEWART, 1983. A dwarf sperm whale (*Kogia simus*) from the Pacific coast of Canada. *J. Mamm.*, 64(3): 505–506.

NISHIWAKI, M., T. KASUYA, K. KUREHA and N. OGURO, 1972. Further comments on *Mesoplodon ginkgodens*. *Sci. Rep. Whales Res. Inst.*, 24: 43–56.

OMURA, H., M. SHIRAKIHARA and H. ITO, 1984. A pygmy sperm whale accidentally taken by drift net in the North Pacific. *Sci. Rep. Whales Res. Inst.*, 35: 183–193.

OWEN, R., 1866. On some Indian Cetacea collected by Walter Elliot, Esq. *Trans. Zool. Sco. Lond.*, 6(1): 17–47, pl. III–XIV.

PINEDO, M.C. and H.P. Castello, 1980. Primeiros registros dos golfinhos *Stenella coeruleoalba*, *Stenella* cfr. *plagiodon* e *Steno bredanensis* para o sul do Brasil, com notas osteologicas. *Bolm. Inst. Oceanogr. (S. Paulo)*, 29(2): 313–317.

ROSS, G.J.B., 1979. Records of pygmy and dwarf sperm whales, genus *Kogia*, from Southern Africa, with biological notes and some comparisons. *Ann. Cape Prov. Mus.* (Nat. Hist.), 11(14): 259–327.

ROSS, G.J.B., 1984. The smaller cetaceans of the South East coast of Southern Africa. *Ann. Cape Prov. Mus.*, 15: 173–410.

VAZ-FERREIRA, R. and R. PRADERI, 1973. Un nuevo ejemplar de *Kogia breviceps* (Blainvile) (Cetacea, Physeteridae) del Atlantico Sudoccidental. Caracteres y notas. *Trab. V Congr. Latinoam. Zool.*, 1: 261–277.

SIGHTING RECORDS OF FRASER'S DOLPHIN IN THE MEXICAN PACIFIC WATERS

ANELIO AGUAYO L.* AND RAFAEL SANCHEZ T.*

Lagenodelphis hosei Fraser, 1956 is distributed in the tropical and temperate waters of the Pacific, Atlantic and Indian Oceans (Perrin, Best, Dawbin, Balcomb, Gambell and Ross, 1973; Tobayama, Nishiwaki and Yang, 1973; Miyazaki and Wada, 1978; Leatherwood, Reeves, Perrin and Evans, 1982; Caldwell, Caldwell and Walker, 1976; Hersh and Odell, 1983).

We report here two additional sighting records of this species in the waters of the Archipelago of Revillagigedo, Mexico (Fig. 1).

The first was a group of 20 animals sighted by one of us (AAL), on July 3, 1981, at 19°47'N, 110°42'W, 54 km off the nearest coast. The robust body, short snout, semifalcate dorsal fin, small flippers and lateral stripe were

