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CEPHALOPOD REMAINS FROM THE STOMACHS OF SPERM WHALES CAUGHT IN THE TASMAN SEA

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Summary

1. Cephalopod remains from the stomachs of 66 sperm whales caught in the Tasman Sea included almost intact cephalopods, detached heads and bodies, 'crowns' of arms, isolated buccal masses and isolated upper and lower beaks (mandibles). 3282 of the 3299 lower beaks were identified to genus and, as far as possible, to species with over 30 species from 14 families.
2. The four species *Octopoteuthis rugosa*, *Octopoteuthis* sp. A, *Taningia danae* and *Histioteuthis atlantica* together comprised over 40% of the lower beaks. Estimates of the weight of flesh represented by beaks of the different taxonomic groups were made from beak size. Three large species *Taningia danae*, *Kondakovia longimana* and an *Architeuthis* species contributed about 80% of the weight of flesh represented by lower beaks. The collection shows that cephalopods contribute an important proportion of the 'standing stock' of nekton in the deep ocean even distant from continental slope areas. Flesh remains in the sperm whale diet suggest that there is a boundary to several squid distributions near 40°S.
3. In 17 species of squids, the size distributions of the beaks collected in the Tasman Sea are closely similar to those of the same species collected off South Africa and Western Australia. In two species, there is a gradual change in size distribution of the beaks across the range from West to East. In the genera *Kondakovia* and *Architeuthis*, the Tasman Sea beaks have different size distributions to those collected further west.

Introduction

This paper describes the cephalopod remains collected from 66 sperm whales caught during commercial whaling activities of a Japanese factory ship in the Tasman Sea while on passage to the Antarctic. The collection is of particular interest since it is from a region in which the cephalopods are very poorly known and because the samples cover a broad latitudinal spread from 31°20′S to 46°56′S and a broad longitudinal spread from 174°28′E to 148°04′E (Fig. 1). The samples comprise both complete cephalopods and parts of cephalopods including a total of 3299 lower and 3335 upper beaks (mandibles). The present study is a useful addition to similar studies made on cephalopods from sperm whales caught off New Zealand (Gaskin & Cawthorn 1967a, b) in the eastern South Pacific (Clarke, MacLeod & Paliza 1976), the North Pacific (Beteshava & Akimushkin 1955; Okutani & Nemoto 1964; Okutani *et al.*, 1976; Kawakami 1976; Clarke & MacLeod, 1980), off Western Australia, the Antarctic and South Africa (Clarke 1980) and in the North Atlantic (Clarke 1962a; Clarke & MacLeod 1974, 1976).

While cephalopods of the Tasman Sea have been very neglected the works of Dell (1952) for New Zealand and Rancurel (1970, 1976a, b) for New Caledonia give useful systematic descriptions from the general area. Cephalopods have been described from stomachs of birds at New Zealand (Imber 1975, 1976, 1978; Imber & Russ 1975) and fish at New Caledonia (Rancurel 1970, 1976a, b).

Material and Methods

Samples of the stomach contents of 66 sperm whales including 20 females, 43 males and three with no data were collected during commercial whaling of a Japanese whale factory ship in November 1970 by arrangement with Dr S. Ohsumi of the Far Seas Fisheries Research Laboratory, Japan Fisheries Agency, Shimizu, Japan. The positions given in Fig. 1 are those of the factory ship, and probably all the whales, from which samples were taken, were killed within 100 miles of the factory. The isobaths on Fig. 1 should only be considered a rough guide since there are considerable inconsistencies between various recent bathymetric charts of the region.

The samples included relatively intact cephalopods, detached heads and bodies, 'crowns' of arms, isolated buccal masses including beaks and isolated upper and lower

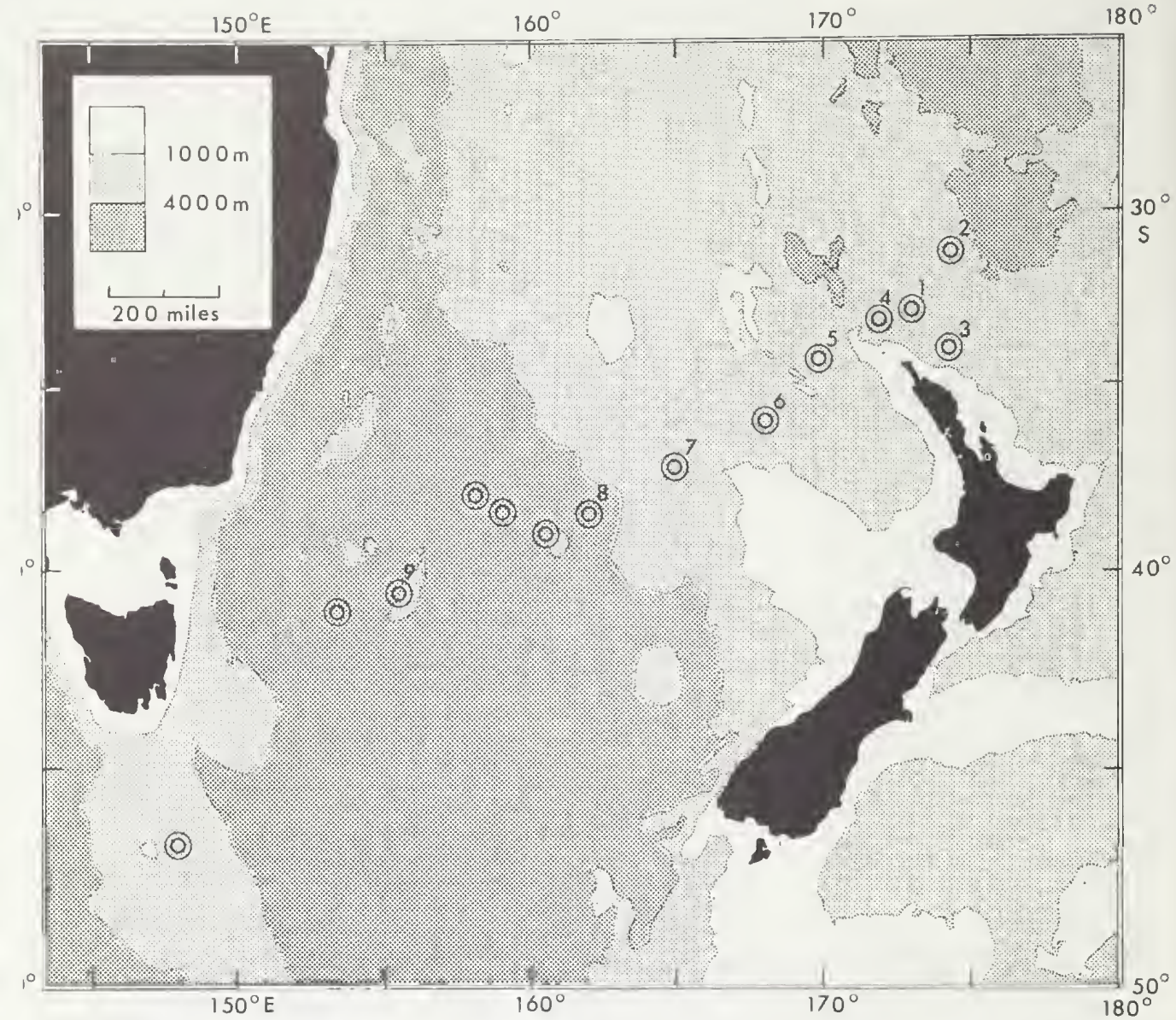


Fig. 1. Position of the factory ship when the sperm whales from which stomach contents were collected were killed. The positions of the catchers when they killed the whales was probably within 100 miles of these factory positions. Isobaths E of 150°E are taken from New Zealand Journal of Geology and Geophysics 13 (1) 1970 and those W of 150°E from International Chart 601 N.Z. 4601, 1971. Beak collections were made at positions 1-9. Flesh of cephalopods was collected at all positions except 4.

beaks. As much information as possible was obtained from the relatively intact specimens and pieces of flesh and the beaks were then sorted. Upper beaks were counted and lower beaks were sorted into groups and the lower rostral lengths (LRL) or, in the octopod *Alloposus*, the hood lengths were measured with vernier calipers to an accuracy of 0.005 cm. Identification of lower beaks was carried out using criteria and methods described elsewhere (Clarke 1962b, 1980). Weights of the cephalopods from which the lower beaks came were estimated from the LRLs and hood lengths using graphs published elsewhere (Clarke 1962b, 1980). The size at which the 'wings' of the lower beaks became darkened is noted since this indicates a stage between im-

maturity and 'maturity' which is useful in comparisons between beaks from different geographical regions. If beaks have flesh attached it is certain that the squid was living in the vicinity in which the whale was captured and noting the occurrence of flesh is important in the study of cephalopod distribution. The presence of beaks of Antarctic species is relevant to an understanding of whale migration (Clarke 1972). Female whales normally go no further south than 40°S and the difference between the squid species represented by beaks in female and male stomachs is relevant to an understanding of cephalopod distribution (Clarke 1980). Comparisons are drawn between the present beaks and similar collections made from sperm whales caught off the western side of South America (Clarke, et al., 1976), South Africa, Western Australia and the Antarctic (Clarke, 1980). Samples off South Africa and Western Australia did not include samples in November, when the present collection was made.

