ASPECTS OF THE BIOLOGY OF, AND FISHERY FOR, THE HOTTENTOT, *Pachymetopon blochii* (VAL.) (SPARIDAE), IN THE WESTERN AND SOUTHWESTERN CAPE.

by

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To my Parents

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ABSTRACT

Data extracted from historic records have been used together with information collected during a survey of major fishing centres in the west and southwest Cape, from Port Nolloth to Struis Bay, to document the development of the handline fishery, with special reference to the fishery for hottentot _Pachymetopon_ _blochii_ (Val.). The fishing communities are described and social conditions are compared with those reported in earlier surveys. Changes in the fishing vessels and tackle used in the handline fishery are described and the economic status of the fishery evaluated. The distribution and availability of _P_. _blochii_ are assessed in relation to the various tackle types and catch methods in different areas and the contribution by this species to the total annual linefish catch is estimated. Total fishing effort expended in the commercial linefishery is used to calculate catch-per-unit-effort indices for the hottentot fishery and the seasonal and long-term trends in these indices are evaluated in relation to past and present constraints on the marketing of this species.

Gut content analysis shows the hottentot to be an omnivore, consuming a wide variety of algae and invertebrate prey associated with kelp (_Ecklonia_ _maxima_ Osbeck) beds. Amphipod crustaceans and rhodophytes are the dominant food items, although hydroids, echinoderms and molluscs are also eaten in smaller quantities. Geographic variation in the diet was negligible, although diurnal and seasonal trends were marked. A progressive change in diet occurs with fish size, the larger hottentot being more herbivorous. The

hottentot diet differs from those of a number of co-occuring sparids in being far more generalized. Diurnal feeding and gut elimination rate evaluation shows that hottentot feed throughout the diurnal cycle, although feeding activity is markedly higher during the rising tide. The tidally-determined feeding cycle is further modified by a lesser tendency to preferentially feed at night. Available mathematical feeding rate simulation models for continuously feeding fish were improved to incorporate an asymptotic consumption rate. The resultant model was used to calculate daily consumption rates for hottentot and the resultant value of 2.5 % body weight per day is compared with values calculated using earlier models, and with published feeding rate values for other species.

The length-mass relationship for P. blochii is described by the equation:

$$\text{Mass(g)} = 3.064\text{E-}5 \times \text{Lf(mm)}^{2.967}$$

and the total length-fork length regression by:

$$\text{Lt(mm)} = 1.0996 \times \text{Lf(mm)} + 1.419$$

The ratio of males to females in sampled catches was 1 : 1.383. Two main spawning seasons occur, in late autumn and summer, although some breeding activity occurs throughout the year. The length at 50 % sexual maturity is 220 mm Lf. Growth rates for males and females did not differ significantly and the combined growth rate is described by the relationship:

$$\text{Lf(mm)} = 538.015\ (1 - e^{-0.097(t + 0.431)})$$

The determined von Bertalanffy growth formula was validated by daily ring counts on scanning electron micrographs of otolith sections and back-calculated length at age values are summarised in an age-key for the species. In order to determine the degree of exploitation of the stock, catch and effort trends are investigated. Landings of hottentot have remained relatively constant, although a slight increase in CPUE appears to have occured since the start of the century. Length-frequency compositions of catches are presented, showing the mean size of fish to be larger on the west coast. The calculated length at first capture sample is 196 mm fork length. The relationship between hook size and length of fish captured is modeled, and it is determined that the size of hooks used in the fishery does influence the size of fish caught. The total mortality and natural mortality are 0.733 and 0.338 $year^{-1}$, respectively, giving a fishing mortality of 0.395 $year^{-1}$. These parameters are also determined separately for Lamberts Bay, Saldahna, Kalk Bay and Gans Bay, and the yield per recruit curves indicate that the current fishing effort is appropriate for efficient utilization of the stock. Finally, available management options and their applicability to the hottentot stock are investigated.

INTRODUCTION

The hottentot fish, Pachymetopon blochii (Val.), is a sparid endemic to southern Africa. It occurs commonly in and around kelp (Ecklonia maxima Osbeck) beds and on subtidal reefs, from Luderitz to the mouth of the Breede River (van der Elst 1981), and forms a major component of the western Cape commercial handline catch.

Research on the species dates back to the start of the century when the Govenment biologist, J.D.F. Gilchrist, made observations on the behaviour, feeding habits, parasitism by crustaceans, and diseases of this species. Further work, including dietary, reproductive and growth studies, was undertaken by Nepgen (1977).

In tracing the history of management of P. blochii, one finds that the Sea Fisheries Act of 1940 introduced the first size limit of 200 mm total length on this species. This Act, which incorporated control over the offshore fisheries (previously neglected in the Cape Fisheries Ordinance of 1920), included numerous new regulations regarding size limits and the protection of reef fish. Under the subsequent Act of 1973, the minimum legal size limit was revised to 220 mm total length, and has remained such. In the December 1984 Amendment to the Regulations, a further restriction, limiting all non-commercial fishermen to 10 fish per man per day, was imposed.

In the light of renewed interest in the linefishery, the hottentot was identified as a species in need of further investigation (Wallace & van der Elst 1983). With the subsequent establishment of the Marine Linefish Research Programme within SANCOR, research into the species was continued.

Research aims were : 1) to undertake an historical review of the linefishery and trace its development; 2) to re-evaluate the feeding and reproductive biology and to determine geographic and/or seasonal variations in these aspects; 3) to concentrate on aspects of stock assessment through catch and effort analysis and by means of growth and mortality rate studies, and 4) to investigate and evaluate the effective control and management of the stock.

LITERATURE CITED

NEPGEN, C.S.DE V. 1977. The biology of the hottentot Pachymetopon blochii(Val.) and the silverfish Argyrozona argyrozona(Val.) along the Cape south-west coast. Investl Rep. Sea Fish. Brch S. Afr. 105:1-35.

VAN DER ELST, R., 1981. A guide to the common sea fishes of southern Africa. Struik, Cape Town.

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1. THE DEVELOPMENT OF THE LINEFISHERY ON THE WESTERN AND SOUTHWESTERN CAPE COAST, WITH SPECIAL REFERENCE TO HOTTENTOT

A number of authors (Gill 1958, Irvin and Johnson 1964, Grindley 1969, Lees 1969, De Jongh 1974, Robb 1975) have described the development and status of the South African pelagic, demersal and long-line fisheries, but no attempt has been made to provide similar information on the handline fisheries of the Cape coast, since Thompson (1913) discussed the establishment of these fisheries more than 70 years ago. Although overshadowed, in terms of tonnage landed and financial turnover, by the larger offshore industries, the handline fishery remains an important local source of income and employment, and many of the practices used have changed little since its foundation. This study investigates the development and current state of the handline fishery in the Western Cape, with special reference to the hottentot (Pachymetopon blochii Val.).

METHODS

In order to obtain data on the distribution of fishing effort, techniques used and the socio-economic condition of the fishery, a survey of the fishing centres between Port Nolloth and Struis Bay was conducted, , appropriate information being acquired with the aid of a questionnaire.

In order to guard against misinterpretation of questions, it was decided that the questionnaire would be completed in the form of a personal interview. This provided the opportunity of standardizing responses and also allowed the subjects to broaden their discussion into areas they felt might provide new and interesting areas for investigation.

In undertaking the survey, the suggestions of Johannes (1981) were taken into consideration and in most cases verified. Without exception, the fishermen reacted with suspicion to outsiders asking pointed questions and it was usually necessary for the investigators to dissociate themselves from the fisheries enforcement body. Effort was made to obtain an unbiased view of the conditions at the different fishing stations by interviewing both regular fishermen and other authoritative persons (factory managers, harbour masters and/or inspectors). As suggested by Johannes (1981), the fishermen interviewed were, in most cases, older men with a broad and well established knowledge of the industry. The reliability of the informants was tested, by asking: 1) questions to which the answers were already known by the interviewer, and 2) plausible questions to which the fishermen could not know the answers.

Data on the development of the handline fishery were obtained from historical records held by the SFRI, University of Cape Town Afrikaaner Collection and the Cape Government Archives.

RESULTS AND DISCUSSION

1. Development of the Linefishery

Development of the fishing areas in the Cape Colony was initially slow, both because the industry was discouraged by the authorities in the newly established settlement, and also because the garrison could offer little protection to those burghers who attempted colonization of the inhospitable and hostile coastline (Thompson 1913, Official Year Book 1918, Muller 1938). This, and the limited equipment available, resulted in the fishing areas remaining restricted to the inshore waters of Table Bay and False Bay. With the inception of British rule in 1795, and the subsequent extention of the colonial boundaries, an expansion of the fishing areas along the West and East coasts became possible (Thompson 1913).

Although some species are now sought on deeper off-shore reefs, the handline fishery has largely remained confined to the inshore areas, and this is especially the case in the fishery for *P. blochii*.

2. The People of the Handline Fishery

Although the Bantus reputedly made no use of the marine resources in early colonial times (Muller 1938, De Jongh 1974), a local clan of Hottentot, the 'Vischmans' were highly skilled at both spear and handline fishing. The Dutch immigrants also brought with them a knowledge of fishing. As the slaves of the early Colony were given the priviledge of fishing on Sundays, many of them took to the industry as a means of income after they had worked out their freedom and the fishery therefore slowly moved into the hands of these Eastern races (Thompson 1913). Chief amongst these were the Malays, who for many years held the monopoly of the fishing operations in Table Bay.

Colonization of the West coast was mainly by deserters from the Colony who further encouraged passers-by, especially the Italians, to join the industry (Lees 1969, Cadle 1983).

As little was known about the socio-economics of the fishing population at the start of the century, a survey of the fishing centres was conducted in 1913 (Advisory Board 1913). This was supplemented by a similar investigation of four harbours (Lamberts Bay, St Helena Bay, Hout Bay and Gans Bay) in 1946 (Social Welfare Dept. 1946).

The survey of 1913 found most of the fishing communities in very poor circumstance. With the exception of Port Nolloth, Hout Bay, Gordon's Bay and Gans Bay, the industry was dominated by coloured fishermen, with Philippinos having the monopoly of the Kalk Bay fishery. The conditions reported in 1946 (Social Welfare Dept. 1946), remained ones of extreme poverty and dependence on the fishery. Lamberts Bay, however, which had previously been considered amongst the poorest communities on the coast (Lees 1969), had become a thriving village in the boom of the pelagic industry. Although the Europeans had the commanding influence, the industry was still reliant on coloured labour. The Hout Bay fishing community had become dominated by coloured fishermen by this time and in

Gans Bay, the now well-established European community, was becoming increasingly dependent on non-white crews (Social Welfare Dept. 1946).

What became immediately apparent in the present survey is the dominance, in the linefishery, of the non-European fisherman. Whereas, at the start of the century, the majority of the fishing communities were entirely dependent on the linefishery for their subsistance, the West coast fisherman today relies on the rock lobster (Jasus lalandii M. Edw) industry for the bulk of his annual income. Although some independent, full-time commercial linefishermen do still operate, most of the fishermen are employed by their local rock lobster factories during the season (November - May). During the off-season they are either paid a weekly retainer fee, kept employed at the factory in maintenance work or part-time line fishing, or they find alternate means of employment. The pelagic fishery also provides ample job opportunities during its seasons, and during the snoek (Thyrsites atun Euph.) runs (April - June) most of the fishermen take to sea in an attempt to make a quick profit.

Although most of the fishermen live in small cottages provided and maintained by the rock lobster companies, accommodation, in the form of municiple apartments and houses, is also provided at some harbours, and in a few cases the fishermen own their own homes.

The Cape South coast is not influenced by the rock lobster fishery, yet many of the fishermen are involved in the collection of abalone

(Haliotis midae L.). Unlike the West coast , where the snoek and hottentot are the two fish species most frequently caught, the linefishery of the South coast targets mainly for kob (Argyrosomus hololepidotus Lac.), geelbek (Atractoscion aequidens C.), yellowtail (Seriola lalandii Val.), panga (Pterogymnus laniarius C.) and silverfish (Argyrozona argyrozona Val.).

From the survey, it was concluded that the inshore linefishing community on the Cape coast is still, in general , of fairly poor circumstance. Most of the fishermen are dependant on other industries for the bulk of their income, and many of the younger generation are leaving the practice to take on more permanent employment with a reliable income.

3. Fishing Methods

The fishery practiced by the Hottentots was strictly shore-based. Detailed descriptions of their methods of fishing with spears, handlines and thrownets are provided by Thompson (1913), Muller (1938) and Raven-Hart (1971).

In the earliest days of the Colony, the Dutch fishermen made use of ship's boats and canoes for both seine-net and line-fishing. As the Company began importing larger vessels, and the demand for the larger, more delicately flavoured line-caught species increased, so the method of handlining became more popular (Thompson 1913).

Although initially boat designs varied greatly, with time the Cape fishing boat evolved. This sailing boat was well suited to the local conditions yet was limited in size and weight due to the necessity of carrying the boats up the beach every evening (Thompson 1913, Muller 1938, Robb 1975).

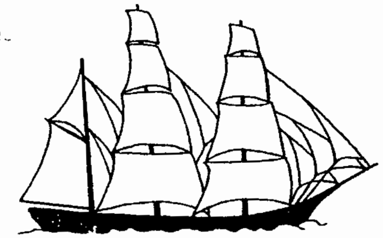
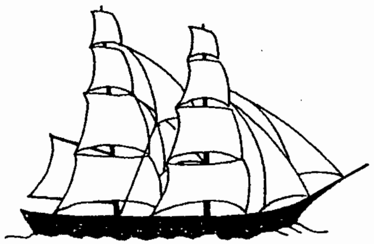
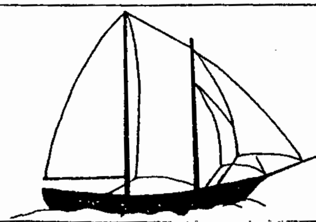
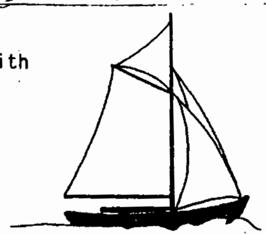
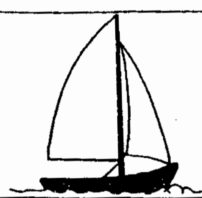
By the end of the 19th Century larger petrol, oil and steam propelled craft began appearing, allowing access to the deep water fishing grounds. Owing to the scarcity of harbours in which bigger boats could shelter, there was a direct transition from small, open rowing craft to steam vessels (Official Year Book 1918). Table 1.1 provides a comparison of the craft of the past with the more modern vessels engaged in the linefishery today. It is interesting to note that the majority of boats involved in the fishery are still small 2 - 6 man boats, and although no longer dependent on sails, they remained shortrange craft functionally little different from the cutters and dinghies of the past.

There has also been little alteration in the basic handline tackle used over the last century. The only major change has been the introduction of nylon line after the second World War, and the consequent use of eyed hooks which could now easily be knotted onto the trace.

Variation in the bait used, as described by Thompson (1913), has also been minimal. Pilchard (Sardinops ocellata Pappe) is the most widely used fish bait for general linefishing today because it is easily obtainable and relatively inexpensive. On the west coast it is exclusively used for catching snoek whereas on the South coast it is used, together with maasbanker (Trachurus capensis Houttuyn)

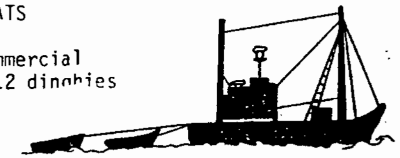
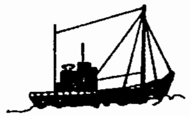
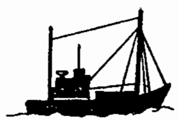
TABLE 1.1 Characteristics of fishing vessels operational (a) before 1920, and (b) in the 1980's, in the general linefishery on the Cape West and South coasts.

a

FISHING VESSELS		LENGTH (metres - l.o.a)	PROPULSION	RANGE OF OPERATION (NAUTICAL MILES)	MAX. NUMBER OF CRAFT OPERATING BETWEEN 1980 & 1900
WHALING BOATS a) Bark-decke		> 20	Square-rigged on fore and main mast. Mizzen mast fore-and-aft rigged	?	6
b) Brig-decked		> 20	Fore and main masts square-rigged	?	±5
FISHING BOATS a) Schooner-decked		15 - 20	Fore-and-aft rigged on all masts	±40	±45
b) Cutter half-decked with centreboard		7.5 - 8.5	Fore-and-aft rigged mast with mainsail and two jibs. Oars - 5-6.5m	±30	±45
c) Dinghy		4.5 - 6.5	Fore-and-aft rigged single mast. Mainsail and jib oars 4.5-6m	15	±500

(Legislative Council 1838-1885. De Jongh 1974. Cadle 1983)

b

FISHING VESSELS		LENGTH (metres - l.o.a)	PROPULSION (NAUTICAL MILES)	RANGE OF OPERATION	NUMBER OF CRAFT OPERATING
CRAYFISH BOATS					
a) Large Commercial with 10-12 dinghies CFBa		15.0 - 20.0	Single skrew diesel	< 100	3 - 4
b) Small Commercial CFBb		10 - 15	Single skrew diesel	< 75	2 - 4
		5 - 10	Single skrew diesel	± 15	3 - 6
LINEFISH BOATS					
a) Decked, commercial lineboats LFBa		8 - 15	Single skrew diesel	< 40	18 - 23
b) Small decked lineboats LFBb		5 - 10	Single skrew diesel	± 15	40 - 45
c) Small undecked or partially-decked motorboats LFBc		4 - 8	Short-shaft diesel	± 12	10 - 12
d) Skiboats LFBd		4.5 - 8.0	Twin outboard or Z-drive	< 15	19 - 24
e) Dinghies LFBe		3 - 5	Single outboard (18-25 Hp)	< 6	125 - 135
f) Rowboats LFBf		3 - 5	Oars	3 - 4	80 - 120

and the recently introduced Japanese pike (Atlantic saury, *Scomberesox* sp.)to catch most linefish species. The most popular and widely used bait on the South coast is squid (*Loligo reynaudi* Orb.). Also easily obtainable commercially, the fishermen prefer this bait as it is tougher than fish bait (H. Venter FDC, pers. comm.).

When fishing specifically for hottentot, rock lobster has remained the favourite and most widely used bait on the West coast, whereas on the South coast its place is filled by redbait (*Pyura* spp. Heller). The most preferred fish bait is steentjie (*Spondyliosoma emarginatum* Cuvier), although pilchard is more frequently used because it is more easily obtainable. Black mussel (*Choromytilus meridionalis* Kr.) and white mussel (*Donax serra* Röding) are also considered good bait for hottentot, although seldom used as the fishermen feel the effort required in collection excessive.

4. Marketing Factors

In the early days of the Colony and up until the introduction of cold storage and the development of transport infrastructure, the various fishing stations supplied their immediate districts only. The fish was mainly used for local consumption, although there was a constant demand by the farmers further inland for food for their labourers. Fishriders would, on occasion, distribute fish to the inland areas (Legislative Council Blue Books 1838 - 1885).

It was thus only in Cape Town that a substantial market was developed and the Malay fish-hawkers of the Peninsula became a familiarity. These colourful characters and their peculiar practices, described by Thompson (1913) and Robb (1975), had by the early 1900's largely been replaced by the fish dealers, or "langane", that are still familiar today. The "langane", or their agents, buy directly from the boats, bidding on individual catches as they are off-loaded. Although some have their own shops or stalls in the suburbs, most of the fish is sold from vehicles, on the roadside, for as much as 200% profit.

The hawkers from the Cape Flats concentrate their efforts mainly on Kalk Bay, as it is the only harbour on the Peninsula at which fish is off-loaded regularly. On occasions they may, however, travel further afield to purchase snoek. At the West coast fishing centres the majority of the fish is sold to the rock lobster factories or to retailing concerns, and on the South coast local dealers buy the catches. These buyers will then sell the produce to the local public, distribute it inland or sell to major retailing companies in Cape Town.

As in the past, wholesale prices today vary between harbours, while remaining relatively constant throughout the year. As would be expected, at those fishing stations where the rock lobster factories provide the boats, the fuel and the bait, the fishermen are paid considerably less per kilogram for their catches than where they operate independantly.

Although most of the linefish is sold fresh or frozen locally, the export market for cured snoek, mainly to Mauritius, established in the mid-1800's (Legislative Council Blue Books 1840 - 1885), is still of major economic importance.

5. The Fishery for Hottentot

Although hottentot occur commonly on the edge of kelp beds on shallow water reefs, they are also caught in deeper water over rock and on offshore pinnacles and blinders throughout their range. They are caught in depths of 3 - 55m and, although mainly omnivorous bottom feeders, are usually lured into the water column by the bait.

Although the species is widely available to the limits of its distribution, the linefishermen at the various fishing centres have specific sites they visit when fishing for them. From mention made by Gilchrist (1903), reports received from fisheries officers (Gilchrist 1905) and from conversation with fishermen, it appears that they make little attempt to search for new banks. The nature of these traditional areas may be of importance, the fish being attracted to pinnacles, blinders and high profile reefs by the increased turbulence and concequent abundance of food.

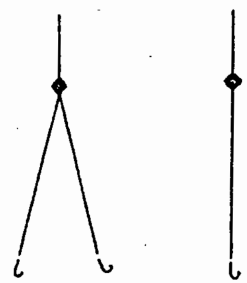
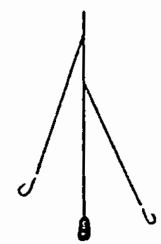
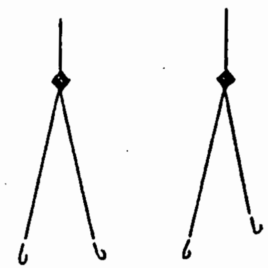
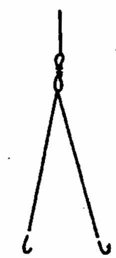
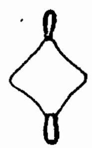
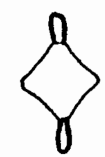
It is interesting to note that fishermen are still landing adequate catches of hottentot from areas they have been exploiting for many years, and have not found it necessary to search for new banks due to declining catches, as is the case with the redfish fishery (A. Penney SFRI, pers. comm.). This implies that the current fishing pressure does not appear to have much impact on the size of the populations.

Although there has been little change in the tackle operational in the hottentot fishery (Table 1.2), the survey of the fishing centres revealed that some subtle variations exist in the types of traces used today. At Port Nolloth and Hondeklip Bay the most common trace is the "Christmas tree" type, with a drop sinker. From Doorn Bay to Kommetjie, both the traditional trace of two equal-length lines, as well as that where one line is slightly longer than the other, are used. From False Bay eastwards however, only the traditional trace is employed. Drift lines, of one or two-hooked traces, attatched to a swivel or small sinker, are also widely utilized, mainly to catch the larger, more "sly" fish.

Another variation is that of the hook sizes used for catching hottentot. In the area from Port Nolloth to St Helena Bay, No. 2/0 and 1/0 hooks are popular, whereas from Saldahna Bay to Hout Bay Nos. 1/0, 1 and 2 are used. A range of even smaller No. 1, 2 and 3 hooks are common from Kommetjie to Hawston. Further east to Struis Bay, where targeting is mainly for other species, the larger No. 3/0, 2/0 and 1/0 are again employed.

It is notable that the area between Saldahna Bay and Hawston, in which smaller hooks are utilized, corresponds with the area in which _P. blochii_ is most intensively exploited. According to local fishermen, the mean size of hottentot caught in this area has declined in recent years and fishermen have resorted to using

TABLE 1.2 The fishing equiptment used in the handline fishery for hottentot, *P.blochii* (Val.), past and present.

EQUIPMENT	PAST		PRESENT			
LINES	Blooded hempen Thickness depending on species sought (Thompson 1913)		Nylon since ± 1950 40 - 60lb breaking strain			
TRACES	Gut twisted with strands of cotton twine About 300mm 	(Thompson 1913)	15 - 35lb Nylon line About 300mm  Christmas-tree	 traditional		 Drift-line
SINKERS	4 - 8 oz Typical Cape pattern 	(Thompson 1913)	< 2 oz  Drop sinker	 free-running ball sinker		 Cape pattern
HOOKS	Stout metal hooks No eyes, flattened ends No. 1/0 mainly also 2/0 and 3/0	(Thompson 1913) (Cloete, pers.comm)	Stout metal hooks - "brown" hooks Eye present Nos. 2/0; 1/0; 1; 2 and 3			
BAIT	<u>WEST COAST</u> Rock lobster	<u>SOUTH COAST</u> Redbait Octopus (Thompson 1913)	<u>WEST COAST</u> Rocklobster Pilchard Black and white Mussel		<u>SOUTH COAST</u> Redbait Steentjie (*S. emarginatum*) Pilchard Black and white Mussel	

smaller hooks in an effort to maintain catch rates, by increasing the catch of smaller fish. Gilchrist (1901) reported a similar decline in hook size in response to a decline in mean size of fish caught in the St Helena Bay area.

Although handlining remains the major method of catching P. blochii, the species is often landed by recreational shore anglers using rod and reel, and by spearfishermen. Lees (1969) and Cadle (1983) report that hottentot form a part of the by-catch of the set-net and beach-seine fisheries (217 kg reported for 1985, SFRI unpublished data), and they are also commonly brought up in rock lobster traps.

In order to establish the intensity and geographical distribution of the modern hottentot fishery around the western and southern Cape coast, data on the numbers and types of boats used, the number of people involved and the time spent fishing, were collected. From these data an estimate of effort was calculated for each fishing centre (Table 1.3).

On the west coast active commercial linefishing is only practiced when the rock lobster season is closed, and this has to be taken into consideration when determining the number of days spent linefishing. Although the season officially closes in May, most companies fill their quotas by the end of March (SFRI, unpublished records). Many fishermen do however revert to small-scale handlining, once the traps have been laid. Although small quantities of fish are landed, the effort directed at linefishing during this

TABLE 1.3 Estimated fishing effort by full-time, commercial fishing boats participating in bottom fishing (i.e. not fishing specifically for the larger migratory shoaling species). Codes for type of boat from Table 1.1 (reg) = boats in regular operation.

