MINKE WHALES OFF BRAZIL

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ABSTRACT

Minke whales are the main catch off Costinha 7°S at the NE tip of Brazil. The whales congregate each September-October-November over the continental slope in water 27°C. About 700 whales are caught per year. All are of the southern hemisphere subspecies *Balaenoptera acutorostrata bonaerensis*.

Caught whales are lengths 7.5–10.7 metres (average 8.5 m) which correspond to ages 7–50 (average 15 years old). All the males and about 90% of the females are mature. In the catch females outnumber males 2 ♀♀: 1 ♂. No foetuses of visible size occur. Lactating females with calf are seldom seen.

Available data do not permit a firm conclusion regarding the length of the reproductive cycle. Some data suggest a one-year cycle, some data suggest a two-year cycle. Calves appear to be born in waters of intermediate temperature and intermediate latitude.

Minke whales are common off Brazil and Durban yet rare off west south Africa. Perhaps they migrate north mainly up the western side of the South Atlantic, unlike sei whales which migrate up both sides.

Suggestions for future research are made.

INTRODUCTION

Tropical whaling station winter catches are of special interest to biologists because they reveal what whales are doing during the reason in which mating and birth occur.

7°S from the equator is the whaling station of Costinha, at the NE tip of Brazil, near Joao Pessoa and 140 km north of Recife (Fig. 1). Brazil has been a member of the International Whaling Commission during 1951–66 and since 1973 and biological data on each whale killed have been supplied to the Bureau of International Whaling Statistics at Sandefjord since 1953. Some basic statistics on Costinha whale catches are given by Paiva (1961) and Paiva and Grangeiro (1965, 1970).

This report gives a general account of the Costinha whaling station and describes the catch of minke whales, which is now the main species caught. The data from Costinha are of exceptional interest because

- the season is the tropical winter
- catching occurs during six months unbroken period
- the effort is constant; one catcher all the time
- the catching area is the same all season long
- the minke whale stock is in virgin condition.

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Minke whales are caught in great numbers in the Antarctic and about 32,000 have been caught in the southern hemisphere since minke whale hunting began in earnest about ten years ago (Table 1).

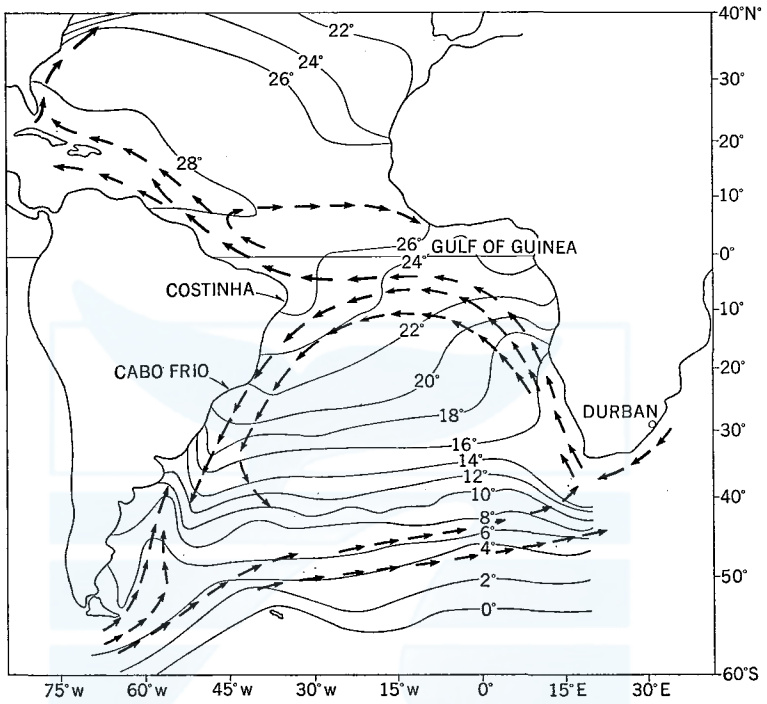

Fig. 1. Atlantic Ocean showing currents (arrows) and October water temperatures.

MATERIAL USED

This paper is based on data on whaling operations and whale catches off Costinha supplied through the kindness of the owners of the station, Compania de Pesca Norte do Brasil, Mr. Kiyohisa Kanda president and Mr. Issao Ishigami manager. The catcher gunner Captain Sato and station foreman Mr. Masahiro Saito supplied much information. Mr. Kanda visited Britain to discuss details with me and two British scientist friends of mine visited the whaling station briefly.

Each whale landed at Costinha has the following particulars recorded

- date killed
- position killed
- length in feet in straight line from snout tip to tail notch
- sex
- whether foetus of noticeable size is present
- stomach contents (in some seasons).

Blubber. The thickness of the blubber on the back of the body just below

TABLE 1. CATCHES OF MINKE WHALES IN THE SOUTHERN HEMISPHERE 1950–APRIL 1975 (DATA FROM BUREAU INTERNATIONAL WHALING STATISTICS)

Year	Antarctic*	Brazil	Durban	Total
1950	—	—	—	—
51	—	—	—	—
52	9	—	—	9
53	—	—	—	—
54	3	—	—	3
55	—	—	—	—
56	42	—	—	42
57	46	—	—	46
58	493	—	—	493
59	103	2	—	105
1960	205	—	—	205
61	162	—	—	162
62	2	—	—	2
63	21	2	1	24
64	101	44	1	146
65	7	67	2	76
66	10	352	5	367
67	18	488	6	512
68	605	456	97	1158
69	59	617	112	788
1970	30	701	171	902
71	44	900	204	1148
72	3054	702	135	3891
73	5745	650	173	6568
74	8000	765	117	8882
75	7000	—	—	7000
Total	25759	5747	1024	32530

* Antarctic catches are listed as follows: 1961/62 catch is listed under 1962 etc.

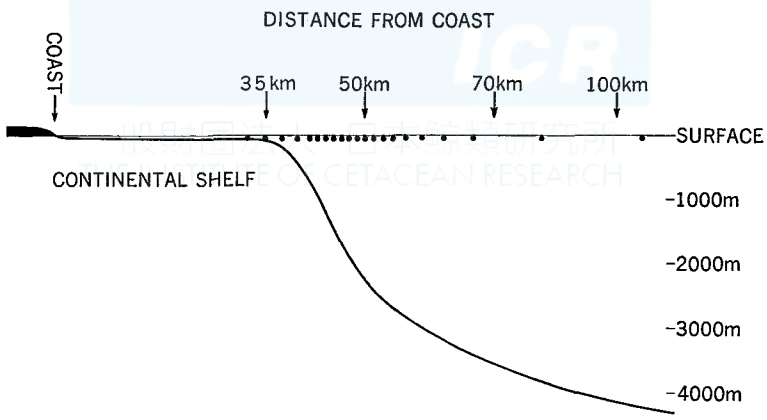

Fig. 2. Distribution of minke whales off Costinha. Dots represent whales. This diagram shows relative abundance of whales, not actual numbers. (Data from whaling company.)

the dorsal fin was measured to the nearest 0.5 cm on all whales caught between August 16th–December 20th, 1974 (see Fig 7).

Testis samples. To determine the degree of spermatogenesis in the testes, samples of testis tissue were preserved from three male whales during each month June–December of the 1974 season. The samples were airmailed for histological examination to Dr. R. F. Macadam of Raigmore Hospital Pathology Department, Inverness, Scotland.

Vagina smear samples. To determine the nature of the "white mucus" in the vagina of female whales, smear slides were made of the contents of the vaginas of three female whales of mature size during each month June–December of the 1974 season. The smears were airmailed to Dr. R. F. Macadam for histological examination.

The Bureau of International Whaling Statistics, Sandefjord, Einar Vangstein director, has supplied data where needed.

Data on minke whales off west south Africa and off Durban have been supplied respectively by the Sierra Fishing Agency manager Mr. R H Shepperd and Dr. Peter Best.

HYDROGRAPHY

Costinha whaling station is located 750 km (470 miles) south of the equator at latitude 7°S on the NE corner of Brazil. The continental shelf is narrow about 30 km wide, and drops steeply into the abyss (Figs. 1 and 2).

A warm equatorial current approaches the coast from the east and becomes divided by the land into north-flowing and south-flowing branches.

During the main whaling season September–October–November, sea surface temperatures over a wide area off Costinha are about 27°C.