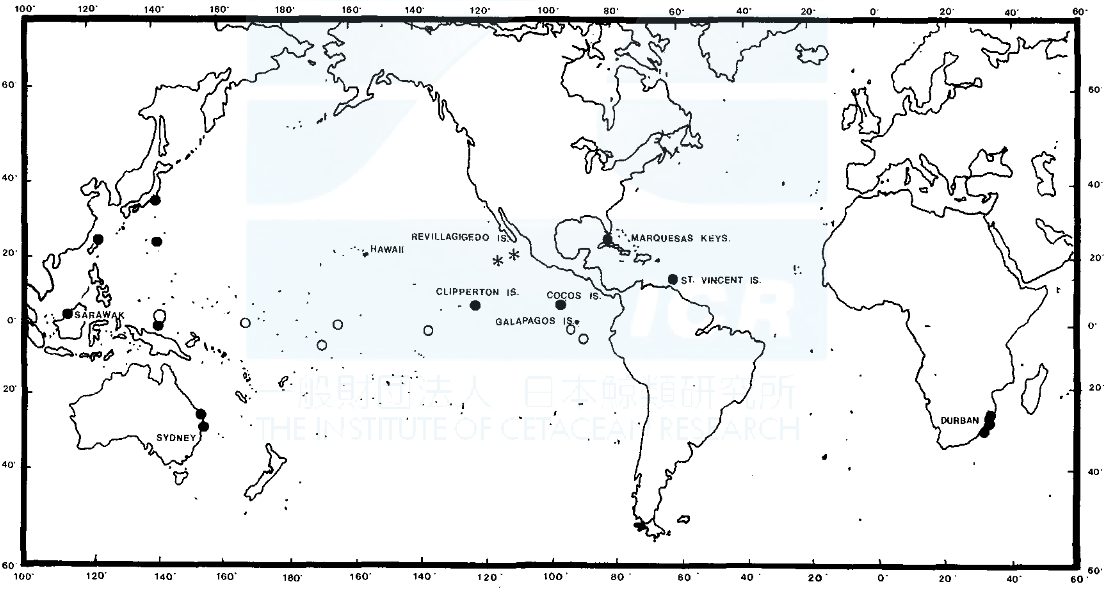


Fig. 1. Records of occurrence of *Lagenodelphis hosei*. Black circles are strandings or captures and white circles are sightings in the published records. Asterisks represent present records.

---

* *Laboratorio de Vertebrados, Facultad de Ciencias, UNAM, Apdo. Postal No 70–572, 04510, Mexico, D.F., Mexico*

Sci. Rep. Whales Res. Inst.,
No. 38, 1987, 187–188

observed. The surface water temperature was 26°C, and the water depth was over 1,000 m.

The second was a group of 3 animals sighted by us on January 18, 1985, at 18°24'N, 114°23'W, 27 km off the nearest coast. The species was identified based on the same characteristics as of the first sighting. The surface water temperature was 25°C, and the water depth there was 3,100 meters.

These sightings represent the most boreal records of this species in the eastern Tropical Pacific.

We want to express our gratitude to Dr Nobuyuki Miyazaki for his help and constructive comments to the present note, and to M.A. de la Mora for drawing.

REFERENCES

CALDWELL, D.K., M.C. CALDWELL and R.V. WALKER, 1976. First records for Fraser's dolphin (*Lagenodelphis hosei*) in the Atlantic and the Melon-headed Whale (*Peponocephala electra*) in the western Atlantic. *Cetology*, 25: 1–3.

HERSH, S.L. and D.K. ODELL, 1983. A mass stranding of Fraser's dolphin from the Marquesas Keys, Florida. p.44. *In: Fifth Biennial Conference on the Biology of Marine Mammals. Abstracts*. November 27– December 1, 1983, Boston, Massachusetts. 112 pp.

LEATHERWOOD, S., R.R. REEVES, W.F. PERRIN and W.E. EVANS, 1982. Whales, Dolphins and Porpoises of the Eastern North Pacific and Adjacent Arctic Waters. A Guide to Their Identification. *NOAA Technical NMFS Circular 444*. 245 pp.

MIYAZAKI, N. and S. WADA, 1978. Fraser's Dolphin in the western North Pacific. *Sci. Rep. Whales Res. Inst.*, 30: 231–244.

PERRIN, W.F., P.B. BEST, W.H. DAWBIN, K.C. BALCOMB, R. GAMBELL and G.J.B. ROSS, 1973. Rediscovery of Fraser's dolphin (*Lagenodelphis hosei*). *Nature*, 241 (5388): 345–350.

TOBAYAMA, T., M. NISHIWAKI and H.C. YANG, 1973. Records of the Fraser's Sarawak dolphin (*Lagenodelphis hosei*) in the western North Pacific. *Sci. Rep. Whales Res. Inst.*, 25: 251–263.

THE SCIENTIFIC REPORTS OF THE WHALES RESEARCH INSTITUTE, TOKYO, JAPAN

NUMBER 1, JUNE 1948

Akiya, S. and S. Tejima. Studies on digestive enzyme in whale. 3–7

Akiya, S., Y. Ishikawa, S. Tejima, and T. Tanzawa. Studies on tryptase from a whale (*Balaenoptera borealis* L.). 8–10

Akiya, S., S. Tejima, and Y. Ishikawa. Studies on the utilization of whale meat by the use of pancreatic tryptase of whales. 11–14

Akiya, S. and F. Kobo. The test culture of some microorganisms with whale meat peptone. 15–16