Area	Type of Boat	No.of Boats Used	Days Fished per Year	Hours Fished per Day	No.of Crew per Boat	Estimated Fishing Effort (Hours)
Port Nolloth	LFB f	+15	50-75	3-4	2-4	9 855
	LFB d	1	120-180	8	4-6	6 000
						15 855
Hondeklip Bay	LFB e & f	5-6	60-144	6-8	2-4	11 781
	LFB f	10	48-60	6-8	2-4	11 340
						23 121
Doorn Bay	CFB a	2	70-105	4-5	30-34	25 216
	LFB e	+3	120-180	6-8	2-4	9 450
	LFB f	+10	35	5-6	2-4	5 790
						40 456
Lamberts Bay	CFB a	2	15	8-10	30-34	8 640
	CFB b ii	6-8	56-84	8-10	6-12	39 690
	LFB e(reg)	4-5	120-180	8-10	2-4	18 225
	LFB e & f	10-15	35	8-10	2-4	11 813
						78 468
Elands Bay	LFB f	60-100	105-140	5-6	2-4	161 760
						161 760
Sandy Point	CFB b ii	2-4	35-75	6-8	6-12	9 936
	LFB c	2	+70	6-8	6-8	6 860
						16 796
Stompneus	LFB d	2	35	8-10	4-6	3 150
	LFB e	3	35	8-10	2-4	2 835
						5 985
Paternoster	CFB b i	2-3	70-105	7	10-20	22 988
	LFB e & f	5-6	70-105	6-8	2-4	10 115
						33 103
Saldahna Bay	LFB a	+6	70-105	6-8	10-14	44 136
	LFB c	+10	70-105	6-8	6-8	42 910
	LFB e	+15	120-180	6-8	2-4	47 250
						134 296
Yzerfontein	LFB d	3-6	240-300	6-8	4-6	42 525
						42 525
Cape Town	LFB a	2	25-35	6-10	10-14	5 760
						5 760
Hout Bay	LFB a	1	30-35	8-10	10-14	3 516
	LFB d	6	70-84	8-10	4-6	20 790
						24 306
Kommetjie	LFB e	15	70-105	5-6	2-4	21 645
						21 645
Kalk Bay	LFB a	3	300-325	6-8	10-14	78 750
	LFB b	+20	300-325	6-8	6-8	306 250
						385 000
Gordon's Bay	LFB a	1	+215	7-8	10-14	19 440
	LFB b	3	+215	7-8	6-8	34 020
	LFB d	2	180-240	7-8	4-6	15 750
						69 210
Hawston	LFB e	5-10	120-180	4-6	2-4	16 875
						16 875
Hermanus	LFB a	1	180-240	8-10	10-14	25 200
	LFB c	1	180-240	8-10	6-8	14 700
						39 900
Gans Bay	LFB e	+40	+120	5-6	2-4	79 200
						79 200
Struis Bay	LFB b	38	+170	6-8	6-8	316 540
						316 540
				TOTAL EFFORT		1 415 121

period is difficult to determine. Taking all these factors into consideration, the linefishing "season" was thus taken to be seven months (April - October).

The effort directed specifically at the hottentot fishery varies dramatically around the coast. On the west coast, the fishermen direct all their effort at hottentot when not targeting for snoek, using specialized bait and frequenting specific catch sites where the species is abundant. Although small quantities of other species may be landed their presence is incidental, hottentot constituting the bulk of the catch. On the south coast however, the species diversity of fish increases and the fishermen devote more effort targeting for those species with a higher commercial value than hottentot (with the possible exception of Hawston). In contrast to the highly specialized snoek lure, which is unlikely to attract shoaling reef fish, the tackle used to catch the preferred south coast species could equally well hook hottentot. Thus although most of the effort is directed at other species, P. blochii will be landed. Only at certain times of year, when the preferred species, which are migratory, are unavailable, do the fishermen target deliberately for hottentot.

The estimated effort calculated from these data, is representative of the commercial linefishery but does not take into account the sporadic increase in effort that may occur in response to the appearance of large shoals of migratory species (snoek, yellowtail, kob, geelbek).

The estimated effort expended in general commercial linefishing at the fishing harbours around the coast is represented diagrammatically in Figure 1.1, the area of the circles being related to the effort in hours spent fishing. The proportion contributed by the hottentot catch to the total landings for that area, was obtained by calculating the mean percentage contribution from the 1984 and 1985 SFRI linefish catch returns, and is illustrated by the shaded portion. It must be emphasized that this represents the proportion of the catch only and not the proportion of the effort.

From Figure 1.1 it becomes clear that there is a general decrease in the proportion of hottentot landed from west to east, indicating that the linefishery progresses from an industry dependant on snoek and hottentot, in the west, to a multispecies fishery on the south coast. Unfortunately, no catch return data are available for Hondeklip Bay, although the results of interviews indicated that hottentot constitute more than half of the catch for this area, thereby complying with the trend.

Although the False Bay fisheries initially targeted for the redfish and migratory species, the decline in their catches was not paralleled by a decrease in the fishing effort. Subsequently the effort switched to those species more easily available, such as _P. blochii_. Hottentot have remained an important commodity of the Kalk Bay and Gordon's Bay fisheries, explaining the increase in the percentage landed at these stations when compared with other harbours on the Peninsula and south coast.

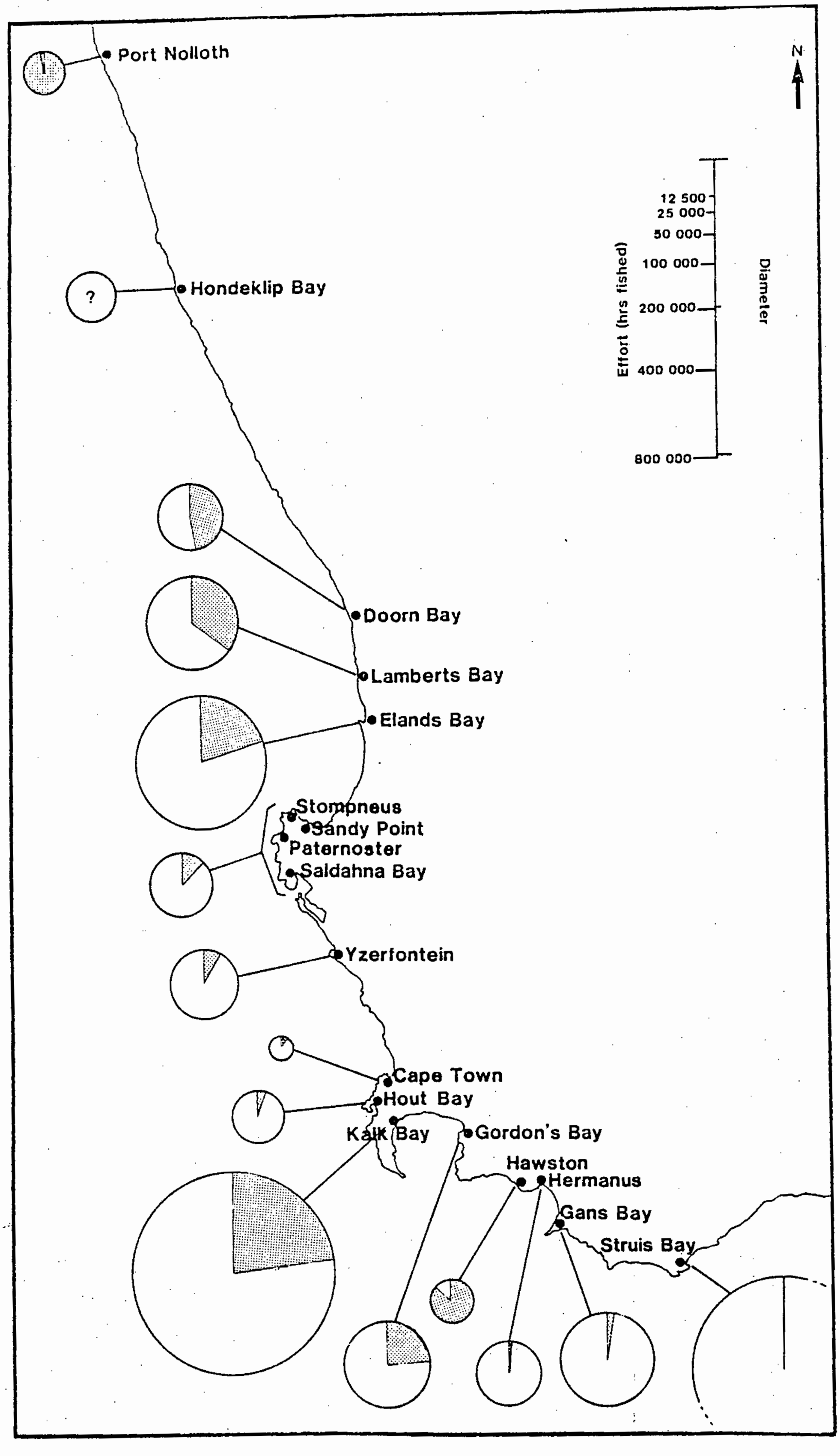


FIGURE 1.1 Map of the west and south-west Cape coast showing the fishing harbours visited during the survey. Estimated annual fishing efforts for the harbours (in man-hours fished) are represented by the diameters of the circles shown. The shaded segment of each circle represents the mean percentage contribution of hottentot to the annual landings of linefish at the harbour concerned during 1984 and 1985.

Although the proportion of hottentot caught at Hawston is unexpectedly high, the actual weight of fish landed is minimal in comparison with other harbours (SFRI, unpublished records). Effort is directed almost entirely at hottentot and red roman (<u>Chrysoblephus laticeps</u> Cuvier), poor landings of the latter species resulting in the high percentage of hottentot for this area.

<u>P</u>. <u>blochii</u> exhibits little or no seasonal fluctuations in its abundance (Provincial Secretary 1927, van der Elst 1981), although the fishermen claim that the adult fish move into deeper water during the winter months to spawn. Analysis of SFRI catch returns, however, identified both seasonal and other temporal trends in the fishery. Plotting daily catches of hottentot, and comparing them with snoek and rock lobster returns (eg. for Lamberts Bay), illustrates how fishing effort for the species decreases over weekends and how the numbers landed decline during the snoek and rock lobster seasons (Fig. 1.2). When compared with monthly landings from the same area for 1897 - 1906 (Fig 1.3), it becomes apparent that the modern situation is little different from that at the start of the century. This emphasizes that the hottentot fishery is very much a fishery of last resort, the proportions of fish landed depending largely on the seasonality of other fisheries.

From Thompson (1913), Muller (1938) and Raven-Hart (1971), who quote the opinions of the early settlers on the popularity of the species, it appears that <u>P</u>. <u>blochii</u> has always been of reasonable commercial value. Although known mainly by the name of hottentot or "hotnotsvis" (Thompson 1913), the species was also referred to

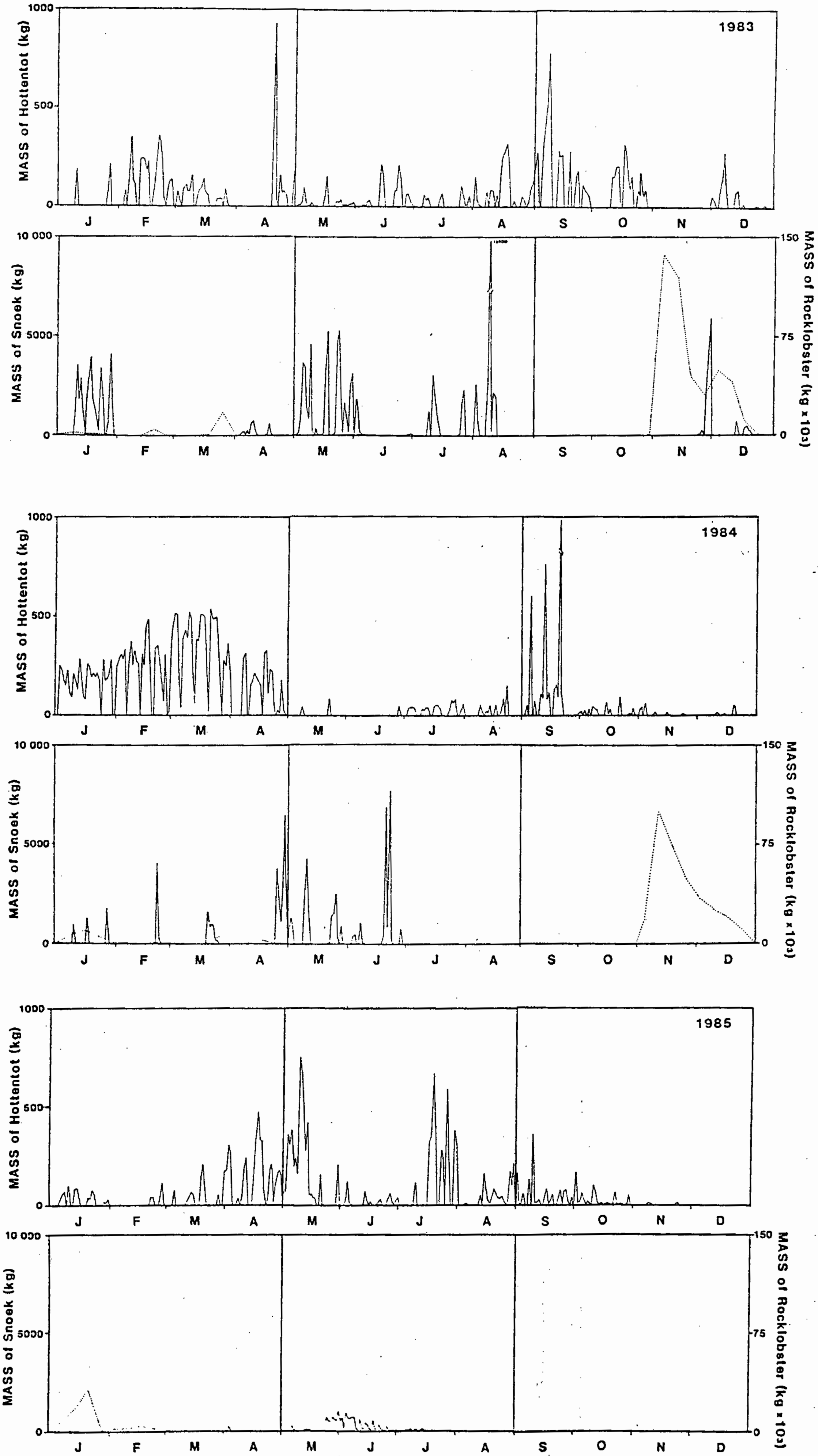


FIGURE 1.2 Daily trends in the reported landings of hottentot at Lamberts Bay, for 1983, 1984 and 1985, compared with daily catches of snoek and weekly catches of rock lobster (.....) for that harbour.

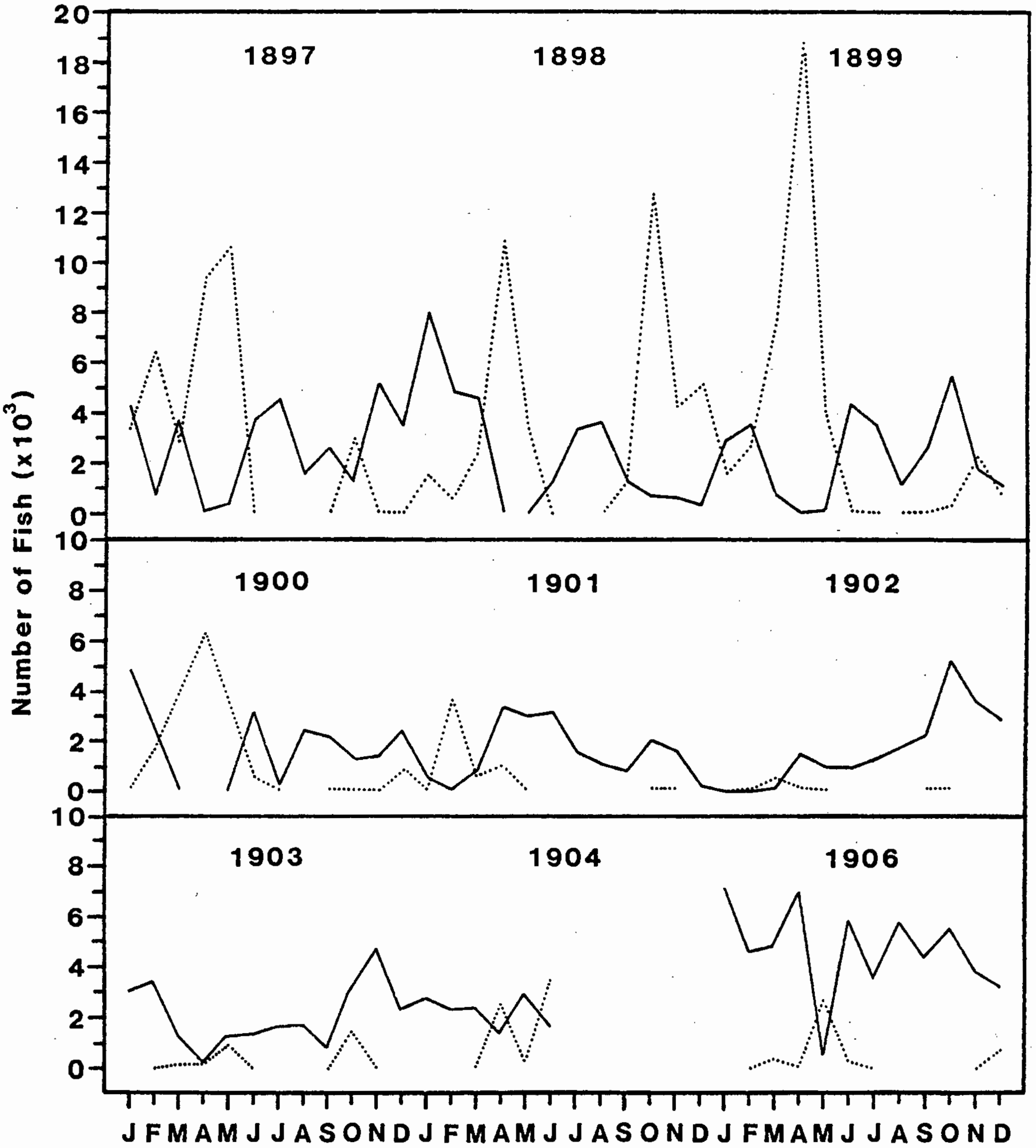


FIGURE 1.3 Monthly trends in the reported landings of hottentot (——) and snoek (...) at Lamberts Bay from 1897 - 1906.

as "hangberger" at the beginning of the century. Today the larger fish are sold as "Kaapse galjoen" whereas the smaller specimens are known as "katjies". By the larger fish dealing concerns they are marketed as "porgy".

Before the advent of cold storage, the species was a popular pickling fish, as well as being dried, salted and sold fresh by the hawkers (Legislative Council Blue Books 1838 - 1885, Thompson 1913, Provincial Secretary 1927). The majority of hottentot today are sold fresh or frozen, the consumer market being dominated mainly by the non-white groups. It is to some extent however, still used as a table fish in European households.

Besides the export of salted hottentot to Holland, mentioned by Thompson (1913), no other reference concerning the export of this species could be traced. More recently however, export of frozen hottentot to France, Greece, Zaire and other African states was undertaken by a number of wholesaling concerns. In accordance with overseas demand, the fish were packed and frozen whole. This however caused the product to acquire a very fishy taste, which subsequently resulted in the collapse of the market.

A number of references (shown in Table 1.4) exist concerning the price of fish in the past, enabling comparison with modern costs.

TABLE 1.4 References used to obtain data on historic wholesale prices of hottentot.

Date	Reference
1659	Thompson (1913)
1822	Thompson (1913)
1897-1906	Gilchrist (1898, 1899, 1900, 1901, 1902, 1903 1904, 1905, 1907)
1911	Williams (1913)
1922	Anon (1922)
1925-1926	Provincial Secretary (1927)
1929	Cape Argus (1929), Cape Times (1929)
1930-1932	Dept. of Mines and Industries (1933)
1935-1939	Dept. of Mines and Industries (1937a, 1937b, 1939, 1949, 1941)

Figure 1.4 illustrates the trends in the price per kilogram of hottentot from as early as 1659. The data recorded by the Government Biologist, Dr. Gilchrist, between 1897 and 1906, indicate that the price by no means remained constant over that period, and that fluctuations may thus be expected for the period between 1659 and 1897, for which no data are available. The average price rose steadily during and after the Boer War (1899 - 1902), especially on the Peninsula, where the demand had increased dramatically due to the temporary increase in the population and the rise in the meat price (Gilchrist 1900).

The average price received by the fishermen for hottentot today is R0. 83 /kg. Taking into account the ever increasing inflation rate, this price may well be comparable with those of 50 years ago. Retailing at between R1. 20 and R2. 60 /kg, hottentot remains one of the least expensive linefish available.

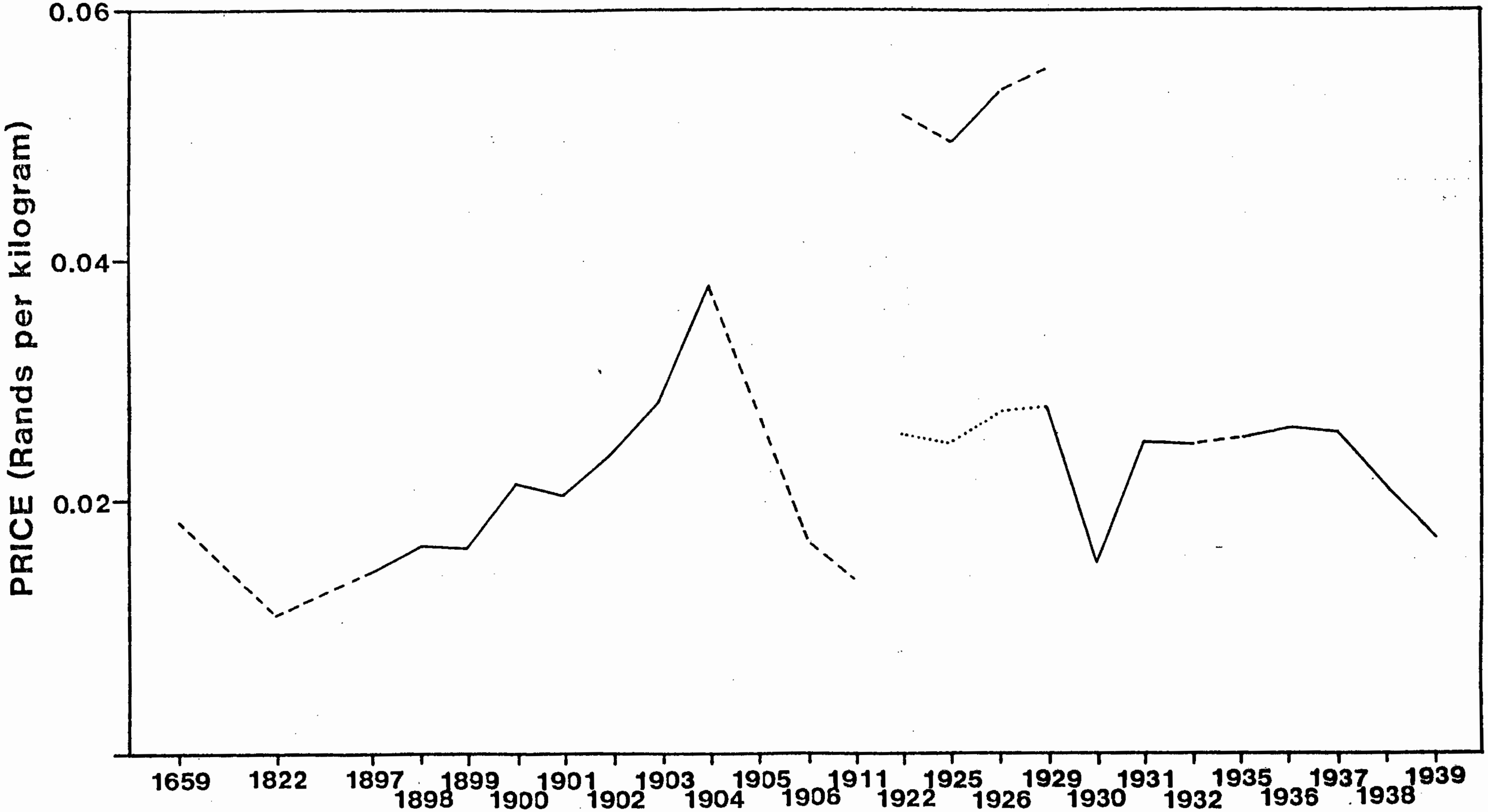


FIGURE 1.4 Trends in the wholesale price per kilogram of P. blochii. The broken line represents periods for which data are unavailable. The dotted line represents a correction made to data assuming 200% profit made on the retail product. Corrected data represents expected wholesale price.

The survey of the fishing centres however indicated that the present market, especially on the west coast, is very poor. The hottentot fishery has always been a subsistance fishery, the fishermen frequently covering the costs of a poor day's fishing by catching hottentot on the return journey. This is especially the case on the south coast, where the fishermen target mainly for other species. However, on the west coast, the rising fuel costs have not been paralleled by increases in the retail price of hottentot, making it increasingly uneconomical for them to spend a day at sea fishing for this species.

CONCLUSION

In tracing the development of the handline fishery, it is apparent that the practice has largely persisted in its traditional form over the last century. The industry remains dominated by the non-white fishermen who, employing the same bait and tackle, regularly return to specific catch sites. Although larger and more powerful craft are being used, the fishery is still today practiced from small short-range dinghies.