Frech bite wounds of the type made by the 40-cm-long whale-biter shark *Isistius* are common on whale off Costinha, suggesting this tiny pelagic shark must be common in the area. (The discovery of the causal agency of these wounds was made by Jones (1971).) Large sharks 1.5–2.5 m long are plentiful over the continental shelf within 30 km of the coast and cause much trouble biting chunks out of the dead buoyed whales, but in oceanic water further out from the coast dead whales are not attacked by large sharks.

HISTORY AND DAILY OPERATIONS AT COSTINHA

Whaling at Costinha started in 1910. Since 1951 inclusive the station has been operated by Compania de Pesca Norte do Brasil (COPESBRA) with head office in Recife. This is a subsidiary of Nippon Reizo K.K. (Japan Ice Storage Co.) of Tokyo and the key personnel are Japanese.

One antarctic-type catcher Seiho Maru No. 2 (306 tons) is used. It leaves port about 0400 hours each day, hunts all day at distance of 30–140 km from the coast, and returns with its catch to port after dark about 2000 hours—midnight. The

whales are cut up during the night. The meat is salted and dried and is sold locally in Paraiba state and the oil is sold for leather tanning in south Brazil. The whaling season is from June to December.

The virgin relative abundance of whale species off Costinha appears from the catches (Table 2) to have been:

minke, sei, humpback and sperm—common
bryde—occasional
fin and blue—very rare

At Costinha, whalers killed the easy-to-kill and large species first and catches have been dominated in turn by humpback, sei and now finally minke and sperm whales (Table 3). Sei and bryde's whales were not recorded separately in the catch records prior to 1967, but have been separated since then. During 1967–74 the catch of sei and bryde's totalled 251 and 25 whales respectively, that is, sei were 90% of the catch of the combined species. The percentage of sei was presumably higher prior to 1960 before antarctic hunting reduced the sei stocks.

Paiva (1961) and Paiva and Grangeiro (1965, 1970) give data on the 1960/67 whale catches of all the species, mainly recording numbers caught each month, mean lengths each month, sex ratios, sexual condition and stomach contents.

Off Cabo Frio whaling station further south in 23°S more fin whales occur than off Costinha but otherwise the relative abundance of whale species is similar at the two places (Table 4).

The once-large stock of humpback whales features little in the catch of either station in recent years due to the fact that it was greatly reduced by hunting in the 1904–1920 period.

TABLE 2. NUMBER OF WHALES KILLED OFF COSTINHA, BRAZIL 7°S DURING 1910–74. (DATA FROM TABLE 3)

English Name	Brazilian Name	No Killed 1910–74	Present Status
Blue	baleia azul	1	rare
Fin	baleia fin	3	rare
Sei	baleia espardate	about 3,600	rare
Bryde	baleia cabeca de suenga	about 350	rare
Minke	baleia minke	5,747	very common
Humpback	baleia preta	1,542	rare
Sperm	cachalote	517	common

MINKE WHALES

Existing knowledge on minke whales

Minke whales are the commonest remaining species of baleen whale in the southern hemisphere and are also common in the northern hemisphere. In the southern hemisphere the latest estimate of the population is 300,000 minke whales (Ohsumi and Masaki, 1974a).

The taxonomy of minke whales became complicated by the discovery that

TABLE 3. WHALE CATCHES OFF COSTINHA 1910–74 (1924–49 DATA FROM PAIVA 1961, OTHER YEARS DATA FROM BUREAU INTERNATIONAL WHALING STATISTICS)

Year	Humpback	Sei*	Bryde*	Minke	Blue	Fin	Sperm	Total
1910			Catch taken but no record kept					
11	102	—	—	—	—	—	—	102
12	342	—	—	—	—	—	—	342
13	352	—	—	—	—	—	—	352
14	317	—	—	—	—	—	—	317
1915–23			No catch taken, station closed					
1924	62	—	—	—	—	—	—	62
25	42	—	—	—	—	—	—	42
26	32	—	—	—	—	—	—	32
27	47	—	—	—	—	—	—	47
28	40	—	—	—	—	—	—	40
1929–46			Catches taken but no records kept					
1947	11	14		—	—	—	—	25
48	21	10		—	1	—	—	32
49	15	18		1	—	—	—	34
1950	24	98		—	—	—	—	122
51	28	151		—	—	—	—	179
52	9	153		—	—	—	1	163
53	8	161		—	—	—	1	170
54	18	183		—	—	—	1	202
55	6	198		—	—	—	1	205
56	14	196		—	—	1	3	214
57	—	115		—	—	—	2	117
58	5	118		—	—	1	4	128
59	8	294		2	—	—	11	315
1960	10	500		—	—	—	1	511
61	11	504		—	—	—	5	521
62	8	272		—	—	—	4	284
63	10	253		2	—	—	7	272
64	—	256		44	—	—	4	304
65	—	149		67	—	—	13	229
66	—	72		352	—	—	24	448
67	—	49	6	488	—	—	20	563
68	—	58	6	456	—	—	39	559
69	—	56	6	617	—	—	75	754
1970	—	23	3	701	—	—	76	803
71	—	18	2	900	—	—	55	975
72	—	5	—	702	—	1	66	774
73	—	6	1	650	—	—	75	732
74	—	2	1	765+	—	—	29	797
Total	1,542	about 3,600	about 350	5,747	1	3	517	11,768

* Sei and Bryde's whales were not distinguished prior to 1957, but Sei probably composed 90% of the catches: see text.

\+ Includes 3 minke killed but lost at sea. Anomalous differences in whale totals in many seasons are caused by circumstances like this: the total killed exceeds the total measured.

southern hemisphere whales have a different colour pattern from northern hemisphere whales (Williamson, 1959; Ohsumi *et al.*, 1970). In nearly all other respects the minke whales of the two hemisphere are identical and it is probably reasonable to consider the whales of the two hemispheres as being no more than separate subspecies with the following names:

Southern Minke Whale *Balaenoptera acutorostrata bonaerensis* Burmeister, 1867.

Northern Minke Whale *Balaenoptera acutorostrata acutorostrata* Lacépede, 1804.

Knowledge of the biology of southern minke whales advanced greatly with the publication of the reports of Ohsumi *et al.* (1970) and Ohsumi and Masaki (1974a and 1974b). The following summary is based on these reports augmented by information from the studies of northern minke whales by Omura and Sakiura (1956) and Jonsgard (1951).

Southern minke whales are born about 2.8 m long after a gestation period of about ten months. Calves are suckled on milk for about four months and are weaned when about 4.5 m long. They become sexually mature at about six years of age when males are about 7.2 m long and females 8.0 m long. Males in which the larger of the two testes weighs more than 0.4 g are usually sexually mature. Minke whales grow to about fifty years maximum age and to maximum lengths of 9.8 m in males and 10.7 m in females (Table 5).

In the Antarctic, most of the whales are large. Of whales caught 54% are females. About 55% of the females and 86% of the males are mature. Of ma-

TABLE 4. WHALES CAUGHT AT CABO FRIO WHALING STATION 23°S NEAR RIO DE JANEIRO 1960–63 BY SOCIEDADE DE PESCA TAIYO LIMITADA. (DATA FROM BUREAU INTERNATIONAL WHALING STATISTICS)

Year	Humback	Sei and Bryde	Minke	Blue	Fin	Sperm	Total
1960	3	250	No catching attempted	—	21	28	302
61	2	453		—	10	97	562
62	3	338		1	49	81	472
63	2	93		—	4	35	134
Total	10†	1134††		1	84	241	1470

† Humpbacks had already been greatly reduced in numbers.

†† Proportion of Sei and Bryde in the combined species catch are not known.

TABLE 5. AVERAGE LENGTH AT SEXUAL MATURITY AND MAXIMUM LENGTH OF MINKE WHALES. SEXUAL MATURITY OCCURS AT ABOUT 6 YEARS OF AGE.

Hemisphere	Area	Mean Length at sexual maturity (m)		Maximum length (m)		Author
		♂	♀	♂	♀	
Southern Hemisphere	Antarctic	7.2	8.0	9.8	10.0	Ohsumi *et al.* (1970) and Ohsumi and Masaki (1974a)
„ „	Brazil	—	—	9.8	10.7	Whaling company
Northern Hemisphere	Newfoundland	—	—	9.1	9.1	Sergeant (1963)
„ „	Norway	6.9	7.3	8.5	9.1	Jonsgard (1951)
„ „	Japan	6.9	7.3	8.8	9.1	Omura and Sakiura (1956)

ture females about 90 % are pregnant, and resting mature females are seldom found in the Antarctic. Immature whales are most numerous in the Antarctic in the early summer (November-December).

Ovulation rate is estimated to be 0.89 per year (Ohsumi and Masaki 1974b).

