OBSERVATIONS ON THE OCCURRENCE AND BEHAVIOUR OF MINKE WHALES OFF THE COAST OF BRAZIL

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ABSTRACT

Field observations on minke whale morphology and physiology, the hydrography and topography of the Brazilian whaling ground and catch statistics from 1963 to 1982 are presented.

In the past 20 years, 12,494 minke whales have been taken off Brazil; only 3 were taken prior to 1963. Of those animals thought to be mature, females predominate in the catch (sex ratio, 2 females: 1 male). The population appears to remain at an exploitable level, although other species in the area have been considerably reduced.

The most important environmental conditions associated with the arrival of the minke whale in these tropical breeding grounds appear to be an optimum temperature of 26–27°C, day-length, reduced turbulence and an amiable surface current.

The behaviour of minke whales in response to various stimuli is described, and in particular their escape reactions, normal swimming speeds, co-ordinated swimming, affinity for mates and response to electric shocks.

INTRODUCTION

The minke whale, *Balaenoptera acutorostrata* (Plate I), is one of the most valuable marine mammals and is now the most common species of baleen whales in the Antarctic. Perhaps, due to its high yield of meat, relative to the rest of the components (Table 1), this species has become an important natural food resource and thus making the commercial whaling economically viable. Despite the claims that the minke whales are increasing in the Antarctic and now considerably more abundant as they were in 1910 (FAO, 1982), the exploitation of this species is regulated by IWC.

The minke whales taken off Brazil are considered as a part of the Area II management stock as defined by the IWC (0°–60°W) although there is some controversy over the applicability of these Areas (originally developed for blue and fin whales) to minke whales (IWC, 1981; 1982). However, much of the whaling would depend on natural population which varies both geographically and seasonally due to fluctuations in the rate of recruitment, mortality, including level of exploitation, growth rate, supply of planktonic krill as food (Ohsumi, Masaki and Kawamura, 1970; Ohsumi, 1979) and other causes of environmental factors. The catch statistics and catch per unit effort (CPUE) values over the past 20 years have

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TABLE 1. PRIMARY MATERIALS DERIVED FROM MINKE WHALES BASED ON ACCUMULATED FACTORY DATA

	Primary Products		Mean Weight (Kg/Whale)	%
1.	Meat		3,500	50.00
2.	Bone		1,260	18.00
3.	Cartilage		7	0.10
4.	Baleen plates		35	0.50
5.	Viscera:	Tongue	70	1.00
		Lungs	56	0.80
		Heart	21	0.30
		Kidneys	14	0.20
		Liver	63	0.90
		Stomach	14	0.20
		Intestine	63	0.90
6.	Blubber:	Dorsal	980	14.00
		Ventral	280	4.00
7.	Fins		42	0.60
8.	Lost Materials:	Blood etc at sea & factory	595	8.50
	Total		7,000	100.00

shown that the recruitment of this species in this area has remained very constant (Singarajah, 1983). With the advent of their breeding seasons, the minke whales arriving off Brazil are characteristically migratory, but the reasons to select this area as their breeding ground with such regularity are little understood.

Previous work on Brazilian minke whales is scanty (Williamson, 1975) and in this paper some aspects of minke whale biology are examined and the feasibility of continuing to exploit this species, together with some of the factors which may influence their migratory behaviour to the breeding ground off Brazil, are discussed.

MATERIALS AND METHODS

Field observations were made on board the catcher boat *Cabo Branco*. The normal operation pattern is that the boat leaves port at about 0330–0400 hours and returns to the factory with its catch at about 2230–2300 hours. Samples were taken both on board the catcher and at the factory though most measurements were made at the latter.

Past data on catches, lengths, reproductive state of the whales and information on stomach contents were kindly provided by SUDEPE (Superintendência Do Desenvolvimento Da Pesca) but some of the early data were missing or considered unreliable. The selected data, covering the whole period of minke whaling, were then transferred to an IBM computer for processing. Blood counts were made on board the catcher; most observations on behaviour patterns were confirmed by photographs, 35 mm colour slides and " Super 8 " cine films. Where necessary, appropriate parts of the whale, including entire baleen series, were transported to the laboratory for confirmation.

RESULTS

MORPHOLOGY

General appearance: The minke whales are the smallest of the rorqual whales which are well adapted for exclusively marine life. The body is somewhat less streamlined with triangular and dorsoventrally compressed head with a strong central ridge (see Plate I). The paired nostrils or " blow holes " are situated at the summit of the head about a metre from behind the tip of the snout which is about 8 cm shorter than the lower jaw. The blow holes are highly dilatable, especially when the animal gasps for breath, which otherwise remain closed by valve-like muscular folds of skin. The blow holes lead to a common median tubular canal about 50 cm long and 8 cm in diameter before leading to the tracheae.

The eyes are small, when compared to the huge body, and dorsolaterally placed. The eye-ball, on dissecting out, measures about 10 cm in diameter and well controlled by the powerful eye muscles and the optic nerve.

No external ear is visible, but the external ear aperture is a horizontal slit of extremely small size, about 5 mm long; normally remains closed by valvular folds within a narrow groove about 9 mm wide and 9 cm long. The centre of the aperture lies about 44 cm behind and on the same level as the eye. The external aperture leads into a complicated tubular canal which is about 6 mm in diameter and its inner surface is lined by fine longitudinal grooves and ridges and having the same colour as the skin, perhaps due to invagination of the skin. The canal, after running about 8 cm towards the tympanic bulla, leads into a " gizzard-like " structure which is often filled with bone marrow-like substance. The canal is now continued from the centre of one side of the muscular gizzard structure and extends until it establishes contact with the ear plug. The conical ear plug (Plate II) fits closely over a membranous, but strong, teat-like structure or " glove finger " (Plate III) and similarity in ear aperture was noticed in fin whales (Laws & Purves, 1956). The broad margin of the glove finger is attached to the hollow part and surrounded by the bony elements in the posterior-ventral region of the tympanic bulla. The canal, connecting the gizzard-like structure and the ear plug, is smooth and devoid of any ridge or groove and the grey colour is generally lacking. The ear bones or tympanic bullae are kidney-shaped, each about 9 cm long and 6 cm broad and weighing 450 g wet and 250 g dry weight. It is perhaps the hardest part of the whole body and is located just anteriodorsal to the foramen magnum and is separated from the external aperture by about 50 cm, on each side.

Ventral grooves: The ventral grooves run lengthwise and parallel to one another reaching anteriorly the chin and posteriorly close to the umbilicus, and extend laterally to a line between the eye and the flipper insertion. The median groove extends from the posterior end of the mandibular symphysis to just short of the umbilicus. This distance between the end of the median groove and the umbilicus has a mean of 84.9 cm, though it varies in the different sexes. However, the minimum distance between the umbilicus and the nearest 6th groove, on either

side of the median groove, remains constant in both sexes at 40.7 cm. This observation is in close agreement with measurement given by Ohsumi *et al.* (1970) to the Antarctic minke whales.

The number of ventral grooves of 660 animals (223 males and 437 females) were counted in 1979 and the mean number in both males and females was 47 (8). Da Rocha (1980) examined 220 males and 452 females and her values (for half the total number) were 21 for males (range 16–35) and 22 for females (range 15–31). The difference in the values may be due to differences in the method of counting; in da Rocha's study, the grooves were counted while the whales were lying in their sides on the flensing platform; while in the present study the grooves were counted while the whale was tied by its tail alongside the vessel, which facilitated the counting.

Skin and colour pattern: The skin is about 3 mm thick, smooth and slippery, supported by a thick layer of panniculus adiposus or the " blubber " from below (Fig. 1). The colour of the skin changes from dark grey on the dorsal aspect of the body to creamy white ventrally. The dark grey colour continues from tip of the snout to the dorsal surface of the caudal fluke, but dips down just below the eye and the dorsal end of the flipper insertion to form a small arch and again midway between the flipper and the caudal fluke thus forming a wider arch; the end