A change which has occurred is the association of the fisherman with the fishery. To a large extent he is no longer solely dependant on the industry for his means of existance. This is especially apparent on the West coast where other fisheries offer more lucrative employment, and where the effort devoted to the line-fishery is consequently less than that directed at the industry on the south coast.

The proportion of effort directed specifically at the hottentot fishery also varies greatly, exhibiting a decreasing trend towards the east where the fishery targets for the more sought after species. Daily catch return figures also indicate that, even on the west coast, catches decline when there is a high availability of snoek, thus emphasizing that the hottentot fishery is largely a "last resort" fishery.

Along the Cape west and south coast however, it is becoming increasingly obvious that more and more fishermen are abandoning the precarious lifestyle of their fore-fathers, and seeking a more secure and rewarding means of employment.

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2. ASPECTS OF THE FEEDING ECOLOGY OF *Pachymetopon blochii*

2.1 THE EFFECT OF FISH SIZE, AREA AND SEASON ON THE DIETARY COMPOSITION

The hottentot fish, *P. blochii* was identified as an important carnivore in the kelp bed community (Velimirov *et al* 1977). Preliminary observations on the diet of this species (Stander & Nepgen 1968, Nepgen 1977), found it to consume planktonic fauna as well. Being non-quantitative, however, these studies failed to consider variation in the diet with area, season or fish size.

This study presents quantitative information on the feeding habits of this species. Change in diet with area, season and size are discussed, and comparisons are drawn with sympatric sparids.

METHODS

Most of the 737 fish examined were obtained through fish dealers or from commercial hand-line fishermen at the sampling sites shown in Figure 2.1.1. The majority of the fish sampled were longer than 200 mm total length. Samples were collected at intervals over the period February 1984 to July 1985. A large sample of hottentot, covering the full size range, was collected in March 1984, in the Dyer Island area by fishing with handlines from a SFRI research vessel. Smaller fish were also speared by SCUBA divers at Rumbly Bay and Partridge Point, False Bay.

The total length and fork length of each fish were measured in millimeters, and the weight determined in grams. The stomach and hindgut were then removed and preserved in buffered 10 % formalin. After determining the settled volume, stomachs were analysed under a stereo dissecting microscope. Gut contents were identified to the lowest possible taxon and assigned a visual percentage volume (Hyslop 1980). Percentage frequency of occurence (Hynes 1950) was calculated for each food category as well as for major food classes. The data for each month, from a specific area, were grouped according to size class. The 96 samples resulting from this grouping were subsequently summarized to provide a generalized view of the diet of P. blochii, and to illustrate a change in diet with area, size, and season. A prey species list was constructed from the food items encountered.

As arc-sine is the suggested transformation for percentage data

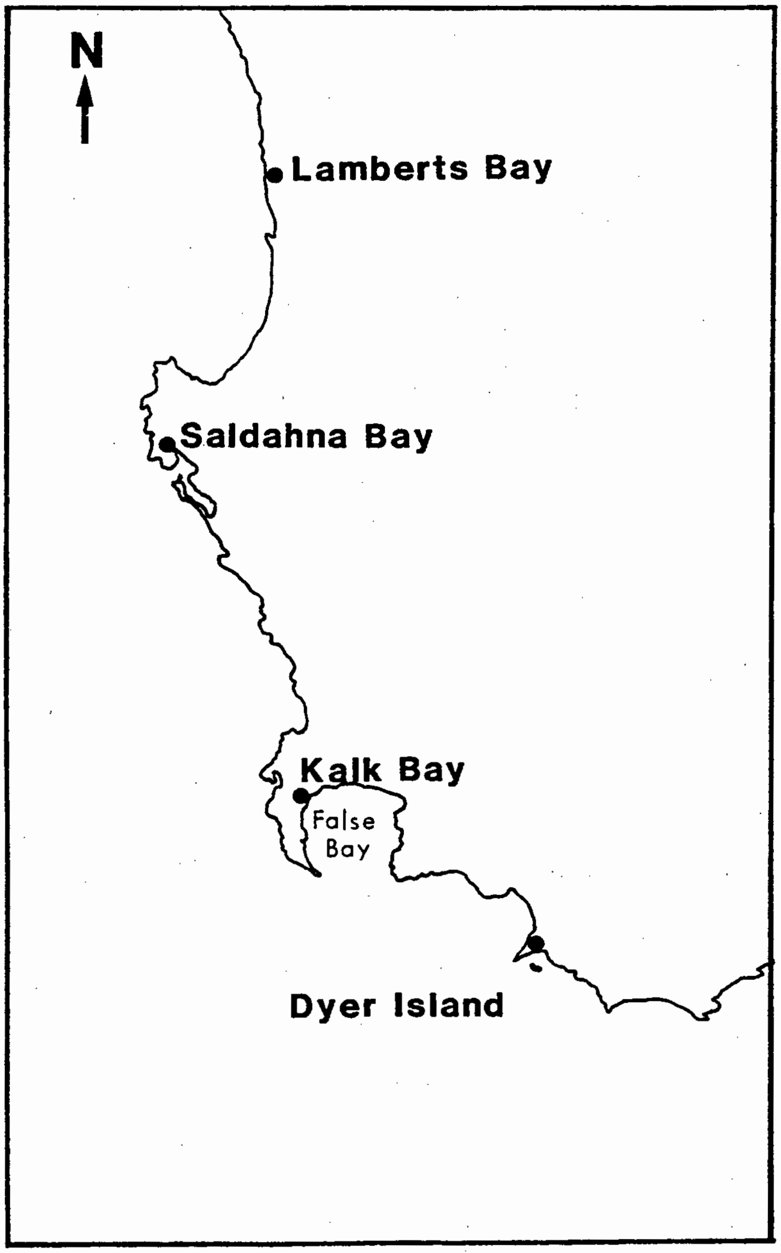


FIGURE 2.1.1 Map of the Cape west and southwest coast, showing the four sites at which hottentot biological samples were colected.

(Zar 1974), this was adopted for the data. Preliminary tests on the raw data, using other transformation choices, also indicated that an arc-sine transformation yielded the most promising results for the classification and ordination analyses.

Interpretation of the data was facilitated by two methods of cluster analysis as proposed by Field et al (1982). The first of these utilized the group average sorting method and Bray-Curtis measure of similarity, to derive a dendrogram showing percentage similarity between different groups of fish. This was complimented by non-parametric multi-dimensional scaling, which uses the same similarity marix to produce an ordination diagram depicted in a two-dimentional form.

Early runs of the entire data set identified samples in which the stomachs of all fish were packed with an individual, often planktonic taxon. These outlyers were excluded from subsequent runs in order to facilitate interpretation of more general, size related geographical and seasonal trends.

RESULTS

Of the 737 P. blochii stomachs sampled, 86 % contained food. The mean percentage volume and percentage occurence, of the major prey classes recorded in the diet of P. blochii are presented in Table 2.1.1, together with comparable percentage occurrence data from Nepgen (1977). Bait organisms (pilchard, squid, redbait, rocklobster and white mussel), were found in 33.5 % of the stomachs, but were not considered in the analysis. Pilchard was found to be the most common bait used.

Of the major prey categories, the most important were amphipods, represented in 64 % of the stomachs examined and contributing 28 % by volume to the diet. Of this volume 31.2 % consisted of caprellids, of which Caprella circur and C. aequilibra were the most common. The remaining percentage volume was dominated by Paramoera capensis and Jassa falcata, the former species contributing to approximately 50 % of the total volume of amphipods recorded. The amphipod species represented, and the proportion of the dominant species in the diet, remained relatively constant throughout the sampling area. Contrary to Nepgen (1977), who found Caprella species only in stomachs also containing algae, this association was not apparent in this study. This suggests that the hottentot will selectively prey on amphipods whilst feeding in the understorey algae, rather than accidentally ingesting these crustaceans whilst grazing, as proposed by Nepgen (1977).

In the category 'Other crustaceans', isopods had the highest

TABLE 2.1.1 Percentage volume and percentage occurence of the individual food items recorded in the stomachs of hottentot during this study and the study by Nepgen (1977)

PREY ITEM	THIS STUDY % VOL	THIS STUDY % OCC		NEPGEN(1977) % OCC
AMPHIPODS				
Caprellids	9.27	41.11		
Gammarids	20.47	60.24	64.3	
OTHER CRUSTACEANS				
Cirripeds	0.61	2.58		
Decapods	2.61	4.48		
Isopods	1.33	14.79		
Megalopa	1.75	2.85	38.6	29.1
Mysids	3.51	9.63		
Ostracods	0.28	9.63		
Stomatopods	2.03	2.58		
Tanaids	<0.01	0.41		
ALGAE	18.73	34.19		58.9
HYDROIDS	11.37	29.58		5.4
ECHINODERMS				
Crinoids	2.80	2.31		
Echinoids	0.02	0.54		
Holothurians	<0.01	0.14	3.0	36.3
Ophiuroids	0.99	2.17		
MOLLUSCS				
Small molluscs	1.36	29.71		
Haliotis	0.05	0.13	30.0	11.8
Loligo	0.40	0.54		
OTHERS				
Anemones	0.37	0.54		<1.0
Echiuroids	<0.01	0.27		
Eggs	<0.01	2.40		
Nematodes	0.03	2.85		
Polychaetes	3.82	13.98		7.5
Pycnogonids	0.19	2.17		<1.0
Sand grains	<0.01	7.90		
Sipunculids	0.04	1.90		<1.0
Teleost rems.	0.12	0.13		3.8
Tunicates	0.69	1.78		1.5
Unidentified	16.96	45.18		

frequency of occurrence. Nepgen (1977), in contrast, reported only a few occurrences of unidentified isopod remains. Although contributing only 1.3 % to the total volume, a high diversity of this prey was encountered in this study. Of the 37 species recognized, Exosphaeroma truncatitelson, Exosphaeroma laeviusculum and Cymodocella sublevis occurred most frequently in the stomachs from Lamberts Bay to False Bay, whereas Dynamenella huttoni and Dynamenella doixus were more common in the diet from False Bay, eastwards. Although isopods were usually found in stomachs also containing algae, this association was not exclusive, suggesting that these crustaceans are selectively ingested.

Other than isopods, mysids, stomatopods and adult and larval crabs contributed most to the percentage volume of this food category (Table 2.1.1). With the exception of mysids, which occur in resident swarms in kelp beds and around sudlittoral reefs, the percentage occurrence of these crustaceans, in the diet, is low. Although mysids exhibit no apparent seasonality, their abundance appears to be related to wave action, numbers decreasing during the winter when storms are frequent (R. Carter NRIO, pers. comm.). This is reflected in the percentage volume and percentage occurrence of this prey in the diet of the hottentot during the year. Although recorded in stomachs throughout the year, they were encountered in larger quantities in fish sampled during autumn. This corresponds with the period of change from the prevailing south/south-east winds in the summer, to the commencement of the northwest storms in winter. Similarly, in late winter/early spring (September), when weather patterns are reverting back to summer conditions, large proportions of mysids were recorded in the stomachs (Table 2.1.2).

Table 2.1.2 Percentage volume and percentage occurrence of mysids recorded in the diet of P. blochii throughout the year, and summarized into seasons.

SEASON	MONTH	% OCC	% VOL	TOTAL %OCC	TOTAL %VOL
	DEC	0.10	0.58		
SUMMER	JAN	-	-	16.67	11.38
	FEB	0.19	10.80		
	MAR	0.12	20.21		
AUTUMN	APR	0.12	22.99	9.06	75.50
	MAY	0.04	32.30		
	JUN	-	-		
WINTER	JUL	0.03	0.17		
	AUG	0.02	0.08	6.86	12.40
	SEP	0.30	12.16		
SPRING	OCT	0.09	0.46		
	NOV	0.15	0.26	11.54	0.71

Decapod crustacea, primarily crabs, Plagusia chabrus, were less common than reported by Nepgen (1977). Together with rocklobster, Jasus lalandii, which occurred on less than 1 % of fish, these prey are seldom included in the diet of P. blochii. Other prey items such as ostracods, barnacles, tanaids and pycnogonids are probably eaten accidentally.

Algae were the second most important identifyable component of the diet, occurring in 34 % of fish and contributing 19 % by volume.

Table 2.1.3 Percentage occurrence of the algal classes recorded in the diet of _P_. _blochii_ from the four sampling areas, and summarized for all areas.

ALGAL CLASS	ALL AREAS	DYER ISLAND	KALK BAY	SALDAHNA BAY	LAMBERTS BAY
RHODOPHYTA	84.3	66.7	100.0	84.4	93.2
CHLOROPHYTA	9.4	16.6	0.0	15.4	3.4
PHAEOPHYTA	6.3	16.7	0.0	0.0	3.4

With the exception of the dominance of a chlorophyte in fish sampled between Betty's Bay and Walker Bay, the results of Nepgen (1977) suggest that rhodophytes are the most frequently occurring algae in the diet of the hottentot. A closer investigation of the algal food category confirms this (Table 2.1.3). The data further indicate that, although a wide diversity of species are consumed, no spatial trends in the proportions of the different algal species eaten, are apparent.

The prevalence of rhodophytes is not unexpected for a species grazing in the understorey of kelp beds where, due to the shading effect of _Laminaria_ and/or _Ecklonia_, this algal group is prolific (Branch and Branch 1981). The species most commonly recorded from the stomach contents correspond with those mentioned by Simons (1976), Field _et al_ (1980) and Branch and Branch (1981) as being the dominant forms in the sublittoral zone, many being epiphytic or parasitic on the kelp plants themselves.

An interesting observation is the abundance of Porphyra capensis in the fish sampled. With a frequency of occurrence in the diet, comparable to the common understorey species, the presence of this species (dominant in the littoral zone), suggests that the fish feed predominantly on the high tide.

There appeared to be a close association between algae and hydroids in the stomachs of hottentot, this food item making up 11 % of the diet, by volume. As the two groups occur sympatrically, hydroids often growing epiphytically on the algae, it would be expected that, whilst grazing unselectively on the understorey algae, the hottentot will simultaneously ingest hydroids.

Obelia geniculata occurred most frequently in samples from Lamberts Bay, whereas Plumularia setacea and Aglaophenia pluma were common in the stomachs from the Saldahna Bay and False Bay areas. Eudendrium was the only genus recorded in fish from the Dyer Island area hydroids contributing a negligible proportion only to the diet of fish in this area.

Although reported by Nepgen (1977), to be the second most important food of the hottentot, echinoderms were recorded in small proportions only during this study. Crinoids and brittle stars were the most common, with echinoid spines and individual holothurians encountered in a few samples only.

The low incidence of echinoderms suggest that they are ingested accidentally. When present, however, crinoids usually contributed significantly to the individual stomach volume. It was noticed that these crinoids all had well developed gonads, and having substantially higher calorific contents as a result of this (Field et al 1980), would be selected over other individuals of the same species. Although consumed in negligible quantities throughout the year, the echinoderm fraction increases during the winter. This may reflect either the breeding season of the crinoids, or an increased selectivity for this prey during a period of reduced availability of amphipods and algae. As with hydroids, crinoids may therefore serve as a dietary substitute or supplement.

The majority of the category 'OTHER', consists of polychaete worms (76.7 % vol ; 76.3 % occ), of which Gunnarea spp., Nereis spp. and Syllis spp. were the most common.

Most of the molluscs ingested were small, intertidal species or larval forms. With the exception of a few samples containing juvenile squid (Loligo reynaudii), or small abelone (Haliotis parva), these small bivalves and gastropods contribute minimally to the percentage volume of food eaten. These, and other prey items in this category, had almost certainly been accidentally consumed in the course of browsing.

Analysis of the hindgut indicated that algae, crustacean exo-skeletons, mollusc shells, echinoderms and the perisarc of hydroids remained clearly recognizeable. This suggests that the soft bodied animals, such as worms, tunicates, anemones and fish must be the major contributers to the large, unidentifyable fraction of the stomach contents. As bait was found in 33 % of the stomachs analysed, these, usually soft bodied, organisms may also contribute significantly to the unidentifyable remains. The elapsed time between catching and preserving the sample is also of importance, and in some cases the samples obtained when the day had been hot or the fishermen returned later than usual, were in an advanced state of digestion, making positive identification of prey items difficult.

The prey species identified from the stomach contents are listed in Appendix 2.1.1.

Having analysed the pooled data from all fish examined, there was reason to suspect that the diet of hottentot may be influenced by fish size, geographical location and season. The data were thus segregated in order to test for consumption patterns that may be associated with these variables.

Closer investigation of the classification of the 96 samples, revealed that on occasions the diet of a sample of fish would deviate markedly from the usual high diversity of food items and be dominated by only one or two of the prey categories. With the exception of a few cases where only amphipods were present, these samples contained stomatopods, mysids or megalopa larvae. As these prey contributed a small proportion only to the mean percentage volume, and their dominance was uncharacteristic of a species which normally exhibits a very generalized diet, these monospecific samples were excluded from the major analysis.

a) Geographic variation

Figure 2.1.2 illustrates that an initial similarity analysis of the edited data failed to group samples in any clear pattern based on collection site. This may be attributable to variations in the size frequency distributions of fish collected from the four localities (Fig 2.1.3).

A further test was conducted by maintaining the size variable constant (size class: 250 - 300 mm), this group being well represented in catches from all study sites. The data separated out into four groups at the 50 % similarity level, but only the Lamberts Bay and Saldahna Bay data formed coherent clusters (Figure 2.1.4). Graphic representation of the data illustrates this separation (Fig 2.1.5).

Although representing the diet of a selected size class only, it appears that fish sampled at Dyer Island consumed proportionally more algae than in other areas. This corresponds with the results of Nepgen (1977), who reported a decline in the proportion of crustaceans in the diet from west to east. Of further interest is that hydroids, otherwise well represented in samples from other localities, were recorded in negligible proportions only in fish from this area.

A possible explanation for this is that, in the event of a high availability of algae, the fish will exhibit selective preference for algae rather than hydroids.

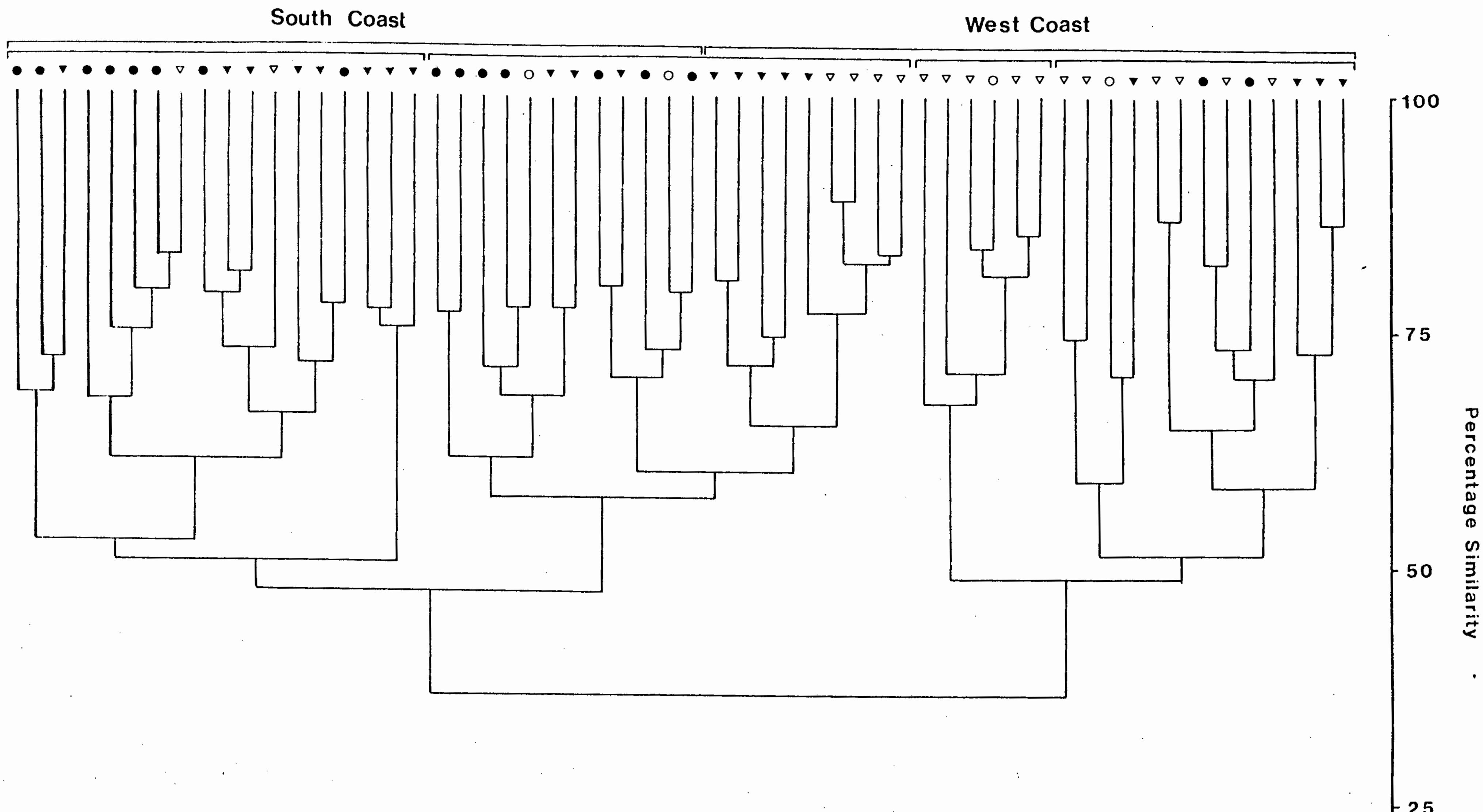


FIGURE 2.1.2 Cluster analysis classification of the diet data of *P. blochii* showing clustering by locality, and illustrating the separation at the 50 % similarity level. (○ = Gans Bay, ● = Kalk Bay, ▽ = Saldahna Bay and ▼ = Lamberts Bay).

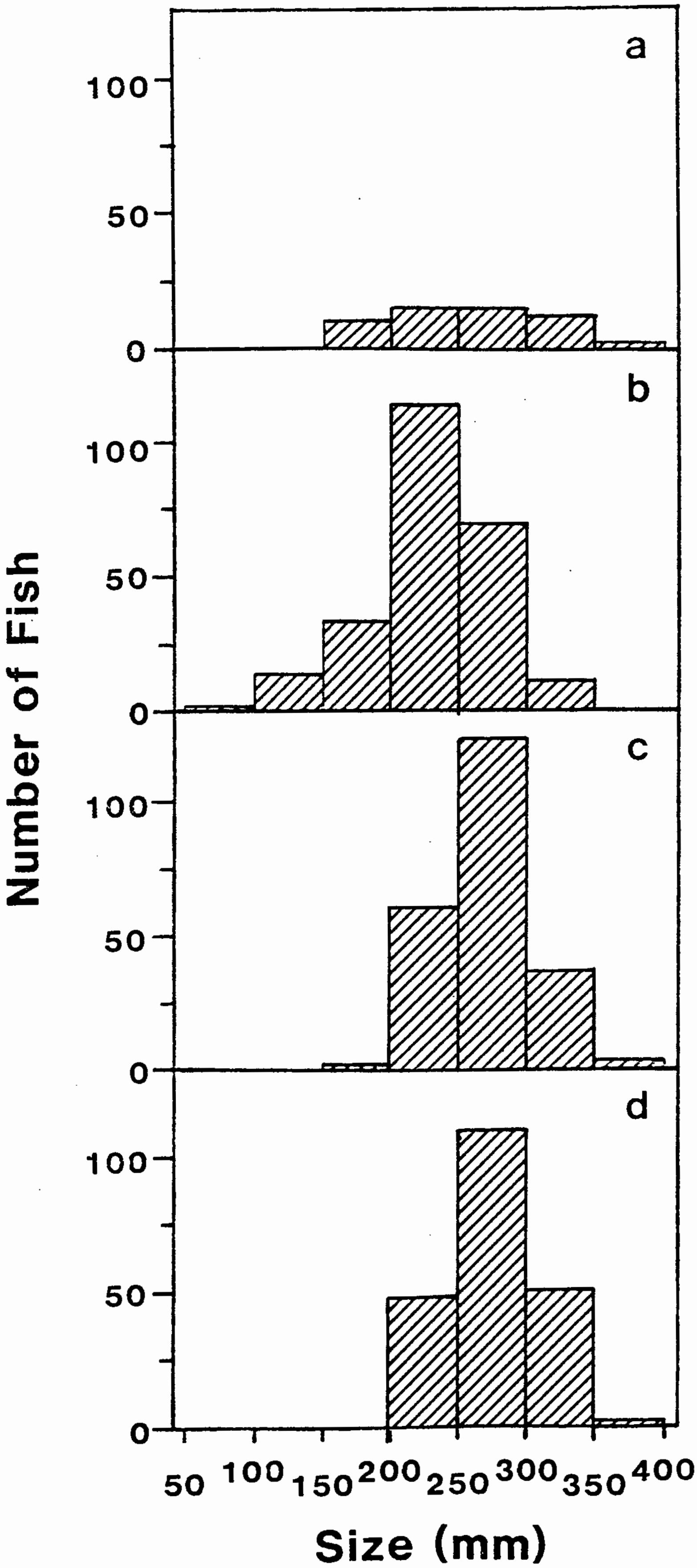


FIGURE 2.1.3 Size frequency distribution of hottentot sampled at a) Dyer Island, b) False Bay, c) Saldahna, and d) Lamberts Bay.