88 % of mature females ovulate in spring August–September when they are still lactating (P. Best, pers. comm. based on examination of 16 lactating females killed off Durban by special permit).

Minke whales are believed to bear one calf per year. A wide range of foetus sizes amongst pregnant females in the Antarctic indicates a long mating season.

The migrations of minke whales are probably an annual oscillation about a central latitude of perhaps 40°S, in which the magnitude of oscillation increases steadily as a whale gets older and larger. Calves, most immature whales, and mature females in resting condition keep to the 20°S–50°S latitudes of mild water temperatures. It is the pregnant females, the larger of the immature females and the mature males which go far south. Whales caught south of 60°S are of average age 15 years and average length 8.5 m (age range 7–50 years, length range 6–10 m).

Mature whales probably make an annual migration from close on the equator to the high Antarctic and back, a distance of about 14,500 km (8,000 nautical miles) round trip. At the southern end of their migration they feed on krill and concentrate right at the edge of the pack ice in 60°S–70°S latitude. They are so aboundant and concentrated that Japanese catchers could kill more than 20 minke whales per day if they wished (Ohsumi, pers. comm.).

Minke whales characteristically divide themvelves into groups dominated by a certain sex or age of whale, more so than in other baleen whale species. This habit makes it very difficult for scientists to obtain the random samples which are required in order to make accurate calculations of the population size etc.

Costinha catches of minke whales

All minke whales caught are of the southern hemisphere type of minke whale *Balaenoptera acutorostrata bonaerensis* as described by Burmeister (1867), Williamson (1959) and Ohsumi *et al.* (1970). See Plate I.

Each year the first minke whales arrive from the south in late June and July. They appear singly about 100 km off the coast over deep ocean water and move slowly north. Later groups appear. Groups of whales usually contain 4 or 5 individuals, which are sometimes of one sex, sometimes mixed sexes. Less frequent pairs of whales are usually one male with one female. The whales mostly swim over 2,500-meter-deep water about 10–30 km beyond the steep edge of the continental shelf, about 40–60 km from the coast (Fig. 2).

Maximum numbers of minke whales are present during September–October–November (Table 6, Fig. 4) and highest catches and highest catches per day are obtained in October. Whales of progressively larger sizes enter the area each successive month and they depart in the same sequence (Fig. 4 and Table 7). In November numbers of whales decrease, groups are no longer seen, only pairs and single whales, and the last individuals leave in December.

The sex ratio among caught whales is 2 ♀♀ 1 : ♂ (67 %♀). The largest individuals caught were several 9.8 m males and several 10.7 m females.

(Sei whales off Costinha, by contrast, during the years 1950–65 when big catches were taken, were caught in greatest numbers during August and September and 40–50 % were females in typical years).

Water temperatures are about 27°C during the September–October–November season of abundance (Fig. 1).

Some minke whales can be seen as far north as the extreme NE tip of Brazil (5°S latitude, 250 km north of Costinha) but the whaling company state that none turn left along the north coast of South America.

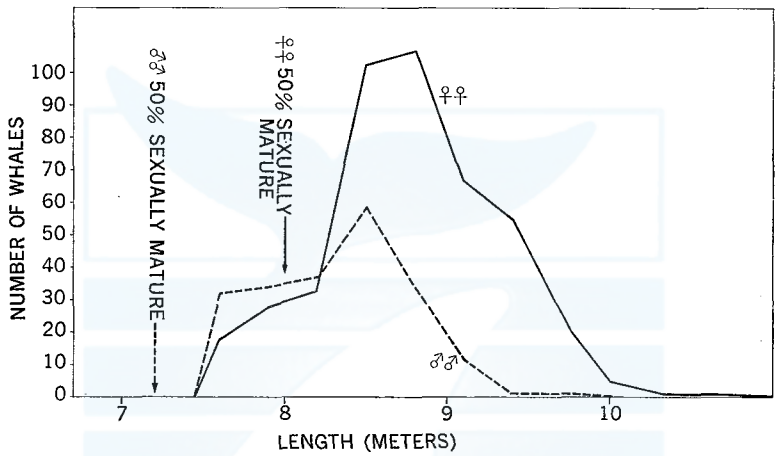

Fig. 3. Lengths of minke whales in a typical season's catch at Costinha (650 whales caught in 1973). The arrows show the mean lengths at which sexual maturity is attained. The males are probably all mature and the females 90% mature. (Data from Bureau International Whaling Statistics.)

Minke whale catches by year, month and sex are given in Table 6 and length frequencies of catches in typical seasons are given in Figs. 3 and 4 and Table 7. Correlation of the length frequencies with the results of Ohsumi *et al.* (1970) and Ohsumi and Masaki (1974b) allows the ages and maturity of the catches to be deduced and the following conclusions reached:

- at the beginning of the season, small numbers of immature females and a very few immature males are present. Most of these are not shot because they are too small to the worth shooting. They leave the area by mid-spring; mid-September.
- mature whales start to arrive in the area in July, and from mid-September onwards nearly all minke whales in the area are mature.
- of the total catch of females about 90 % are mature, of the total catch of males about 100 % are mature.
- the ages of whales in the catch range 7–50 years old with average age 15

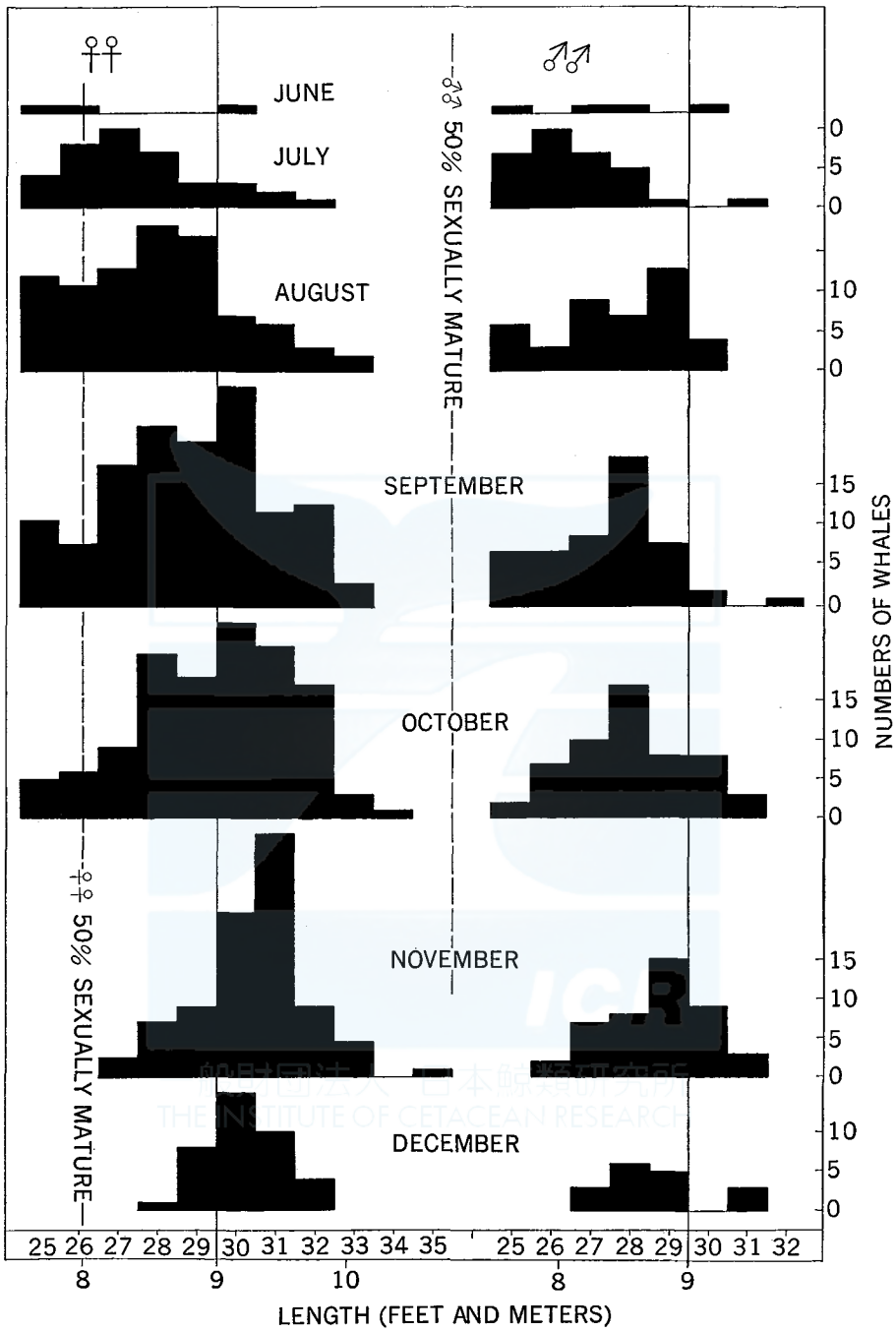

Fig. 4. Length frequencies of each month's catch of minke whales in a typical season at Costinha (762 whales caught in 1974). Whales of progressively larger sizes enter the area each successive month and depart in the same sequence. (Data from Bureau International Whaling Statistics.)