Nakai, T. Chemical studies on the freshness of whale meat. I. Evaluation of freshness and changes in quantity of several kinds of nitrogen in whale meat following deterioration of freshness. 17–26

Nakai, T. Chemical studies on the freshness of whale meat. II. On comparison between whale meat and beef on deterioration of freshness and autolysis. 27–30

Tawara, T. On the simultaneous extraction of vitamin A-D and vitamin B_2 complex from the liver of a fin whale (Nagasu-Kujira, *Balaenoptera physalus* L.). 31–37

Tawara, T. Studies on whale blood. I. On the separation of histidine from whale blood. 38–40

Nakai, J. and T. Shida. Sinus-hairs of the sei-whale (*Balaenoptera borealis*). 41–47

NUMBER 2, DECEMBER 1948

Ogawa, T. and S. Arifuku. On the acoustic system in the cetacean brains. 1–20

Yamada, M. Auditory organ of the whalebone whales. (Preliminary report). 21–30

Nakai, T. Chemical studies on the freshness of whale meat. III. Effect of hydrogen-ion concentration on decrease in freshness and titration curve of whale meat with HCl and Na_2CO_2. 31–34

Ishikawa, S., Y. Omote, and Y. Soma. Analytical distillation of vitamin A in the whale liver oil. 35–41

Ishikawa, S., Y. Omote, and H. Kanno. Molecular distillation of sperm whale blubber oil. 42–45

Kaneko, A. Molecular distillation of fin whale liver oil. 46–50

Akiya, S. and K. Takahashi. Determination of tryptophane in whale meat. 51–54

Ishikawa, Y. and S. Tejima. Protein digestive power of sperm whale pancreatic enzyme. 55–60

Tsukamoto, S. Experiment on digestion of whale meat by koji-mould. 61–66

NUMBER 3, FEBRUARY 1950

Ogawa, T. and T. Shida. On the sensory tubercles of lips and of oral cavity in the sei and the fin whale. 1–16

Ohe, T. Distribution of the red marrow in bones of the fin whale. 17–22

Hosokawa, H. On the cetacean larynx, with special remarks on the laryngeal sack of the sei whale and the aryteno-epiglottideal tube of the sperm whale. 23–62

Akiba, T., T. Tsuchiya, M. Umehara, and Y. Natsume. Bacteriological studies on freshness of whale meat. (Report No. 1). 63–70

Ishikawa, Y. Protein digestive power of sperm whale pancreatic enzyme. II. 71–78

Mori, T. and M. Saiki. Properties of fats and oils contained in various parts of a sperm whale body. 79–84

Tawara, T. and R. Fukazawa. Studies on kitol. I. Preparation of kitol from whale liver oil. 85–88

Tawara, T. and R. Fukazawa. Studies on kitol. II. Influence of kitol fraction on the determination of the International Unit of Vitamin A. 89–91

Tawawa, T. and R. Fukazawa. Studies on kitol. III. The effect of sunlight, air and heat on the vitamin A and kitol fractions. 92–95

NUMBER 4, AUGUST 1950

NUMBER 5, JUNE 1951

NUMBER 6, DECEMBER 1951

NUMBER 7, JULY 1952

NUMBER 8, JUNE 1953

NUMBER 9, JUNE 1954

Fujino, K. On the body proportions of the fin whales (*Balaenoptera physalus* (L)) caught in the northern Pacific Ocean (I) (Preliminary report). 121–163

Nishiwaki, M., T. Hibiya and S. Kimura. On the sexual maturity of the sei whale of the Bonin waters. 165–177

Uda, M. Studies of the relation between the whaling grounds and the hydrographical conditions (I). 179–187

NUMBER 10, JUNE 1955

Hosokawa, H. Cross-sections of a 12-mm. dolphin embryo. 1–68

Nemoto, T. White scars on whales (I) Lamprey marks. 67–77

Omura, H. and T. Nemoto. Sei whales in the adjacent waters of Japan. III. Relation between movement and water temperature of the sea. 79–87

Omura, H., K. Fujino and S. Kimura. Beaked whale *Berardius bairdi* of Japan, with notes of *Ziphius cavirostris*. 89–132

Fujino, K. On the body weight of the sei whales located in the adjacent waters of Japan (II.) 133–141