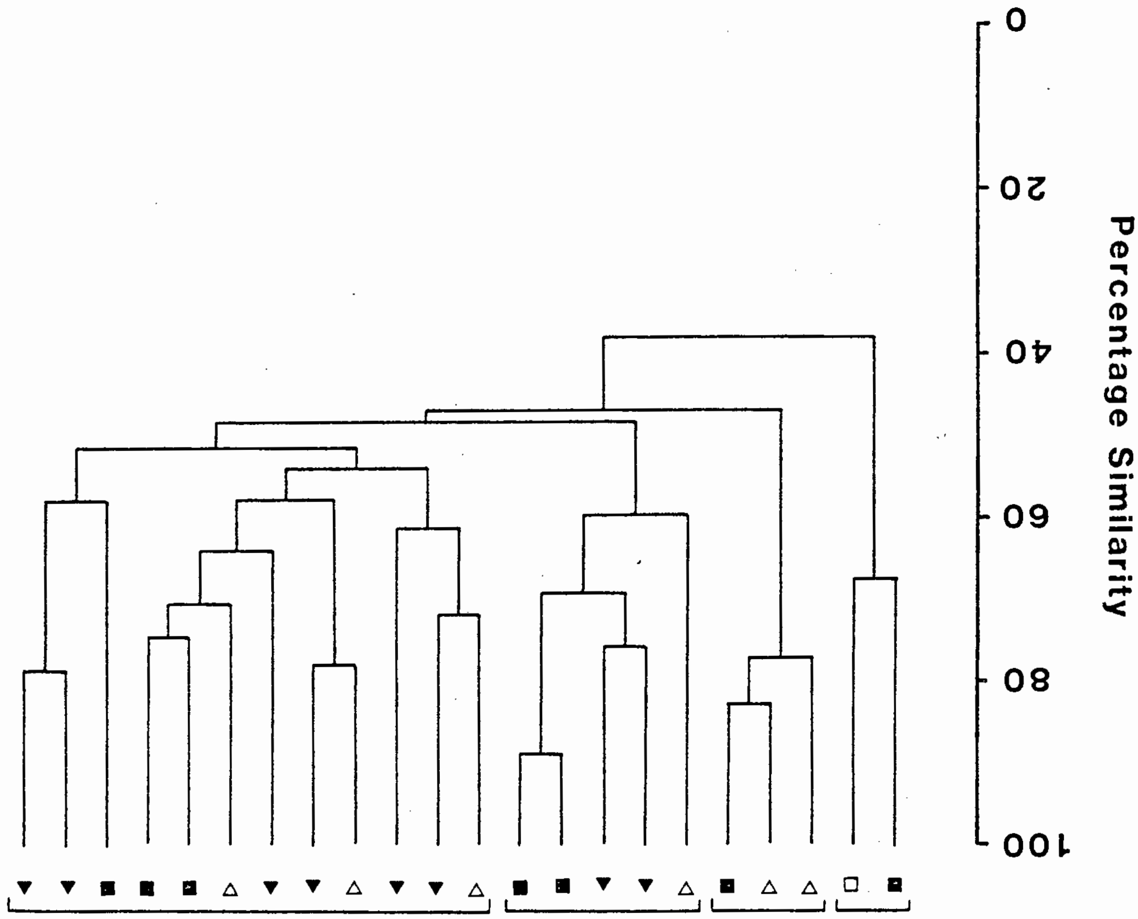


FIGURE 2.1.4 Cluster analysis classification of the diet of 250 - 300 mm fork length P. blochii, illustrating geographic separation at the 50 % similarity level. (□ = Gans Bay, ■ = Kalk Bay, △ = Saldahna Bay and ▼ = Lamberts Bay).

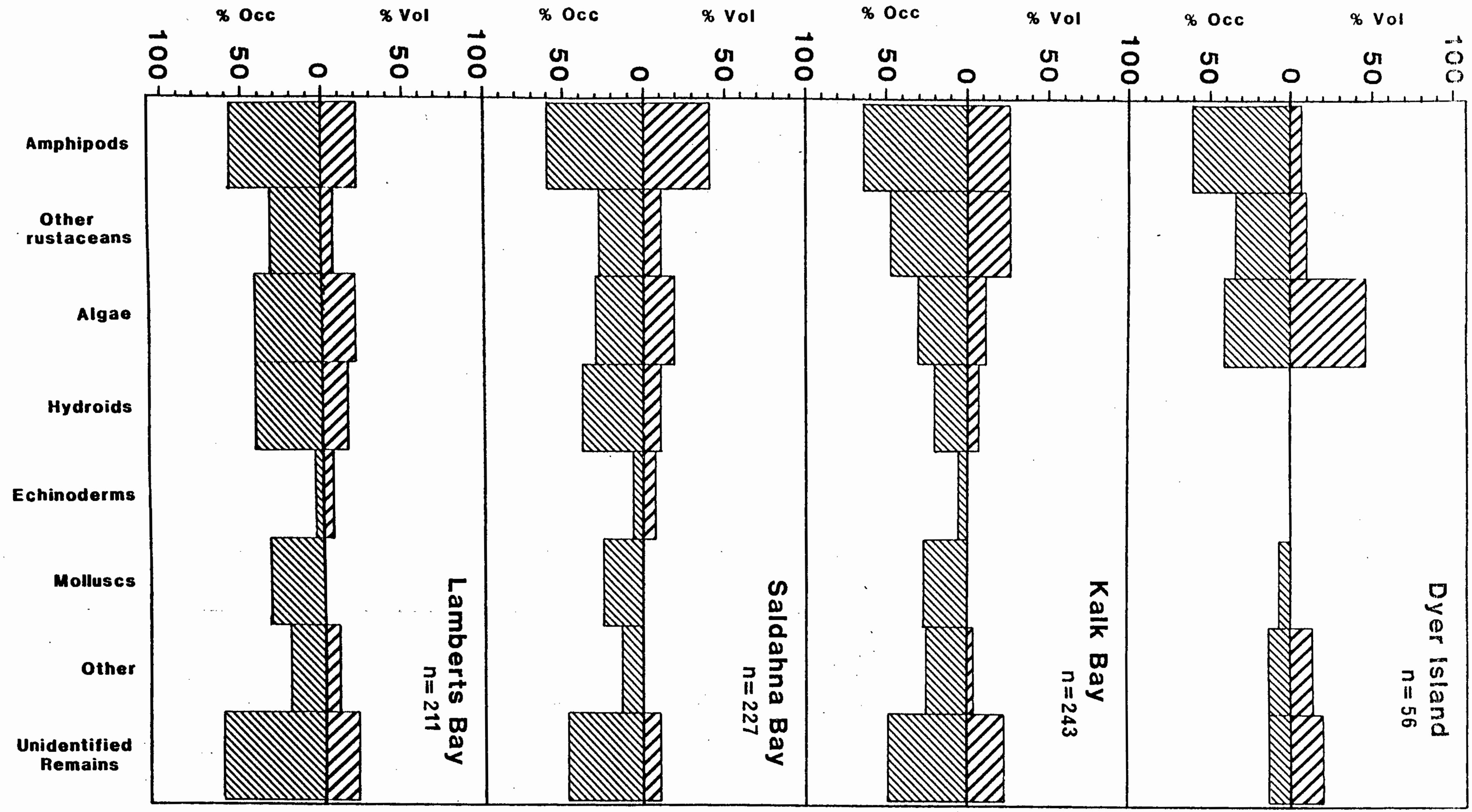


FIGURE 2.1.5 The mean percentage volume and percentage occurrence of the major prey classes in the diet of P. blochii (250 - 300 mm fork length), recorded at a) Dyer Island, b) False Bay, c) Saldahna Bay, and d) Lamberts Bay.

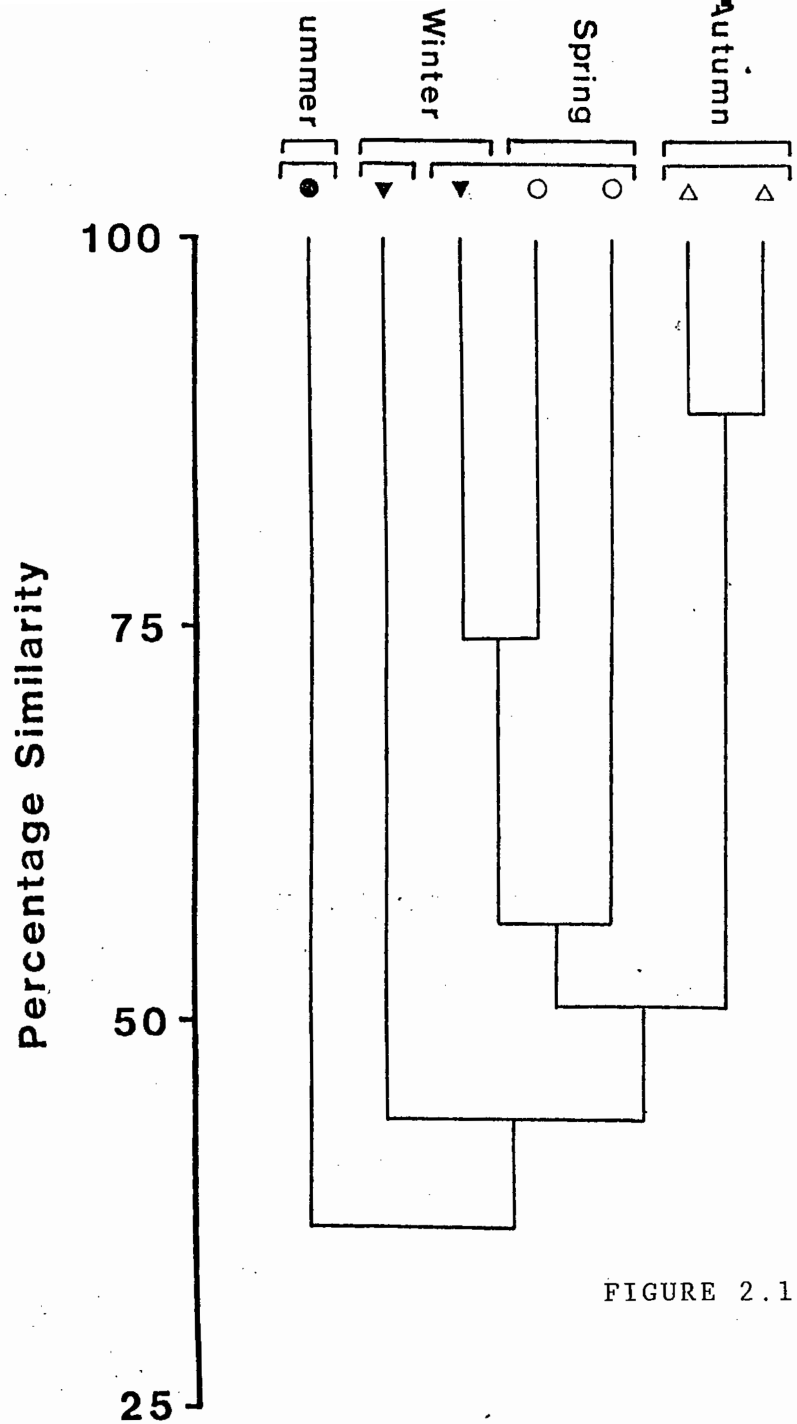
As algal abundance decreases however, proportionally more hydroids are ingested. Having similar calorific values to rhodophytes (Field et al 1980), hydroids may therefore serve, not only as a supplement to, but also a substitute for the algal food category, when this major source is scarce.

b) Seasonal trends

Subsequent data selection, keeping both the locality and size variables constant (size class: 250 - 300 mm, locality: Lamberts Bay), indicated that seasonal changes in diet can also be distinguished, both the classification and multidimensional scaling determining clear separation (Figure 2.1.6).

When presented graphically (Figure 2.1.7), these seasonal trends become more noticeable. The data suggest that during the warmer months the hottentot consumes proportionally more algae than amphipods. During autumn and winter however, the volume of algae eaten decreases. These trends were not, however, as strongly evident in data from other sites.

As would be expected, many of the algae occurring in kelp beds are less abundant during winter. Hymenema, for example, is washed up in large quantities during May and June. This may be due to increased wave action, or, as in the case of the epiphytic and parasitic species (eg Carpoblepharis spp.), a decrease in the availability of host plants, for Ecklonia and Laminaria exhibit a decline in biomass during the winter months (N. Jarman SFRI, pers. comm.).



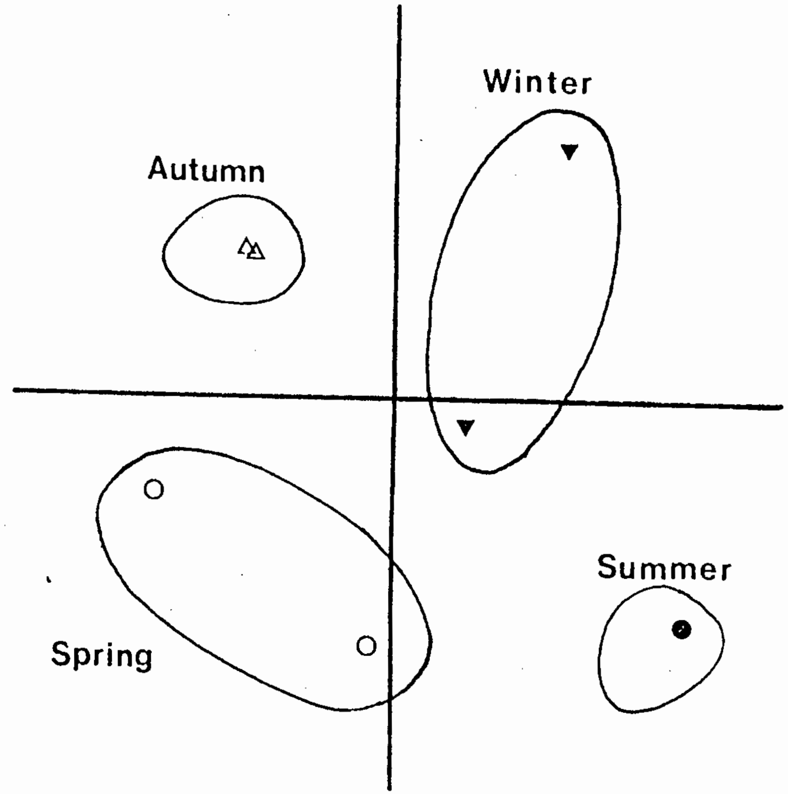


FIGURE 2.1.6 Cluster analysis classification and ordination plot of the diet of 250 - 300 mm fork length *P. blochii*, from Lamberts Bay only, illustrating seasonal trends in the diet.

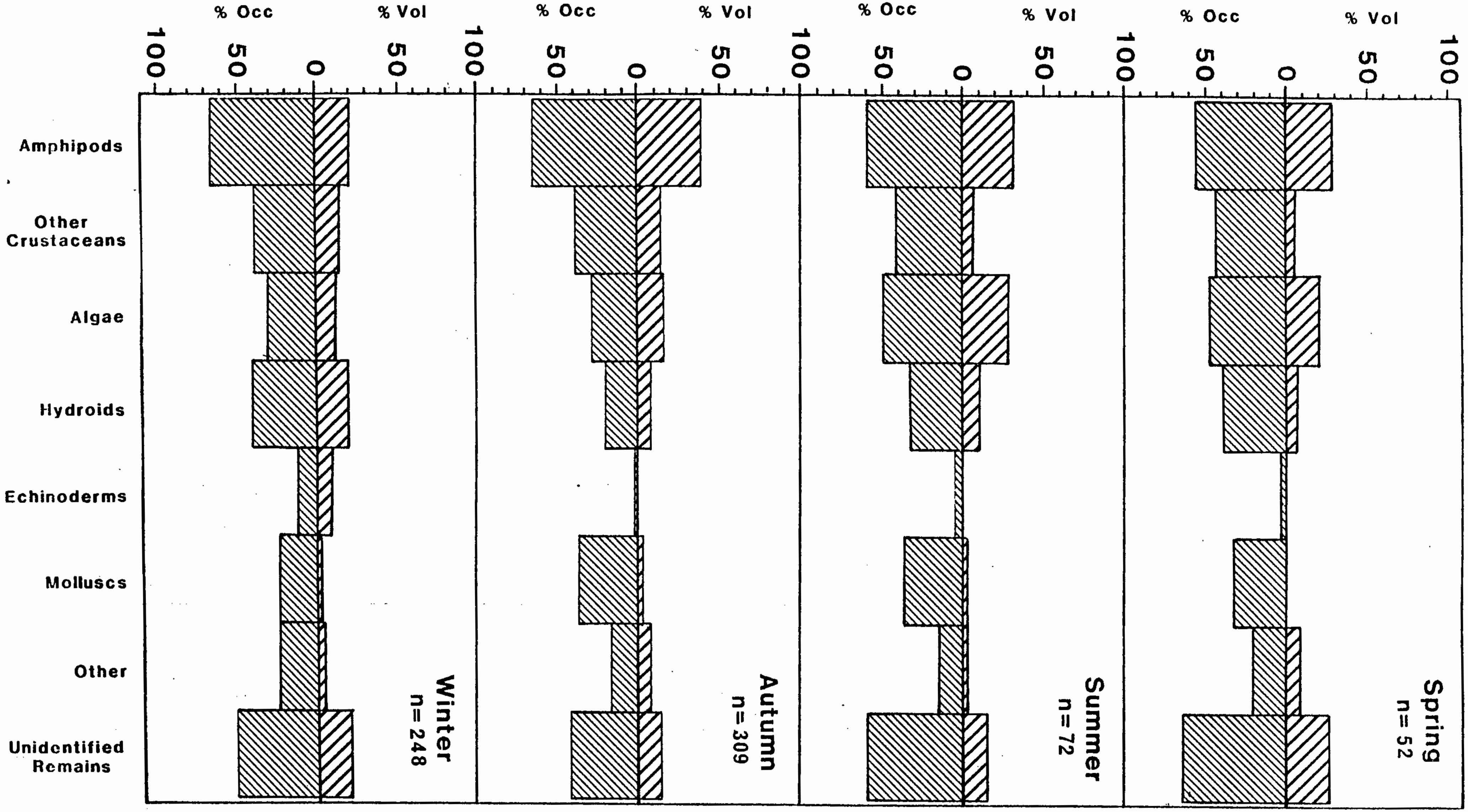


FIGURE 2.1.7 Mean percentage volume and percentage occurrence of the major food items recorded in the diet of P. blochii, throughout the year.

Spring = October, November
Summer = December, January, February
Autumn = March, April, May
Winter = June, July, August, September

As these genera are those most commonly recorded in the diet of _P. blochii_, the seasonal variation in both percentage occurrence and percentage volume of algae is not unexpected. The seasonal change in the diet, identified by the cluster analysis, is thus most likely attributable to the fluctuation in availability of this food source in the environment.

c) Variations in diet with fish size

Although initial cluster analysis techniques failed to separate samples of different sized fish, from the four study areas, into clear size related groups, this was attributed to inter-site variations in diet of adjacent size classes. By selecting a month in which a full size range of fish was collected at each sampling station, and re-running the programme, a change in diet with size was, however, identified. Figure 2.1.8 indicates that some distinction can be made between the diets of small and large fish.

Figure 2.1.9 illustrates the changing proportions of the various food categories in fish of increasing size. The most noticeable trend is the progressive decline in the proportion of amphipods eaten and the corresponding increased reliance on algal browsing (Fig 2.1.10).

Changing feeding patterns with size were also evident from direct underwater observations of fish in the field. Juveniles were seen occuring singly, or in small groups, leaving the shelter of caves, crevices and overhangs for short periods only, to feed.

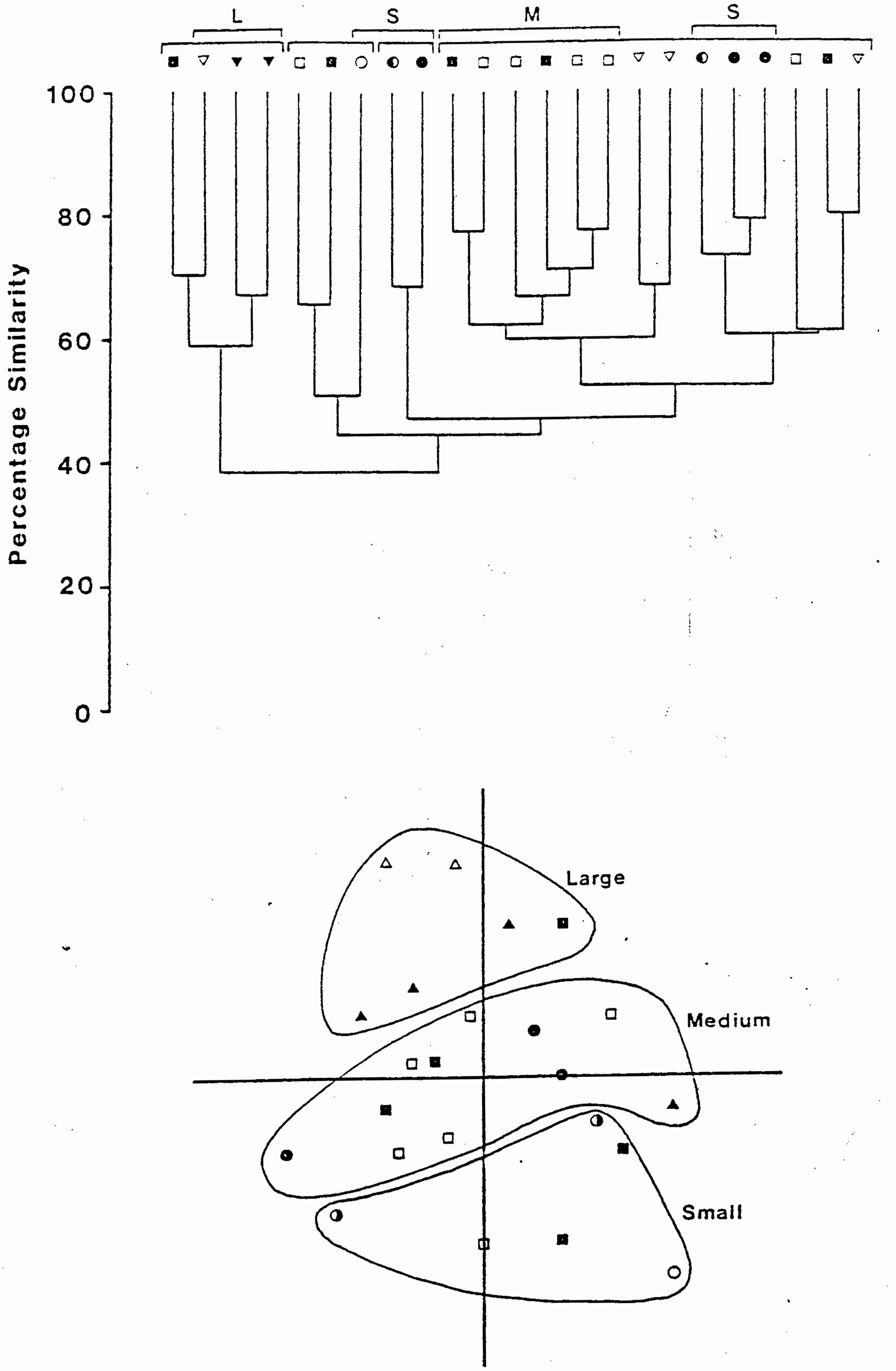


FIGURE 2.1.8 Cluster analysis classification and ordination plot of the diet of the full size range of P. blochii, illustrating a change in diet with size.

(○ = 50 - 100 mm, ◑ = 100 - 150 mm, ● = 150 - 200 mm, □ = 200 - 250 mm, ■ = 250 - 300 mm, △ = 300 - 350 mm, ▲ = 350 - 400 mm).

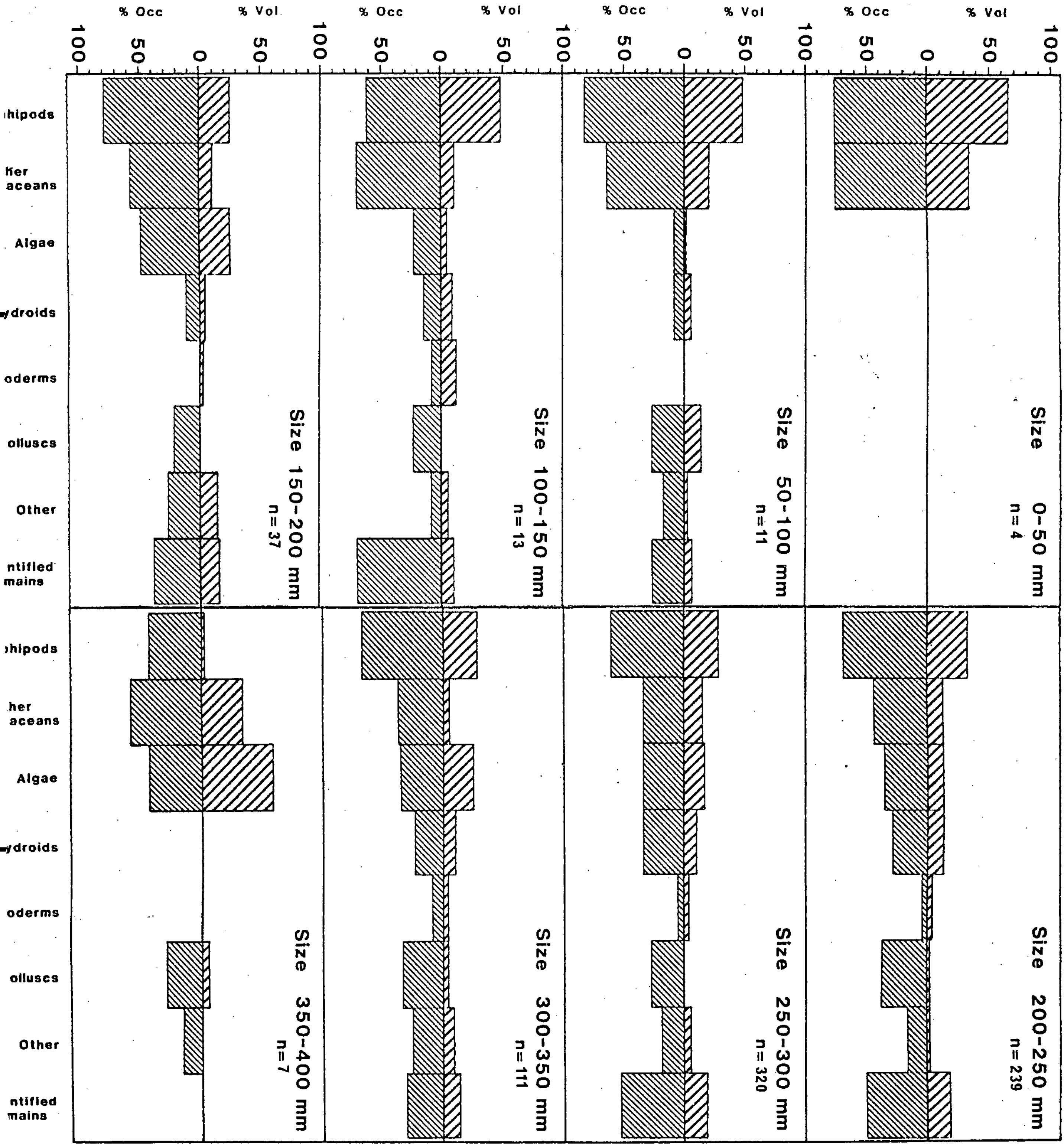


FIGURE 2.1.9 Percentage volume and percentage occurrence of the major prey categories recorded in the different size classes of hottentot.