TABLE 6. MINKE WHALES KILLED IN EACH MONTH OFF COSTINHA, BRAZIL 1969–74. (DATA FROM WHALING COMPANY)

		No. minke whales killed								
		June	July	Aug	Sept	Oct	Nov	Dec	year	%♀
1969	♂	1	21	34	49	48	48	6	207	
	♀	5	28	54	88	102	105	28	410	67%♀
	Total	6	49	88	137	150	153	34	617	
1970	♂	2	47	49	44	44	32	6	224	
	♀	6	52	86	110	104	104	15	477	68%♀
	Total	8	99	135	154	148	136	21	701	
1971	♂	6	32	38	92	114	43*	*	325	
	♀	0	45	62	159	199	110*	*	575	64%♀
	Total	6	77	100	251	313	153*	*	900	
1972	♂	3	10	33	57	49	61	18	231	
	♀	2	12	51	108	138	117	43	471	67%♀
	Total	5	22	84	165	187	178	61	702	
1973	♂	—	4	26	45	64	60	11	210	
	♀	—	2	62	99	146	108	23	440	68%♀
	Total	—	6	88	144	210	168	34	650	
1974	♂	4	31	42	53	55	44	17	246	
	♀	3	38	89	137	127	84	38	516	68%♀
	Total	7	69	131	190	182	128	55	762	
6-year total	♂	16	145	222	340	374	288	58	1443	
	♀	16	177	404	701	816	628	147	2889	67%♀
	Total	32	322	626	1041	1190	916	205	4332	

* Catch stopped due to Brazilian local quota having been reached.

TABLE 7. MEAN LENGTHS OF MINKE WHALES IN EACH MONTH CAUGHT AT COSTINHA DURING 1966–67. (FROM PAIVA AND GRANGEIRO 1970)

Month	Males mean length *m* (no. measured)		Females mean length *m* (no. measured)	
	1966	1967	1966	1967
July	7.8 (13)	7.9 (14)	8.1 (12)	7.9 (22)
August	7.9 (11)	8.0 (21)	8.3 (17)	8.5 (39)
September	8.2 (25)	8.4 (27)	8.3 (64)	8.8 (83)
October	8.6 (33)	8.3 (46)	9.0 (98)	8.8 (133)
November	8.7 (25)	8.4 (40)	9.1 (52)	8.9 (67)

years old, the same as typical Antarctic catches.

During September–October–November a whitish mucus is found in the vagina of all female whales, also occasionally in late August and early December. The lips of the vagina of these females are a reddish colour. None of the female whales contain a visible embryo in the uterus.

About twelve mothers with calf are seen each year.

The stomachs of nearly all the whales are empty. A little krill is found in the stomachs of about 3 % of the whales.

5,747 minke whales have been killed off Costinha so far plus a further 200 whales have been taken by factory ships in the Antarctic region 15°W–70°W which presumably are from the same stock. So far there are no signs of depletion of the minke whales off Costinha: average lengths of whales and catch per day's hunting are not decreasing (Table 8).

In August 1972 the catcher made a single voyage 400 km eastward out into the open ocean. Although the main concentration of minke whales was located close beyond the continental shelf edge, a few minke whales were seen all the way out as far as the catcher went.

TABLE 8. CATCH OF MINKE WHALES PER DAY'S HUNTING IN PEAK MONTH OF SEASON (i.e. October) AND AVERAGE LENGTH OF SEASONS CATCH OFF COSTINHA 1966–74. (DATA FROM WHALING COMPANY).

Year	No. caught per day's hunting in October	average length *m*	
		males	females
1966	4.2	8.3	8.8
67	5.1	8.3	8.7
68	4.3	8.3	8.7
69	4.8	8.3	8.6
1970	4.8	8.3	8.8
71	5.0	8.2	8.8
72	6.0	8.7	9.2
73	6.8	8.3	8.9
74	5.9	8.2	8.6

Blubber thickness results. The method of measuring the blubber thickness was the same as used by Ohsumi *et al.* (1970), in order to obtain comparable results. Due to the fact that off Costinha whales of progressively larger size occur in successive months, simple averaging of blubber thickness measurements does not produce a useful result. Therefore I selected for analysis only whales of a certain length range, and selected the range 8.4–9.3 m (27.5–30.5 feet), as plenty whales of this size occurred in all months. About one half of all the whales caught were in this length range. The blubber thickness of males and females in this length range are shown in Figs. 5 and 6.

The results allow the following conclusions to be made:

- females have slightly thicker blubber than males. This is the opposite to Ohsumi *et al*'s (1970) findings in the Antarctic, where males had thicker blubber than females.
- the blubber of females is thicker than the blubber of males by about 0.5 cm. among whales killed in August and increases steadily to 1.1 cm thicker among whales killed in December.
- although male whales after September become thinner in successive months, among females the blubber is thicker in whales killed in successive months. The whales are not feeding, therefore cannot be getting fatter due to feeding. The increase in blubber thickness among females is presumably due to

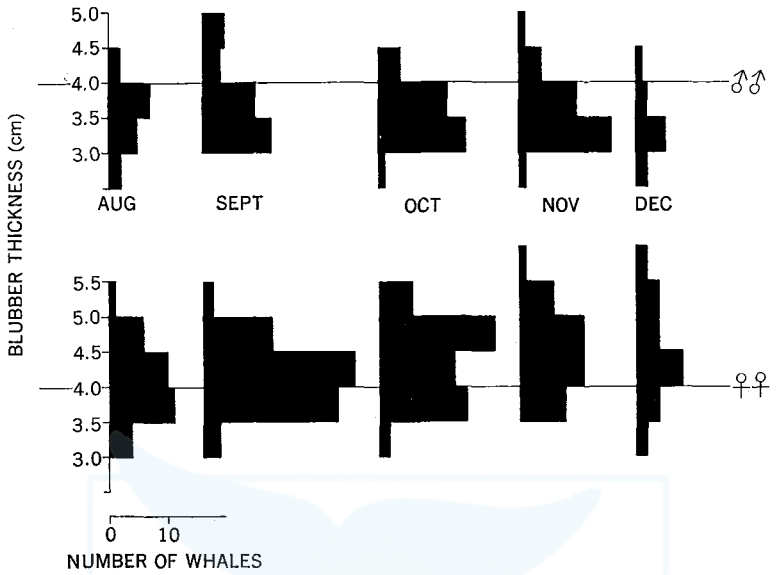

Fig. 5. Blubber thickness of whales in length range 8.4–9.3 m (27.5–30.5 feet) caught off Costinha during August 16-December 20th 1974. 118 males and 215 females were in this length range, which is about half of all whales killed during this period.

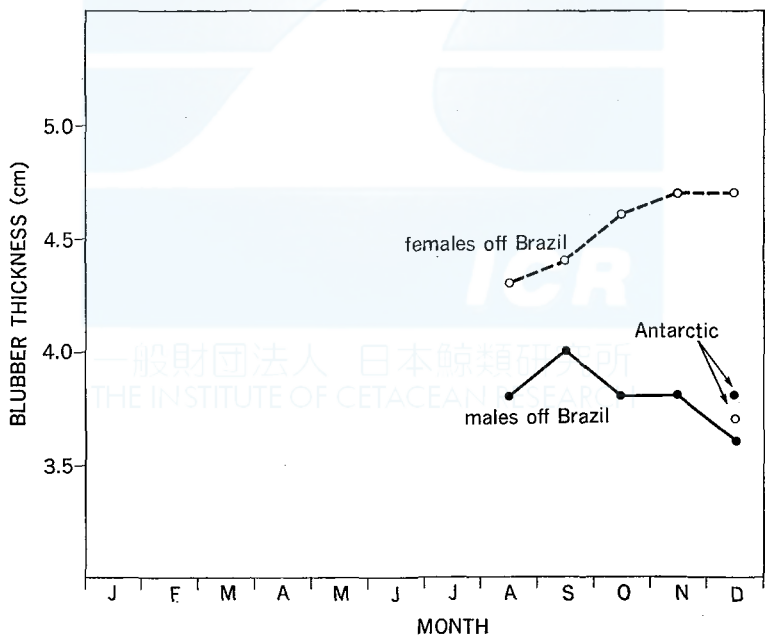

Fig. 6. Mean blubber thickness of southern minke whales in length range 8.4–9.3 m in different months of the year. August-December data from off Brazil calculated from Fig. 5, December data from Antarctic (Ohsumi et al 1970, Fig. 4).

greater fatness among the new whales which enter the area each month.