Results

Cephalopods present in the region

The samples include 3299 lower and 3335 upper beaks. The number of lower beaks of each taxon collected from whales at each station is shown in Table 1. Almost half the taxa were found at more than 75% of stations.

Five taxa, *Histioteuthis atlantica* (Hoyle, 1885) (B3), *H. miranda* (Berry, 1908) (A3), *Taningia danae* (Joubin, 1931), *Pholidoteuthis boschmai* Adam 1950 (A) and *Galiteuthis armata* Joubin, 1898, were present at all nine stations. Seven taxa, *Octopoteuthis* spp., *Megalocranchia* sp., *Ancistrocheirus lesueuri* (d'Orbigny, 1839), *Pholidoteuthis boschmai* Adam, 1950 (B), *Lepidoteuthis grimaldii* Joubin, 1895, *Octopoteuthis* B and *Cycloteuthis akimushkini* Filippova, 1968, were present at eight out of nine stations.

The percentage contribution and the estimated contribution by weight of each taxon represented by beaks are shown in Table 2.

Over 30 species from 14 families are represented by lower beaks and over 40% of the lower beaks were from the four species *Octopoteuthis rugosa* Clarke, 1980, *Octopoteuthis* sp. A, *Taningia danae* and *Histioteuthis atlantica* (B3).

All taxa except *Moroteuthis* A and *Vampyroteuthis infernalis* Chun, 1903 were present in both male and female whales; these were only present in female whales.

Notes on the Material

Family OCTOPOTEUTHIDAE

Four species belonging to this family are represented by lower beaks. *Octopoteuthis rugosa* and *Taningia danae* are also represented by reasonably intact specimens, crowns, etc. The separation of the two smallest of the three *Octopoteuthis* species is not always possible from beak structure but they have distinct LRL peaks and little error will be introduced if these species are separated at an arbitrary LRL of 1.15 cm Fig. 2).

Octopoteuthis sicula Rüppell, 1844 was reported by Rancurel (1970) in stomachs of *Alepisaurus ferox* caught off New Caledonia. Otherwise the genus is not known from the region.

Flesh of *Octopoteuthis* was found between 31°S 174°E and 47°S 148°E (Figs. 1 & 3).

Three hundred and eighty-six of the lower beaks grouped as *Octopoteuthis* A are indistinguishable from *O. rugosa* except for the latter's smaller size. Similar beaks with the same size range and with peaks at the same LRL were present in samples collected at Albany, Western Australia but were not found in South Africa (Clarke, 1980) or off Peru and Chile (Clarke *et al.*, 1976).

Forty-nine of the beaks belong to a third, much larger, species of this genus, *Octopoteuthis* B. Beaks with LRLs of 1.05, 1.15 and 1.5 cm have undarkened wings and are from young members of this species. One buccal mass of the species was found at 37°S 165°E.

The LRL range and peak of these beaks is similar to beaks described as *Octopoteuthis* sp. B from whales caught off Iceland (Clarke & MacLeod 1976). A specimen believed to be this very large *Octopoteuthis* has been caught by a trawl off the United Kingdom and will be described elsewhere.

TABLE 1

The lower beaks collected from whales caught near the positions in the Tasman Sea shown in Fig. 1

Family	Species	Station (No of samples in parentheses) 1 (1)	2 (1)	3 (1)	4 (4)	5 (4)	6 (7)	7 (6)	8 (5)	9 (1)	No Data	Total
Octopoteuthidae	*Octopoteuthis rugosa* } *Octopoteuthis* sp. A. }	125	102	242	0	92	11	41	98	2	2	715
	Octopoteuthis sp. (giant) B	1	1	3	0	9	15	10	7	2	1	49
	Taningia danae	40	29	35	5	59	65	34	51	8	22	348
Histioteuthidae	*Histioteuthis* A1 *?meleagroteuthis*	2	0	22	0	1	0	3	0	0	0	28
	A2 *bonnellii corpuscula*	0	0	19	0	1	86	20	2	4	11	143
	A3 *miranda*	2	2	55	1	21	14	4	13	6	3	121
	A4 *dofleini*	0	0	136	2	74	22	36	25	0	3	298
	A spp.	0	2	11	0	1	2	0	0	1	0	17
	B3 *atlantica*	16	16	86	6	89	53	27	61	15	1	370
	B4	0	0	2	0	6	1	1	0	2	0	12
	B spp.	0	0	6	0	1	0	1	7	1	0	16
Cranchiidae	*Megalocranchia* sp.	0	2	23	2	13	76	25	68	13	24	246
	Galiteuthis armata	2	6	5	2	6	26	5	12	4	0	68
	Taonius pavo	0	0	0	3	2	2	5	9	0	0	21
	Galiteuthis sp. B	0	5	3	0	1	0	1	5	0	0	15
	Mesonychoteuthis hamiltoni	2	0	1	0	0	1	1	5	1	0	11
Onychoteuthidae	*Moroteuthis robsoni*	0	4	8	0	12	23	13	68	1	6	135
	Moroteuthis A	0	0	0	0	0	0	0	10	0	0	10
	Kondakovia longimana	0	0	0	2	12	57	13	11	2	5	102
Pholidoteuthidae	Pholidoteuthis boschmai A	2	1	6	1	7	18	13	35	7	0	90
	B	0	2	15	3	19	14	5	17	6	1	82
Enoploteuthidae	*Ancistrocheirus lesueuri*	2	0	11	5	13	41	13	26	2	3	116
Lepidoteuthidae	*Lepidoteuthis grimaldii*	11	7	3	0	3	9	8	11	1	4	57
Architeuthidae	*Architeuthis* spp.	0	0	2	0	2	13	18	8	3	8	54
Chiroteuthidae	*Chiroteuthis ?joubini*	0	0	12	0	1	0	3	0	0	0	16
	sp. C	1	2	10	0	2	6	4	4	0	1	30
Ommastrephidae	*Todarodes* sp.	4	3	16	1	5	3	0	6	0	0	38
Cycloteuthidae	*Cycloteuthis akimushkini*	0	1	5	2	7	3	4	3	2	2	29
	?Discoteuthis	0	1	16	0	3	0	1	1	0	0	22
Mastigoteuthidae	*Mastigoteuthis* A	0	0	1	1	1	6	2	4	0	1	16
Alloposidae	*Alloposus mollis*	0	0	1	0	0	3	2	0	0	0	6
Vampyroteuthidae	*Vampyroteuthis infernalis*	0	0	1	0	0	0	0	0	0	0	1
Others		0	1	3	1	8	0	3	0	0	1	17
Totals		210	187	759	37	471	570	316	567	83	99	3299

Flesh of *Taningia danae* is present at nine stations between 33°S and 47°S (Figs. 1 & 3) but it would appear to be more common to the south and west of the area since 58% of male whales with flesh contained the species to the south of 38°S and west of 162°E and only 9% of males contained it to the north and east of this position. 43% of 37 male whales and 8% of 13 female whales containing flesh included flesh of this species.

It seems likely that the genus *Taningia* is composed to two species, one not yet described, but until more specimens become available we shall keep both size groups under the one species heading.

Family HISTIOTEUTHIDAE

Beaks in this collection, within this family, fall into eight main groups named for convenience *Histioteuthis* A1-A4 and B1-B4 (Fig. 4) according to size and structure. Beaks of six of these groups have already been described and several positively identified (Clarke 1980). There are 33 beaks which are very probably of

TABLE 2

The importance by number and weight of cephalopods represented by lower beaks from stomachs of sperm whales sampled in the Tasman Sea expressed as a percentage of samples containing flesh