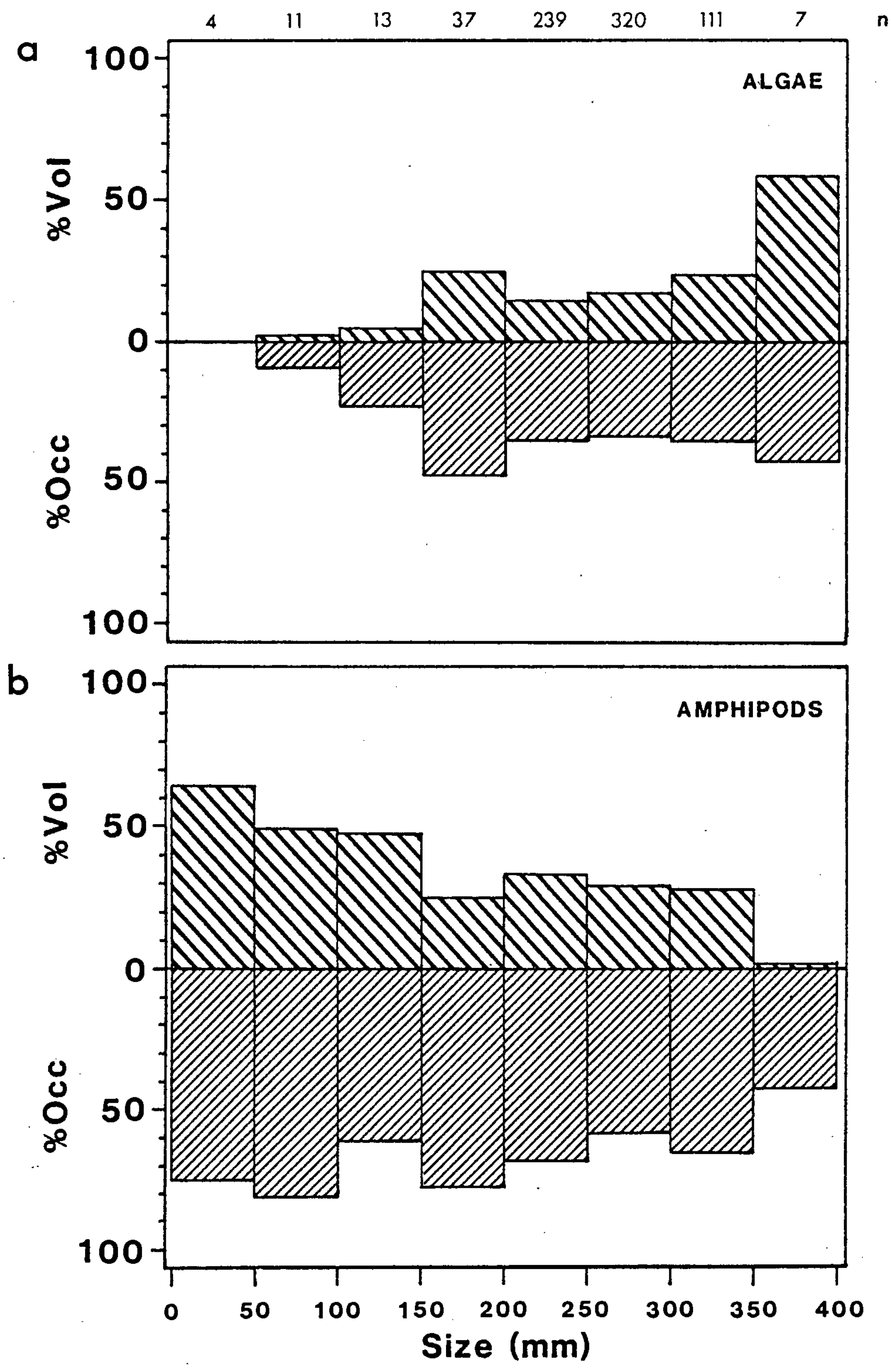


FIGURE 2.1.10 Percentage volume and percentage occurrence of a) algae, and b) amphipods recorded in the diet of P. blochii from all sampling areas.

As they attain a size of 150 - 200 mm, the feeding excursions are prolonged and the fish may join the foraging shoal for extended periods before retreating to cover.

The proportion of algae occurring in the diet will therefore increase with the adoption of the shoaling habit. A similar trend of an early dependence on small crustacea, followed by a change to an omnivorous or largely vegetarian diet, was reported by Vaughan (1978), for the sea bream (Archosargus rhomboidalis).

DISCUSSION

Analysis of the diet of P. blochii shows that the species is largely an omnivorous benthic feeder, exhibiting a varied preference for a high diversity of organisms occurring in the understorey of kelp beds, and on subtidal reefs. Being opportunistic feeders however, they will also prey readily on mysids, stomatopods and megalopa, when these are swarming in midwater, although this may necessitate deviating from the normal grazing behaviour.

The most important components of the diet, in terms of volume, were amphipods, algae and hydroids, together accounting for 60 % of the total stomach contents, and 72 % of identifiable material.

Although the species found in the stomachs of hottentot compares favourably with those found by Stander and Nepgen (1968) and Nepgen (1977), the proportions of the major food items differ (Table

2.1.1), noteably, the relatively high proportions of crustacea, hydroids and small molluscs, and the paucity of echinoderms recorded during the present study.

In any event, Nepgen (1977) uses only the percentage occurrence method in his dietary analysis. The two major criticisms levelled at this method are that it gives no indication of the relative amounts of food present in the stomach and that, without information about the potentially available food and the feeding preference of the fish, one cannot determine whether a high percentage occurrence value is the result of a high availability or a strong preference for that item (Berg 1979; Hyslop 1980). In order to compare values taken at different times or different sampling areas, it is therefore necessary to supplement percentage occurrence data with a quantitative method, either volumetric or gravimetric.

As Nepgen (1977) did not distinguish between size classes in his investigation, this discrepancy in results could be size related. In a species with such opportunistic feeding habits, differences are, however, expected. Differences in depth and geographic location of sampling sites may also influence results.

Considering the highly generalized and opportunistic feeding habits of the species, it is perhaps not surprising that the similarity analysis failed to reveal major systematic variations in diet with locality, season or fish size. What did, however, become evident is the marked increase in the proportions of algae in the diet with increasing fish size.

In view of the reported absence of cellulase in teleosts (Lagler, Bardach & Miller 1962, in Blaber 1974), and the large amounts of apparently undigested plant material present in the hindgut, it would be of considerable interest to determine the amount of nutrition that hottentot are able to obtain from it. The algae may serve merely as a substrate for epiphytic diatoms which are subsequently digested, as found by Blaber (1974) for R. holubi and Joubert and Hanekom (1980) for D. sargus. Alternatively the seaweeds may be digested to some extent by cellulase producing gut microflora (Stickney & Shumway 1974), or as suggested by Montgomery and Gerking (1980), nourishment may be extracted from the algae by enzymatic penetration of the cell walls or digestion of cell contents after they are leached from the cells.

Comparing the diet of P. blochii with those of other South African sparids (Table 2.1.4), indicates that the hottentot exhibits a large preferrence for algae, second only to Diplodus sargus (Joubert & Hanekom 1980). Although some algae were recorded in the diets of most of the species, it appears that they select the green and brown algae rather than the rhodophytes.

Similarly for amphipods, these authors report low percentage volumes and percentage occurrences, the crustacean fraction of the diets being dominated by other sub-classes. Of interest is the total absence of crustaceans in the diet of D. sargus, the only other species exhibiting strong herbivorous tendencies (Joubert &

TABLE 2.1.4 Comparison of percentage consumption of various food items by P. blochii and other South African sparids.

SPECIES	FOOD ITEM RED ALGAE	GREEN ALGAE	BROWN ALGAE	AMPHIPODS	HYDROIDS
Diplodus sargus (Joubert and Hanekom 1980)	71 %O	63 %O	0	0	0
Rhabdosargus globiceps (Buxton and Kok 1983)	0	3 %V	6 %V	0.6 %V	0
Argyrozona argyrozona (Nepgen 1977)	0	0	<1 %O	5.7 %O	0
Chrysoblephus laticeps (Buxton 1984)	0	0	0	4.6 %V	0
Pachymetopon aeneum (Buxton and Clarke 1986)	0.2 %V	0.3 %V	1.3 %V	0.04 %V	26.6 %V
P. blochii	16 %V 84 %O	1.8 %V 9.4 %O	1.2 %V 6.3 %O	29.7 %V 64.3 %O	11.4 %V 29.6 %O

Hanekom 1980), indicating that the rate of consumption of algae and their associated crustaceans occurs independently, and that amphipods are thus not accidentally consumed along with their algal habitats.

Hydroids are poorly represented in the diets of other sparids, with the exception of P. aeneum, where they make up 27 % of the diet (Buxton & Clarke 1986). Although closely related to P. blochii, the blue hottentot consumes less than 2 % algae and negligible quantities of amphipods. As demonstrated by Buxton (1984) for the roman, the diet of small and large fish may differ considerably. It was therefore not unexpected to find a separation into small, medium and large fish, in the cluster analysis. The poor separation of the clusters however indicates that considerable dietary overlap occurs between the size classes and the differences are therefore not as distinct as those reported for the roman.

In conclusion therefore, P. blochii exhibits a strongly omnivorous feeding habit, exhibiting a unique reliance on the combination of algae, amphipods and hydroids as major elements of a highly variable diet. Being an opportunistic feeder, it is capable of exploiting a wide range of food materials available at different depths, areas or seasons. Although dietary overlap exists between P. blochii and the sympatric D. sargus, the generalist approach to feeding of the hottentot will contribute to co-existence and to its ability to dominate the inshore ichthyofauna of the western and southern Cape Province.

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APPENDIX 2.1.1

List of all food items and prey species found in stomachs of P. blochii sampled at major landing sites during 1984 and 1985.

PHYLUM CNIDARIA
CLASS Hydrozoa
Aglaophenia pluma
Amphisbetia sp.
Antennella quadriaurita
Antennella sp.
Eudendrium sp.
Gattya humilis
Kirchenpaueria pinnata
Obelia dichotoma
Obelia geniculata
Plumularia setacea
Salacia articulata
Salacia elisii
Sertularella arbuscula
Sertularia sp.
Symplectoscyphus macrogonus
Symplectoscyphus sp.
Thecocarpus formosus
CLASS Anthozoa
Actinaria sp.
Bunodosoma capensis

PHYLUM BRYOZOA
Onchoporella buskii
Bicellariella ciliata
Menipea sp.

PHYLUM NEMATODA
Unidentified nematode worms

PHYLUM SIPUNCULIDA
Unidentified sipunculid worms

PHYLUM ECHIURIDA
Unidentified echiurid worms

PHYLUM ANNELIDA
CLASS Polychaeta
Ampharetae sp.
Glycera sp.
Gunnarea sp.
Harmathoe sp.
Nephtys sp.
Nereis sp.
Onuphis sp.
Pectinaria sp.

Pherusa sp.
Phyllodoce sp.
Pista sp.
Pseudonereis sp.
Sabellid species
Syllis armillaris
Syllis sp.

PHYLUM CRUSTACEA
CLASS Ostracoda
Cypridina sp.
Pontocypris sp.
CLASS Copepoda
Calanoides carinatus
Caligus sp.
Candacia bipinnata
Centropages brachiatus
Centropages chierchiae
Copilia mirabilis
Corycaeus sp.
Eucalanus pileatus
Eucalanus subcrassus
Metridia lucens
Nanocalanus minor
Pleuromamma gracilis
Pleuromamma robusta
Rhincalanus nasutus
Sappharina sp.
Scolecithrix danae
Temora discaudata
Undinula darwini
Urocorycaeus sp.
CLASS Cirripedia
Balanus maxillaris
Notomegabalanus algicola
CLASS Malacostraca
Subclass Hoplocarida
Squilla armata
Subclass Peracarida
Order Mysidacea
Mysidopsis major
Mysidopsis similis
Gastrosaccus psammodytes
Order Cumacea
Bodotria sp.
Gynodiastyllis fulgiolus
Hallana ecklonide
Iphinae capensis
Nannas access
Order Tanaidacea
Tanais philetaerus
Tanais sp.
Order Amphipoda
Amaryllis macrophthalma
Ampelisca palmata
Aora kerguelteni

Atylus capensis
Caprella aequilibra
Caprella cicur
Caprella penantis
Caprella scaura
Ceradocus rubromaculataus
Cyproidea ornata
Ericthonius brasiliensis
Hoplopleon medusarum
Hyale grandicarnis
Hyperiid sp.
Ischyrocerus anguipes
Ischyrocerus carinatus
Ischyrocerus gorgoniae
Jassa falcata
Lysianassa ceratina
Lysianassa variegata
Maera vagans
Mallacoota subcarinata
Megaluropus agilis
Monocilodopsis longimana
Ochlesis levetzowi
Paramoera capensis
Parathemisto gaudichaudi
Podocerus inconspicuus
Urothoe elegans

Order Isopoda

Anilocra capensis
Arcturella lineata
Austroarcturus foveolus
Cilicaea latreillei
Cirolana hirtipes
Cirolana imposita
Cirolana littoralis
Cymodoce unguiculata
Cymodocella magna
Cymodocella pustulata
Cymodocella pustulata
Cymodocella sublevis
Cymothoidea sp.
Dynamenella dioxus
Dynamenella huttoni
Dynamenella macrocephala
Excirolana natalensis
Exosphaeroma antikrausii
Exosphaeroma laeviusculum
Exosphaeroma porrectum
Exosphaeroma planum
Exosphaeroma truncatitelson
Exosphaeroma varicolor
Gnathia sp.
Ianiropsis palpalis
Idarcturus platysoma
Jaeropsis stebbingi
Jaeropsis sp.
Neastacilla tranquilla

Notasellus capensis
Paranthura punctata
Paridotea reticulata
Paradotea rubra
Parisocladus perforatus
Parisocladus stimpsoni
Sphaeramene microtylotos
Sphaeramene polytylotos

Subclass Eucarida

Order Euphausiacea

Euphausia lucens
Euphausia recurva
Nyctiphanes capensis

Order Decapoda

Plagusia chabrus
Plagusia megalopa
Jasus lalandii (juvs.)

PHYLUM CHELICERATA

CLASS Arachnida

Unidentified marine mite

CLASS Pycnogonida

Austroraptus thermophilus
Bohmia sp.
Colossendeis colossa
Endeis clipeatus
Nymphon setimanus
Parapallene sp.
Tanystylus sp.

PHYLUM MOLLUSCA

CLASS Gastropoda

Crepidula porcellana
Etoniella nigra
Gibbula zonata
Haliotis parva
Marginella bensoni
Marginella capensis
Patella granularis
Tricolia neritina
Tricolia sp. n.

CLASS Bivalvia

Alrania winslavae
Aulacomya ater
Choromytilus meridionalis
Docomphala arifica
Granulina psuestes
Hiatula arctica
Jacintha sp.
Lasaea adansonii
Lasaea rubra
Neocardia angulata
Rissoa sp.
Vitrinella fulva

CLASS Cephalopoda

Loligo reynaudi

Octopus granulatus

PHYLUM ECHINODERMATA
CLASS Crinoidea
Annametra occidentalis

CLASS Echinoidea
Parechinus angulosus (spines)
CLASS Holothuroidea
Unidentified holothurians
CLASS Ophiuroidea
Amphiura capensis
Amphipholis sp.
Ophiactis carnea
Ophiothrix foveolata
Ophiothrix sp.

PHYLUM CHORDATA
CLASS Ascidiacea
Diplosoma sp.
Leptoclinides sp.
Pyrosoma sp.
Pyura stolonifera
CLASS OSTEICHTHYES
TELEOSTEI
Clinus sp.

ALGAE
DIVISION CHLOROPHYTA
Bryopsis sp.
Enteromorpha sp.
Ulva sp.
Caulerpa holmesiana

DIVISION PHAEOPHYTA
Dictyota dichotoma
Dictyotaceae species
Ecklonia maxima
Ectocarpus sp.
Ralfsia expansa
DIVISION RHODOPHYTA
Acrosorium acrospermum
Acrosorium maculatum
Acrosorium sp.
Aristothamnion collabens
Botryocarpa sp.
Botryoglossum platycarpum
Carpoblepharis flaccida
Carpoblepharis minima
Carradoria sp.
Carradoria virgata
Ceramium absoletum
Ceramium capense sensu papenfuss
Ceramium flexuosum
Ceramium planum-complex

Delesseria kylinii (med.)
Delessaria sp.
Dicurella affinis
Dicurella flabellatus
Epymenia obtusa
Grateloupia filicina
Griffithsia confervoides
Herposiphonia sp.
Heterosiphonia sp.
Hymenema venosa
Jania sp.
Orcasia pulla Simons ?
Plocamium suhrii
Polysiphonia sp.
Polyopes constricta
Porphyra capensis
Pterosiphonia cloiophylla
Ptilogon sp.
Rhodymenia sp.
Streblocladia camptoclada
Suhria vittata
Tayloriella tenebrossa

2.2 CONSUMPTION RATES AND DIURNAL FEEDING CYCLES

The composition of the diet has been determined for many of the commercially important linefish species caught around the South African coast (Nepgen 1977, Joubert and Hanekom 1980, Buxton and Kok 1983, Buxton 1984, Bennett and Griffiths 1986, Buxton and Clarke 1986, amongst others), but as yet no attempts have been made to determine their diurnal rhythms of feeding and elimination, or to estimate their rate of food consumption. One of the principal reasons for this is the practical difficulty in obtaining adequate samples of fish over a regular time series. The hottentot fish is, however, readily captured by handline at all times of day and is thus an ideal experimental animal for the estimation of diurnal feeding patterns and daily ration. In the following study, it has been attempted to utilize the hottentot in order to develop suitable techniques by which these parameters may be estimated from samples of fish collected in the field, at different times of day.

METHODS

Any estimate of feeding periodicity or daily ration, based on an analysis of stomach contents, requires a knowledge of the rate of simultaneous gastric evacuation.

This was determined by capturing a sample of 140 fish over a 45 minute period of intensive handline fishing at a site off Robben Island (Figure 2.2.1).

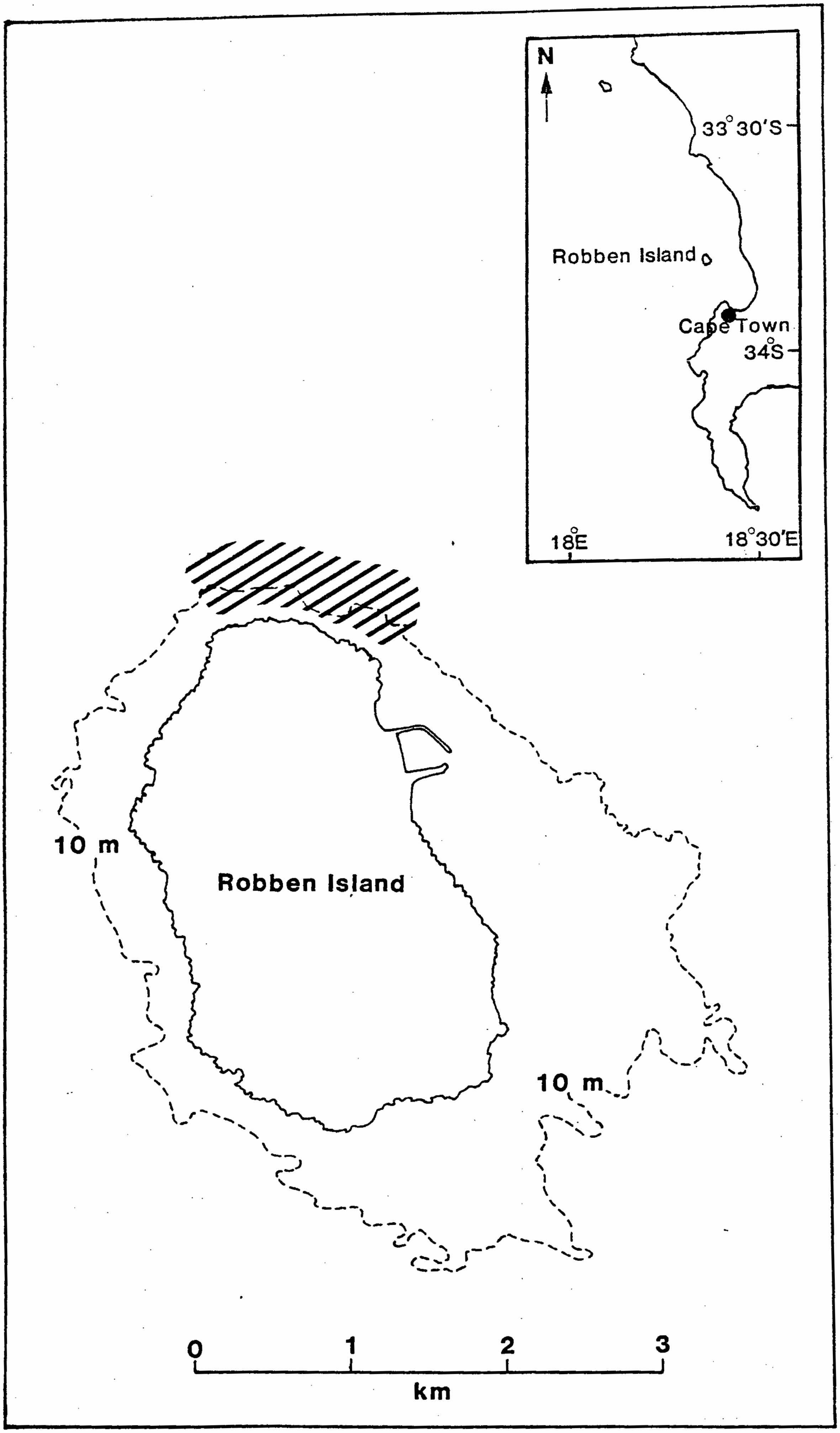

FIGURE 2.2.1 Map of Robben Island showing the site at which fish were caught for cyclical feeding and gut elimination study. (Inset: Cape Peninsula showing the position of Robben Island.)

The specimens were transferred to food-free holding tanks on the research vessel where they were continuously supplied with fresh sea water pumped from the study site.

Eleven of the fish were sacrificed immediately upon capture, their fork lengths recorded and the stomach and hindgut of each removed and frozen separately. The remainder of the catch, confined to the tanks, were sampled in the same way at three hourly intervals over a 36 hour period.

Due to the difficulties of weighing fish on board ship, length measurements were converted to mass equivalents using the regression equations given by Nepgen (1977).

After removing excess surface moisture by blotting, stomach contents were weighed, to the nearest milligram, and sorted under a stereo-dissecting microscope. In order to standardize the effect of variation in fish size, the data were converted to express the stomach contents mass as a percentage of wet fish body mass.

As enzymatic reactions follow an exponential relationship (Fabian et al 1963, in Elliott & Persson 1978), it is reasonable to assume that gastric evacuation similarly proceeds exponentially (Elliott 1972, Doble & Eggers 1978, Elliott & Persson 1978, Lane et al 1979).

The gastric evacuation rate constant (R) was thus determined using the equation

$$S_t = S_0 e^{-Rt}$$

where S_0 is the quantity of food in the stomach at the start of the experiment (t_0), and S_t is the stomach content mass at each successive sampling period, t.

Diurnal feeding activity and ration were assessed by collecting a further sample of 15 fish at three-hourly intervals over 24 hours. All material was obtained by handlining off dinghies at Robben Island. The fish were processed as described above, although the stomach contents were sorted into major taxa and each prey group was assigned a visual percentage by volume.

In order to model the feeding and elimination cycles, the assumption made is that the pattern of feeding and elimination follows a 24 hour cycle.

As the amount of food consumed by a fish is expected to increase to an asymtote as the fish becomes satiated, the relationship

$$S_t = S_\infty (1 - e^{-k(t - to)})$$

was applied to the feeding portions of the cycle, where S_∞ is the stomach content mass at infinity and k is a constant.

As suggested by Hughes (1986), the full data set, and not just a single mean stomach mass per time interval, was utilized in estimating the parameters of the equation.

Using ETAL1, a programme developed by Gaschutz, Pauly and David (1980) for iteratively fitting von Bertalanffy-type curves to irregularly spaced data by the transformed logarithmic error method, curves were fitted to the individual data for the feeding phases.

The resultant constants S_{∞}, k and t_o were then used to predict the start (S_{to}) and end percentage stomach mass (S_t) values of each feeding phase. These were subsequently used to determine the constant b, in the exponential equation

$$S_t = S' e^{-bt}$$

describing the elimination phases, where S' is the stomach content mass at the start of the elimination phase. As compensation must be made for simultaneous ingestion during the elimination phase, the rate b, determined from this will differ from the elimination rate (R), calculated earlier.