- female minke whales caught during August–December off Brazil appear to be fatter than those caught in the Antarctic during December (Fig. 6.) and males are of similar fatness. This contrasts with other rorqual species. However this may be due to accidented differences between my and Ohsumi's technique for measuring the blubber.

Testis results. Dr. R. F. Macadam reports "Testis specimens" from only seven mature whales caught off Brazil were well preserved and these included specimens from August, September, October and Novembers. These specimens, plus testis specimens from five mature whales caught in the Antarctic during November-December 1971 (kindly supplied by Dr. S. Ohsumi) were examined.

The specimens were fixed in 10% formol saline at the whaling station, and later embedded in paraffin wax, sectioned 5 microns thick and stained with Haematoxylin and Eosin and also by the Masson trichrome technique. Plate 4 shows photographs of testis specimens representative of whales caught in Brazil and in the Antarctic.

Testes from the seven whales caught off Brazil during August-November all showed many sperm in the tubules and active spermatogenesis in progress. These whales must have been capable of fertilizing femals. Plate 5 shows a single tubule and the numerous sperm in it magnified X1000.

Testes from the five whales caught in the Antarctic during November-December were not so well preserved as the Brazil specimens. All five whales showed a low degree of spermatogenetic activity and only a few sperm."

Vagina smear results. Dr. R. F. Macadam reports "the smears were well preserved and consisted of mucus containing many vaginal epithelial cells, many micro-organisms and no sperm. In humans, sperm in the female vagina disintegrate 2–3 days after copulation. Therefore the absence of sperm in the vaginas of these 18 females only indicates that none of them had mated within three days prior to being caught. They may nonetheless have mated during other days of the month."

Fig. 7. Position on body at which blubber thickness was measured. The position fulfils the requirements of being accessible on a hauled-up carcase, on the line of one of the main flensing cuts and identifiable with accuracy.

West South Africa and Durban catches of minke whales

Off west south Africa, minke whales are uncommon. Gunners operating out of Saldanha reported that they never saw minke whales there (Williamson, 1959).

TABLE 9. LIST OF ALL MINKE WHALES SEEN IN AREA 0°–30°S 0°–17°E OFF SW AFRICA DURING 2½ YEARS ALMOST CONTINUOUS WHALING BY FACTORY SHIP "SIERRA" NOV 1972–MAY 1975. (ALL MINKE WHALES SEEN WERE KILLED. DATA FROME SIERRA FISHING AGENCY)

Date	Lat	Long	Temp Sea Surface	Length *m*	Sex	Sexual Condition	Stomach Contents
March 17, 74	13°33′S	11°21′E	23°C	9.4	M	mature	empty
June 11, 73	5°46′S	10°36′E	24°C	7.3	F	?	empty
Nov 8, 73	7°02′S	11°23′E	26°C	8.2	M	mature	empty
Nov 20, 74	14°27′S	11°27′E	21°C	8.8	F	mature, no visible foetus	empty
Nov 21, 72	16°10′S	10°55′E	22°C	9.7	F	mature, no visible foetus	some krill

TABLE 10. COMPARISON OF CONDITION OF MINKE WHALES OFF COSTINHA 7°S, DURBAN 30°S AND ANTARCTIC OCEAN 55°–65°S. (COSTINHA DATA FROM WHALING COMPANY, DURBAN DATA FROM P. BEST PERS. COMM., AND ANTARCTIC DATA FROM OHSUMI *ET AL* 1970, AND OHSUMI AND MASAKI 1974b).

	Costinha, Brazil 7°S	Durban S Africa 30°S	Antarctic Ocean 55°S–65°S
Months in which minke are most abundant	Sept-Oct-Nov	all months some present	Dec–Jan–Feb
Temperature of sea surface during season of abundance	27°S	20–25°C	0°C
% of all whales caught that are sexually mature	95	mature and immature present (see text)	70
% of mature females that are accompanied by calves	3	small numbers during August-September	0
% of mature females that have no calf and no visible foetus	97	?	7
% of mature females that are pregnant with visible foetus and have no calf	0	0	90
Mean length of foetuses	—	—	0.27 m (December)
% female among whales at sea	about 60%	unknown	Great variations in different areas
% female among killed whales	67% ♀	30% ♀	54% ♀ but great variations in different areas
% stomachs containing food	3	?	55
Grouping of whales at sea	Many small groups and a few single whales. Most groups are of 4–5 whales.	Small groups and a few single whales. Some lactating mothers with young calf during August-September.	Many groups of 2–6 whales, a few single whales and a few groups of up to 100 whales. Groups usually dominated by one sex.

Mr. R. H. Shepperd reports that the factory ship " Sierra " during 2½ years almost continuous whaling Nov 1972–May 1975 in the area 0°S–30°S, 0°–17°E off west south Africa has only sighted five minke whales (Table 9). They were all shot and proved to be mature animals.

During the same period the " Sierra " sighted several thousand sei whales.

Off Durban 30°S (Table 10) Dr. Peter Best reports that minke whales are present in moderate numbers all year round in waters which range 20°–25°C annually. They appear to be most numerous during winter and spring (June–November). The annual catch of about 150 minke is a mixture of sexually mature and immature animals. During August-September in sea of temperature about 20°C some lactating mothers with young calves are seen each year.

DISCUSSION

Separation of north and south atlantic stocks. South Atlantic minke whales migrate as far north as NE Brazil 5°S and on the African side odd individuals migrate to off Angola with 5°S the extreme northernmost record to date (Table 9). The nearest localities from which north atlantic minke whales have been recorded are Florida and the Mediterranean (Moore and Palmer, 1955; Scattergood, 1949). About 5,000 km separates the nearest records, thus it seems unlikely that members of the north and south hemisphere stocks ever meet.

Route of northward migration. By what routes do whales travel from the Antarctic to NE Brazil? After the feeding season, most whales all round the Antarctic head north. In wide areas of the Indian and Pacific Oceans there is no land and the whales must meet and mate successfully in mid ocean. In the western South Atlantic most whales, after a northward swim of varying length seem likely to strike the sloping coast of South America at some point. The slope of the coast " funnels " the whales together and causes them to become concentrated as they proceed northwards. For those whales which continue furthest into warm waters, the NE corner of Brazil is the focal point where maximum concentration occurs.

It seems probable that most minke and sei whales which arrive off Costinha have followed the continental shelf edge from varying distances further south, while a smaller number have arrived direct from the open ocean. The minke whales off Costinha concentrate about 20 km beyond the edge of the continental shelf (Fig. 2). Further out to sea and on the shallow continental shelf there are only a few minke whales.

The low-frequency noises made by rorquals can be heard at distances of at least 180 km (Cummings and Thompson, 1971, p. 1197) and thus minke whales on the open ocean, when they get within this range of the continental slope, probably hear and are attracted to the concentration of whales.

The virtual absence of minke whales off west south Africa, and yet their presence off the eastern southern Africa (Durban) and eastern south America, suggests an assymmetry in the autumn northward migration from the Antarctic. It appears that minke whales migrate chiefly up the western side of the southern

atlantic, heading into the south-flowing Brazil current, but keep clear of the north-flowing Benguela current.

If this is the case, the coast of Brazil may be the mating ground of minke whales from a wide sector of the Antarctic.

Sei whales in contrast migrate up both sides of the South Atlantic.

Length of the reproductive cycle. Studies to date conclude that minke whales bear one calf each year and have a one-year reproductive cycle; thus reproduce twice as fast as all the larger rorqual species.

In truth, available data are not conclusive on this matter. Some facts suggest a one-year cycle, some facts suggest a two-year cycle.

Evidence which suggests a one-year cycle:

- about 88% of mature female minke whales ovulate during the latter part of the lactation period, in August–September (see section 'Existing knowledge on minke whales'). This makes it possible for minke whales to become pregnant during late lactation, thus producing one calf per year. Overlapping of lactation with pregnancy does not occur in the larger rorquals, all of which have a resting period of several months between the end of lactation and mating (Fig. 5).