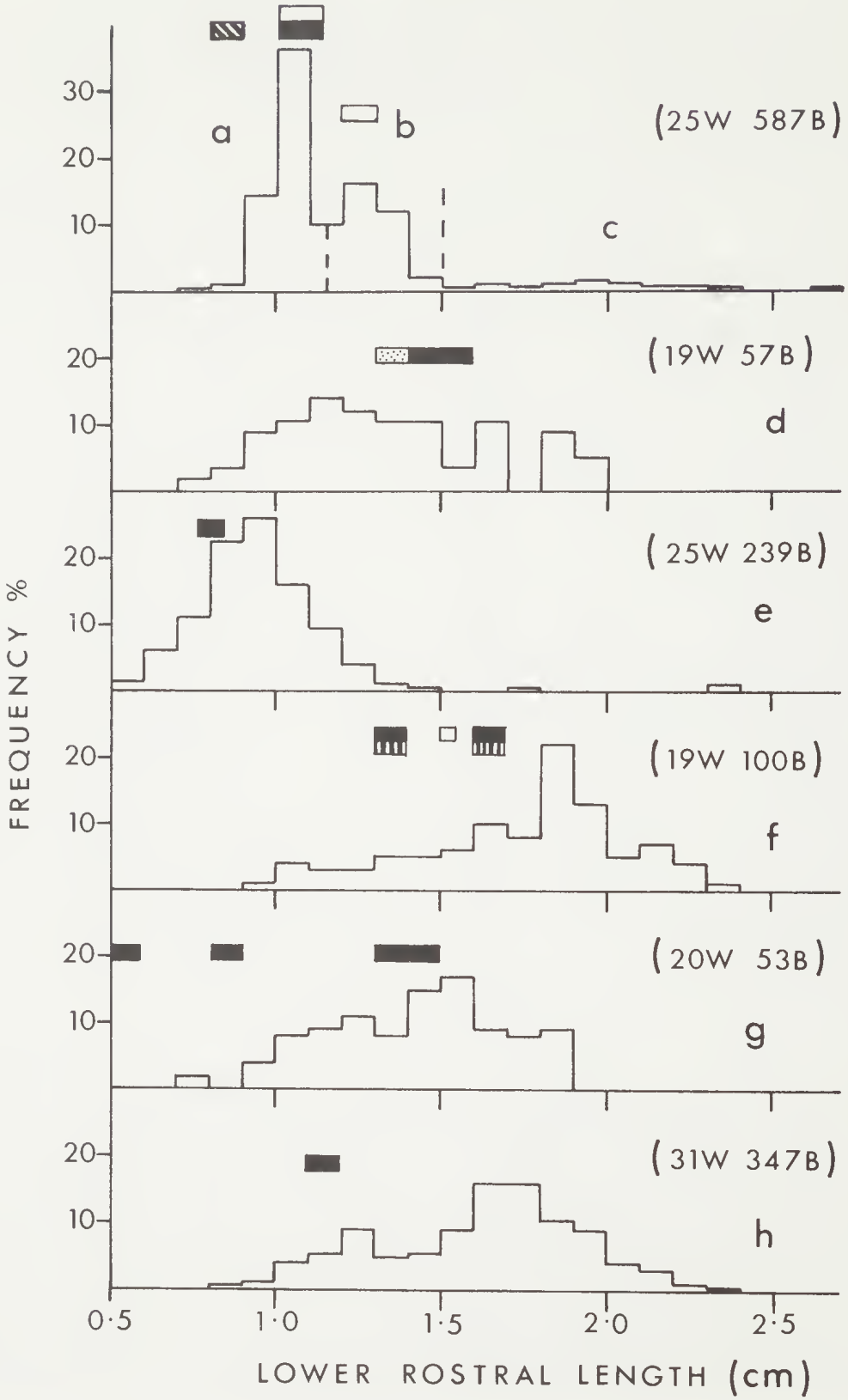
Species	No.	%	Estimated weights Mean (g)	Total (kg)	Total (%)	Family No. %	Family Wt. %	% of whales in which found	% of samples with flesh
Octopoteuthis rugosa	329	10.0	337	110	0.9	33.7	45.3	65	18
Octopoteuthis sp. A	386	11.7	526	203	1.7				
Octopoteuthis sp. (giant) B	49	1.5	1 781	87	0.7			61	—
Taningia danae	348	10.5	14 378	5 004	42.0			97	33
Histioteuthis A1	28	0.8	92	3	—	30.4	1.8	16	—
A2	143	4.3	152	22	0.2			48	48
A3	121	3.7	598	72	0.6			58	—
A4	298	9.0	310	61	0.5			61	—
A spp.	17	0.5	155	3	—				—
B3	370	11.2	148	55	0.5			90	12
B4	12	0.4	258	3	—			23	—
B spp.	16	0.5	126	2	—				—
Megalocranchia	246	7.5	320	79	0.7	11.0	3.6	81	20
Galiteuthis armata	68	2.1	251	17	0.1			68	14
Taonius pavo	21	0.6	405	9	0.1			39	2
Galiteuthis sp. B	15	0.5	113	2	—			19	—
Mesonychoteuthis hamiltoni	11	0.3	28 909	318	2.7			29	—
Moroteuthis robsoni	135	4.1	2 007	271	2.3	7.5	22.7	77	—
Moroteuthis A	10	0.3	3 539	35	0.3			6	—
Kondakovia longimana	102	3.1	23 433	2 390	20.1			61	—
Pholidoteuthis boschmai A	90	2.7	1 653	149	1.3	5.2	3.5	58	15
B	82	2.5	3 179	261	2.2			65	—
Ancistrocheirus lesueuri	116	3.5	1 468	170	1.4	3.5	1.4	84	40
Lepidoteuthis grimaldii	57	1.7	2 500	143	1.2	1.7	1.2	58	10
Architeuthis spp.	54	1.6	41 164	2 223	18.7	1.6	18.7	65	12
Chiroteuthis ?joubini	16	0.5	68	1	—	1.4	—	10	—
sp. C	30	0.9	142	4	—			35	—
Todarodes sp.	38	1.2	2 913	111	0.9	1.2	0.9	39	—
Cycloteuthis akimushkini	29	0.9	1 126	33	0.3	1.6	0.4	45	4
?Discoteuthis sp.	22	0.7	692	15	0.1			16	—
Mastigoteuthis sp.	16	0.5	1 906	30	0.3	0.5	0.3	39	—
Alloposus mollis	6	0.2	612	4	—	0.2	—	10	—
Vampyroteuthis infernalis	1	—	—	—		—	—	3	—
	17	0.5	1 001	17	0.1	0.5	0.1	26	—
	3 299	100.0	3 609	11 907	99.9	100.0	99.9		

several, as yet undescribed species, which are dealt with under two headings, *Histioteuthis* A & B spp.

The size group of beaks identified as *Histioteuthis* A1? *meleagroteuthis* (Chun, 1910) was rarely found at Durban or in Western Australia and it is possible that this represents a different species from that found off Donkergat.

Beaks of *Histioteuthis bonnellii corpuscula* Clarke 1980, A2 were present from 34°S 170°E to 40°S 155°E. One crown and a complete specimen were collected at 36°S 168°E and 38°S 158°E respectively.

Beaks of *Histioteuthis miranda* (Berry 1908) (A3) occur in samples extending across the entire geographical range sampled (Table 1). One male and three female whales had flesh of the species in their stomachs which included three crowns and one complete specimen. Beak sizes are closer to the South African than to the Western Australian beaks of this group. While this may suggest more than one species is included here, the almost intact squids show that


(25W 587B)
a
b
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(19W 57B)
d
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e
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f
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g
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h
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FREQUENCY %
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LOWER ROSTRAL LENGTH (cm)