In order to estimate the gross daily consumption (Cg), it is necessary to correct for elimination that may be occuring during periods of nett increase in stomach content mass (feeding phases), and equally, any feeding that may take place during periods of nett elimination.

The consumption for each feeding or elimination phase (Cf and Ce, respectively) will therefore be the sum of the instantaneous elimination rate and the nett increase in stomach contents mass for that period, and is described by the general equation

$$C = [S_{t}' - S_{t}] + \int_{t}^{t'} RS \, dt$$

This can subsequently be modified to

$$Cf = S_{t}' - S_{t} + RS_{\infty} \left(t + \left(\frac{e^{-k(t - to)}}{k}\right)\right) \Big|_{t}^{t'}$$

for the feeding portion, and

$$Ce = S_{t}' - S_{t} + RS_{t} \left(\frac{e^{-bt}}{-b} \Big|_{t}^{t'}\right)$$

for the elimination portion of the cycle, where t and t' are the time at the start and end of each period, respectively.

The daily ration (Cg), is then calculated by obtaining the sum of the consumption rates determined for the two feeding and the two elimination phases.

$$Cg = Cf_{1} + Ce_{1} + Cf_{2} + Ce_{2}$$

Finally, in order to test the applicability of the model, the data were fitted to the original Bajkov method (in Elliott & Persson 1978), the corrected Bajkov method (Eggers 1979) and the model proposed by Elliott and Persson (1978).

RESULTS

The course of gut elimination in starved P. blochii is illustrated in Figure 2.2.2 and is represented by the equation

$$S_t = 1.2675 \times e^{-0.3724t}$$

This indicated that the gut will be 99 % evacuated over a period of 12h22.

Although the fish did not take the bait as readily during certain of the sampling periods, 3 hourly catches were maintained over the 24 hour period, suggesting that at least some of the fish are feeding at all times of day.

Analysis of diurnal fluctuations in stomach content mass (Figure 2.2.3), illustrates that the hottentot exhibits two feeding and elimination cycles daily. These appear to be closely correlated to the tidal cycle, feeding activity increasing during the incoming tide, whilst being greatly reduced during the ebb tide, resulting in a nett decline of stomach contents mass.

The solutions to the equations fitted to the feeding and elimination phases are presented in Table 2.2.1. Gross consumption rates for each of the four phases are also given.

The two feeding phases, both corresponding to the flood tides, together accounted for 80 % of the total consumption.

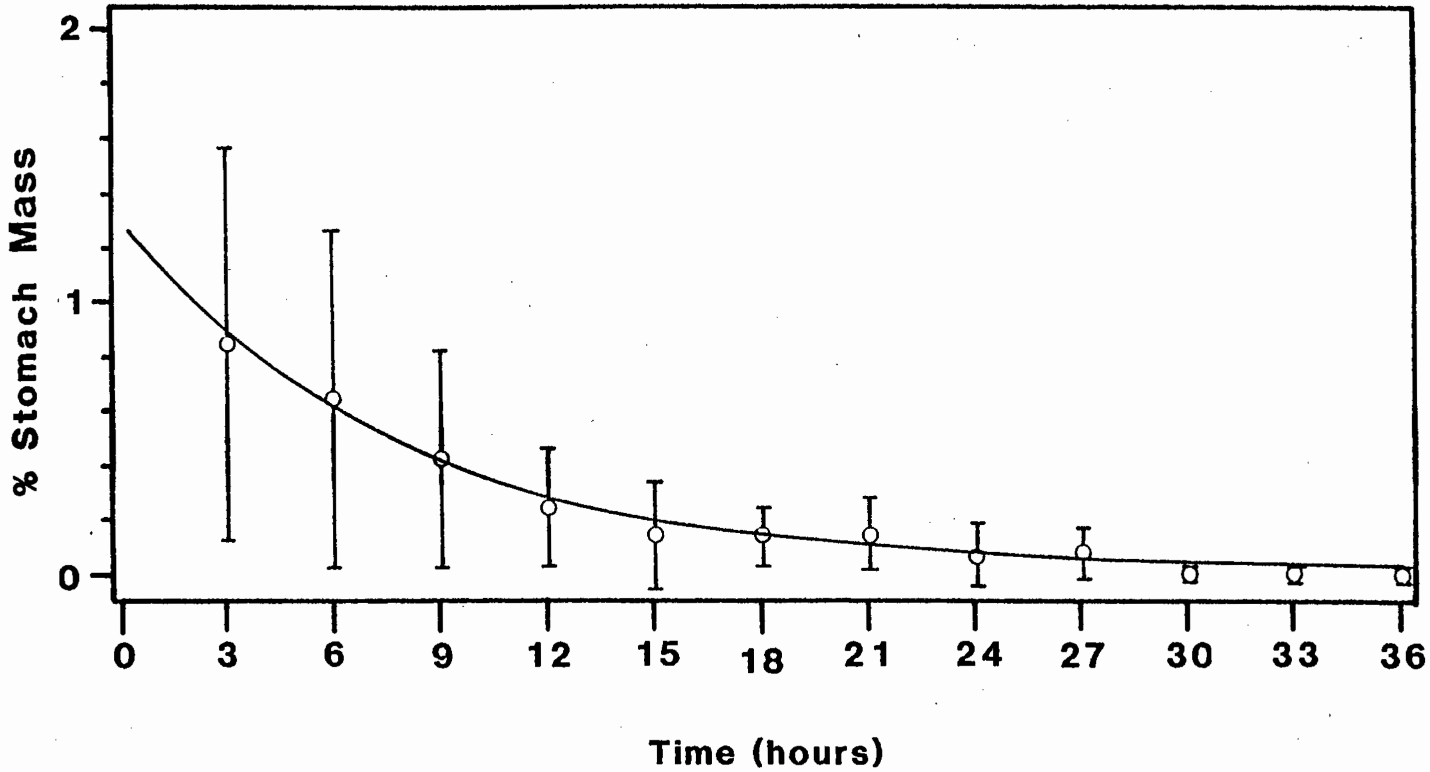

FIGURE 2.2.2 The mean stomach mass (as a % of body mass) of starved P. blochii, showing the exponential gut elimination curve. Vertical bars represent one standard deviation.

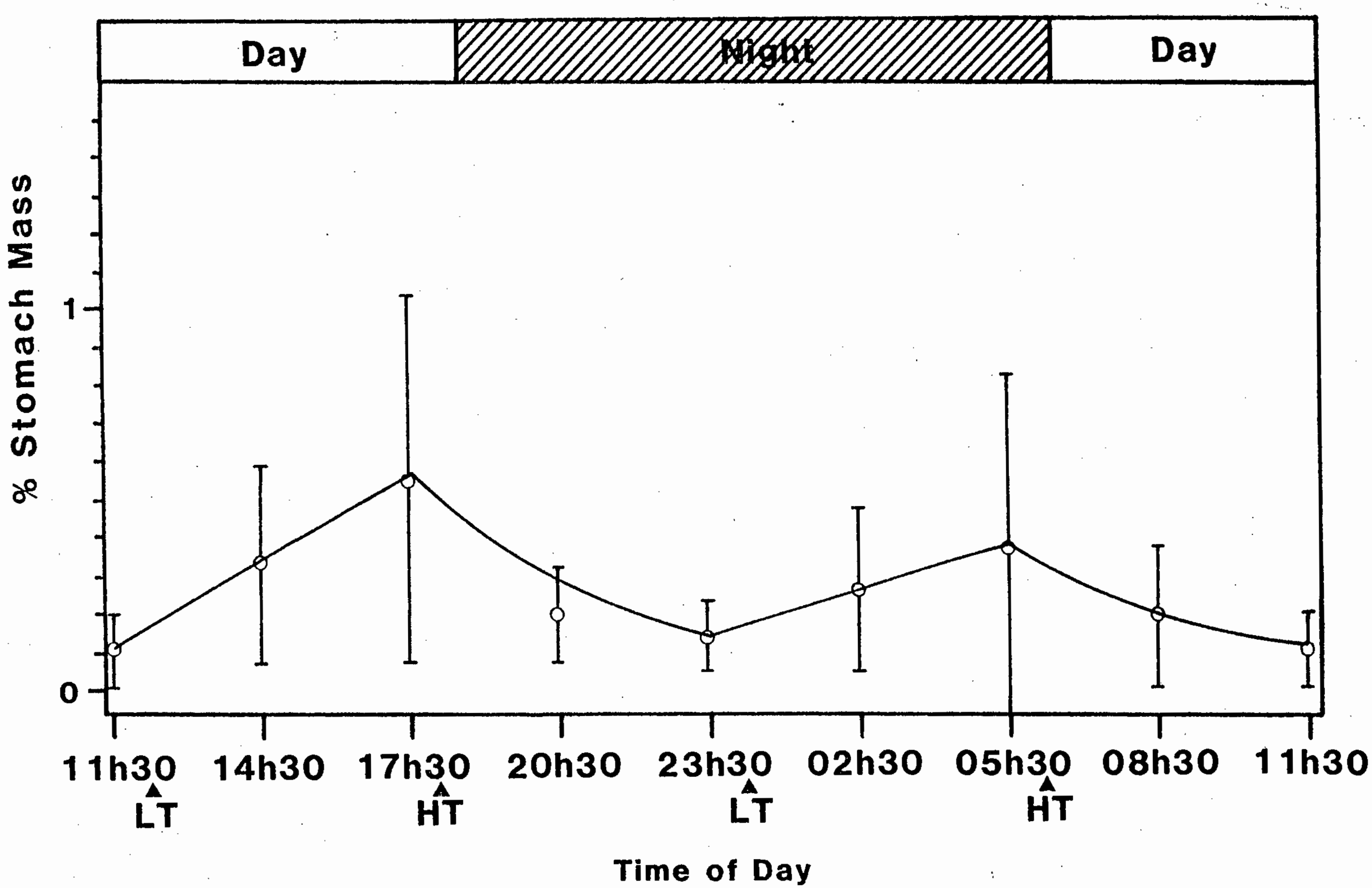

FIGURE 2.2.3 The mean stomach mass (as a % of body mass) of P. blochii over a 24 hour period showing the diurnal feeding cycle. Vertical bars represent one standard deviation.

The remaining 20 % is taken during the periods of nett elimination, over the ebb tides.

As regards the diurnal rhythm, there was little difference between the consumption patterns by day and by night. As some 41.5 % of the gross daily ration is consumed during the night, this indicates that feeding is not greatly reduced at this time.

TABLE 2.2.1 a) S_{∞} ,k and to values for the feeding phases of the 24 hour feeding cycle of P. blochii, and the subsequently calculated S_{to} and S_t values and consumption rates (% body mass per day)
b) S' and b values for the two elimination phases in the 24 hour feeding cycle, and the consumption rates (% body mass per day)

(NOTE: for the purpose of calculating the equations, curves were assumed to start at t = 0.)

a)

PARAMETER	FEEDING 1	FEEDING 2
S_{∞}	15.415	26.839
k	0.005	0.002
to	-1.46	-3.672
S_{to}	0113	0.146
S_{tn}	0.564	0.383
Cf	1.210	0.827

b)

PARAMETER	ELIMINATION 1	ELIMINATION 2
S'	0.564	0.383
b	0.226	0.203
Ce	0.273	0.225

A plot of the proportions of each of the major prey groups present in the stomachs, over the 24 hour sampling period (Figure 2.2.4), however, indicates that there are temporal trends in the type of food taken and that these follow a diurnal rather than a tidal rhythm. By day the hottentot appears to graze preferentially on benthic algae, crinoids and hydroids. In the latter part of the night, however, crustaceans become the most important food item, making up over 60 % of stomach contents. Although found in small quantities only, polychaetes were most abundant in the diet around dawn and dusk. This possibly reflects the crepuscular habits of this prey.

Finally, Table 2.2.2 presents the consumption results calculated by other methods suggested in the literature.

TABLE 2.2.2 The consumption rates of _P. blochii_ (% Body mass per Day) calculated using various methods suggested in the literature.

METHOD	CONSUMPTION RATE
ORIGINAL BAJKOV METHOD (Elliott & Persson 1978)	0.566
CORRECTED BAJKOV METHOD (Eggers 1979)	0.971
ELLIOTT AND PERSSON, 1978 a)	2.662
ELLIOTT AND PERSSON, 1978 b)	2.270
PRESENT MODEL	2.535

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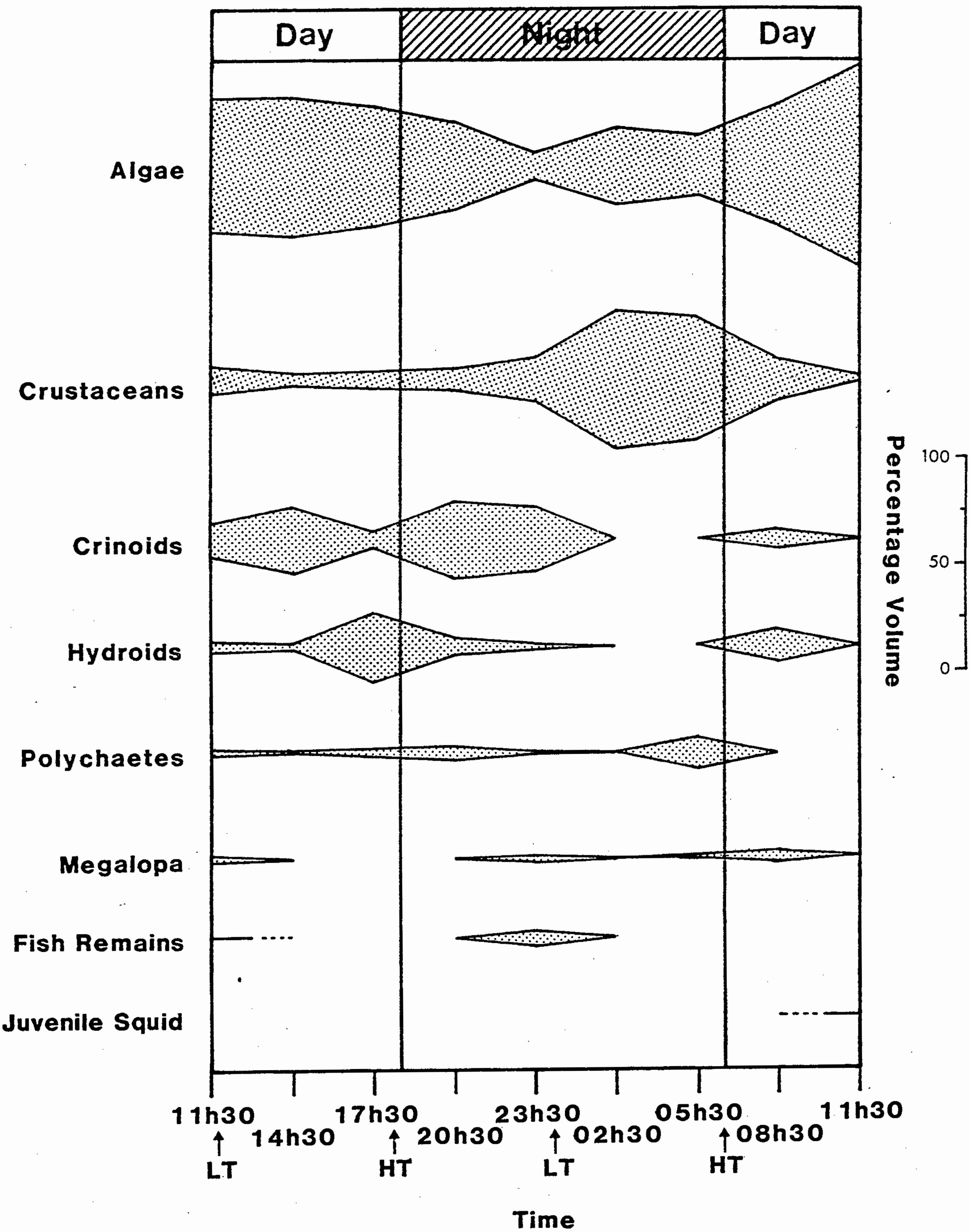

FIGURE 2.2.4 Mean weight of the main food categories in the diet of P. blochii, sampled over a 24 hour period, expressed as a % of the total weight of all prey items in all fish sampled.

DISCUSSION

The pattern of gastric evacuation of the hottentot appears to conform closely to the exponential model proposed in Figure 2.2.2, complete evacuation taking about 12 hours. As the hottentot was found to feed continuously, over the 24-hour period, rather than exhibiting exclusive feeding and elimination phases, accurate estimates of the evacuation rate could not be established <u>in situ</u> as done by Blaber 1974, Staples 1975a, and Doble & Eggers 1978). It was therefore necessary to isolate a sample of fish and subsequently determine the time required for complete gastric evacuation, in a food free environment.

Although Thorpe (1977) found that serial sampling of fish, denied access to food, underestimates the digestion rate, a modification of his method was adopted in this study, as it was felt this would give the more accurate result. The sampling technique used differed from that of Thorpe (1977) in that only one catch, rather than successive catches made at 3 hourly intervals, was serially sampled.

A number of assumtions are implicit in applying the model to field populations, noteably that the pattern of evacuation is independent of the nature and quantity of food being consumed (El-Shamy 1976), and that it is unaffected by capture and transfer of the experimental individuals. This latter presupposition is a serious limitation* common in the methods proposed for determining the gut emptying rate. Although Swenson and Smith (1973) claimed that handling of fish, during their laboratory experiments, had no effect on the digestion rate, the stress of being hooked, and subsequently transferred to holding tanks, must be considered in this study. This, together with the effect of starvation, noted by Thorpe (1977), suggests that the evaluation of 12h 22 for 99 % evacuation, may indeed be an underestimate.

The feeding activity exhibited by the hottentot appears to be more strongly influenced by the tides than by the diurnal cycle. This is in contrast to the results of other studies which were, however, conducted in fresh water or closed estuarine environments, and thus had no tidal influences.

Almost all the feeding seems to take place during the rising tide, although there is some consumption during ebb as well. The reasons for this are obscure, but are presumably related to prey availability. Although some food is taken from the intertidal zone (eg *Porphyra capensis*), most is undoubtedly derived from sublittoral resources, and there is no clear reason why this should be more accessible during high tide. Of interest, however, is that the increase in feeding activity at flood tide, confirms the reports of fishermen who claim that the fish bite only at this time.

It appears that, although feeding still occurs during the night, the activity is reduced when compared with that exhibited during daylight hours. This was further confirmed by night-time diving observations, which found the fish to be more placid and evenly spaced, usually seeking the cover of caves or crevices in the reef. This contrasts with their daytime behaviour which involves active grazing in shoals of various sizes.

This change in feeding habit is likely to contribute to the observed temporal change in diet. An increase in the relative availability of crustaceans in the plankton is reflected in the higher proportions of this prey in the nocturnal diet. Many benthic crustaceans emerge into the water column at night for feeding, dispersal or reproduction and are thus vulnerable to predation by hottentot.

Various models for estimating daily consumption in fish have been proposed in the literature. The Bajkov method (Bajkov 1935, in Eggers 1979) which is appropriate in a diel situation, where the level of food at the onset of feeding in two successive days is nearly the same, and which is applicable to fish feeding continuously over 24 hours (Elliott 1979), has however, been found to underestimate the daily ration (Thorpe 1977, Elliott & Persson 1978). Similarly, the method of Thorpe (1977) has been reported to underestimate the daily food consumption (Elliott & Persson 1978), and was therefore not considered for this study. The alternative models proposed by Eggers (1977), Elliott and Persson (1978) and Lane _et al_ (1979), however all make the simplifying assumption that the feeding rate remains constant, a condition which is considered unlikely in the natural situation.

Although Elliott and Persson (1978) consider the case where the relationship between the cumulative amount of food consumed and time follows an asymtotic curve, the derivation of their constant b, is not clear (equation 10 & 11). It was therefore decided to develop a new model, for continuous feeding over 24 hours, which assumes an asymtotic feeding rate.

From Figure 2.2.3, it becomes evident that, although a von Bertalanffytype equation was fitted to the feeding portions of the data, the resultant curves are almost linear.

As the curves are representative of both consumption and simultaneous elimination, however, the asymtotic nature of the feeding curves will be disguised.

In comparing the results obtained using our model, with those calculated using other methods, both the original and the corrected Bajkov methods (Elliott & Persson 1978, Eggers 1979) give an underestimate of the daily consumption rate.

As the inherent assumption of the Elliott and Persson (1978) model is that the feeding rate is constant, its application to the present data will give an overestimate of the daily ration, if one presumes feeding continues during the elimination phases (Table 2.2.2 Elliott & Persson 1978 a)). If however, one assumes that feeding ceases during elimination, an underestimate will result (Table 2.2.2 Elliott & Persson 1978 b)).

The daily ration, of 2.5 % body mass/day, using the present model, differs only slightly from the results obtained using the method of

Elliott and Persson (1978), indicating that it would seem to offer an acceptable alternative, when dealing with a fish exhibiting continuous feeding.

This ration is close to the 2 - 4 % body mass/day reported for four species of fish by Keast and Welsh (1968) and the 2 - 6 % for yellow perch or 0.5 - 4.5 % for sockeye salmon reported by Nakashima and Leggett (1968) and Doble and Eggers (1978), respectively.

As the hottentot has been shown to exhibit both a seasonal and size related change in diet, and a decrease in feeding activity at low water temperatures (as reported by fishermen), has been confirmed by diving observations, the fish abandoning their active shoaling behaviour to retreat, singly or in small groups, into caves and overhangs, care must be excercized in drawing definitive conclusions from the results of this study.

Thorpe (1977) found a great variation in the daily ration figures in samples from different years, and Nakashima and Leggett (1978) experienced differences of similar magnitude in samples from day to day. Similarly, it has been demonstrated that daily ration and feeding rhythms can vary markedly with season and fish size (Staples 1975b, Nakashima & Leggett 1978), and that water temperature can determine both feeding intensity and digestion rate (Mathur 1973).

This indicates that the results of short term, <u>in situ</u> experiments provide only a "snapshot" of the chronological feeding habits and consumption rates of a species.

An additional complicating factor is the dual influence of the tidal and diurnal cycle on the feeding periodicity. The daily change in the dominant, tidal rhythm will result in a constant variation in the height and position of the feeding peaks. The diurnal influence will subsequently have the further effect of either suppressing or enhancing these peaks, depending on what time of day the high tide occurs.

The consumption rate figure of 2.5 % body mass/day calculated for P. blochii, must therefore be considered an estimate only. This study however highlights that, in attempting to accurately ascertain the feeding chronology and food consumption of a marine teleost, a more extensive sampling programme, involving sampling the complete size range of the population, at short intervals for a period of 48 hours or more, regularly throughout the year, must be undertaken. Furthermore, it is suggested that, in a species exhibiting constant feeding, the method of calculating the daily ration proposed here, be adopted. Although results obtained with our model may not differ significantly from those obtained using the method of Elliott and Persson (1978), it is considered that this model is more realistic, as it assumes an asymtotic rather than a constant feeding rate.

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3. REPRODUCTION AND GROWTH

Aspects of the reproductive biology and growth of the hottentot were researched to some extent by Nepgen (1977). This study, however, failed to consider spacial variations. The marked hydrographical differences evident over the distribution range of the species, suggest that these may influence both the reproductive seasonality and growth rate. These apects of the biology of the hottentot were thus re-evaluated, and variations with area were investigated.

MATERIALS AND METHODS

Data were collected between February 1984 and July 1985, with most of the 1595 fish sampled being obtained through fish dealers or commercial handline fishermen at the sampling sites shown in Figure 2.1.1. The majority of these specimens were larger than 200 mm total length. Smaller fish were collected by spearfishing. The total length and fork length of each fish were measured in millimetres and the mass determined in grams.

Scales for age determination were removed from between the upper edge of the pectoral fin and the lateral line, and were subsequently dry-mounted between microscope slides. Preliminary examination under weak magnification, with transmitted light, failed to reveal clear or consistent increment patterns. Consequently the sagittae were adopted for age determination. These were examined under weak magnification and reflected light, under water against a dark background, lateral surface upwards. In order to define the relationship between otolith radius and fish length, the radius of each otolith was measured to the nearest 0.01 mm. Replicate counts of the alternating opaque (appearing white) and hyaline (appearing dark) zones were made at >2 week intervals by the same reader.

Preliminary results suggested the misinterpretation of both juvenile and false rings as annual growth zones. Measurements of the distance from the nucleus to each visible ring were thus made on 182 otoliths. Using the growth curve of Nepgen (1977) as a guideline, the true annual increments were identified by back-calculation. This method was suggested by Thomas (1984) for cases where secondary rings or irregular annuli present problems in assessment of age. This subsample was read by a second reader for confirmation.

As some of the larger otoliths proved difficult to interpret, these were sectioned and mounted in DPX resin on a glass slide. When viewed under transmitted light readability was, in most cases, enhanced.

A von Bertalanffy growth equation was fitted to the age data using the absolute error model discussed by Hughes (1986). The jackknife technique (Efron 1982), was used to calculate the standard errors and coefficients of variation of the von Bertalanffy parameters and the lengths at age.

In determining the otolith growth rate, a von Bertalanffy equation was fitted to the weighted means of the observed otolith radii at age, using 'ETAL1' (Gaschutz, Pauly and David 1980).

The importance of substantiating a growth curve, using some method of validation, is emphasized by Beamish and McFarlane (1983). Otoliths from small fish (<200 mm total length) were thus prepared for viewing with a scanning electron microscope, according to the techniques described by Thomas (1985). The otoliths were examined at 700 - 1000 X magnification, and only those in which the centres could be located were considered for further investigation. Micrographs were taken in series and 20 x 25 cm prints were compiled into a montage. Where visible, rings were counted from the otolith centre along the line of maximum growth, whose length was determined using a measuring wheel. By simple proportion, the measured radii, at 20 cm intervals on the montage , were scaled to distances on the otolith. Using the otolith radius-at-age relationship, the predicted age in days was calculated for the intervals and compared with observed ring counts from the montage.