Evidence which suggests a two-year cycle:

- The 27 cm average length of foetuses in December Antarctic catches (Table 10) indicates that mating must occur in about September (compare Omura and Sakiura, 1956, Fig. 23). A ten-month pregnancy would result in calves being born in July and the four month lactation would last till November. However, during September-October-November, hundreds of calf-less mature females arrive off Costinha. These females cannot have born a calf recently, therefore it seems impossible that they are producing one calf per year.
- The 0.89 per year ovulation rate of minke whales is basically similar to, although somewhat higher than, the ovulation rates of the other rorqual species (Table 12). (It must be remembered that all these rates are estimates only). If minke whales really reproduced twice as fast as other rorquals, their ovulation rate should be double that of other species—about 1.4 ovulations per year. But it is not near this value.

  The 0.89 per year ovulation rate of minke whales could not allow *all* the females of the population to bear a calf every year but it is nonetheless compatible with the existence of a basic one-year cycle. An individual female during a ten year period could have 8 calves at one year intervals and one calf after a two year interval (assuming all ovulations produce calves).

  As pregnancy and lactation total 14 months duration, a one-year cycle can only exist if new pregnancy occurs two months before the end of lactation, that is; the cycles overlap by two months.

  The fact that in the Antarctic 90% of mature female minke whales are pregnant, compared with 66% among blues, 80% among fine and 69% among sei (Table 11) does not clarify the reproduction rate. It is

compatible *either* with minke whales having a higher reproductive rate than the other species (though hardly double the rate of the other species) *or* with minke whales having a two-year cycle in which resting mature females have the habit of seldom entering the Antarctic.

By examination of the ovaries of mature females caught off Costinha it should be possible to obtain the vital missing evidence.

If these calf-less whales are only just ovulating or have not yet ovulated, they must have passed a true resting stage since parting from their calf and thus must have a two-year reproductive cycle.

If the whales have already ovulated (and in this case they will presumably be in early pregnancy) then it is likely that they ovulated and mated puring lactation, and this overlap would allow a one-year reproductive cycle.

Further data are needed to clarify the reproductive cycle of minke whales.

TABLE 11. COMPARATIVE DATA ON SOUTHERN HEMISPHERE RORQUAL SPECIES DURING THE COOL-WATER SUMMER FEEDING SEASON

Species	greatest numbers of adults furthest south	% females in catch	% mature in catch ♂♂	% mature in catch ♀♀	% of mature females that are pregnant	timing of migration of immatures
Blue	December[1]	47[1]	?	?	66[1]	later than matures[2]
Fin	January[1]	50[1]	?	?	80[1]	later than matures[2]
Sei	February[3]	?	94[4]	92[4]	69[3]	
Minke	?	54[5]	86[6]	55[6]	90[5]	earlier than matures[5]

Sources of data. 1=Mackintosh 1942, p 270, Table 25 and Fig. 27.
2=Laws 1961, p 341. 3=Gambell 1968 p 39–40 and Table 5.
4=Doi *et al* 1967, table 14. 5=Ohsumi and Masaki 1974b.
6=Ohsumi *et al* 1970 p 107.

TABLE 12. OVULATION RATES PER YEAR OF RORQUAL WHALES

Species	average number of ovulations per year	evidence used to calculate th value	author
Blue	0.69	Average of the average number of recent ovulations in several hundred antarctic whales of three sexual classes (pregnant, resting and recently-ovulated non-pregnant).	Laurie in Purves and Mountford 1959 p 139 based on Laurie 1937, p 250
Fin	0.72†	Average of ovulation rates from three types of 2-year breeding cycles, found by counting corpora albicantia in several hundred antarctic whales.	Laws 1961, p 463
	0.77	Average rate in 6 marked antarctic whales captured 19 or more years later, found by counting corpora albicantia.	Ohsumi 1964, p 66
Sei	0.69	No of oestrous cycles in 2-year breeding cycle x average number of ovulations per oestrous, found by counting corpora albicantia in 644 whales caught off Durban.	Gambell 1968, p 123
Minke	0.87	No of corpora albicantia in 1359 antarctic whales of known age	Ohsumi and Masaki 1974, p 9

† value halved from original 1.43 consequent to Roe's (1967) discovery that ear plugs of southern hemisphere fin whales accumulate only one (not two) growth layers per year—see Gambell (1968) p 124.

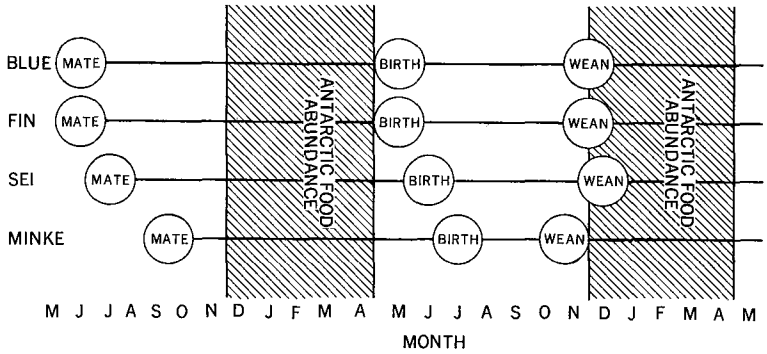

Fig. 8. Reproductive cycles of rorqual whales: comparison of timing of events. (Blue and Fin data from Mackintosh and Wheeler 1929 and Laws 1959, Sei data from Gambell 1968, Minke data from Omura and Sakiura 1956 and present report).

Location, season and temperature of giving birth. The presence of calves with their mothers in 20°C water off Durban 30°S, but seldom in 27°C water off Costinha 7°S suggests that minke whales give birth in relatively cool and southerly waters and do not usually, bring their calves into the warmest waters. This is interesting because scientists traditionally believe that all whales bear their calves in the warmest part of their range. In minke whales it is chiefly the mature adults which enter the truly hot tropical waters. What is the purpose of this?

Newly weaned minke calves off Japan are not found in water colder than about 15°C (author's data) thus presumably suckling occurs in waters of about 20°–15°C and females do not enter waters cooler than 15°C until after parting from their calf.

What catch of minke whales can be sustained indefinitely off Costinha? If the southern hemisphere population estimate of 300,000 minke whales is correct, and if they are equally distributed around the longitudes, then about 45,000 are living in the 15°W–70°W western part of the South Atlantic and about 75,000 in the whole South Atlantic.

The annual yield that this population could sustain cannot be determined at present but it will have to be shared between Costinha and the factory ships which hunt the same stock in the Antarctic.

Future research

1 At Costinha a biologist should spend a season and:
- examine the uteri of all females to check whether tiny embryos are present or absent
- examine ovaries of all females to determine presence or absence of corpora lutea
- take samples of testes in each month to determine state of spermatogenic activity
- take samples from *every* female of the vagina contents, examine them for

sperm and thus discover whether any of the whales are actually mating.

2 Whale-searching cruises and tagging should be used to investigate:
- is there a belt of minke whales stretching between Brazil and Africa during the winter season?
- what numbers of minke whales are present in winter in mid-ocean areas, off the west coast of S. America and off the east and west coasts of Australia? Do northward migrating minke keep to the west warm-current sides of the southern oceans?
- in what temperature and latitudes does mating occur?
- in what temperatures and latiudes are calves born?

3 A factory-ship should be asked to catch samples of minke whales at all latitudes on its way to and from the Antarctic.

SUMMARY OF NEW KNOWLEDGE ABOUT MINKE WHALES

The data from Costinha reveal the following new facts
- immature whales precede mature whales in the migration to the north (Fig. 4).
- as whales get older and larger they migrate north later in the season (Fig. 4, Table 7). The main concentration occurs during September-October-November.
- the 2 ♀♀: 1 ♂ sex ratio among caught whales at Costinha, even making allowance for gunners selecting large and therefore female whales preferentially, suggests that there is a real imbalance of the sex ratio off Costinha and that many of the smaller mature males do not migrate so far north
- mature whales go much further north to 7°S and into warmer water 27°C than do immature whales
- calves are born and suckled somewhere to the south of and in less warm temperatures than the waters in which the adults congregate off Costinha
- immature whales precede mature whales in the migration to the feeding grounds (whereas in blue and fin whales the mature animals move south before the immatures; see Table 11).
- the simultaneous presence during November–December of considerable numbers of minke whales both off Brazil and in the Antarctic 7,000 km to the south indicates either or both of the following: that there is great variation in timing of migration between different individual adult whales and/or separate high latitude and low latitude stocks of minke whales exist. The results of analysis of blubber thickness in different months also support this conclusion.