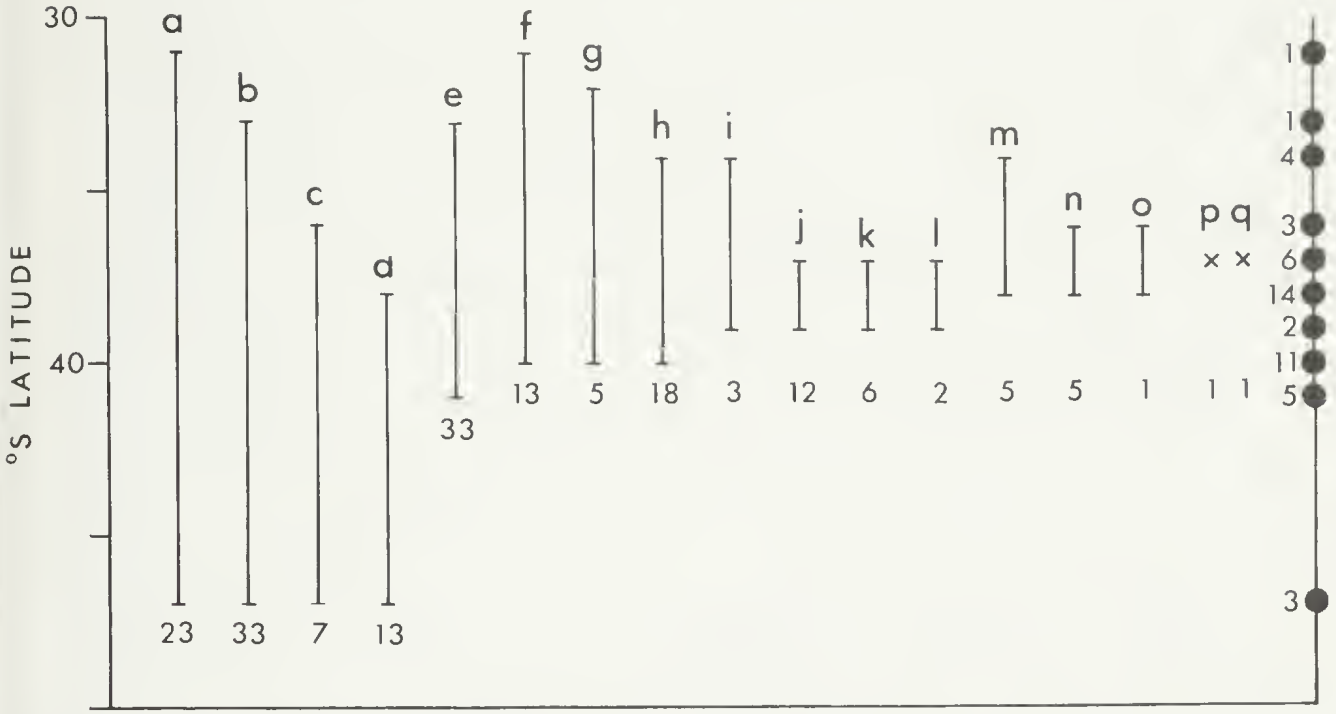


Fig. 3. The latitudinal distribution of cephalopod groups as shown by flesh collected from the stomachs of sperm whales caught in the Tasman Sea. To the right the latitudinal positions of the factory ship and the number of samples at each position are given. The cephalopod groups are arranged in order of their most southern occurrence. Numbers along the bottom show the number of cephalopods in each group represented by flesh. a, *Octopoteuthis*; b, *Taningia*; c, *Moroteuthis*; d, *Pholidoteuthis*; e, *Ancistrocheirus*; f, *Galiteuthis* sp. A; g, *Lepidoteuthis*; h, *Megalocranchia* sp.; i, *Histioteuthis* A3; j, *Histioteuthis* B3; k, *Architeuthis*; l, *Cycloteuthis*; m, *Histioteuthis* B4; n, *Chiroteuthis*; o, *Histioteuthis* A2; p, *Taonius pavo*; q, *Octopoteuthis* B.

H. miranda is found from South Africa to the Tasman Sea and the evidence, so far, supports the conclusion that the size variation of beaks is merely a reflection of the size variations of a single species.

Beaks of *Histioteuthis* ? *dofleini* (Pfeffer 1912) (A4) are present in samples taken from 34°S 174°E to 38°S 162°E. Some beaks with LRLs up to 0.73 cm have undarkened wings.

Seventeen of the *Histioteuthis* A beaks appear to differ from all the above groups and are probably from several unrecognized species.

Fig. 2 Percentage frequency histograms of the rostral lengths of lower beaks. a, *Octopoteuthis rugosa*; b, *Octopoteuthis* sp. A; c, *Octopoteuthis* sp. B; d, *Lepidoteuthis grimaldii*; e, *Megalocranchia*, sp.; f, *Kondakovia longimana*; g, *Architeuthis* sp.; h, *Taningia danae*. The number of whales (W) and beaks (B) are indicated. Horizontal bars indicate peaks of beaks of the same species from whales caught off South Africa (black), Western Australia (white), South America (hatched), New Zealand (shaded) and in the Antarctic (vertical hatching).

Flesh of *Histioteuthis atlantica* (B3) was found in whales from 37°S 165°E to 38°S 158°E and in one female and several male whales. Beaks of the species from whales caught off New Zealand were slightly larger with a peak at 0.5-0.6 cm (Gaskin & Cawthorn 1967). A beak measuring 0.41 cm has undarkened wings.

Beaks identified as *Histioteuthis* species B4 (Clarke 1980) contributed over 7% of the beaks in whales caught off Western Australia.

Sixteen beaks are of the *Histioteuthis* B type but cannot be referred to a species.

Family CRANCHIIDAE

The beaks of this family fall into five groups, three of which have been described elsewhere (Clarke 1980). While these groups have been given species names certain reservations about the specific identity are held which are stated here or elsewhere. (Voss 1974; Clarke 1980).

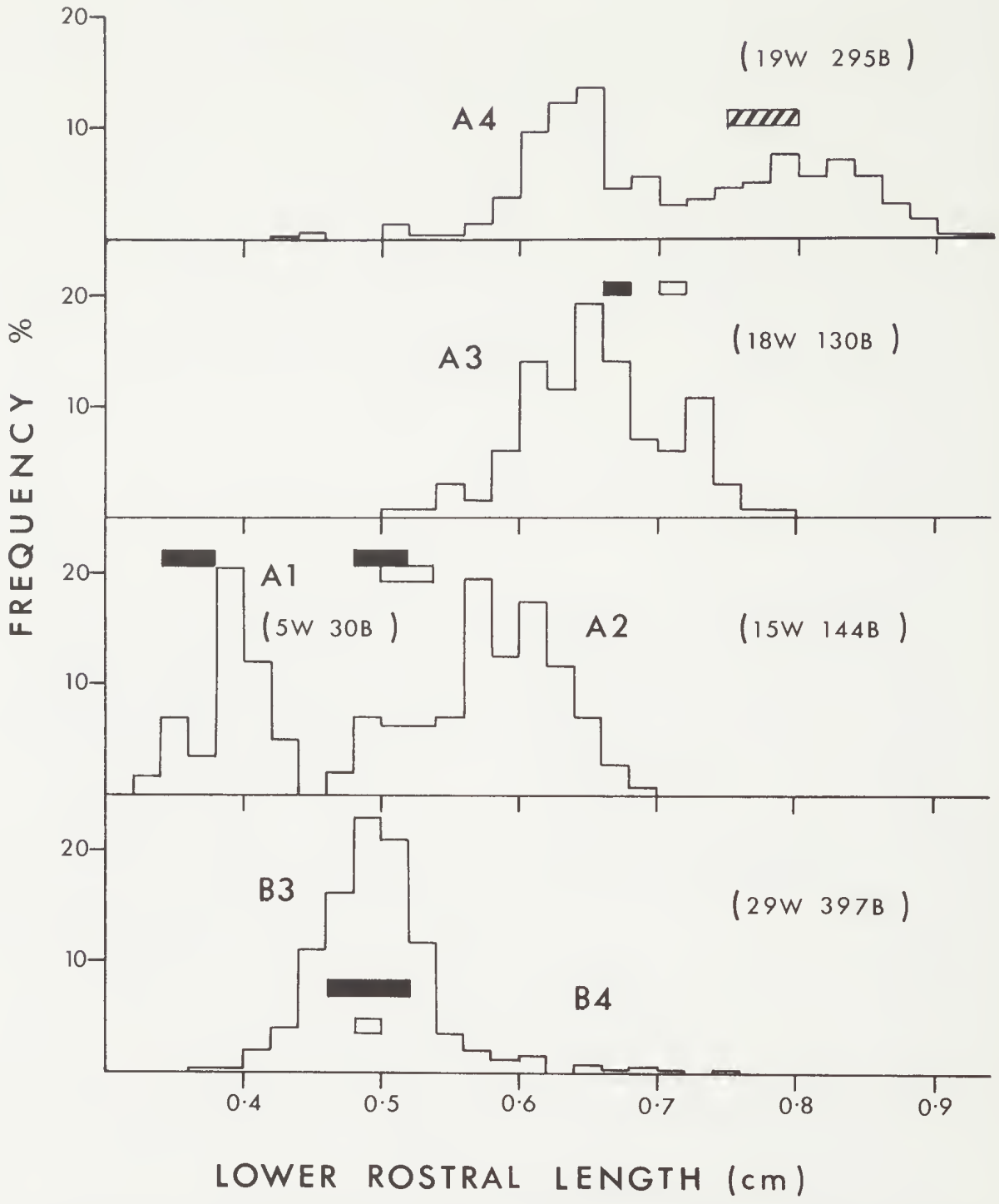


Fig. 4. Percentage frequency histograms of the rostral lengths of lower beaks of *Histioteuthis* A1-A4, B3 and B4. The number of whales (W) and beaks (B) are indicated. Horizontal bars indicate peaks of beaks of the same species from whales caught off South Africa (black), Western Australia (white) and in the Antarctic (hatched).

Two hundred and forty-six of the lower beaks cannot be distinguished from beaks of *Megalocranchia* sp. (described as *Phasmatopsis cymoctypus* by Clarke 1962c, 1980; Voss (1980) synonymised this genus with *Megalocranchia*) (Voss, 1974), and are found in whales throughout the sampling area (Table 1). Flesh of the species is present in both male and female whales extending from 34°S 170°E to 40°S 155°E (Fig. 3). Three beaks (LRLs 1.7, 2.30, 2.38 cm) apparently of this species, extend the size range to 2.38 cm (Fig. 2).

The flesh of this species consists of twelve crowns, six of which have undarkened or only partly darkened wings on lower beaks with a range of 0.56-0.71 cm. Features of the species which could be distinguished from four of these crowns are as follows. Arm length formula in three crowns is I<IV<II<III. In one of these the arm lengths are 18.5 (I), 23 (II), 26 (III) and 21.5 cm (IV) and the tentacle length is 37.5 cm with a club length of 7.5 cm. Suckers on the middle of arm III are much bigger, with a diameter of 0.76 cm, than on other arms, at 0.47 cm (specimen with a LRL = 0.85 cm). The arms have elongated cirri down their borders and attenuated, whip-like ends. The tentacle manus bears four rows of suckers with elongated, trumpet-shaped outer segments. The carpus is distinct with 10-12 suckers and about the same number of pads.