Nishiwaki, M. On the sexual maturity of the Antarctic male sperm whale (*Physeter catodon* L.). 143–149

Ohta, K., T. Watarai, T. Oishi, Y. Ueshiba, S. Hirose, T. Yoshizawa, Y. Akikusa, M. Satô and K. Okano, Composition of fin whale milk. 151–167

NUMBER 11, JUNE 1956

Omura, H. and H. Sakiura. Studies on the little piked whale from the coast of Japan. 1–37

Nishiwaki, M., T. Hibiya and S. Kimura. On the sexual maturity of the sperm whale (*Physeter catodon*) found in the North Pacific. 39–46

Fujino, K. On the body proportions of the sperm whales (*Physeter catodon*). 47–83

Fujino, K. On the serological constitution of the fin whales II. Further studies on blood groups. 85–98

Nemoto, T. On the diatoms of the skin film of whales in the northern Pacific. 99–132

Hoshina, T. and Y. Sugiura. On a skin disease and a nematode parasite of a dolphin, *Tursiops truncatus* (Montagu, 1821). 133–138

Iwai, E. Descriptions on unidentified species of dibranchiate cephalopods. I. An oegopsiden squid belonging to the genus *Architeuthis*. 139–151

Iwai, E. Descriptions on unidentified species of dibranchiate cephalopods. II. A cranchiidae squid of the genus *Taonius*. 153–161

Uda, M. and K. Nasu. Studies of the whaling grounds in the northern sea-region of the Pacific Ocean in relation to the meteorological and oceanographic conditions. (Part I). 163–179

Kimura, S. and T. Nemoto. Note on a minke whale kept alive in aquarium. 181–189

Ishikawa, Y. A characteristic property of whale oils concerning the absorption of gases. I. On the absorption of carbon dioxide by whale oils. 191–213

NUMBER 12, JUNE 1957

Omura, H. Osteological study of the little piked whale from the coast of Japan. 1–21

Nishiwaki, M. Age characteristics of ear plugs of whales. 23–32

Nemoto, T. Foods of baleen whales in the northern Pacific. 33–89

Nasu, K. Oceanographic conditions of the whaling grounds in the waters adjacent to Aleutian Islands and the Bering Sea in summer of 1955. 91–101

Kimura, S. The twinning in southern fin whales. 103–125

Ichihara, T. An application of linear discriminant function to external measurements of fin whale. 127–189

NUMBER 13, SEPTEMBER 1958

NUMBER 14, SEPTEMBER 1959

Fujino, K. and John E. Cushing. Blood typing of dried whale erythrocytes with ^{131}I labelled antibody. 101–106

Ichihara, T. Formation mechanism of ear plug in baleen whales in relation to glove-finger. 107–135

Nasu, K. Surface water condition in the Antarctic whaling Pacific area in 1956–57. 137–143

Ohsumi, S. (Kimura). A deformed fin whale foetus. 145–147

Nemoto, T. Food of baleen whales with reference to whale movements. 149–290

Yamada, M. and F. Yoshizaki. Osseous labyrinth of cetacea. 291–304

Nakai, T. Distribution of amino acid in proteins from various parts of whale body. 305–326

NUMBER 15, NOVEMBER 1960

Nishiwaki, M. Ryukyuan humpback whaling in 1960. 1–16

Ohsumi, S. Relative growth of the fin whale, *Balaenoptera physalus* (Linn.). 17–84

Fujino, K. Immunogenetic and marking approaches to identifying subpopulations of the North Pacific whales. 85–142

Nasu, K. Oceanographic investigation in the Chukchi Sea during the summer of 1958. 143–158

Tokita, K. and ECG Research Group. Electrocardiographical studies on bottlenosed dolphin (*Tursiops truncatus*). 159–165

NUMBER 16, MARCH 1962

Omura, H. Bryde's whale occurs on the coast of Brazil. 1–5

Omura, H. Further information on Bryde's whale from the coast of Japan. 7–18

Nishiwaki, M. Ryukyuan whaling in 1961. 19–28

Nemoto, T. A secondary sexual character of fin whales. 29–34

Omura, H., M. Nishiwaki, T. Ichihara and T. Kasuya. Osteological note of a sperm whale. 35–45