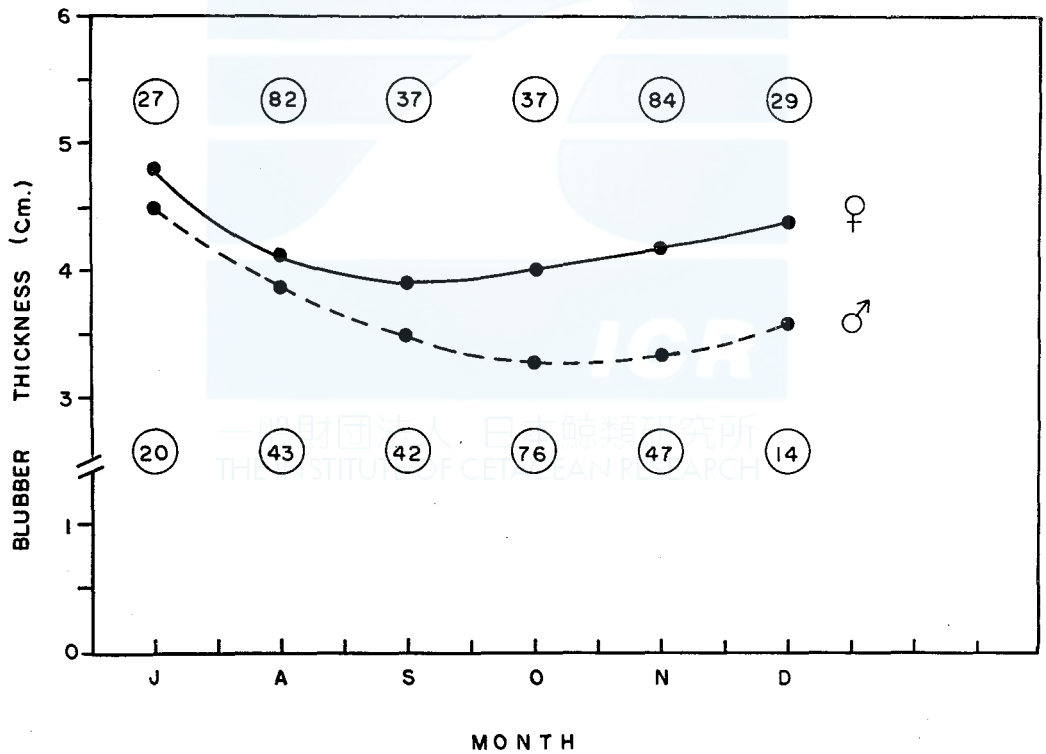

Fig. 1. Blubber thickness of males and females of the same whaling season. Numbers shown within circles represent mean sample.

of this second arch then curves up, like a broad inverted dorsal fin, to a median lateral line to merge with the dorsal surface of the fluke, on each side. The cream colour extends from chin to the caudal end, including the ventral surface of the fluke though the margins of the latter are usually edged with dark grey. The creamy bracket marks above the flipper are usually inconspicuous.

These colour patterns are essential in identifying the Antarctic stocks of minke whales, and seem to be of adaptive value. Usually with the slightest tilt of the body in the water, these peculiar colour patterns cause to reflect a bright bluish-green light, particularly when the whales swim up side down, which enables them to be easily recognized from a distance of about 800 meters.

Jaws: The two jaws are symmetrical, but the lower jaw is about 8 cm longer than, and protrudes beyond, the upper jaw (see Plate I). The upper jaw on each side measures, on an average, 186 cm between the tip of the snout and the gape of the mouth. But, beyond this point, the baleen laminae are carried in by a short segment, about 28 cm long, which curves inward and terminates bluntly as a triangular end. It is along this rear end that the greatest number of smaller baleen laminae are arranged in multiple rows.

Baleen plates: The strongly keratinized horny structures though called baleen plates, all are not truly plates. These horny structures are fused together at their top ends by interlaminar cement-like substance to form the " baleen series " (Plate IV) and suspended from each side of the upper jaw. The cemented part, which apparently represents the " gum ", varies in height and width according to the size of the plates inserted.

On the basic characteristics of size, shape and position, the plates could be grouped into mainly four categories:

1. The smallest rod-like structures in the anterior segment of the jaw, usually 8 in number, are arranged in double rows fairly close to each other. Each of these rod-like structures measures about one cm from below the line of fusion and provided with usually 4 very stiff filaments (Plate V A).
2. These are followed by the transitional plates which are small rectangular laminae and variable in number (Plate V B).
3. Next in series, occupying the major part of the jaw, are the larger plates, on an average 237 of them, arranged transversely at intervals of 0.4–1 cm between laminae. They are inserted by the smallest side and run undivided between lingual and labial margins in a single row (see Plate IV). However, the size of the individual plates varies and the largest plates are always confined to the mid-region while others, in gradually diminishing order of size, run towards both extremities of the jaw until they merge with the transitional laminae. These laminae are not typically triangular as commonly described, but rather combinations of inverted triangles and rectangles; the triangular part increases in size at the expense of rectangular part as the plates reach the mid-region of the jaw. The labial side of the largest plates measures about 40 cm and is smooth and devoid of any filaments, but on the lingual side only the hypotenuse, just below the rectangualr part, is frayed out into fine flexible

filaments (see Plate IV). The filaments also vary in number and length; the largest plate on the average consists of 380 filaments and the longest of these being 10 cm.

4. By contrast, the " plates " on the rear end of the baleen series are very much reduced in size, about 2 cm tall and rectangular type of laminae which are disproportionally numerous and grossly overlap and relatively difficult to count, unless the series is cut into segments. The bristles are less stiff and vary between 4 and 12 per plate (Plate V C).

Perhaps for this reason, Williamson (1973) concluded that for rorquals, it was too difficult to accurately count the rear plates and he called them, including the anterior rod-like plates, as " hairs ". Previous studies (van Utrech *et al.* 1978; Ohsumi *et al.* 1970; da Rocha, 1980) have clearly not included all the " hairs " in their counts. Best (1978) followed the procedure followed by Williamson (1983).

During the 1981 season, the baleen plates from 26 whales, 13 males and 13 females, were examined. Except for the colour pattern, no asymmetry was observed between the right and the left hand side of the blaeen series. The baleen laminae can be further divided into 3 on the basis of colour: (i) creamy white; (ii) creamy white with black edge and (iii) black (see Plates IV & V). The results are given in Table 2. The baleen series on the right side comprised an average of 111 all white plates, including the rod-like " plates " or " hairs ", at the anterior end, covering about 50 cm of the jaw. The plates in the mid-region comprised an average of 127 white/black plates. The posterior all black laminae include about 87 plates and about 2,050 smaller laminae. The pattern on the left hand side is the same but the proportion of all white plates is lower; on average there are only 63 all white plates covering 20 cm.

While the function of the colour difference on the two sides remains curious, but the enormous number of the smaller laminae, though look vestigeal in form, are adaptations that are functionally more evolved to increase the efficiency and rapidity perhaps during filter-feeding.

Flippers: Between 1979 and 1981, 1,745 animals, 619 males and 1126 females, were examined for flipper colouration. The flippers are elongated and more wing-like. There appeared to be no difference between the sexes; the flippers are about 1 m in length (Plate VI) and 30 cm wide, being light grey apart from a dark grey calyx shaped on the dorsal surface next to the body. No white stripes were observed in Brazilian minke stock, but the under margins turn out to be slightly

TABLE 2. MEAN NUMBER OF BALEEN LAMINAE FOR MINKE WHALES FROM BRAZIL

		Colour pattern		
		(i)	(ii)	(iii)*
Males	right	106.6	128.3	2131.5
	left	73.7	156.7	1913.0
Females	right	116.0	126.3	2051.0
	left	51.8	187.5	2112.0

* posterior black laminae are from approximate estimates.

whitish.

Flukes: In 1980, the flukes from 49 animals, 20 males and 29 females, were examined. The flukes were on average about 118 cm in length, and narrower in males than in females. The notch was about 7 cm deep and 4 cm at its widest part. A considerable strength is centered just anterior to the fluke, the tail-stock (Pl. VII).

Dorsal fin: A fleshy dorsal fin about 38 cm in height is situated about two thirds of the length of the body, more proximal to the flukes, and neatly curved (Pl. VIII) pointing caudally. Both dorsal fins and caudal flukes are devoid of any bony elements.