Beaks of *Galiteuthis armata* are closely similar to beaks described elsewhere from *Teuthowenia megalops* (Prosch, 1849) (called *Taonius megalops* by Clarke 1980). They are present over the entire geographical range sampled and from both male and female whales. Flesh is in samples from 31°S 174°E to 40°S 155°E (Figs. 1 & 3) and is present in both male and female whales.

Five crowns of this species were collected but only one of them, with a LRL of 0.79 cm was in sufficiently good condition to provide useful information. This crown, collected at 31°S 174°E has arms which bear suckers and no hooks and measure 11.0 (I), 13.0 (II), 15.5 (III) and 14.5 cm (IV). The tentacle is 22 cm long with a club of 3 cm and has a distinct, large, single tentacular hook. These features prevent this species from being a *Taonius* as previously thought from beaks collected off South Africa and Western Australia and it should be grouped in *Galiteuthis*.

Beaks of *Taonius pavo* (Lesueur 1821) which were described by Clarke (1980) are in samples from 34°S 174°E to 38°S 162°E (Fig. 1). Flesh is only present in one whale, a male caught at 37°S 165°E and consists of a crown in very poor condition with incomplete arms and no tentacles.

Beaks identified as *Galiteuthis armata* were found in beak samples extending from 31°S 174°E to 38°S 162°E (Fig. 1) from both male and female whales. No flesh was collected.

No flesh of *Mesonychoteuthis hamiltoni* Robson, 1925 was collected.

Family ONYCHOTEUTHIDAE

Beaks of this family fall into three distinct groups which have been described elsewhere (Clarke 1980), *Moroteuthis robsoni* Adam, 1962, *Moroteuthis* A and *Kondakovia longimana* Filippova, 1972.

Flesh of *Moroteuthis robsoni* occurs from 36°S 168°E to 47°S 148°E (Figs. 1 & 3) and only in male whales. All the beaks have darkened wings; beaks from elsewhere darken at a LRL of 0.5 cm.

Beaks identified as *Moroteuthis* A (Clarke 1980) only occur in two samples, both from female whales caught near 38°S 162°E and one of them contains nine of the ten beaks. No flesh was collected.

Beaks of *Kondakovia longimana* are present in samples collected between 34°S 174°E and 40°S 155°E (Fig. 1) from thirteen male and five female whales. The species was very much rarer than this in female whales off South Africa because it is an Antarctic species which, from evidence collected so far, was not thought to extend far enough north to be eaten by female whales (which do not normally go further south than 40°S). Its presence in so many female whales shows that it must extend either further north or the female whales must go further south than in the Indian Ocean and Atlantic sectors. No flesh was collected. Although we have expressed its weight as a percentage of the diet it must be remembered that this species is, as far as we know, a high latitude species which

contributes considerably more to the diet when the whales are in the Antarctic and nothing in most of the region sampled here i.e. in latitudes lower than 40°S.

Family PHOLIDOTEUTHIDAE ?

The beaks of this family fall into two distinct groups which have been described by Clarke (1980). However, specimens containing these two types of beak could not be distinguished and have all been referred to *Pholidoteuthis boschmai*. Taxonomic difficulties and lack of any tentacles on specimens described by Clarke from whales' stomachs, which are much larger than any collected in other ways, places some doubt on the inclusion of these beaks in *Pholidoteuthis* and the family Pholidoteuthidae. However, the beaks and the squids are very distinctive and it is only the correct name and systematic position which are in any doubt.

Beaks identified as *Pholidoteuthis boschmai* A occur throughout the entire range of sampling (Fig. 1) and in samples from both male and female whales. Flesh was collected from whales killed between 38°S 162°E and 47°S 148°E. It includes five almost complete but damaged specimens (three mantles of the species were also found but could be either A or B). Measurements which could be taken are given in Table 3.

Beaks identified as *Pholidoteuthis boschmai* B are present in whales caught throughout the region sampled (Fig. 1). Flesh is present in samples from 38°S 159°E to 41°S 153°E (Fig. 3). It comprises one complete squid and two crowns. A female with a DML of 33 cm has nidamental glands 9.5 cm long which suggests she was not actively laying eggs.

Family LEPIDOTEUTHIDAE

Flesh of *Lepidoteuthis grimaldii* came from whales killed between 33°S 172°E and 40°S 155°E (Fig. 3) and from both male and female whales. The flesh includes a head and separate body. The LRL is 1.75 cm and the DML is 54 cm.

This species was previously collected from the stomachs of *Alepisaurus ferox* caught at 16°27′S, 166°22′E between the New Hebrides and New Caledonia (Rancurel 1970).

Family ARCHITEUTHIDAE

Taxonomic difficulties make the naming of species within the single genus of this family, *Architeuthis*, very difficult (Dell 1970). Flesh of *Architeuthis* includes a complete female with a LRL of 0.78 cm and a DML of 41.5 cm (Table 3). While the specimen is in too poor a condition to provide much detail, its proportions supplement those few given for specimens collected in South Africa. The arms bear several large subequal suckers which have a diameter of 0.6 cm on arms I, II & III and 0.4 cm on arm IV and the suckers gradually decrease in size to the ends of the arms. No sucker rings are present. There are 30 large suckers on the tentacular club which increase in size to the seventh from the proximal and from 7th to 17th they are approximately the same size. This is an immature female with undarkened wings on the lower beak and nidamental glands 2.2 cm in length. *Architeuthis kirki* Robson, 1887 has been redescribed by Dell (1970) from a specimen stranded in New Zealand, and it seems likely that the beaks described here belong to the same species.

Family CHIROTEUTHIDAE

Beaks tentatively identified as *Chiroteuthis* ? *joubini* Voss, 1967 (see Clarke 1980) are present in 10% of beak samples taken from two female and one male whales between 34°S 174°E and 37°S 165°E (Fig. 1, Table 1). No flesh was collected. Beaks of a closely similar species from whales caught off Peru (called *'Chiroteuthis* A' in Clarke *et al.*, 1976) had a very marked peak at 0.50-0.60 cm. Beaks referred to *Chiroteuthis* sp. C (see Clarke 1980) came from throughout the region sampled. Flesh of the species was collected from 36°S 168°E to 38°S 158°E (Fig. 3). The flesh includes one complete specimen and two crowns but few measurements could be obtained because of their poor condition (Table 3).

Family OMMASTREPHIDAE

Beaks of *Todarodes* sp. (see Clarke 1980) were collected from whales caught at all stations south to 38°S (Table 1). No flesh was collected and this is surprising considering the

species is very muscular and flesh was well represented in South African whales.

Beaks of the related genus *Nototodarus* which were collected from sperm whales caught off New Zealand had a peak at 0.80-0.90 cm. (Gaskin & Cawthorn 1967).

Family CYCLOTEUTHIDAE

Beaks belong to two genera in this family. The first, *Cycloteuthis*, is easily distinguished by the lower beaks. The second group is thought to be *Discoteuthis* but lack of comparative material from large animals makes this identification less certain (see Clarke 1980).

Beaks of *Cycloteuthis akimushkini* (see Clarke 1980) were collected from whales throughout the region sampled. Only two male whales contained flesh of the species and these were caught at 37°S 165°E and 39°S 160°E (Fig. 3).

Beaks tentatively identified as ?*Discoteuthis* (see Clarke 1980) occurred in samples from 31°S 174°E to 38°S 162°E (Fig. 1). No flesh was collected.

Family ?MASTIGOTEUTHIDAE

Beaks of ?*Mastigoteuthis* B (See Clarke 1980) are present in samples from 34°S 174°E to 38°S 162°E (Fig. 1). No flesh was collected.

The largest beak with a LRL of 2.08 cm is well outside the range for the group at South Africa and is possibly another species.

Family ALLOPOSIDAE

Beaks of *Alloposus mollis* Verrill, 1880 (see Clarke 1980) were present in two males and a female whale caught from 34°S 174°E to 37°S 165°E. No flesh was collected.

Family VAMPYROTEUTHIDAE

One beak of *Vampyroteuthis infernalis* Chun, 1903 was collected at 34°S 174°E from a 40 ft (12.2 m) female whale.

Other Species

Seventeen or 0.5% of the beaks included several species which could not be identified. LRLs varied from 0.40 to 1.80 cm. Even the family of the largest beak could not be ascertained although it must have come from a large squid weighing perhaps over 9 kg (from curve X Clarke 1962b).

Distribution within the Region

Fig. 1 shows the stations (numbered 1-9) from which beaks and flesh were collected from whale stomachs. Fig. 3 shows the limits of latitude from which flesh of each taxon was collected. As digestion in sperm whales is probably rapid and the whales do not move far between ingestion and digestion, the occurrence of flesh indicates the distribution of the taxa (Clarke 1980).