Ichihara, T. Prenatal dead foetus of baleen whales. 47–60

Nishiwaki, M. *Mesoplodon bowdoini* stranded at Akita Beach, Sea of Japan. 61–77

Nishiwaki, M. Observation on two mandibles of *Mesoplodon*. 79–82

Sinclair, John. An early dolphin embryo (*Stenella caeruleoalbus*) in serial sections. 83–87

Nemoto, T. Food of baleen whales collected in recent Japanese Antarctic whaling expeditions. 89–103

Uda, M. Subarctic oceanography in relation to whaling and salmon fisheries. 105–119

NUMBER 17, FEBRUARY 1963

Nishiwaki, M., S. Ohsumi and T. Maeda. Change of form in the sperm whale accompanied with growth. 1–14

Ohsumi, S., T. Kasuya and M. Nishiwaki. The accumulation rate of dentinal growth layers in the maxillary tooth of the sperm whale. 15–35

Ichihara, T. Photometric method for counting laminae in ear plug of baleen whale. 37–48

Yoshikawa, T. and T. Suzuki. The lamination of the masseter of the humpback whale. 49–52

Fujino, K. Intra-uterine selection due to maternal-foetal in compatibility of blood type in the whales. 53–65

Cushing, John E., K. Fujino and N. Calaprice. The Ju blood typing system of the sperm whale and specific soluble substances. 67–77

Nemoto, T. New records of sperm whales with protruded rudimentary hind limbs. 79–81

Nemoto, T. and K. Nasu. Stones and other aliens in the stomachs of sperm whales in the Bering Sea. 83–91

Nishiwaki, M. Taxonomical consideration on genera of *Delphinidae*. 93–103

Nasu, K. Oceanography and whaling ground in the subarctic region of the Pacific Ocean. 105–155

NUMBER 18, MARCH 1964

NUMBER 19, APRIL 1965

NUMBER 20, SEPTEMBER 1966

Tsuyuki, H. and S. Itoh. Studies on the oils contained in blubber of a southern elephant seal. 213–221

NUMBER 21, JUNE 1969

Omura, H., S. Ohsumi, T. Nemoto, K. Nasu and T. Kasuya. Black right whales in the North Pacific. 1–78

Nishiwaki, M. and Y. Hasegawa. The discovery of the right whale skull in the Kisagata shell bed. 79–84

Ohsumi, S. Occurrence and rupture of varginal band in the fin, sei, and blue whales. 85–94

Hosokawa, H., S. Igarashi, T. Kamiya and K. Hirosawa. Morphological characteristics and myelinization of acoustic system in the dolphins (*Stenella caeruleoalba*). 95–123

Mol, T. and P.J.H. van Bree. A short contribution to the history of whaling in Japan during the 17th century. 125–129

Tsuyuki, H. and S. Itoh. Fatty acid composition of finless porpoise oil. 131–135.

Tsuyuki, H. and S. Itoh. Fatty acid composition of many toothed pilot whale oil. 137–141

NUMBER 22, JUNE 1970

Omura, H., T. Ichihara and T. Kasuya. Osteology of pygmy blue whale with additional information on external and other characteristics. 1–27

Nishiwaki, M. and T. Kasuya. Recent record of gray whale in the adjacent waters of Japan and a consideration on its migration. 29–37

Kasuya, T. and D. W. Rice. Note on baleen plates and on arrangement of parasitic barnacles of gray whale. 39–43

Nishiwaki, M. and T. Kasuya. A Greenland right whale caught at Osaka Bay. 45–62

Nasu, K. and Y. Masaki. Some biological parameters for stock assessment of the Antarctic sei whale. 63–74

Ohsumi, S., Y. Masaki and A. Kawamura, Stock of the Antarctic minke whale. 75–125

Kawamura, A. Food of sei whale taken by Japanese whaling expeditions in the Antarctic season 1967/68. 127–152

Nemoto, T. and K. I. Yoo. An amphipod, *Parathemisto gaudichaudii* as a food of the Antarctic sei whale. 153–158

Tobayama, T., S. Uchida and M. Nishiwaki. Twin foetuses from a blue white dolphin. 159–162

Machida, S. A sword-fish sword found from a North Pacific sei whale. 163–164

Tsuyuki, H. and S. Itoh. Fatty acid components of black right whale oil by gas chromatography. 165–170