ACKNOWLEDGMENTS

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Dr. R. F. Macadam of Raigmore Hospital Pathology Department, Inverness, Scotland carried out the histological examinations of the vagina smear and testis samples.

Larry Foster of General Whale, California made the beautiful drawing of the whale (Plate I).

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EXPLANATION OF PLATES

PLATE I

Southern Minke Whale *Balaenoptera acutorostrata bonerensis* Burmeister 1867. Drawn by Larry Foster of General Whale, California from photographs of alive and dead specimens.

PLATE II

Baleen plates of a typical Southern Minke Whale caught off Brazil. Note the assymetry of the pigmentation; the pale plates extend further back on the right side than on the left side, as also occurs in the fin whale.

PLATE III

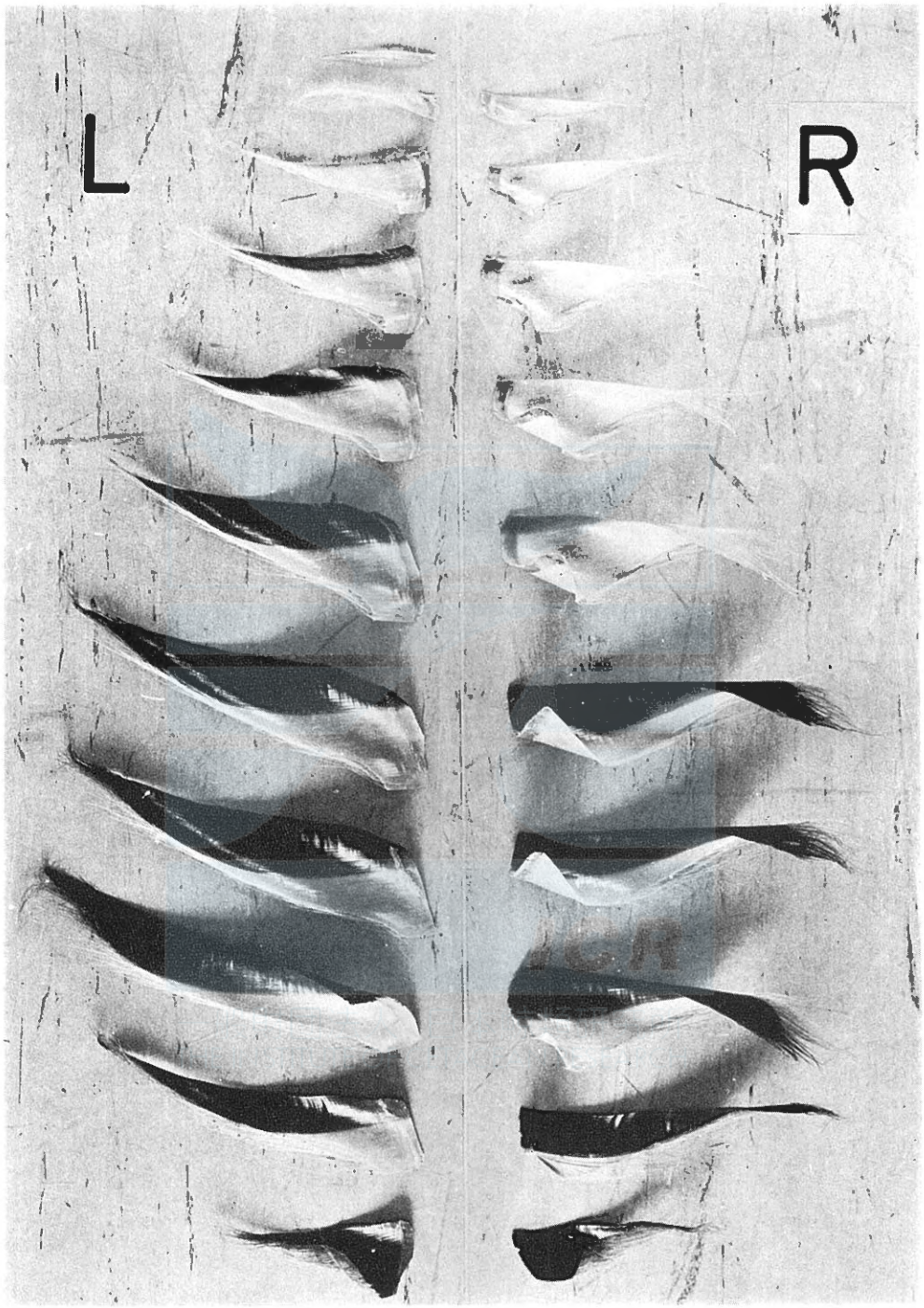
Unusual case of minke whales trapped over-winter in pack ice in a coastal fjord of Graham Land, Antarctica. In normal winters these individuals might be off Brazil. (From Taylor 1957, photos copyright of British Antarctic Survey.)

Plate IV

Comparison of testis of two mature whales caught off Brazil with testis of two mature whales caught in the Antarctic. In the Brazil whales, active spermatogenesis is occurring; in the Antarctic whales very little spermatogenes is is occurring. Sperm are visible only in the Brazil specimens and are the tiny black dots in the tubles. Magnification X150. Photographs by Dr. R. F. Macadam.

Plate V

Testis tubule showing many sperm (the tiny black dots are the nuclei of the sperm heads). From 9.1 m whale caught off Brazil, November 7 1974. Magnification X1000. Photograph by Dr. R. F. Macadam.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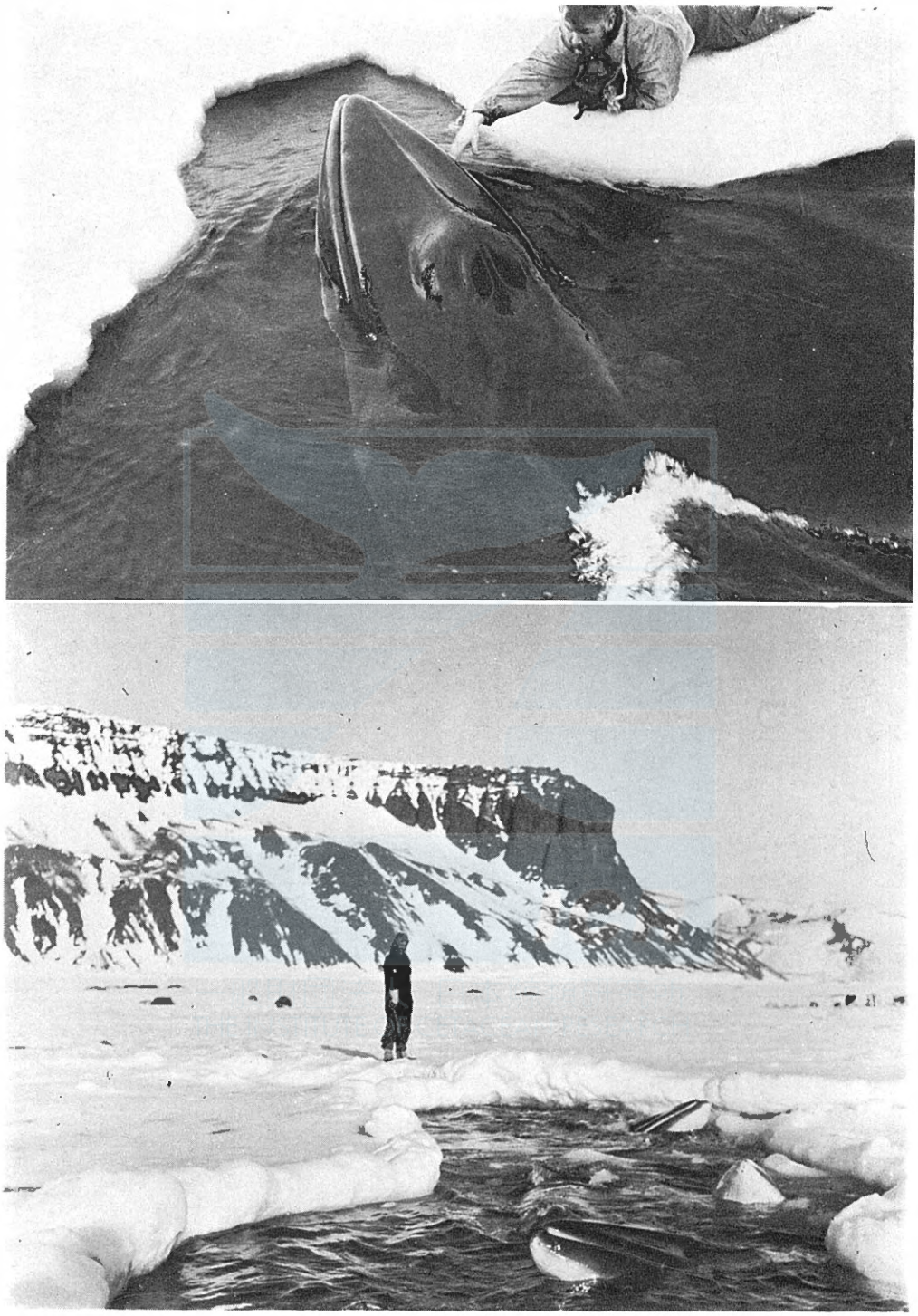