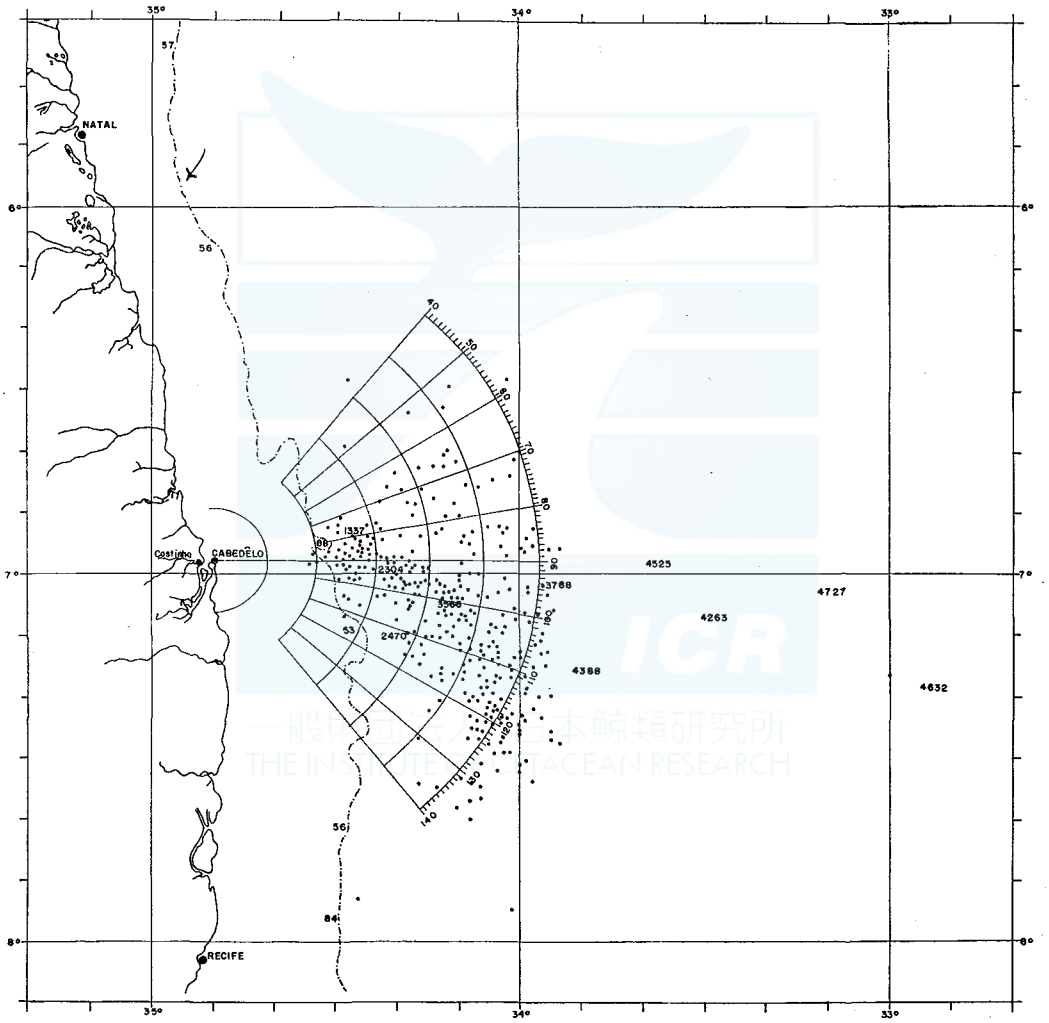

Fig. 2. Positions of minke whales caught during 1980 season, superimposed on tract chart. The broken line represents the continental edge of Brazil and the discrete numbers indicate depths in meters.

Hairs: Very few hairs were seen; usually on the rostrum and on the sides of the mandible. The hairs, particularly from the latter, arise from 7 small pits (each*

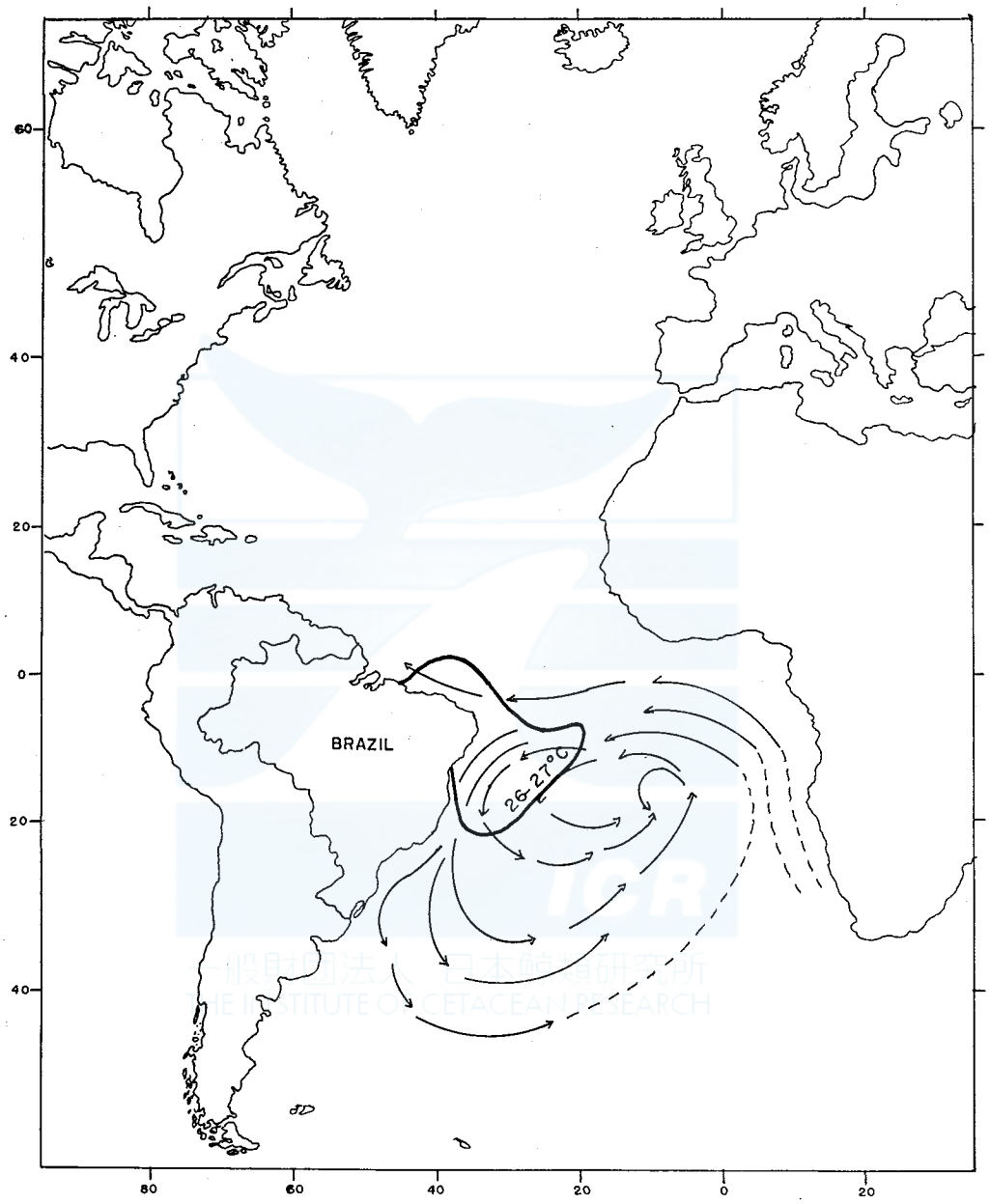

Fig. 3. Surface currents and an isothermic stretch of the whaling area off Brazil, in the Southwest Atlantic. Surface temperature distributions are based on 20 years daily recordings during each whaling season.

* Since this paper going to the press, asymmetrical disposition and variation of number of pits, particularly in a few females had been observed.

side). The hairs are creamy colour and about 4 cm tall and can be easily pulled out. *External sexual characteristics:* As in the other whale species, the vaginal orifice lies immediately anterior to the anus whereas the penal slit is clearly separated from the anus. In many females a creamy yellow substance was found in the vagina; which may have meant that they had recently copulated. Histological analysis is required to confirm this.

WHALING AREA

Topography and hydrography: The tract records of the whaling boats over several years reveal the whaling grounds off Brazil, which extend from 6°–8°10′S and 32°20′–35°00′W, to have remained very constant. The continental shelf extends to about 20 miles from the coast where it drops abruptly from 60 m to 3–4,000 m (Fig. 2). The sea floor in the shelf area is irregular and rocky. The most important hydrographic feature of the area is its proximity to the equatorial current systems. The south equatorial current flows westwards near the equator towards South America. On reaching the Brazilian coast it divides into two: most of the warm water moves northwards towards the Caribbean while the remainder turns south forming the weak Brazil current. This meets the cold Falkland current (Fig. 3). The whaling area is largely under the influence of the south equatorial current. From June, when it is particularly strong, to September,

TABLE 3. MONTHLY MEAN TMPERATURES (°C) BASED ON DAILY RECORDINGS FROM JUNE TO DECEMBER EACH YEAR OF THE WHALING AREA, LAT. 6°S-8°10'S AND LONG. 32°20'W-35°00'W.

Year	June	July	August	September	October	November	December
1963	*25.00	26.10	26.05	27.74	26.35	—	—
1964	27.23	27.12	27.74	27.00	26.35	—	—
1965	27.35	26.98	26.26	26.97	26.71	—	—
1966	27.70	27.14	26.64	26.15	27.01	26.71	—
1967	27.45	26.70	26.16	26.13	26.95	26.42	—
1968	26.10	26.41	26.01	26.01	26.80	27.02	—
1969	27.73	26.42	26.77	26.80	26.74	27.03	27.56
1970	27.20	26.80	26.40	26.40	26.90	27.90	27.00
1971	27.80	27.10	26.50	26.40	26.50	26.90	—
1972	28.00	27.60	27.10	26.90	27.00	27.30	27.80
1973	28.10	27.60	26.40	26.80	27.00	27.90	27.80
1974	27.80	27.60	26.40	26.80	27.00	27.90	27.80
1975	27.90	27.50	26.70	26.60	27.10	27.60	27.80
1976	27.30	26.90	26.60	26.60	27.00	27.40	—
1977	28.30	28.30	28.00	26.60	26.90	27.70	27.80
1978	—	—	26.90	27.00	27.40	27.70	27.80
1979	—	27.40	27.50	27.70	27.80	28.00	28.40
1980	28.50	27.80	27.70	27.40	27.60	27.90	28.10
1981	—	27.62	26.86	26.91	27.77	27.84	—
1982	—	27.89	27.38	27.25	27.53	27.70	27.83

* Based on only 4 days recordings.