NUMBER 23, SEPTEMBER 1971

Ohsumi, S. Some investigations on the school structure of sperm whale. 1–25

Kawamura, A. Influence of chasing time to stomach contents of baleen and sperm whales. 27–36

Kasuya, T. Consideration of distribution and migration of toothed whales off the Pacific coast of Japan based upon aerial sighting record. 37–60

Omura, H. A comparison of the size of vertebrae among some species of the baleen whales with special reference to whale movements. 61–69

Omura, H., M. Nishiwaki and T. Kasuya. Further studies on two skeletons of the black right whale in the North Pacific. 71–81

Nishiwaki, M. and T. Kasuya. Osteological note of an Antarctic sei whale. 83–89

Hosokawa, H. and T. Kamiya. Some observations on the cetacean stomachs, with special considerations on the feeding habits of whales. 91–101

Lugassy, A. A., E. Korostoff and J. L. Rabinowits. Influence of incremental lines upon the compressive strength of sperm whale dentin. 103–110

NUMBER 24, NOVEMBER 1972

NUMBER 25, SEPTEMBER 1973

NUMBER 26, NOVEMBER 1974

NUMBER 27, SEPTEMBER 1975

NUMBER 28, OCTOBER 1976

waters. 129–135

Yamasaki, F., H. Satomi and T. Kamiya. An observation on the papillary projections at the lingual margin in the striped dolphin. 137–140

Kasuya, T. and N. Miyazaki. An observation of epimeletic behavior of *Lagenorhyncus obliquidens*. 141–143

Kawakami, T. Squids found in the stomach of sperm whales in the northwestern Pacific. 145–151

Leung, Y. M. Life cycle of *Cyamus scammoni* (Amphipoda: Cyamidae), ectoparasite of gray whale, with a remark on the associated species. 153–160

Kagei, N., T. Tobayama and Y. Nagasaki. On the helminthum of Franciscana, *Pontoporia blainvillei*. 161–166

Tsuyuki, H. and S. Itoh. Fatty acid component of lipid of *Euphausia superba*. 167–174

Naito, Y. The occurrence of the phocid seals along the coast of Japan and possible dispersal of pups. 175–185

Naito, Y. and M. Oshima. The variation in the development of pelage of the ribbon seal with reference to the systematics. 187–197

NUMBER 29, DECEMBER 1977

Kasuya, T. Age determination and growth of the Baird's beaked whale with a comment on the fetal growth rate. 1–20

Miyazaki, N. On the growth and reproduction of *Stenella coeruleoalba* off the Pacific coast of Japan. 21–48

Kawamura, A. On the food of Bryde's whales caught in the South Pacific and Indian Oceans. 49–58

Herman, L. M. and R. C. Antinoja. Humpback whales in the Hawaiian breeding waters: population and pod characteristics. 59–85

Aminul Haque, A.K.M., M. Nishiwaki, T. Kasuya and T. Tobayama. Observations on the behaviour and other biological aspects of the Ganges susu, *Platanista gangetica*. 87–94

Yamasaki, F., S. Komatsu and T. Kamiya. A comparative morphology of anal tonsils in Platanistidae. 95–100

Nemoto, T., R. L. Brownell, Jr. and T. Ishimaru. *Coconeis* diatom on the skin of Franciscana. 101–105

Castello, H. P. Food of a killer whale: Eagle sting-ray, *Myliobatis* found in the stomach of a stranded *Orcinus orca*. 107–111

Nishiwaki, M. and A. Sasao. Human activities disturbing natural migration routes of whales. 113–120

Yoshida, K., N. Baba, M. Oya and K. Mizue. On the formation and regression of corpus luteum in the northern fur seal ovaries. 121–128

Abe, H., Y. Hasegawa and K. Wada. A note on the air-sac of ribbon seal. 129–135

Kawamura, A. and T. Furuno. On the northern extremes of pack ice observed by whaling vessels in the summer of the Antarctic seasons 1957/58–1962/63. 137–141

NUMBER 30 DECEMBER 1978

Kasuya, T. The life history of Dall's porpoise with special reference to the stock off the Pacific coast of Japan. 1–64

Miyazaki, N. and M. Nishiwaki. School structure of the striped dolphin off the Pacific coast of Japan. 65–116

Clarke, R., A. Aguayo L. and S. B. del Campo. Whale observation and whale marking off the coast of Chile in 1964. 117–178

Miyazaki, N. and S. Wada. Observation of cetacea during whale marking cruise in the western tropical Pacific, 1976. 179–196

Goodall, R. N. P. Report on the small cetaceans stranded on the coasts of Tierra del Fuego. 197–232

Miyazaki, N. and S. Wada. Fraser's dolphin, *Lagenodelphis hosei* in the western North Pacific. 231–244

Nemoto, T. Humpback whales observed within the continental shelf waters of the eastern Bering Sea.