The percentage of samples which contained flesh of each taxon is given in Table 2.

Although the samples containing flesh of cephalopods have a longitudinal spread of 25°, oceanic variations which influence distribution on a large scale are greatest from north to south and the composition of the cephalopods in these samples is probably most influenced by their latitude. In Figure 3 many species seem to have a southern boundary near 40°S. Flesh of all these species except for *Histioteuthis* B4 was also collected in South Africa at 30-35°S (Durban and/or Donkergat; Clarke 1980). The present collection gives strong support to the conclusion made previously (Clarke 1980) that there is a boundary to many squid distributions near 40°S. Some squids such as *Histioteuthis bonnellii corpuscula*, A2 and *H. atlantica* B3 appear to be restricted to a rather narrow latitudinal distribution (Fig. 3) but, as flesh was collected in South Africa as far north as 30°S, this cannot be a general feature and must be treated with caution in interpreting the Tasman Sea collection.

Four groups extend further south than the 40°S limit of some distributions. Of these *Taningia danae* and *Moroteuthis robsoni* are known to live off South Africa and Western Australia and to extend much further south to South Georgia at about 55°S (Clarke 1980). *Pholidoteuthis boschmai* does not appear to live off South Georgia but, although it extends as far north as Durban at 30°S, it is more numerous at Donkergat and Western Australia at about 35°S and it does seem that this species may have a centre of distribution near the

latitude of 40°S which seems to act as a limit to some species. *Octopoteuthis* flesh considered here is a mixture of *O. rugosa* and *Octopoteuthis* sp. A. The former was present off South Africa and absent off South Georgia and this, together with the present material, suggests the southern limit of distribution is between 47°S and 55°S, possibly at the Antarctic Convergence.

Perhaps the most southerly extension of *Octopoteuthis*, *Taningia*, *Moroteuthis* and *Pholidoteuthis* (Fig. 3) shows that these species can extend much closer to the Subtropical Convergence than the other species which may be less tolerant of short term fluctuations in water conditions which might be expected close to a region of convergence.

Comparison with other regions

Comparison of sizes

The lower rostral length (LRL) distributions for all the taxa are given in Figs. 2, 4-6. In each figure the position of the peaks of similar distributions are indicated where possible for the same taxa collected from whales caught off South Africa, Western Australia, New Zealand, South America and in the Antarctic.

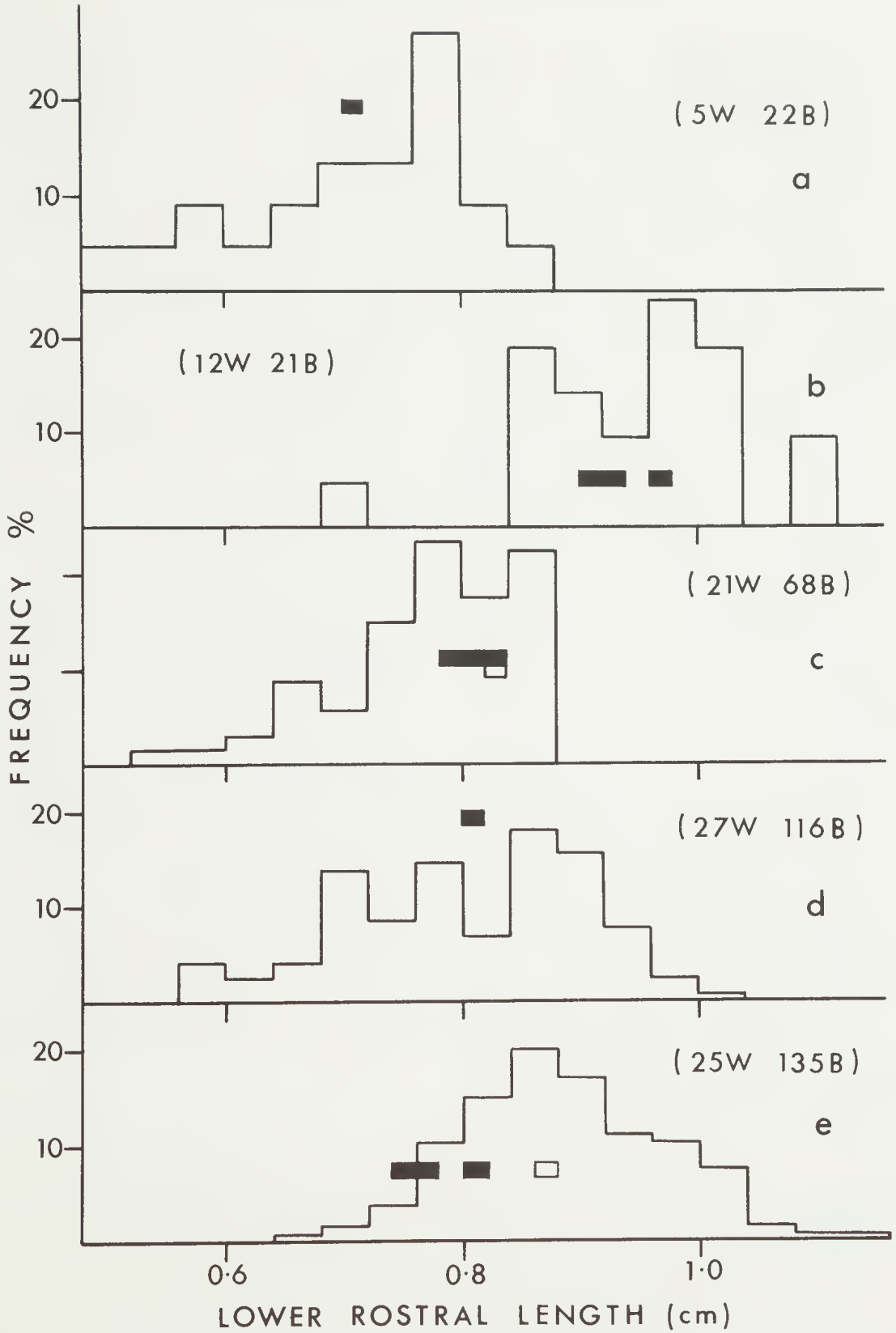
The following 17 groups have peaks which are at very similar LRLs in the areas in which they occur and any difference is not considered significant from the evidence available: *Octopoteuthis rugosa*, *Octopoteuthis* sp. A, *Lepidoteuthis grimaldii*, *Megalocranchia* sp. (all in Fig. 2), *Histioteuthis* ?*meleagroteuthis* A1, *H. miranda* A3, *H. atlantica* B3 (Fig. 4), ?*Discoteuthis* sp., *Taonius pavo*, *Galiteuthis armata* (when compared with *Taonius megalops* see Clarke 1980), *Ancistrocheirus lesueuri*, *Moroteuthis robsoni* (Fig. 5), *Chiroteuthis* sp. C, *Mastigoteuthis* A, *Moroteuthis* A, *Todarodes* sp. and *Pholidoteuthis boschmai* B (Fig. 6).