TABLE 4. SOME ENVIRONMENTAL PARAMETERS OF THE WHALING AREA OFF THE COAST OF BRAZIL (LAT. 6°S-8°10'S AND LONG. 32°20'W-35°00'W), AVERAGE BASED ON *DAILY AND **MONTHLY RECORDINGS DURING 4 YEARS 1979-1982.

Month	Current velocity* Knot/Hr	Salinity** ‰	Oxygen** ml/l	Extinction** Coefficient
June	1.04	34.60	7.80	0.15
July	0.97	34.82	8.04	0.90
August	0.83	35.00	7.60	0.11
September	0.98	35.00	8.20	0.09
October	0.74	35.40	7.90	0.10
November	0.60	35.50	8.00	0.14
December	0.60	35.50	8.20	0.17

there is a strong southerly wind, which from mid-September until December becomes easterly.

Measurements of temperature, current velocity and salinity (Tables 3 and 4) reveal that the temperature and salinity remain fairly constant throughout the year. The velocity of the current decreases from 1.04 knots in June to 0.60 in December. Visibility under water improves considerably after July partly due to decrease in precipitation.

Biotic factors: Flying fish, *Exocoetus sp.*, are very common in the whaling grounds and schools of dolphins (12–20 animals) are also often seen. The whale louse, *Cyamus balaenopterae*, is found on minke whales (Ohsumi *et al.*, 1970). As the whales move into warmer waters, these ectoparasites fall off, probably in response to the warmer water, leaving small oval shaped scars which are about 5 cm×4 cm×4 cm. The large white shark, *Carchardon carcharias* and the hammerhead shark, *Sphyrna zygaena* are quite common in the whaling area, and often tear chunks of meat from the ventral side of dead, buoyed whales. Occasionally, Remoras or suckerfish and lampreys were seen to be attached towards the ventral side of the buoyed whales.

BEHAVIOUR

Behaviour during the hunt: Off Brazil, minke whales are commonly seen in small groups, 2–6 animals, and only rarely as singles or in larger groups, about 10–14 animals. The animals in pairs swim fairly close to one another (10–12 m) and sometimes very close. Undisturbed minke whales swam at about 8–10 knots; estimated by comparison with the velocity of the boat. Some authors (Kasuya *et al*, 1965; Mitchell, 1978) have reported " ship seeking " behaviour for minke whales although no such evidence was found in tropical waters and the minke whales off Brazil appeared to be indifferent to the presence of the vessels. Absence of " ship seeking " behaviour in the Antarctic minke whales also has been reported particularly during the last IWC/IDCR cruise (IWC, 1982).

During chasing, the whales can swim faster than the boat (17 knots) for short periods. However, after about 10–12 n miles they surface regularly and more

frequently, often cutting right across the bow of the ship, when, of course, they are easy to harpoon. When hit with the harpoon some animals attempt to escape with such force that they break the loop end of the whale line and swim rapidly (estimated at about 24 knots) away, usually following a fairly straight course and profusely bleeding which was traceable for more than a killometer. In all harpooned whales, it was noticed that the spray of water during blowing was mixed with blood. Direct evidence indicated that this was due largely to rupture of blood vessesls, even though an explosive charge in the lungs could not be ruled out.

Epimeletic behaviour: On one occasion, a pod of three whales, later found to be two females and one male, were pursued at full speed. A female was harpooned and was eventually brought to the ship, during which time the other two whales remained with the female, swimming in large circles around her. Within an hour the second female was harpooned and took out the full 700 m whale line, diving and circling in an attempt to escape. During this time the male swam close to the female, diving and blowing in synchrony. This continued for some 13 minutes before the female was brought to the side of the boat and killed by electrication. Even then the male made no attempt to escape and fell easy prey to the gunner.

Electric shocks: Most of the harpooned whales do not die instantly and are frequently winched back and shot a second or even a third time after which an

TABLE 5. COMPARISON OF CATCHES, SEX RATIOS AND PERCENTAGES OF MINKE WHALES FOR THE PERIOD FROM 1963 TO 1982.

Year	Male /	Female /	Indeterminate*	Total	Sex Ratio Male : Female	CHI Square/P Values
1963	—	2	—	2	— —	— —
1964	16	28	—	44	1 : 1.75	0.06<0.8
1965	26	42	—	68	1 : 1.62	0.73>0.5
1966	119	233	—	352	1 : 1.96	0.04<0.9
1967	154	334	—	488	1 : 2.17	0.69<0.5
1968	151	305	—	456	1 : 2.02	0.01>0.9
1969	204	413	—	617	1 : 2.02	0.02<0.9
1970	227	474	—	701	1 : 2.09	0.28<0.7
1971	330	570	—	900	1 : 1.70	4.01<0.5
1972	231	470	1	702	1 : 2.03	0.33>0.5
1973	210	440	—	650	1 : 2.10	0.15<0.7
1974	246	515	4	765	1 : 2.09	0.87>0.5
1975	380	658	1	1,309	1 : 1.73	5.21<0.1
1976	279	497	—	776	1 : 1.78	2.04>0.2
1977	330	664	6	1,000	1 : 2.01	0.01>0.9
1978	225	463	2	690	1 : 2.05	0.92<0.8
1979	242	496	1	739	1 : 2.05	0.09<0.8
1980	315	587	—	902	1 : 1.86	1.03<0.3
1981	244	504	1	749	1 : 2.25	0.17<0.7
1982	288	566	—	854	1 : 1.96	0.06<0.9
Total	4,217	8,261	16	12,494	1 : 1.95	

* Due to loss

electric shock is applied. Initially intermittent shocks are applied to which the whales respond violently. After these, a continuous current is applied for three minutes during which even the strongest whale becomes restrained, apart from some lashing of the flukes. This is soon followed by the drooping of the lower jaw. Perhaps, it might be safest for the crew to wait until the lower jaw droops before tying the whale to the ship.

CATCH STATISTICS FOR BRAZIL

Paiva (1961) and Williamson (1975) gave some details of catches from Brazil for the period of 1910, when whaling began, to 1974, but these include mostly the larger species. Prior to 1966, larger whales (humpbacks up to 1928 and then sei and Bryde's whales and occasional blue, fin and sperm whales) dominated the

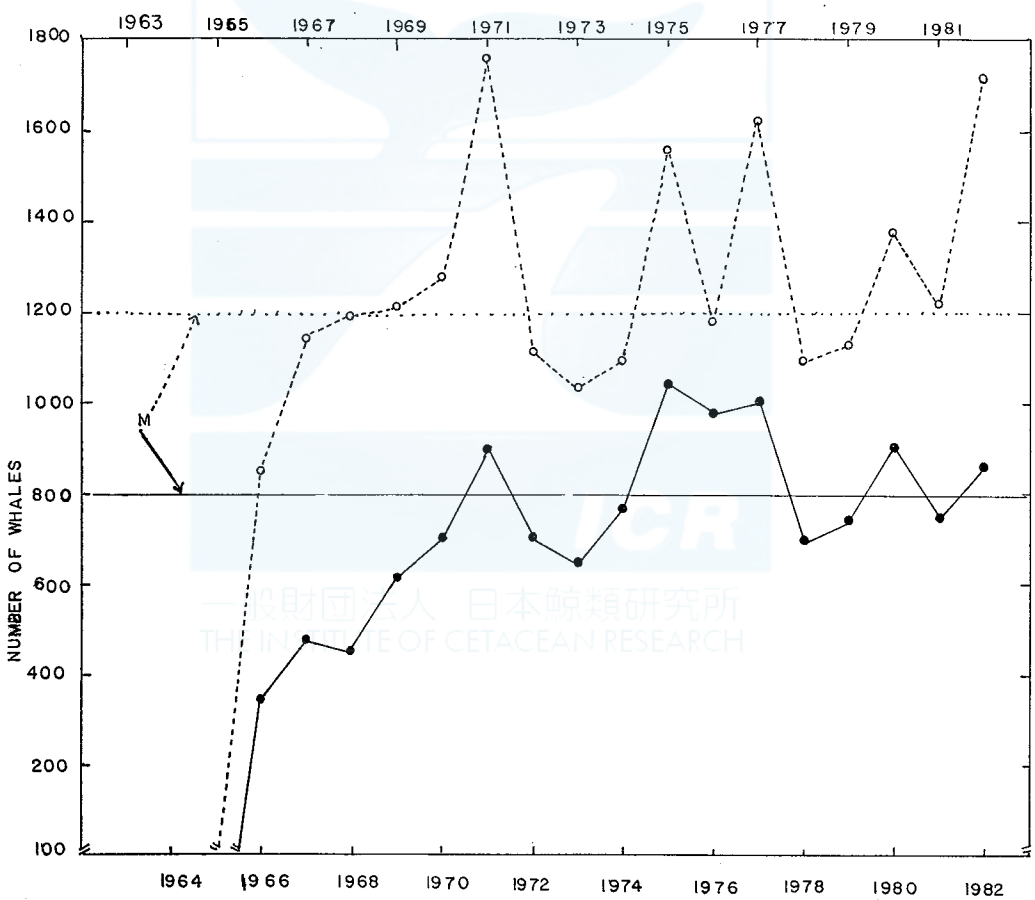

Fig. 4. The relationship between catch (●) and sighting (○); the pattern of minke whales caught fluctuates almost correspondingly with changes in population sighted. M indicates means.

catch. Only 3 minke whales were taken prior to 1963. However, catches of minke whales increased only during the last 20 years (Singarajah, 1983) while most of the others are now protected.