NUMBER 31, DECEMBER 1979

NUMBER 32, DECEMBER 1980

NUMBER 33, DECEMBER 1981

NUMBER 34, DECEMBER 1982

NUMBER 35, MARCH 1984

NUMBER 36, MARCH 1985

NUMBER 37, MARCH 1986

NUMBER 38, MARCH 1987

一般財団法人　日本鯨類研究所
THE INSTITUTE OF CETACEAN RESEARCH

SUBJECT INDEX

Taxonomy, Body proportion and Osteology

Anatomical and Histological study

Anal tonssil, Platanistidae 29: 95–100
Ovary 38: 75–89
Corpus luteum, *Callorhinus* 29: 121–128
Red bone marrow, *B. physalus* 3: 17–22
Embryo, *Stenella* 10: 1–68, 16: 83–87
Size of cell 13: 269–301
Epidermal cyst 31: 93–94

Body and organ weight

Eubalaena glacialis 13: 1–52, 21: 1–78
Balaenoptera musculus 3: 132–190, 4: 184–209, 125–183
B. musculus brevicauda 22: 1–27
B. physalus 3: 132–190, 4: 184–209, 7: 125–183
B. borealis 4: 1–13
B. edeni 10: 133–141
B. acutorostrata 22: 75–125
Megaptera noveangliae 7: 125–183, 14: 49–87
Physeter catodon 4: 1–13, 7: 125–183
Mesoplodon ginkgodens 24: 43–56
Lagenodelphis hosei 25: 251–263
Stenella attenuata 26: 157–226
S. coruleoalba 33: 27–67
Platanista gangetica 24: 87–108, 26: 265–270
Pontoporia blainvillei 26: 265–270
Mirounga leomina 20: 211–212
Dugong dugon 31: 129–132

Age determination

Crystalline lens 3: 132–190, 4: 115–161
Baleen plates 4: 162–183, 6: 133–152
Ear plug 12: 23–32, 14: 107–135, 17: 37–48, 18: 29–48
Baleen whales 7: 87–119
Balaenoptera physalus 13: 155–169, 18: 49–88, 20: 17–82
B. acutrostrata 37: 17–30
Physeter catodon 13: 135–153, 17: 15–35, 20: 1–16
Berardius bairdii 29: 1–20
Globicephala macrorhynchus 35: 57–91
Tursiops truncatus 32: 39–66
Stenella caeruleoalba 8: 133–146, 24: 57–79, 28: 73–106, 29: 21–48
S. attenuata 26: 157–226, 28: 73–106
Platanista gangetica 24: 87–108
Pontoporia blainvillei 31: 45–67
Collorhinus ursinus 17: 191–195
Dugong dugon 30: 301–310
Phoca kurilensis 33: 131–135