Gonad samples were examined fresh where possible. A visual assessment, based on macroscopic features, was made of the maturity stages of each fish, in order to determine reproductive seasonality. Classification of the maturity stages are summarized in Table 3.1. Males and females were assessed separately. The paired gonads were weighed, and gonadosomatic indexes (GSI) were calculated by expressing gonad mass as a percentage of the total mass. In

TABLE 3.1 Gonad maturity stages and the criteria used in allocation of gonads to the various stages.

Stage	State	Males	Females
1	Immature or inactive	Testes narrow, ribbon-like, pink or transparent.	Ovaries thread-like, translucent, rose-coloured, no ova visible.
2	Early development or recovery	Testes slightly enlarged, white or off white in colour.	Ovaries rounded and slightly enlarged. Translucent, pale yellow, immature ova barely visible. Superficial blood vessels developing.
3	Later development	Testes greatly enlarged, cream-like milt extruded under considerable pressure.	Ovaries opaque and yellow. Individual pigmented opaque ova present. Superficial blood vessels well developed.
4	Ripe	Gonad at maximum size, flat, opaque, firm, and white organs. Viscous milt present in varying quantities.	Ovaries at maximum size, yellow and turgid. Ova tightly packed, some translucent, but not easily separated from the matrix.
5	Ripe and running	Testes as in stage 4. Milk-like milt extruding under slight pressure.	Ova translucent and larger than in stage 4. Easily extruded under light pressure.
6	Partially spawned	Testes large and turgid. Milt still present. Varying degrees of haemorrhaging evident.	Ovaries large and turgid. Ova still present but varying degrees of haemorrhaging evident.
7	Spent	Testes smaller than stages 5 and 6, flaccid and haemorrhaged.	Ovaries flaccid due to evacuation, haemorrhaging extensive.

addition, the condition factor of each fish was determined according to the method of Le Cren (1952):

$$\text{Condition factor (K)} = \text{Mass(g)} / a \cdot Lf^{b}$$

where a = the intercept, and b = the exponent of the fork length (Lf) - mass relationship.

Monthly means for the GSI and K, for separate sexes and sampling areas were subsequently calculated. Using the UCT Saclant 3-D package, three-dimensional response surfaces were obtained by plotting mean monthly GSI and fork length against months, thereby giving a detailed view of the spawning period.

RESULTS

The size characteristics of the total sample and of males and females separately are presented in Table 3.2 and the length frequency distributions in Figure 3.1. Females appear to be slightly larger than males in both mean length and mass. The length-mass relationship for males is

$$\text{Mass(g)} = 3.2603\text{E-}5 \times \text{Lf(mm)}^{2.955} \quad (n = 351 ; r^2 = 0.98)$$

and that for females is

$$\text{Mass(g)} = 2.2223\text{E-}5 \times \text{Lf(mm)}^{3.026} \quad (n = 498 ; r^2 = 0.98)$$

No statistically significant difference in the length-mass relationship between sexes is evident however ($0.2 > p > 0.1$). The combined relationship is described by

$$\text{Mass(g)} = 3.064\text{E-}5 \times \text{Lf(mm)}^{2.967} \qquad (n = 1546 \; ; \; r^2 = 0.97)$$

and the total length-fork length regression by

$$\text{Lt(mm)} = 1.0996 \times \text{Lf(mm)} + 1.419 \qquad (n = 1431 \; ; \; r^2 = 0.99)$$

The sex ratio of males to females for the 846 specimens examined was

1 : 1.383

A seasonal oscillation is apparent when plotting monthly sex ratios (Fig 3.2), the females being more common during the summer. Although the peaks and troughs of the curve are not significantly different from the sample mean, significant differences are evident when comparing the summer peak with the troughs in June 1984 and 1985 (Table 3.3).

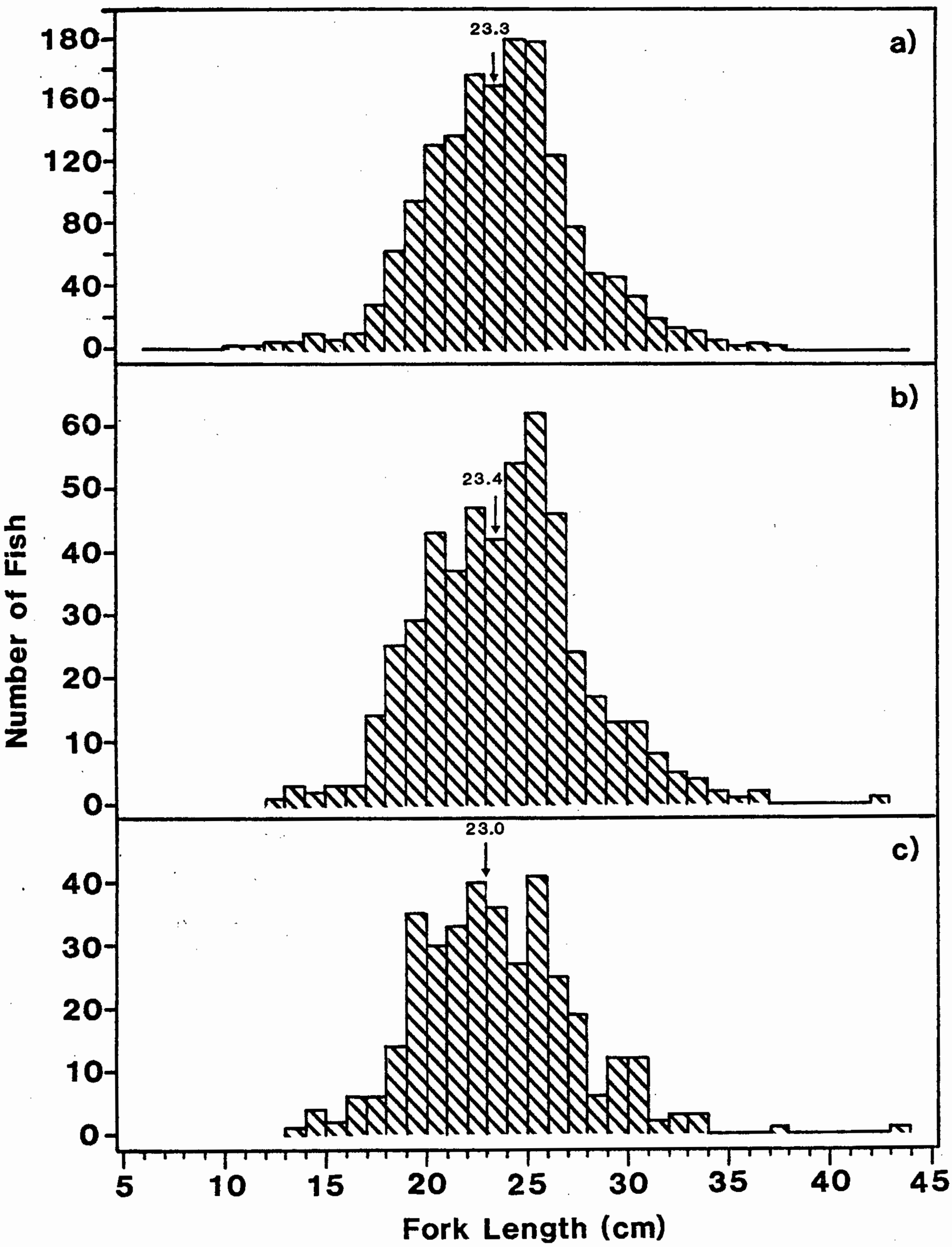


FIGURE 3.1 Overall length frequency distributions of a) both sexes, b) females and c) males sampled during this study. Arrows represent the means.

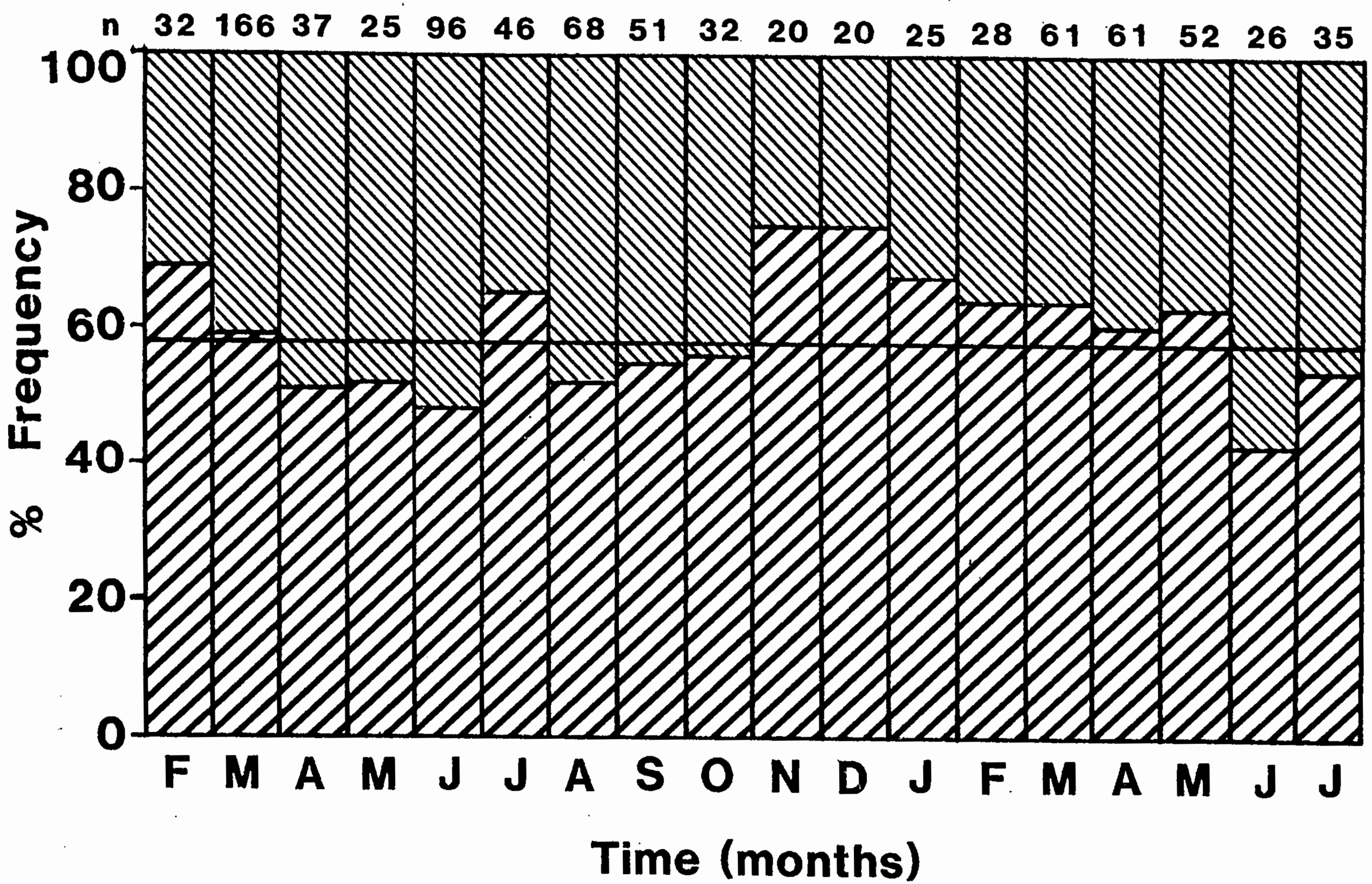


FIGURE 3.2 Variations in the monthly sex ratios of _P. blochii_ from all areas. The solid horizontal line represents the sample mean.

TABLE 3.2 General statistics for P. blochii sampled during this study.

PARAMETER	MEAN	SD	SE	MAX	MIN	N
Whole sample						
Fork length (mm)	237.8	38.8	0.98	433	67	1595
Mass (g)	375.2	195.7	4.98	2100	7	1547
Males						
Fork length (mm)	234.8	39.1	2.06	433	133	359
Mass (g)	360.1	197.9	10.57	2100	62	351
Females						
Fork length (mm)	238.8	39.8	1.78	425	129	501
Mass (g)	380.8	211.5	9.48	2000	54	498

Gonad examination suggests that the hottentot maintains a low level of breeding throughout the year. When plotting the monthly GSI for males and females separately (Fig 3.3), peaks occur in late autumn-/early winter, and during summer. The same trends are evident for the different sampling areas. Figure 3.4. shows the mean monthly condition factor. Taking a K value of 1 to be the idealized condition of the fish, the resultant curve does not deviate markedly from this. It appears that fish are in good condition prior to the autumn/winter spawning. Condition deteriorates steadily throughout winter, reaching a minimum during the breeding season in November to January. No difference in this trend was observed spatially or with sex.

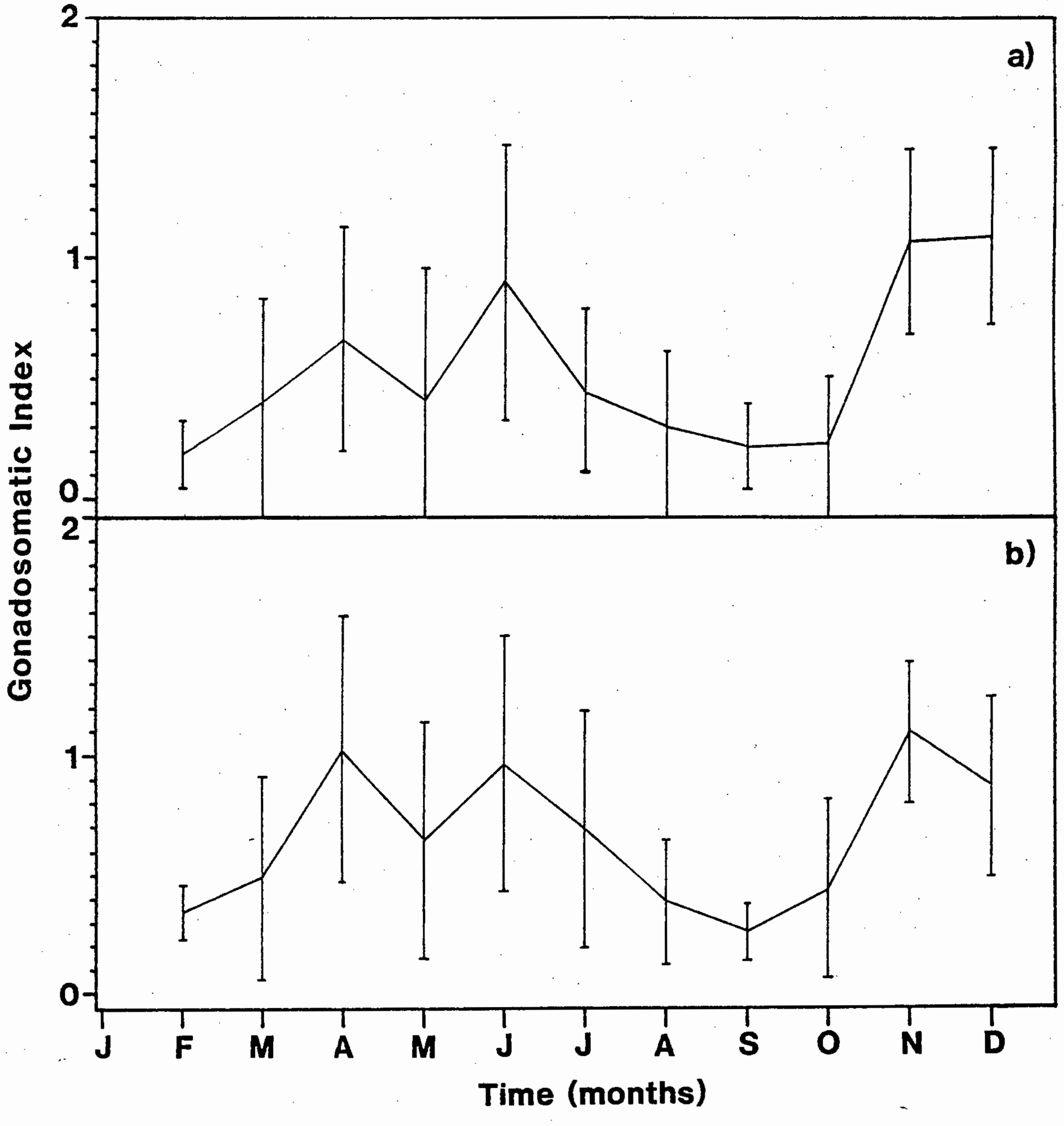


FIGURE 3.3 Seasonal variation in the gonadosomatic index in a) male and b) female P. blochii. Data are given as the mean ± S.D.

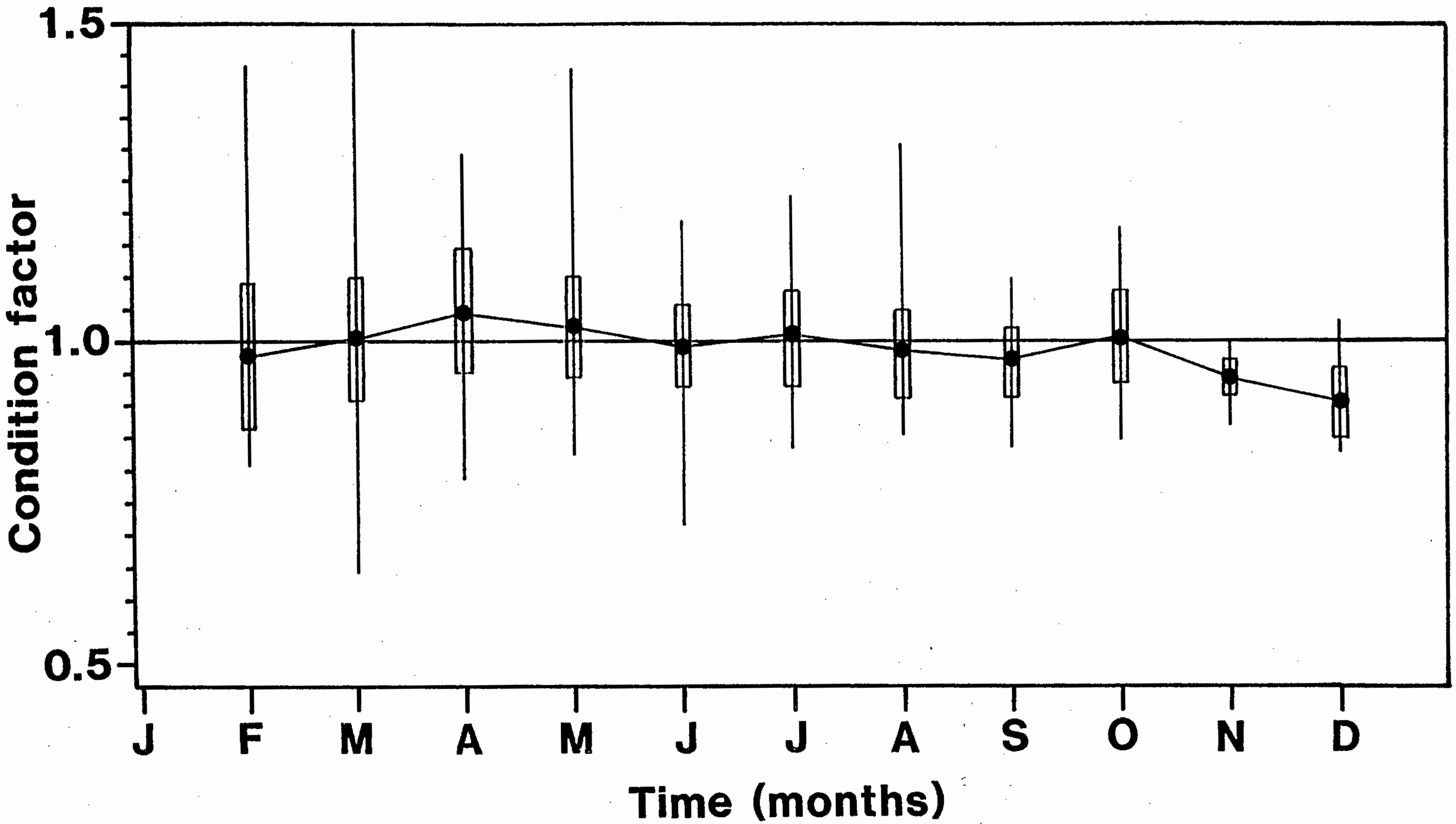


FIGURE 3.4 Seasonal variation in the condition factor of *P. blochii*. Solid dots represent the mean, the bar is one S.D. and the vertical line the range.

TABLE 3.3. Probabilities of the Chi-squared test for comparisons of monthly sex ratios.

Comparison	Test Value	Probability
June 1984 - November 1984	5.879	$0.025 > p > 0.01$
November 1984 - June 1985	8.333	$0.005 > p > 0.001$
June 1984 - mean	4.038	$0.05 > p > 0.025$
November 1984 - mean	2.362	$0.25 > p > 0.10$
June 1985 - mean	1.341	$0.25 > p > 0.10$

By relating gonad activity to fork length, an estimate of the size at sexual maturity was obtained. Only fish caught during May, June, November and December (i.e. the autumn and summer peaks) were used. Due to the fact that fish with active developed ovaries were found throughout the year, and that not all fish are reproductively active at the same time, the length at maturity cannot be precisely established. An eyefit curve to the 3 cm running mean, indicated 50 % maturity at approximately 220 mm fork length (Fig 3.5). The smallest reproductively active fish sampled had a fork length of 169 mm.

As the mean monthly GSI plots identified little difference between the male and female spawning cycles, these data were combined in constructing the 3-D mean GSI response surface (Fig 3.6). This clearly illustrates the two spawning seasons as well as the length at which the fish begin to mature, thereby serving as an effective summary of the results. Although the single peak apparent in the larger size classes (>30 cm Lf), appears to confirm the reports of fishermen that the big fish spawn primarily during winter, this is thought rather to reflect the absence of data for these size

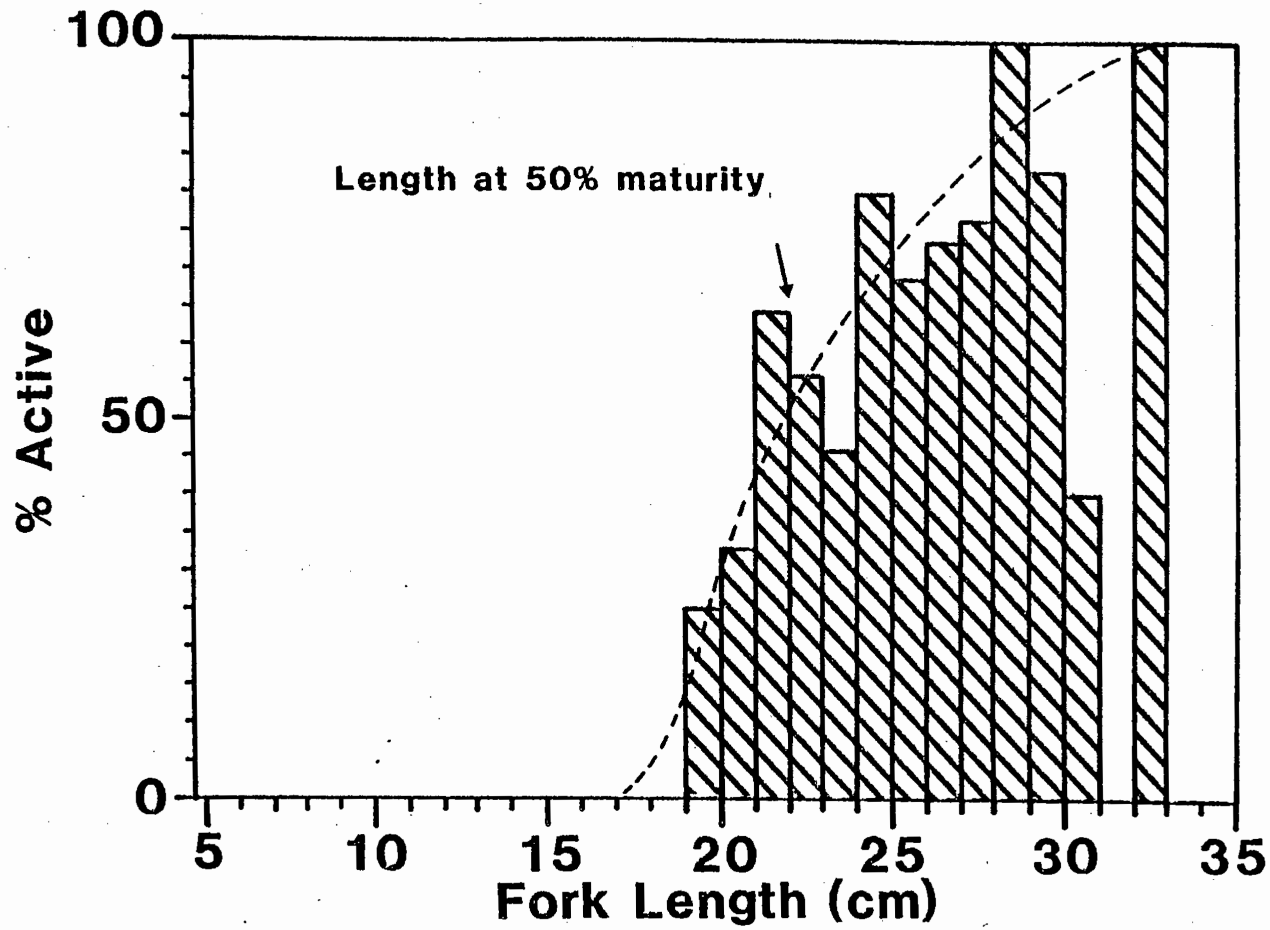


FIGURE 3.5 Percentage active gonads (stages 3 - 7) in _P. blochii_ of increasing length during the peak spawning seasons.