Table 5 gives details of Brazilian catches between 1963 and 1982. The season generally lasts from June to December but for a variety of reasons no whaling occurred in either of those months in 1967, 1968, 1971, 1976, 1978, 1979 or 1981. During the period 1963–1982, 12,494 minke whales have been caught: prior to 1963 3 were caught making a total for the area of 12,497.

Fig. 4 shows the number of minke whales sighted and the number of minke whales caught between 1963–1982.

SEX RATIO

Fig. 5 shows the catch composition by year and month for the greater period of minke whaling and the average lengths of males and females. There is a significant difference between the number of males and females in the catches and the overall ratio is 1 male: 1.95 females; not significantly different from 1:2. This remains fairly constant by month although the percentage of females is lowest at the beginning of the season (Fig. 5). This factor, along with the sex ratio in captured schools, often 1 male: 2 females or 2 males: 3+females, may suggest that minke whale are not monogamous.

DISCUSSION

Although a comprehensive anatomical description of southern minke whales has been given by Ohsumi *et al.*, (1970), the present study has provided additional information with respect to the whales off Brazil. Despite somewhat vestigeal in form and character, the omission by previous workers (Williamson, 1961; van Utrecht *et al*, 1962; Ohsumi *et al*, 1970; da Rocha, 1980) to include in the count of the very large number of the baleen plates of the posterior segment was perhaps solely due to their size. Nevertheless, these are true baleen plates and they could not be justifiable excluded.

Variation in flipper colour patterns have been described by several authors (Taylor, 1957; Williamson, 1959; Ohsumi *et al*, 1970; Doroshenkho, 1975; Best, 1978). Data from Brazilian operations show that a single flipper type, devoid of a white stripe, predominates. However, on rare occasions (e.g. in 1980 and 1981, about 0.2% of the annual catch) a second type, with a white stripe, was recorded. The animals were small, about 7 m, and Best (pers. commun.) informed me that " they might be a diminutive form of the species ".

The morphology of minke whales off Brazil and in the Antarctic and the temporal distribution of the whales strongly suggest that the whales migrate between these two areas. Data collected over several years on the distribution of minke whales off Brazil clearly show that they generally occur in a relatively small area ($<$15,000 n. miles^2). Their high density in this tropical habitat is further confirmed by the CPUE estimates.

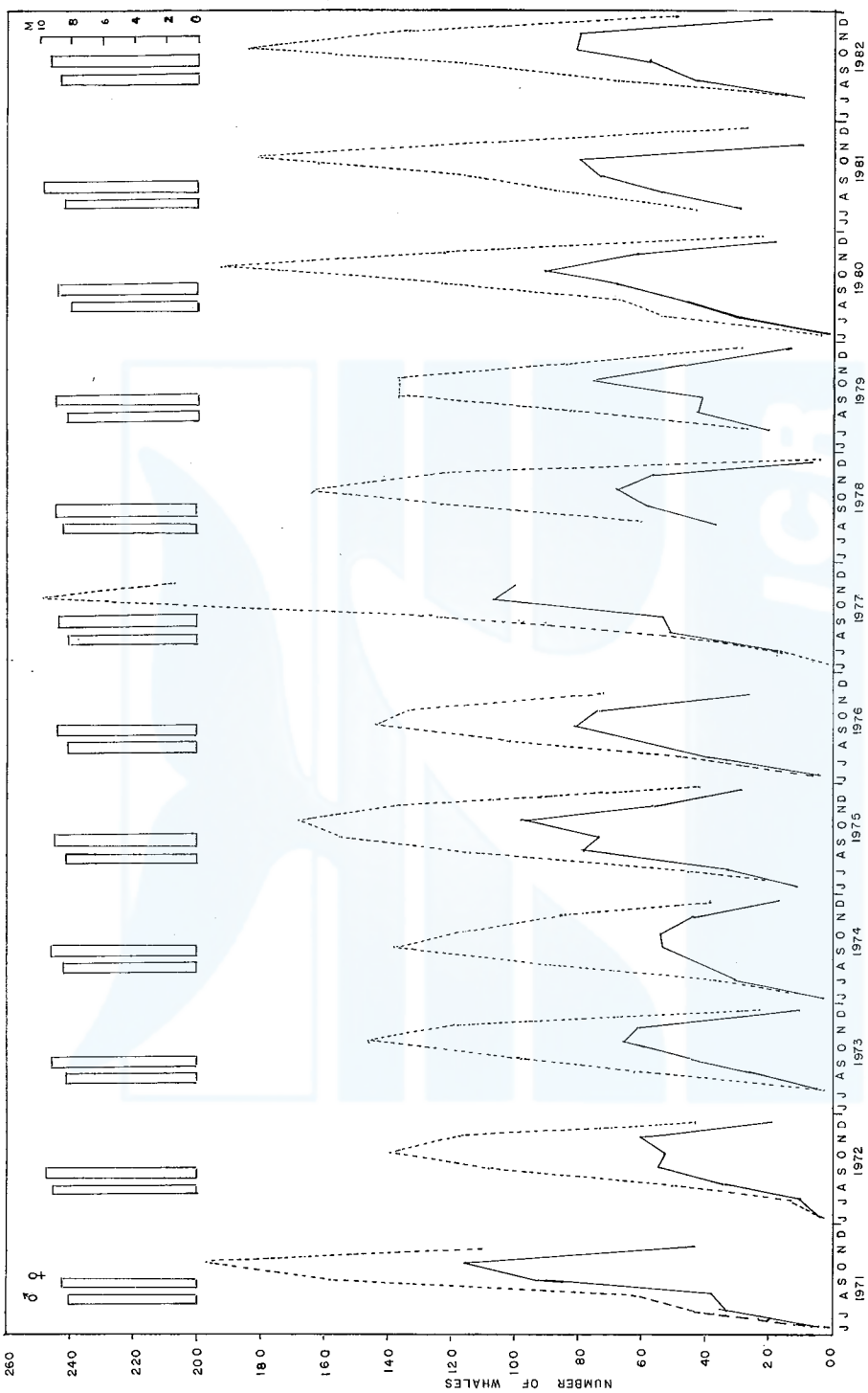

Fig. 5. Relationship between numbers of males (solid line) and females (broken line) minke whales taken monthly. Open histograms compare the mean lengths of males and females on yearly basis.

The concentration of the minke whales into this area for breeding is presumably a result of the physical and biotic characteristics of the environment. Temperature and perhaps day length seem likely to be important factors influencing the migrations of whales. Minke whales begin to arrive in the region in the latter part of June, although the peak months are September, October and November by which time:

1) precipitation has considerably diminished;
2) the strong SE wind has changed to a moderate E wind concomitant with reduced turbulence;
3) the water is more transparent;
4) the temperature has dropped very slightly (perhaps to an optimal level);
5) the surface current is less strong;

and these factors may influence the minke whales. However, it must be remembered that the first three points also have the practical effect on making the whales easier to see and so the increase in sightings may to some extent be due to this. In addition, the increasing numbers of whales from June to September may in fact have more to do with the conditions in the Antarctic which affect the rate of leaving there rather than the prevalent conditions on arrival off Brazil.

It is interesting to note that the testes from males which were caught in the peak period are generally larger than those taken earlier (Table 6 and Fig. 6). A similar trend is seen in ovary weights although the range is greater.

As yet, we have not found a satisfactory technique for estimating the age of the minke whales taken off Brazil: Christensen's (1980) method using the tympanic bullae was tried but found to be too tedious for routine samples; problems were also found with the reading of ear plugs, particularly of younger animals, and often the counts of the left and the right plugs were different. As a result of this we have no estimate of age at sexual maturity for the animals off Brazil.