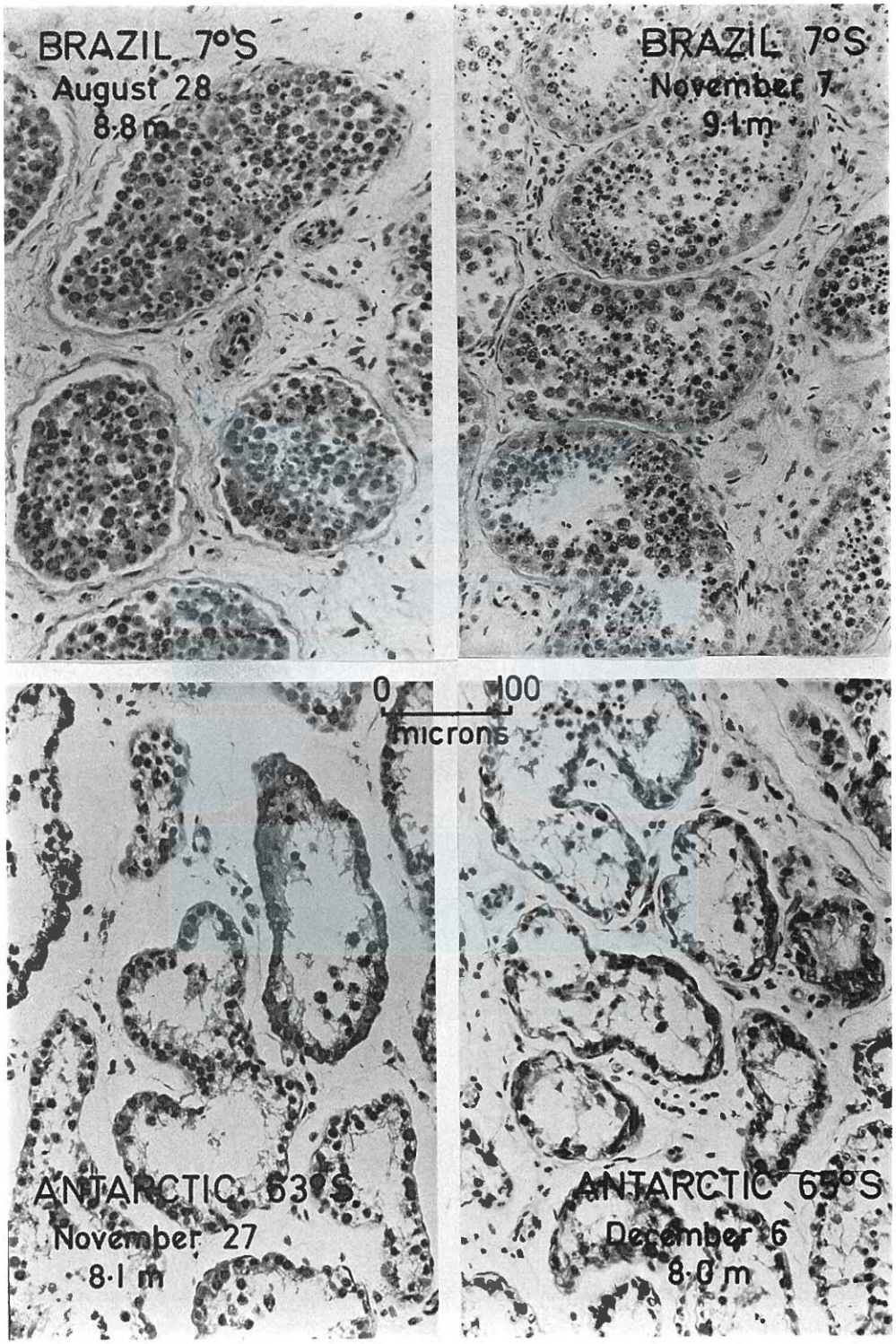
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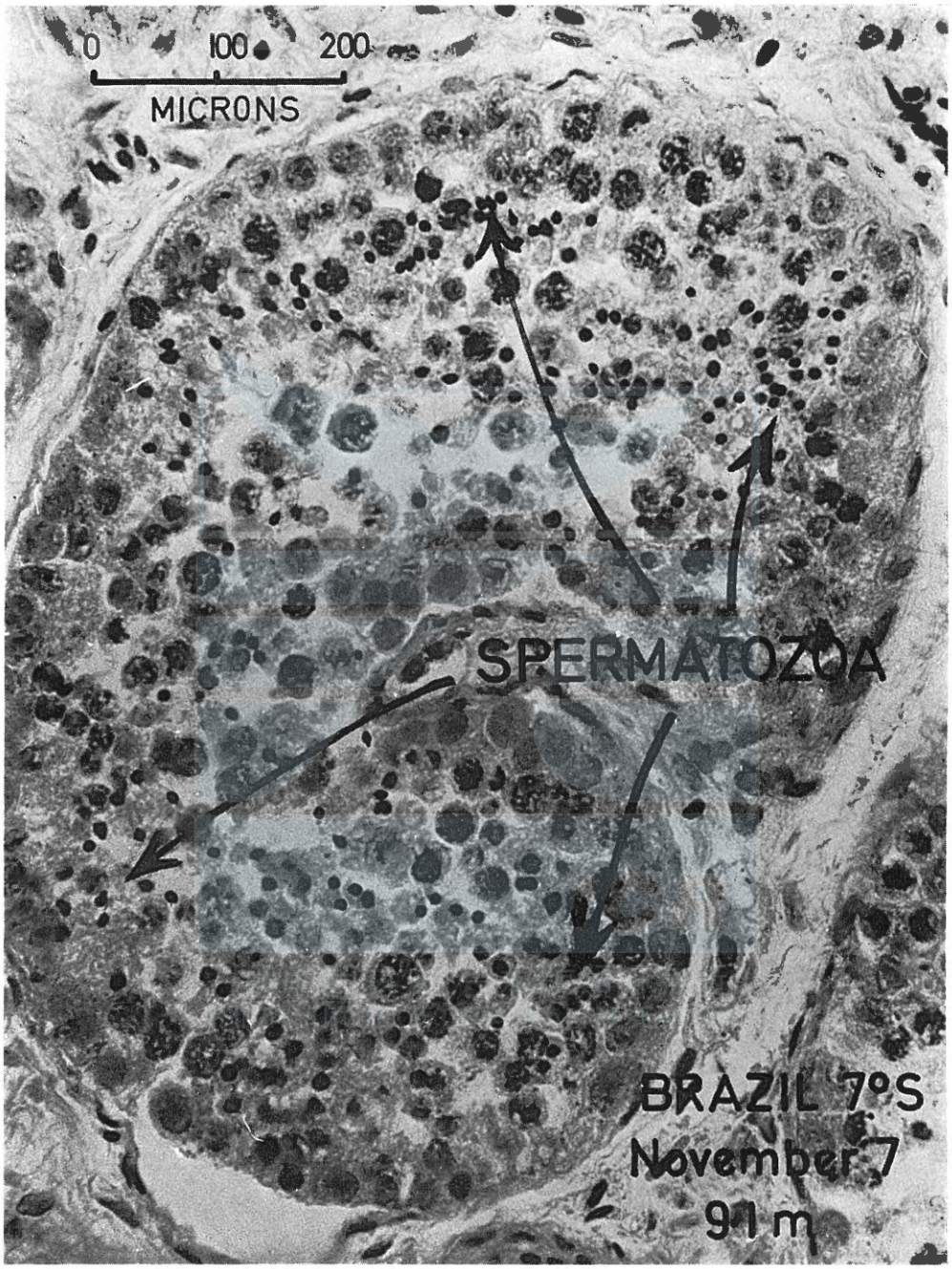
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