Population study

Balaena mysticetus 35: 1–16
Eubalaena glacialis 13: 1–52, 21: 1–78
Eschrichtius robustus 5: 71–79, 13: 201–205, 22: 29–37, 22: 39–43, 26: 1–14
Balaenoptera musculus 3: 132–190, 4: 27–113, 5: 91–167, 6: 73–131, 7: 125–183, 8; 147–213, 37: 155–165
B. physalus 3: 119–131, 3: 132–190, 4: 27–113, 5: 91–167, 6: 73–131, 7: 125–183, 8: 147–213, 11: 85–98, 12: 103–125, 13: 97–133, 13: 145–169, 15: 85–142, 17: 53–65, 18: 1–27, 18: 49–88, 34: 59–91, 37: 1–16
B. borealis 3: 119–131, 4: 27–113, 9: 89–103, 22: 63–74, 34: 59–91, 37: 47–60
B. edeni 3: 106–118, 3: 119–131, 9: 89–103, 9: 165–177, 10: 79–87, 14: 1–33, 16: 7–18, 28: 1–35, 30: 291–300, 34: 59–91
B. acutorostrata 11: 1–37, 11: 181–189, 19: 37–43, 22: 75–125, 37–59, 35: 17–38, 36: 1–34, 36: 35–39, 38: 47–73
Megaptera novaeangliae 4: 27–113, 6: 73–131, 7: 125–183, 8: 81–102, 8: 147–213, 14: 49–87, 15: 1–16, 16: 19–28, 29: 59–85, 30: 245–247, 37: 31–46
Physeter catodon 3: 106–118, 3: 119–131, 4: 27–113, 6: 153–165, 7: 121–124, 7: 125–183, 8: 147–213, 10: 143–149, 11: 39–46, 13: 135–153, 17: 15–35, 19: 1–35, 20: 1–16, 23: 1–25, 35: 39–46, 37: 167–172
Ziphius cavirostris 10: 89–132, 24: 35–41
Berardius 27: 111–137
B. bairdii 10: 89–132, 13: 213–214, 23: 111–122, 29: 1–20, 37: 61–83
Mesoplodon grayi 38: 107–115
Odontoceti 34: 1–47
Oreinus orca 13: 85–96
Globicephala macrorhynchus 35: 57–91
Globicephala macrorhynchus and *G. melaena* 27: 95–110, 36: 97–106
Stenella coeruleoalba 12: 191–192, 22: 159–162, 24: 57–79, 26: 227–243, 28: 73–106, 29: 21–48, 30: 65–115, 36: 107–138
S. attenuata 26: 157–226, 26: 226–243, 28: 73–106, 36: 107–138
Lagenorhynchus obliquidens 35: 129–157
Lagenodelphis hosei 30: 231–244
Phocoenoides dalli 30: 1–64, 35: 93–105, 35: 107–128, 36: 139–152, 37: 99–102, 38: 125–140
Neophocaena phocaenoides 31: 1–44
Cephalorhynchus commersonii 32: 149–154, 36: 153–164
Platanista gangetica 24: 87–108, 24: 109–115, 27: 81–94, 29: 87–94
Genetic, toothed whale 38: 141–163
Pontoporia blainvillei 31: 45–67
School, baleen whales 18: 89–110
Corpora albicantia 18: 123–148

Food and feeding

Whaling ground, environmental

Parasite, scar and skin disease

Chemical study

Krill 28: 167–174
Metal, *Dugong* 31: 125–128
Organochlorine compounds, *Dugong* 31: 125–126
Mesoplodon 38: 91–105

Miscellaneous

Hybrid 34: 109–121
Hind limb 8: 127–132, 12: 197–208, 17: 79–81, 19: 135–136
Hermaphroditism 8: 215–218
Siamese twins 38: 165–169
Prenatal dead fetus 16: 47–60
Malformed fetus 12: 193–195, 14: 145–147, 23: 139–140, 26: 259–263
Jacobson's organ 33: 125–126
Dicephaly fetus 33: 127–129
Albino 13: 207–209
Carotinoid body color 31: 97–99
Deformed jaw 13: 211–212, 31: 101–103
Vestigial teat 25: 277–278
Strange organ 27: 139–140
Electrocardiogram, *Tursiops* 15: 159–165
Electric shock 6: 177–185
Compressive strength, dentin 23: 103–110
Flattened head harpoon 6: 199–207
Sighting, Fraser's dolphin 38: 187–188

AUTHOR INDEX

THE SCIENTIFIC REPORTS OF THE WHALES RESEARCH INSTITUTE

昭和62年3月15日 印刷
昭和62年3月30日 発行

財団法人 日本捕鯨協会
編輯者 鯨類研究所
東京都江東区大島3丁目32番11号

編輯責任者 大村秀雄

印刷者 研究社印刷株式会社
埼玉県新座市野火止7-14-8

Printed by
Kenkyusha Printing Co.
Niiza-shi, Saitama 352

定価 4,000 円

Obtainable from Japan Publication Trading Co. Ltd.,
Sarugakucho, Chiyoda-ku, 1-2-1, Tokyo **101**