Masaki (1979) examined age at sexual maturity in minke whales taken by Japanese expeditions in the Antarctic using four techniques: (i) the age (from ear plugs) at which 50% of the animals are sexually mature, i.e. have either at least one corpus luteum or albicans, or have one testis of at least 0.4 kg; (ii) the relationship between age (from ear plugs) and the number of ovulations; (iii) using length at sexual maturity and the growth curve (age from ear plug); (iv) from the transition phase of the ear plug. The results from all four methods suggested a female age at sexual maturity of about 6–7 years. Direct evidence for males was more limited due to the scarcity of immature animals in the catches and the need for further histological analyses to confirm to 0.04 kg criterion of Ohsumi *et al.* (1970). However, assuming that the transition phase in the ear plug was formed at sexual maturity then the age at sexual maturity for males was about 6 years. If the 0.4 kg criterion is true then almost all the males caught in Brazilian waters are mature (Table 6). Using the maturity criterion of technique 1, da Rocha (1980) estimated the lengths at maturity of males and females off Brazil to be about 25 ft and 26.5 ft respectively. This is slightly higher than Masaki's Area II values of 23.3 ft and 26.1 ft.

TABLE 6. FREQUENCY DISTRIBUTIONS OF WEIGHTS OF TESTES

Weight (g)	July		August		September	
	Left	Right	Left	Right	Left	Right
50					1	1
100	1	1	1	1		
150	2	1			1	
200	1	2			1	2
250			1	1	1	1
300			1	3	1	1
350	1	1	3	1		
400			1	2		
450			1			
500	1	1	4	4		
550			3	2		
600	1	2			2	1
650	1		1	1	1	
700	1		1	3	4	4
750					1	2
800		1	1	1	2	3
850				1		
900			2		1	1
950						
1,000	2	1	3	2	1	
1,100	1	2		2	4	8
1,200	2	1	2	2	2	1
1,300		1	2	1	3	1
1,400					2	3
1,500				1	1	1
1,600			2	1	2	1
1,700	1		1	2	1	1
1,800		2	3	2	2	1
1,900	2	1	1	1	1	1
2,000			1			3
2,100	1	1	1	4	1	1
2,200					1	2
2,300			3	1	1	
2,400	1	1	1			
2,500						
2,600	1					
2,700						
2,800		1	1	2		2
2,900			1		1	
3,000					2	1
3,200						
3,400						
3,600						
3,800						
4,000						
4,200						
4,400			1			
4,600				1		
Σ	20	20	43	42*	41*	42
Mean	1,052.5	1,100.0	1,296.5	1,207.5	1,237.8	1,242.9
Combined Mean	1,076.3		1,252.4		1,240.4	
Overall Mean=			1,428.53			

* 1 lost during flensing.

OF BRAZILIAN MINKE WHALES BASED ON 1979 SEASON

October		November		December	
Left	Right	Left	Right	Left	Right
2	2				
1	1				
2	1	1	1		
	1				
1					
		1	1		
2	3	1			
	1				
4	4		1		
2	1				
1	1	1	1		
3	1			1	
1					
4	6				
11	12	2	2	1	2
3	3	2	2		
2	2	1	1		
6	8	2	2	2	2
2	1	1	2	1	2
2	2	2	3	1	1
	2	4			
6	2	4	8	1	1
1	6	3	3	1	1
3	2	6	4	1	
	4	3	1	1	1
2	1	3	5		
1	2	2		1	
1		2	2		1
			1		
	1	1	1	2	1
1	1			1	2
1	2	2	2		
3	1	3	3		
1	1	2			
1					
1	1				
			1		
75	75	47	47	14	14
1,386.7	1,429.3	1,839.4	1,833.3	1,877.4	1,864.3
1,408.0		1,836.1		1,867.9	

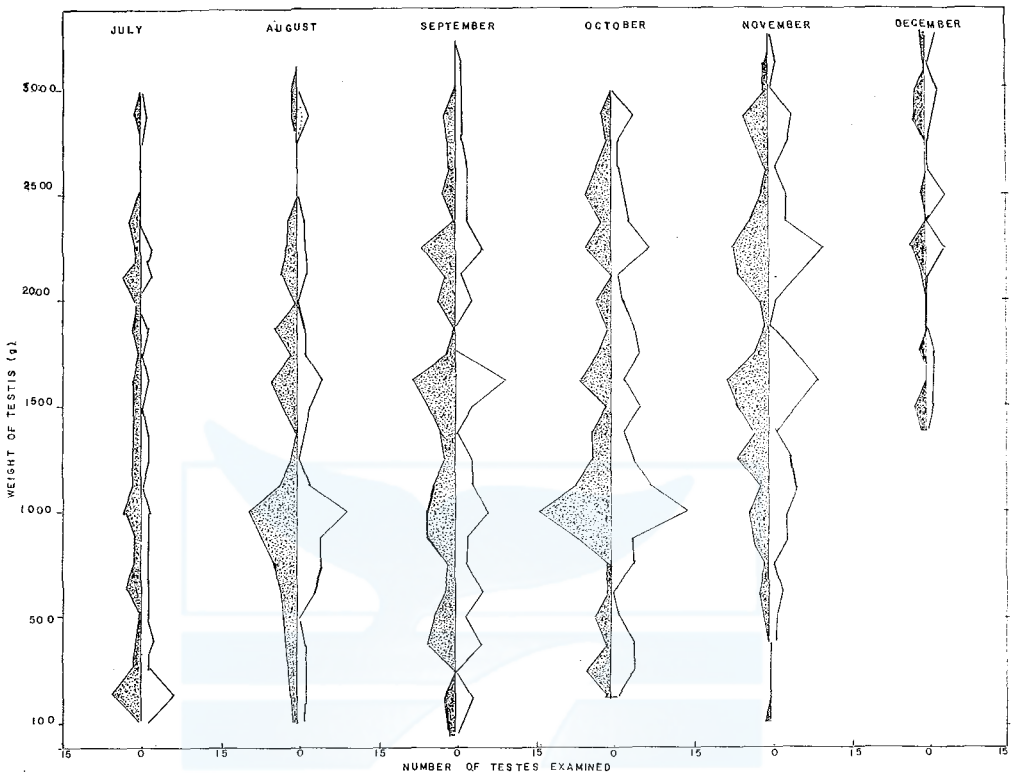

Fig. 6. Weight frequency histogram for the testes of minke whales caught off the coast of Brazil during the 1980 season.

Masaki (1979) estimated the gestation period for minke whales to be about 9 1/2 months, with the peak mating period in early to mid-October and the peak calving period in late July using the method of Laws (1959), and data from the whole Antarctic. If this is true, then if the waters off Brazil were calving grounds, one might expect to see large numbers of calves in the area. However this is not the case. This may be because the females calve elsewhere or because calving occurs much later in the season. If the latter is true then one might expect to find a high proportion of pregnant (near term) females in the catch in the early part of the season, decreasing as the season progresses. Unfortunately, there are few reliable records on pregnancy off Brazil to date.

Population estimates of minke whales in southern hemisphere is far from complete at the present; and there is no close agreement among previous estimates (Ohsumi *et al*, 1970; Williamson, 1975; Best, 1979; Chapman, 1979; Holt, 1980). Although minke whales in the Antarctic are claimed to be increasing (FAO, 1982), Watson & Riche (1981) place the population of southern minke whales at 150,000–300,000. However, the minke whales arriving off the coast of Brazil to breed are variations of the southern stock (Williamson, 1975), but no estimates on absolute population for the Southwest Atlantic has been worked out. Recent