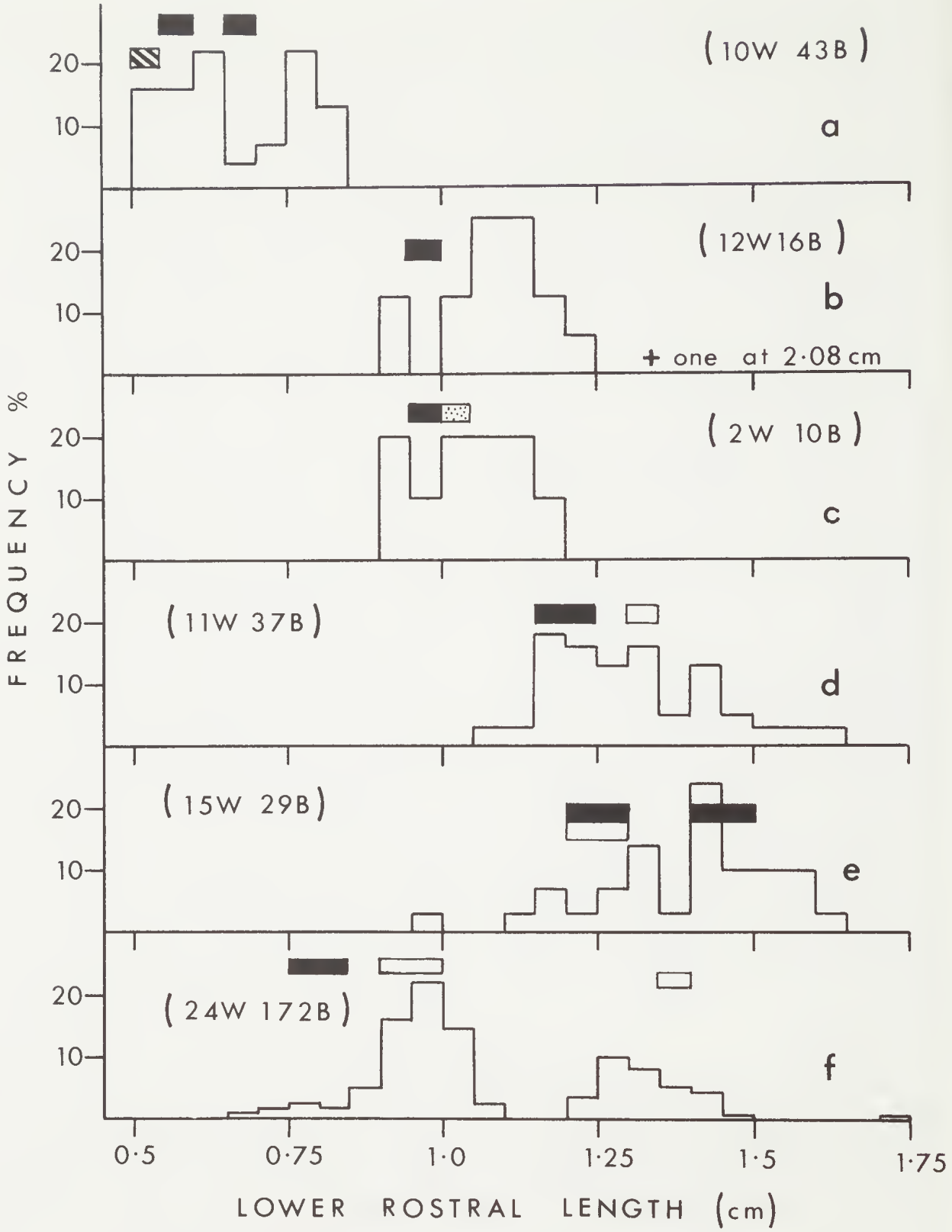
The LRLs of *Kondakovia longimana* have a range of 0.93-2.4 cm and a peak at 1.8-1.9 cm (Fig. 2). The upper limit of the range is higher than elsewhere where the maximum is 2.15 cm and there are 13 beaks larger than 2.15 cm in this collection. In addition, the peaks of the LRLs in whales caught off South Africa and in the Antarctic lie at both 1.3-1.4 and 1.6-1.7 cm and the peak for the small sample off Western Australia is 1.5-1.55 cm. Clarke (1980) showed that there is a marked change in size of the beaks through the year and interpreted this as a reflection of a two year growth to spawning and death. From July to November the LRL under the peak decreases and larger beaks become scarcer, presumably because the spawners are dying off. The peak of the present beaks is at the LRL which would be expected if the spawners continued growing or if some individuals did not spawn but continued growing. Thus we have the possibilities that in the Antarctic sector south of the Tasman Sea there may be a stock (or perhaps a different race or species) growing to a larger size than in sectors to the west as far as South America or an immigration of spawned and/or large individuals from the sectors to the west.

A beak of *K. longimana* with a LRL of 1.67 cm has undarkened wings and another just over 1.7 cm has no wings (this was probably undarkened in life). Below 1.7 cm 18 beaks have darkened wings and 12 have undarkened wings and darkening takes place between 1.05 and 1.7 cm. Darkening of the beaks in the South African and Atlantic sector of the Antarctic takes place at 0.9-1.2 cm. This is a very important difference between beaks of the Tasman Sea and the more western sectors since it shows that the stock of the Tasman Sea cannot derive merely from migration of large and spawned squids from the west but must be a stock with individuals growing to a larger mature size. Whether it can be regarded as the same species or should be more properly classed as a different species from *K. longimana* will only be clear when flesh can be collected.

LRLs of *Architeuthis* sp. have a range of 0.70-1.90 cm and a main peak at 1.5-1.6 cm (Fig. 2). This is different from the peaks found in beaks from whales caught off South Africa.

Fig. 5 Percentage frequency histograms of the rostral lengths of lower beaks of a ?*Discoteuthis*; b *Taonis pavo*; c *Galiteuthis armata*; d *Ancistrocheirus lesueuri*; e *Moroteuthis robsoni*. The number of whales (W) and beaks (B) are indicated. Horizontal bars indicate peaks of beaks thought to be the same species from whales caught off South Africa (black) and Western Australia (white).


20
10
(5W 22B)
a
20
10
(12W 21B)
b
FREQUENCY %
(21W 68B)
c
20
10
(27W 116B)
d
20
10
(25W 135B)
e
0·6
0·8
1·0
LOWER ROSTRAL LENGTH (cm)


(10W 43B)
a
(12W16B)
b
+ one at 2·08 cm
(2W 10B)
c
(11W 37B)
d
(15W 29B)
e
(24W 172B)
f
20
10
FREQUENCY %
0·5
0·75
1·0
1·25
1·5
1·75
LOWER ROSTRAL LENGTH (cm)

At Durban the main peak was at 0.50-0.60 cm with a small peak at 1.40-1.50 cm and at Donkergat the main peak was at 0.80-0.90 cm with just a suggestion of a peak at 1.3-1.4 cm.

The largest beak having undarkened wings has a LRL of 1.4 cm and the smallest one having darkened wings is the same size. This is different from South African beaks where the largest with undarkened wings is 1.1.cm and the smallest darkened is about 0.7 cm.

Differences in LRLs between South African and the present beaks may be caused by the difference in seasonal sampling. Off Durban 63% of the beaks were collected prior to June when most of the LRLs were 0.50-0.60 cm and no beaks were collected after September. Similarly, off Donkergat, only 18% were collected after August. The present beaks were all collected in November and, as beaks of a similar size are present off South Africa it is possible that growth through the year accounts for the difference between the regions and that the same species is involved. However, some doubt is introduced by the size of the beaks when the wings become darkened. This could be a regional difference in one species or merely a sample variation.

The LRL peak of *Taningia danae* at 1.2-1.3 cm is close to, and probably corresponds with, the main peak at 1.1-1.2 cm off South Africa (Fig. 2). The main peak at 1.6-1.8 cm is probably represented in samples from Western Australia (only 30 beaks). In some months in the South African samples there is a suggestion of a peak at a similar size. Wings of the beaks darken at a LRL of 0.8-1.6 cm which is closely similar to the species off South Africa and Western Australia and supports the conclusion that some beaks of the group with large LRLs are present in these regions.

Fig. 6 Percentage frequency histograms of the rostral lengths of lower beaks of a *Chiroteuthis* sp.; b **Mastigoteuthis**; c *Moroteuthis* 'A'; d *Todarodes* sp.; e *Cycloteuthis akimushkini*; f *Pholidoteuthis boschmai*. The number of whales (W) and beaks (B) are indicated. Horizontal bars indicate peaks of beaks thought to be the same species from whales caught off South Africa (black), western Australia (white), South America (hatched) and in the Antarctic (shaded).

The LRLs of *Histioteuthis bonnellii corpuscula* (A2) have a range of 0.46-0.70 cm and a peak at 0.56-0.58 cm (Fig. 4). These compare with a range of about 0.44-0.58 cm and a peak at 0.48-0.52 cm in South Africa and 0.50-0.54 cm off Western Australia. The difference between the three areas is possibly not significant although the species does seem to become larger from west to east.

The LRLs of *Histioteuthis ?dofleini* A4 have a range from 0.42 to 0.93 cm and peaks at 0.64-0.66 cm and 0.78-0.80 cm (Fig. 4). This compares with a peak at 0.75-0.80 cm in the Antarctic. Many but not all beaks under the peak at a smaller size are immature. This second peak may represent a different size group but we cannot rule out the possibility that another species is present.

LRLs of *Cycloteuthis akimushkini* have a range of 0.95-1.65 cm and a peak at 1.40-1.45 cm (Fig. 6). Beaks from whales caught off South Africa had a rather ill-defined peak at 1.20-1.30 cm. However, in the later half of the year the LRLs are slightly larger and in September the peak is at 1.30-1.40 cm and in October there is a secondary peak at 1.40-1.50 cm. At Albany in April and September combined, the peak is well defined at 1.20-1.30 cm. Thus, the present beaks seem to be slightly larger than those from further west and this could be caused by growth, since these beaks were collected later in the year (November) than elsewhere.

LRLs of *Pholidoteuthis boschmai* A have a range of 0.65-1.10 cm and a peak at 0.95-1.00 cm (Fig. 6). The peak at Donkergat is 0.75-0.80 cm, at Durban 0.80-0.85 cm, at Albany 0.90-1.00 cm (Clarke 1980) and 0.90-1.00 cm in New Zealand (Gaskin & Cawthorn 1967). Thus, beaks to the west and east of Australia are the same size and are larger than off South Africa.