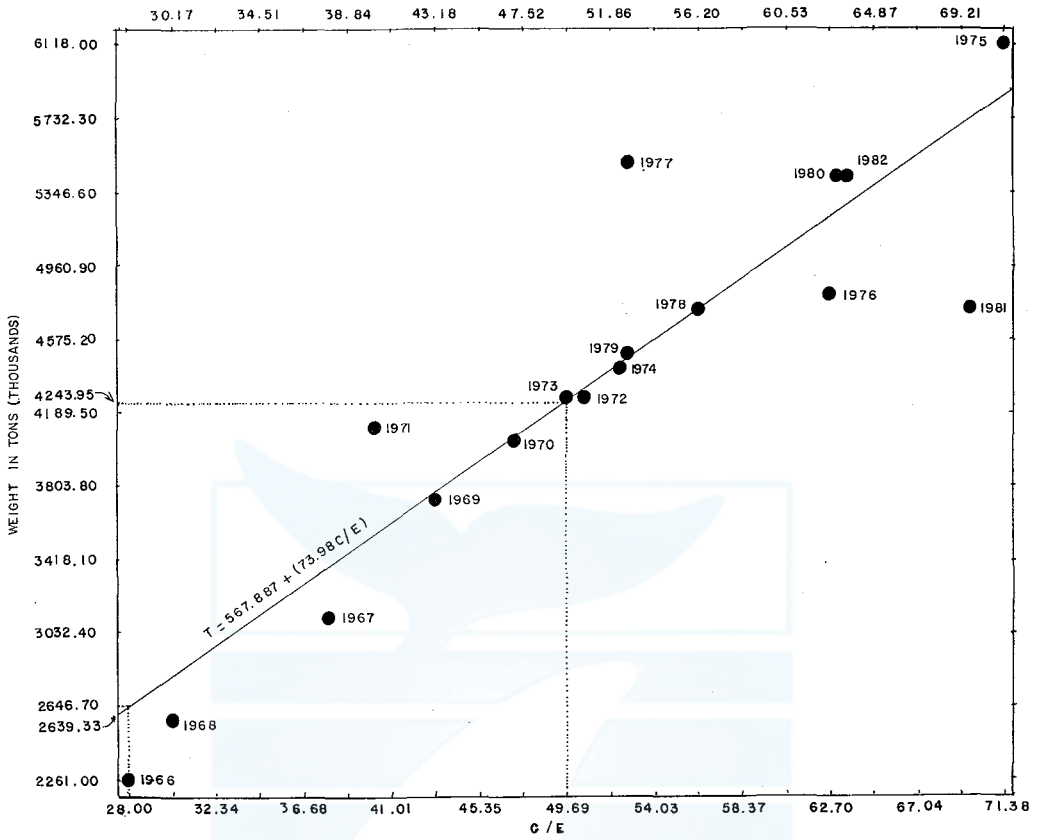

Fig. 7. Correlation between the catch per unit effort (C/E) and the abundance of minke whales. Regression line calculated from 17 years consistent data.

marking experiments to relate stock identity and estimates of its population have met with only limited success; of the 29 minke whales marked off the coast of Brazil (Butterworth & Best, 1982) none so far has been recaptured.

The regression line (Fig. 7) for the more consistent peak seasons, covering almost the entire minke whaling period from the Brazilian whaling ground, shows that the relationship between catch per unit effort and abundance is fairly constant with a few exceptions. The significant variablity in abundance particularly during 1966, 1971, 1977 and 1981 might be due to a variety of causes, the chief being operational and other factors peculiar to Brazil, including the quota system imposed by IWC.

Sex data, throughout the whaling period, both monthly and annual catch, show characteristically that the females far out number the males, and these observations are quite contrary to those reported in the Antarctic (Kasuya & Ichihara, 1965; Ohsumi *et al*, 1970). The reversal of the sex ratio of the same species in varying geographical conditions perhaps suggests the segregation of the sexually mature whales which may be associated with hormonal state of the individuals.

In respect of the sex ratio, the Brazilian minke whales resemble the population of the Arctic pattern where Jonsgard (1951) noted that the females numerically dominated the males.

Several lines of evidence indicate that the Brazilian minke whales could be regarded as spatial and temporal stock in a transient habitat, but their biotic potential or capacity to increase in population will very much depend on the limiting factors which prevail in their native relatively stable Antarctic habitat.

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EXPLANATION OF PLATES

PLATE I

Breathing and escape reaction of a female minke whale for harpoon shot. Also, note the difference of length between the lower and upper jaw and the triangular rostrum with the strong central ridge.

PLATE II

The ear-plugs which fit snugly upon the conical end of the "glove-finger"; the right and the left side plugs often vary considerably in size.

PLATF III—A & B

The pair of ear bones or tympanic bullae of the same female whale measuring 9.20 m body length. Macrophotography; the marker represents 1 cm. The surface view of the photograph is actually the vertical plane of the tympanic bullae, facing each other in the natural position, with their membranous "glove finger" pointing posterior and ventrally. A: inner aspect. B: outer aspect.

PLATE IV

A small segment of the baleen series just anterior to mid-region of the jaw. Note the colour pattern (black/white); the lingual margin of the hypotenuse of the triangular part of the plate is frayed out into fine flexible filaments. Note also the height of the cementation.

PLATE V

The different types of reduced baleen plates. A; anterior rod-like plates ("hairs"), B; the transitional rectangular laminae, C; the posterior reduced rectangular laminae (see text).

PLATE VI

The flipper, more like a wing and a calyx shaped mark on the dorsal surface next to the body. Note the distinct absence of stripes or patches on the flipper of the Brazilian minke whales.

PLATE VII

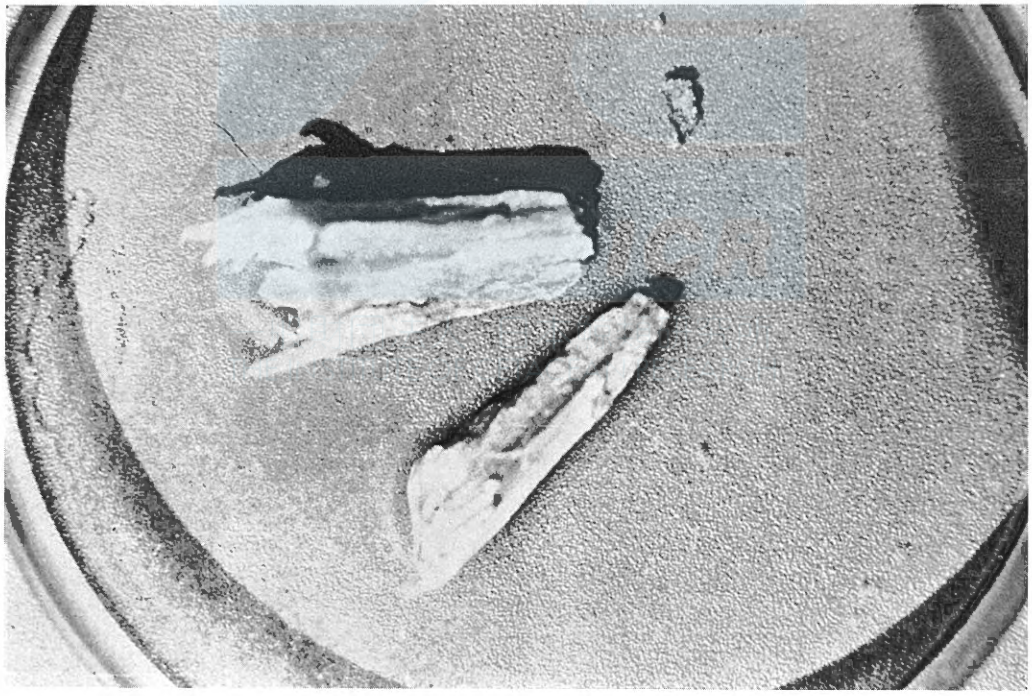
The fluke of a male which is usually narrower than that of the female. The whale strikes the tailstock in response to harpoon shot and in an atttempt to escape.