Comparison of species

The percentage contribution of the families represented are compared with collections from sperm whales killed in five areas of similar latitude in Fig. 7 (see Clarke 1980; Clarke, MacLeod and Paliza 1976). Clearly the whales of the Tasman Sea collection eat much more Octopoteuthidae, slightly more Lepidoteuthi-

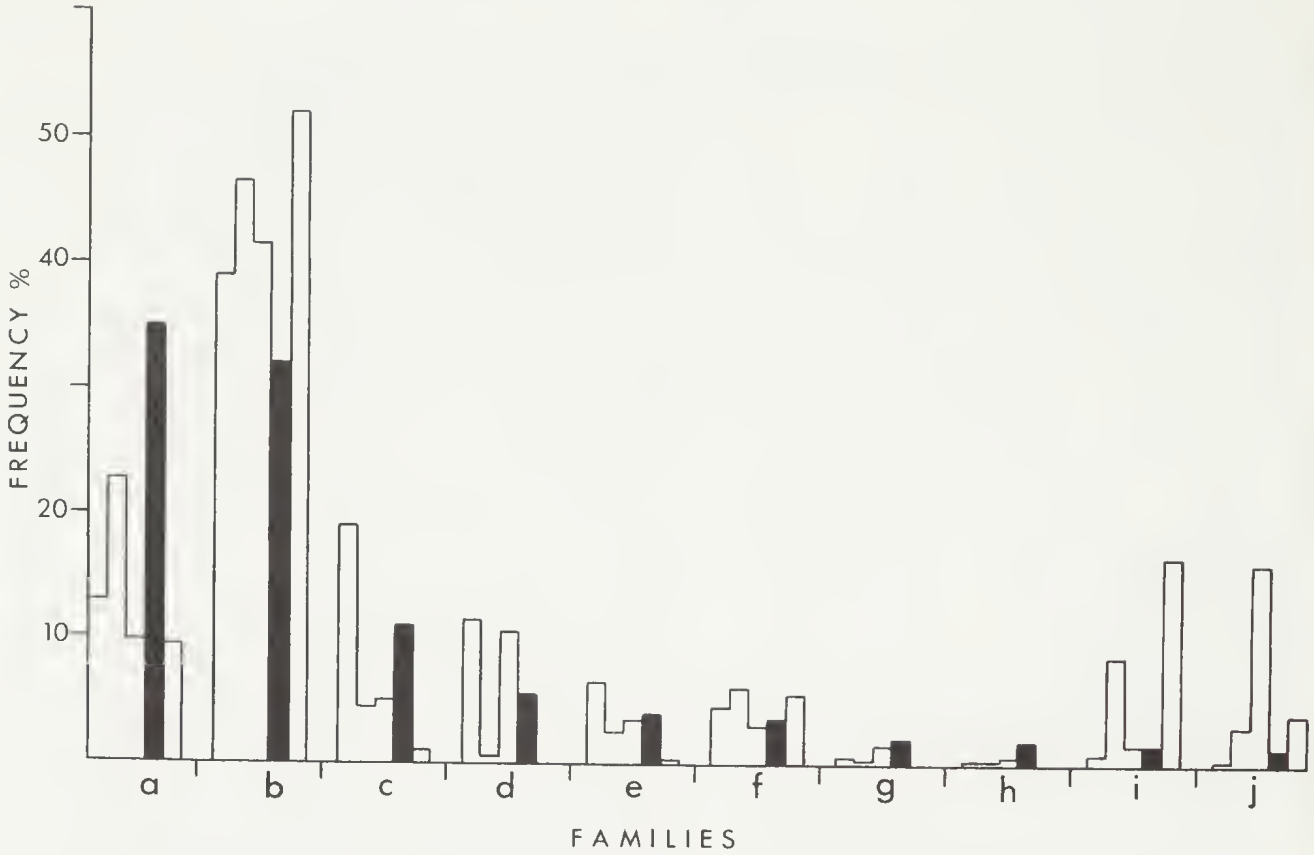


Fig. 7 A comparison of the percentage occurrence of the principal families of cephalopods from stomachs of sperm whales caught in five regions of the southern hemisphere. For each family the columns run from left to right (west to east), Donkergat (South Africa), Durban (South Africa), Albany (Western Australia), Tasman Sea and western South America. Tasman Sea percentages are shown in black. a Octopoteuthidae; b Histioteuthidae; c Cranchiidae; d Pholidoteuthidae; e Onychoteuthidae; f Enoploteuthidae; g Lepidoteuthidae; h Architeuthidae; i Chiroteuthidae; j Ommastrephidae.

dae and Architeuthidae and fewer Histioteuthidae than whales of the other regions.

Whale distribution

While male whales longer than about 37 feet (11.3 m) in length move to and from latitudes higher than 40°S, smaller males and females are rarely encountered south of this latitude (Slijper *et al.* 1964). This is reflected in the composition of beaks in the stomach and the typically Antarctic cephalopod species, *Kondakovia longimana* and *Mesonychoteuthis hamiltoni* are less commonly found and less numerous in the female and small males than in the large males. In whales caught off South Africa the females and small males (less than 39 ft (11.9 m) in length) had less than 1% and the larger males more than 12% of the beaks of these Antarctic species while, in the Tasman Sea collection, females have 1% and the males 6.3%. 82% of the males and 54% of the females from which beaks were collected have Antarctic species. Beaks of Antarctic species were collected from whales caught at all stations 1-9 except at the most northerly station No. 2 (Fig. 1). At station 6, four of the male whales had a large percentage (10, 26, 27 and 37% respectively) of beaks of Antarctic species which may suggest they were together in a school which had just previously moved north from higher latitudes. 60% of the beaks from Antarctic species from female whales occurred in two females caught at station 8. They were very large females 39 and 41 ft (11.9 and 12.5 m) long and must have been rather far south to pick up so many beaks of Antarctic species.

The smallest male having Antarctic beaks was 39 ft but there was only one smaller than this (38 ft, 11.6 m). Presumably the reason females in general have far fewer beaks of Antaretie speeies is that they only just cross the northern limit of the Antaretie squids while the males have far more beaks of Antaretie species beeause they wander right aeross the Convergenee and into higher latitudes.

Discussion

This eolleetion is of partieular interest because all the whales containing eephalopod flesh in their stomaehs were probably eaught where the depth of water exeeeds 1000 m and at some stations even 4000 m (Fig. 1). Indeed, many of these samples were eolleeted a great distanee from land or a eontinental slope and, beeause digestion of the flesh is rapid (Clarke 1980), this must mean that the squids eoneerned are widespread and not restrieted to eontinental slope areas in the Tasman Sea. A similar wide distribution is also indieated by eolleetions in the Antaretie and South Atlantie and this, together with the widespread oeeurrenee and large population of sperm whales, suggests that eephalopods must form a large proportion of the 'standing stoek' of nekton and the reservoir of protein in the deep oeeans. This is partieularly interesting sinee net-eaught eephalopods are too few and too small to suggest such a significant role in the food chains of the deep oeean.

In the oeeans of the Southern Hemisphere a warm subtropieal water mass meets a cold subantaretie water mass at the Subtropieal Convergenee (Deacon 1937; Rotsehi & Lemasson 1967). In the south of the Tasman Sea this eonvergenee extends from near Tasmania to the northern end of New Zealand and therefore lies roughly parallel with and slightly to the south of the line of stations from which samples were taken (Fig. 1). The hydrology or bathymetry of the Tasman Sea does not suggest any obvious diseontinuity aeross the line of stations (Fig. 1) whieh might act as a barrier to distribution and aeeount for the limits of speeies eolleeted. We do not know the actual position of the Convergence in November 1970.

Certainly at the longitude of Tasmania the East Australian eurrent pushes the Subtropieal Convergenee further south than its usual latitude whieh is nearer 40°S at other longitudes and in November, when the samples were eolleeted, the Convergenee is near its most southerly position (Rotsehi & Lemasson 1967).

To judge from the absenee of flesh of Antaretie squids in the whales eaught at 47°S the Convergenee was south of the most southerly station (47°S) at that time.

TABLE 3

Dimensions of some squids eolleeted from the stomaehs of sperm whales eaught in the Tasman Sea (cm)

[ ] = tips missing

	Pholidoteuthis					*Architeuthis*	*Chiroteuthis*		
	1	*2*	*3*	*4*	*5*		*1*	*2*	*3*
Sex	F					F			
Mantle Length	33	61	56.5	44	40	41.5	≏15		
Width						≏11			
Circumference			32			26			
Arm Length I						[32]	18	17.5	20.5
II						43.5	25	23.5	
III		24		22	20	49	[30.5]		32
IV	20.5					45.5			
Tentacle Length		71		68		140			
Club Length		16		16		22			
Fin Length		23	21.5	18.5	17	20	6.5		
Width	19	33	28.5	26	28	8	5.5		
Nidamental gland L	9.5					2.2			
LRL						0.78	0.73	0.70	0.76

All, or very nearly all, the species found in the Tasman Sea collection as flesh or beaks are also represented in collections made off South Africa and Western Australia and it is remarkable that in 17 species the size distributions are closely similar in the three regions.

Where size is quite different in the regions, as in the case of *Kondakovia* and *Architeuthis* in the Tasman Sea collection, there must be a suspicion that more than one species of cephalopod is concerned.

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