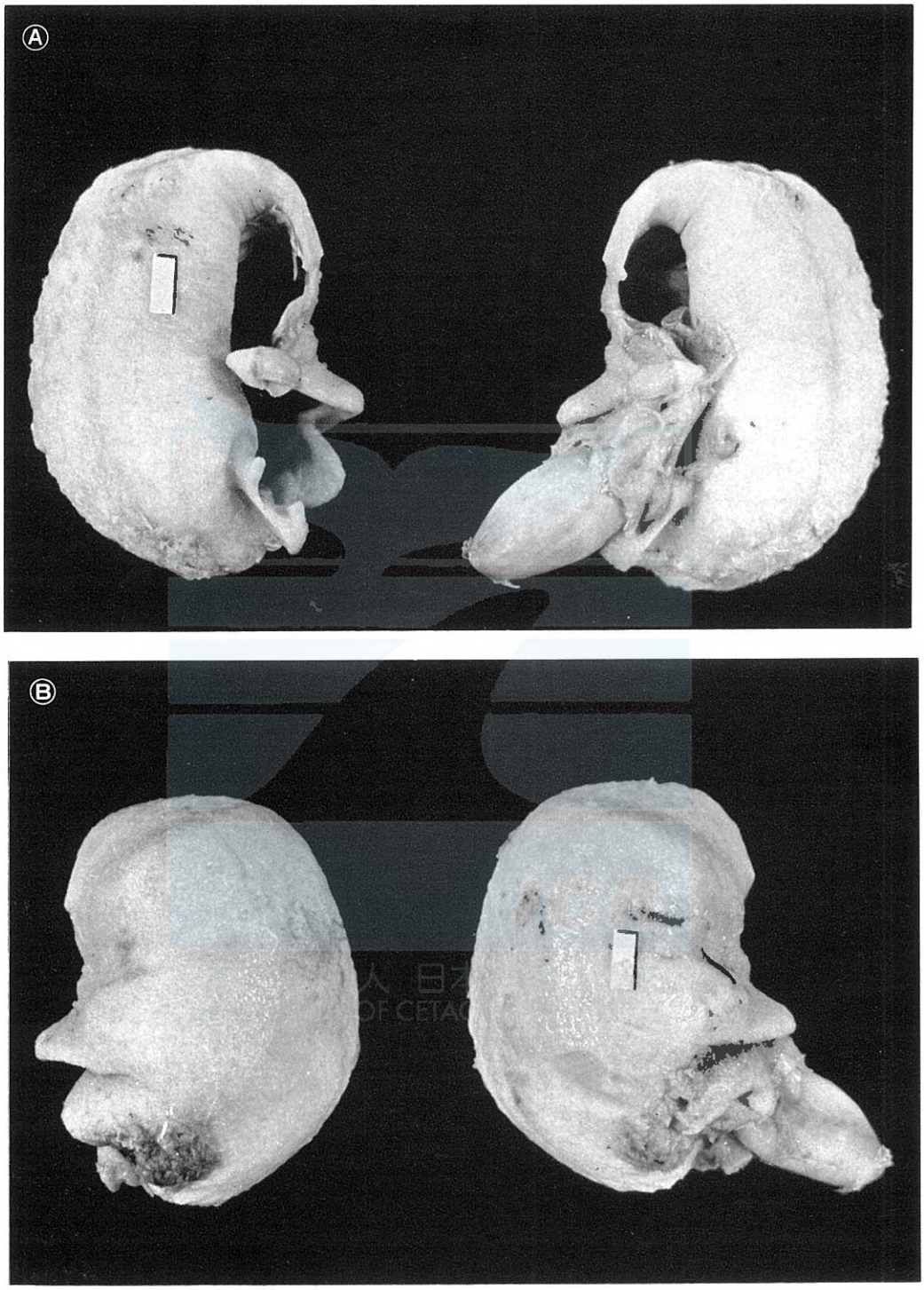
PLATE VIII

The dorsal fin; situated more toward the caudal end of the body.

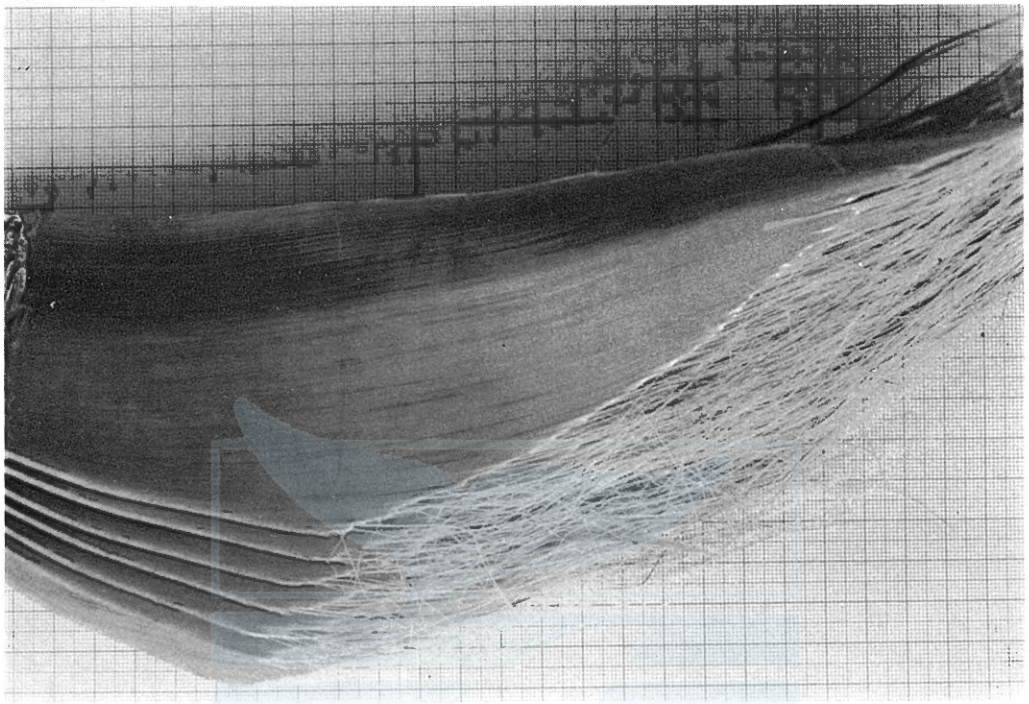
(PL. I)

(PL. II)




A
B

(PL. IV)



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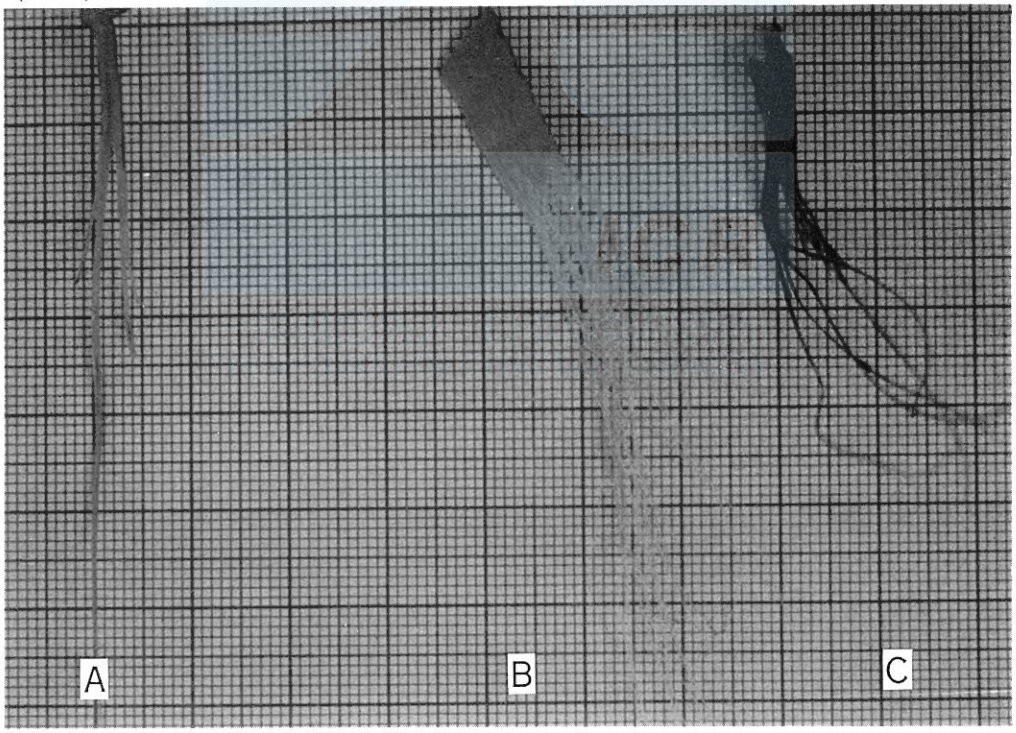
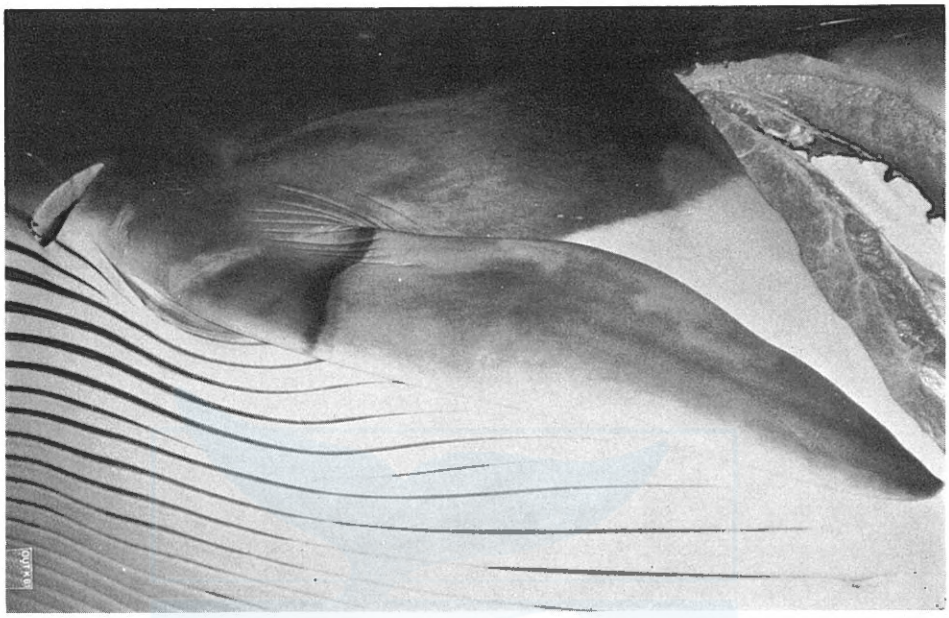


(PL. VI)



(PL. VII)