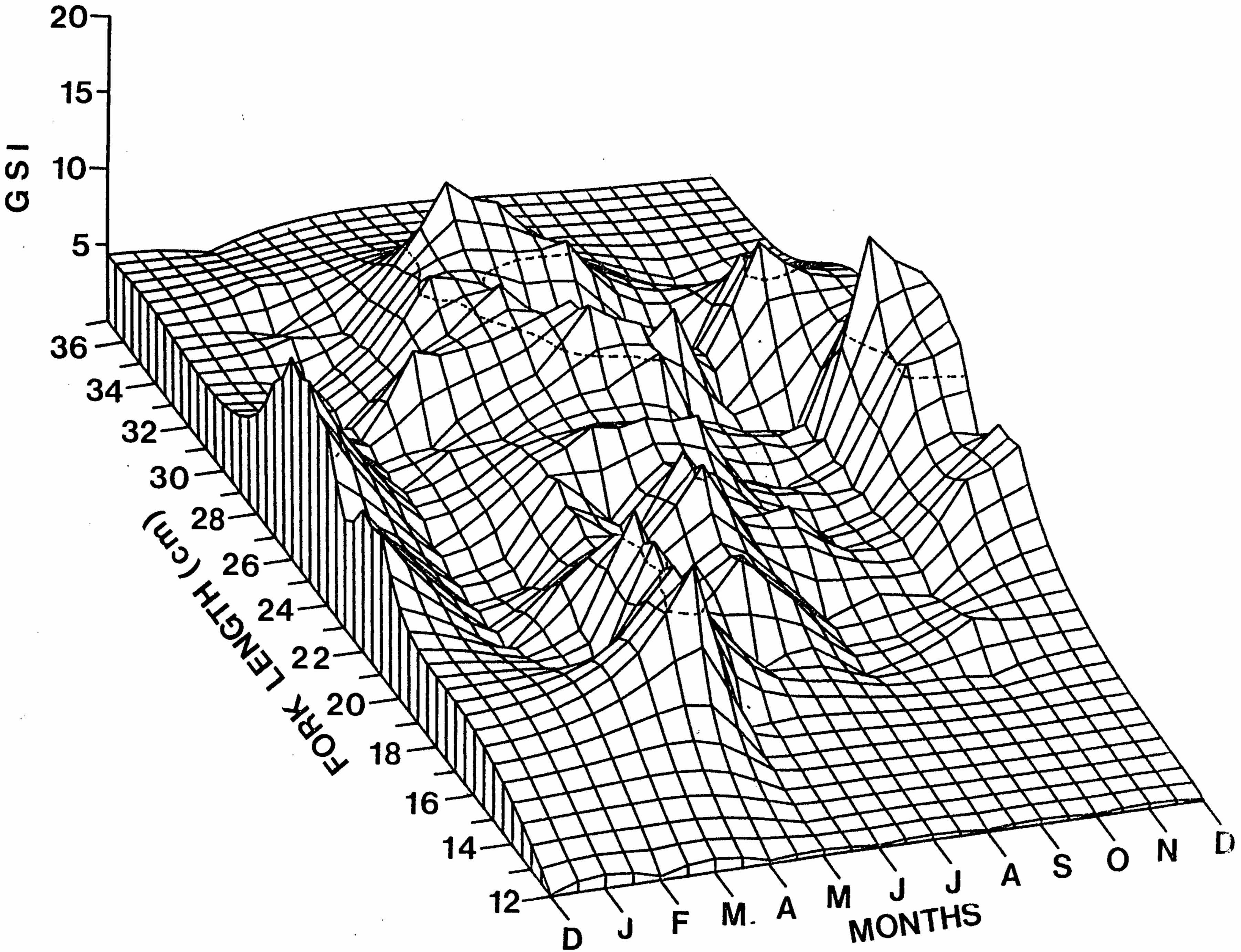


FIGURE 3.6 Response surface showing mean monthly gonadosomatic index for P. blochii of increasing size.

classes for the summer months. No spatial variation in either spawning peaks or size at sexual maturity was evident.

Of the 662 otoliths examined, a subsample of 182, for which the observations of two readers agreed fully, was used in constructing the growth curve. The otoliths of the smallest fish examined (85 mm and 103 mm Lf) had opaque nuclei with one distinct hyaline ring, surrounded on the outside by the first opaque zone. These fish were thus assumed to be one year old (i.e. in their second year of growth). Figure 3.7 illustrates the juvenile and false rings evident in these otoliths. In some cases as many as three false rings were recorded between the second and third year of growth. As the annual growth zones occur closer together with age, the false rings become more difficult to recognize in larger otoliths.

Of the 45 otoliths prepared for electron microscopy, only three yielded results. Although the centres were visible in all of these, direct total increment counts were not possible as rings were obscured for substantial distances, only becoming readable towards the edge of the section ($\pm$ 35 % of the otolith). This made interpolation difficult.

In the zones where rings were present, deep intersections and convergence of rings were common. Figure 3.8 gives an example of portions of a montage of scanning electron micrographs.

a

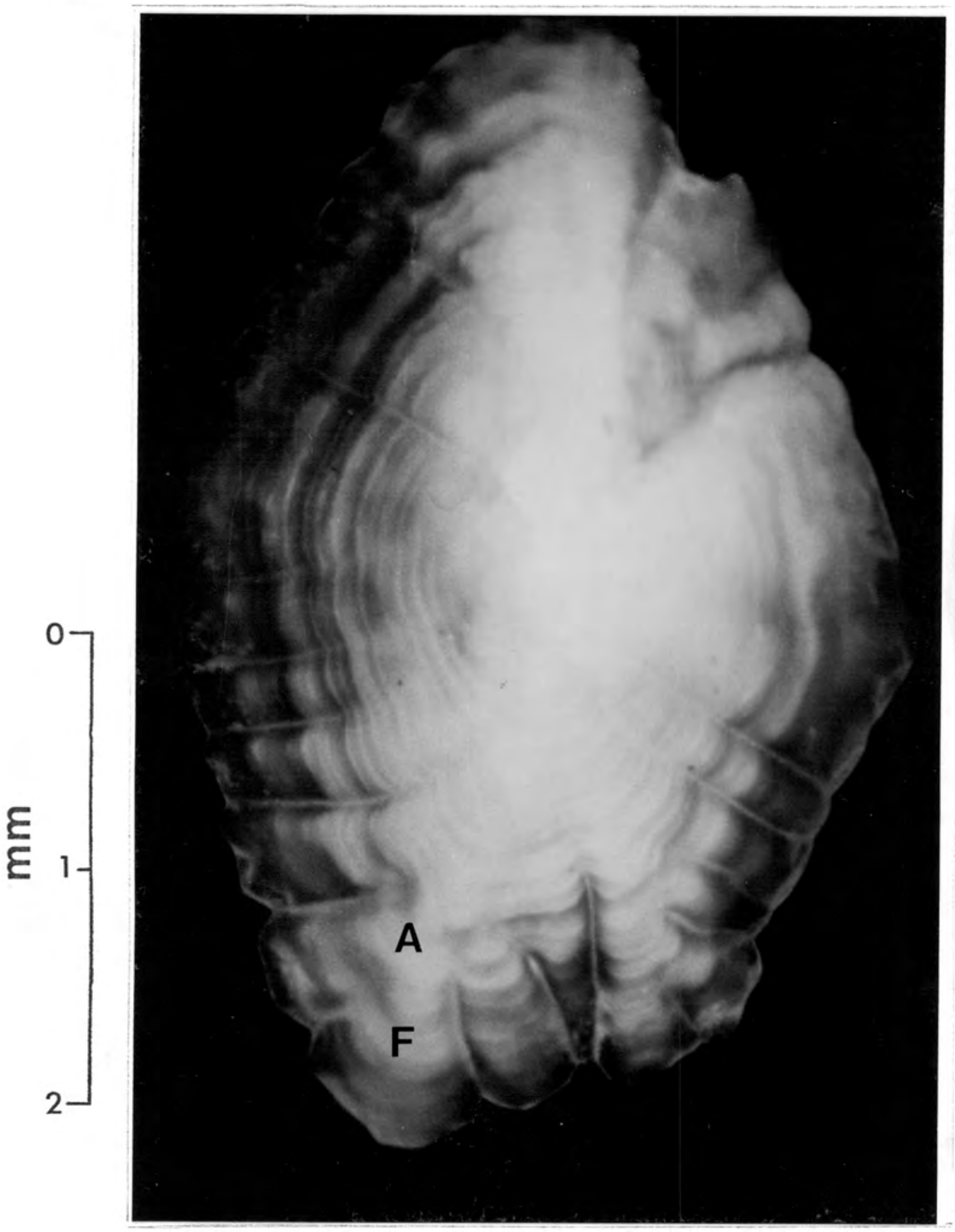
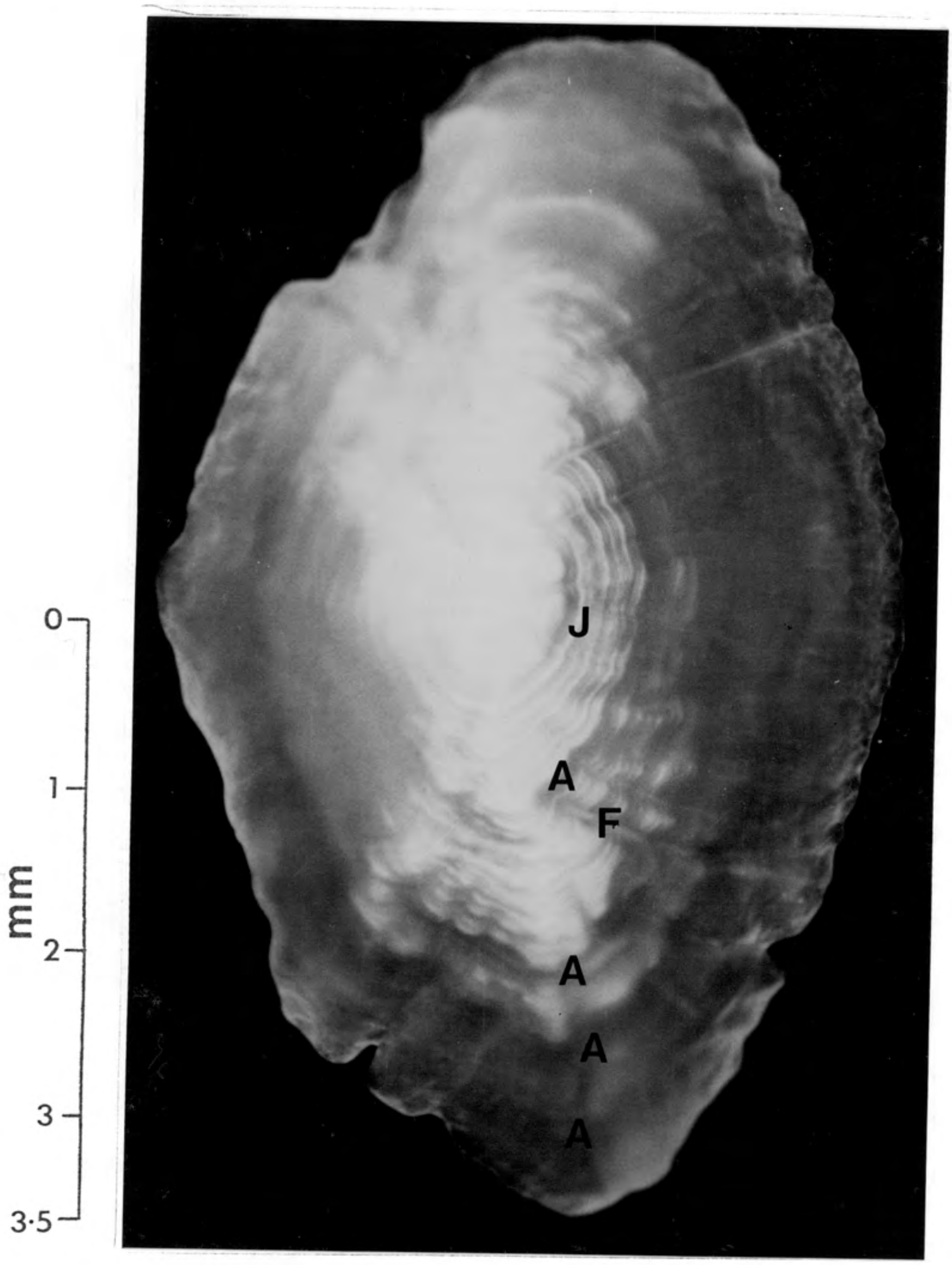


FIGURE 3.7 Otoliths of a) a 1 year old (85 mm Lf) and b) a 5 year old (157 mm Lf) fish, showing the juvenile rings (J), false rings (F) and the true annuli (A), as interpreted during this study.

b



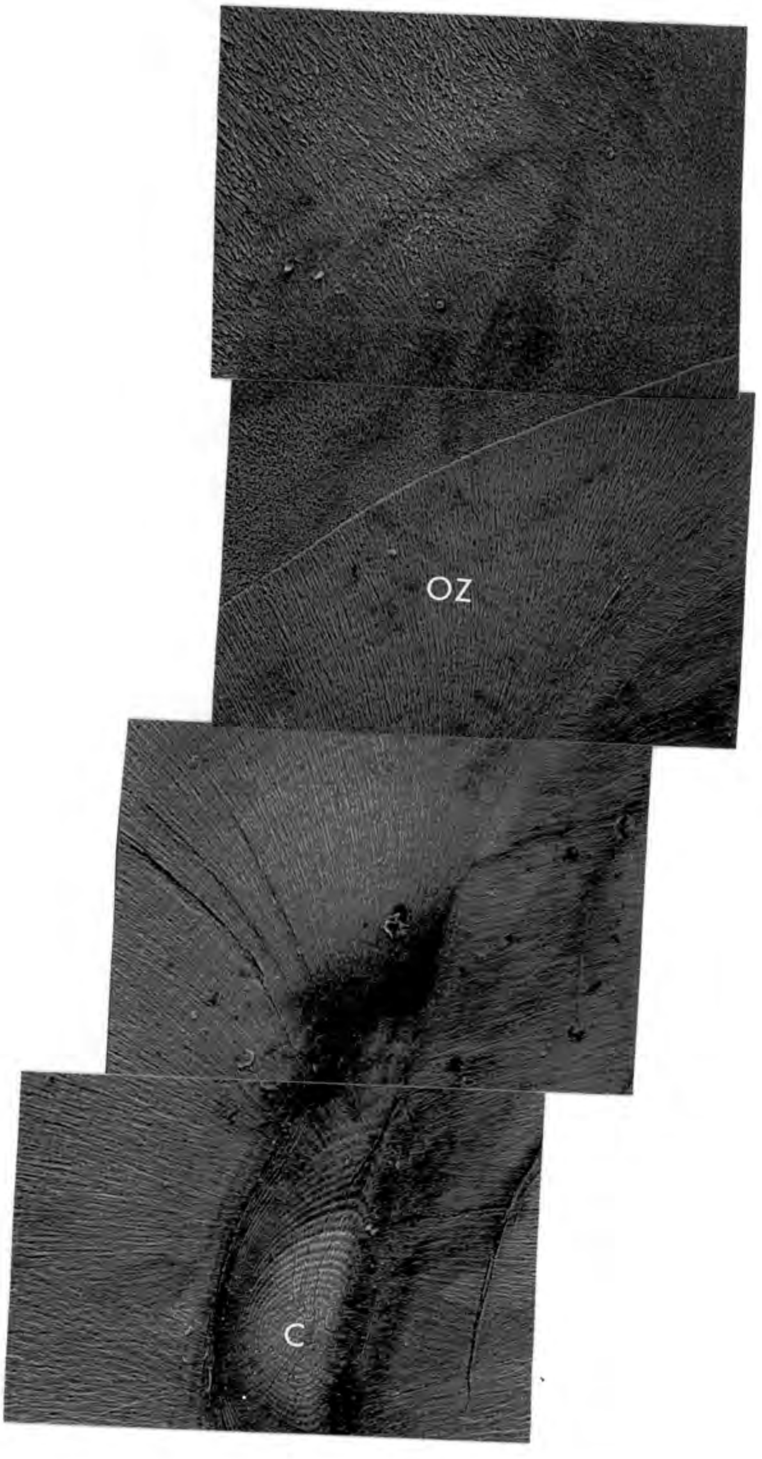
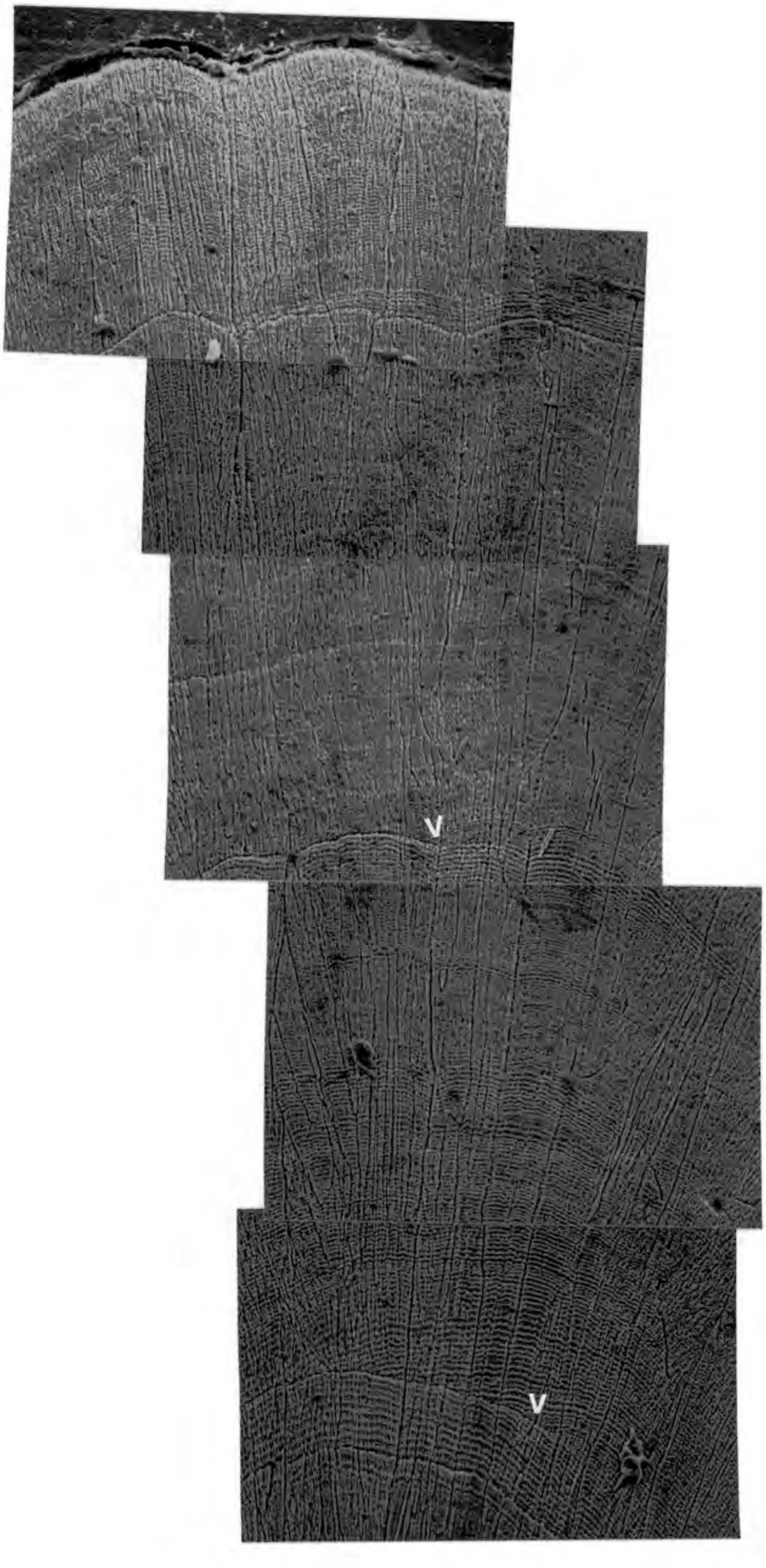


FIGURE 3.8 Electron micrographs of sectioned otoliths of P. blochii showing:
a) Daily rings spreading concentrically from the centre (C) into the zone of obscured rings (OZ).
b) Daily increments with periodic variations in thickness, intersections and convergence of rings (arrows), closer to the edge of the otolith.

b



The relationship between otolith radius and fork length (Fig 3.9) is best described by a power curve where:

$$OR(mm) = 0.909 \times Lf(mm)^{0.737} \quad (r^2 = 0.86)$$

Otolith growth rate is described by:

$$OR(mm) = 7.173\ (1 - e^{-0.226\ (t\ +\ 0.149)})$$

Table 3.4 compares the observed number of growth increments per measured interval on the micrographs, with the number predicted by this equation. Figure 3.10 illustrates the similarity between the theoretical curve and those resulting from observed measurements.

Otolith radii and annulus measurements, for each fish, were corrected to those expected for a fish of that length, using the method of Ricker and Lagler (Bagenal and Tesch 1978):

$$A_e = A_o \times OR_e / OR_o$$

where A_e = expected distance to the nth annulus, A_o = the observed annulus radius for a fish of given fork length, OR_o = total observed otolith radius and, OR_e = the adjusted radius.

Taking into consideration the underlying assumed error distributions, as emphasized by Hughes (1986), the absolute error model was found to be the most appropriate method of fitting a curve to the data.

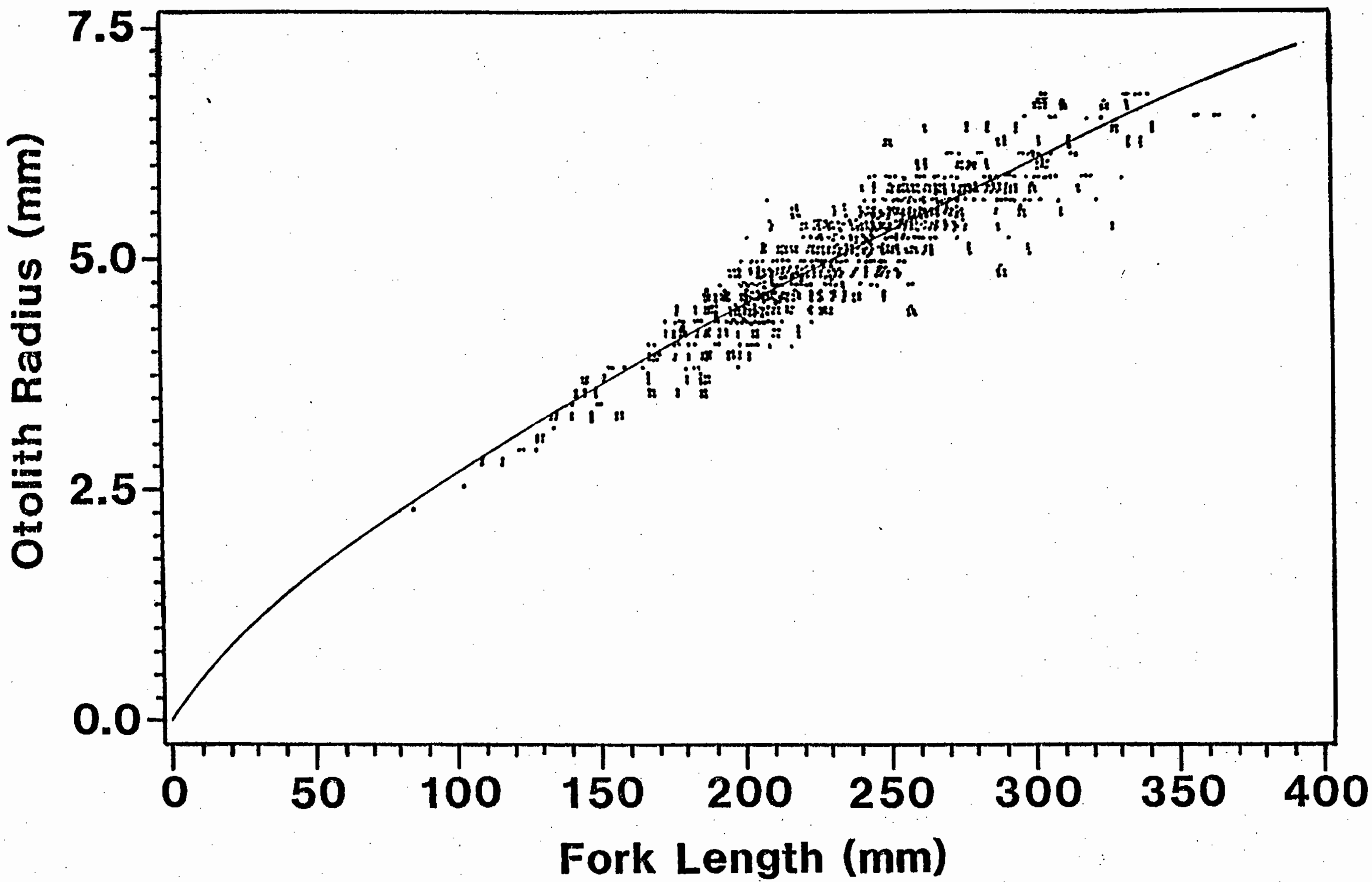


FIGURE 3.9 Fork length : otolith radius relationship for *P. blochii*.

TABLE 3.4 Observed and predicted daily ring counts from scanning electron micrographs of three *P. blochii* otoliths.

Sample	Otolith radii (mm)	Age	No of days	No of rings
Fork length: 144 mm	3.729	1133	104	112
Otolith radius:	3.501	1029	94	92
3.729 mm	3.280	935	98	98
	3.058	845	85	85
	2.836	760	81	85
	2.615	679	76	72
	2.393	603	74	67
	2.172	529	25	21
	2.094	504		
Fork length: 129 mm	2.966	809	79	82
Otolith radius:	2.756	730	75	85
3.343 mm	2.546	655	71	70
	2.337	584	31	29
	2.243			
Fork length: 170 mm	3.857	1194	308	
Otolith radius:	3.160	886	123	116
3.857 mm	2.844	763	114	102
	2.528	649	107	96
	2.212	542	25	23
	2.133	517		

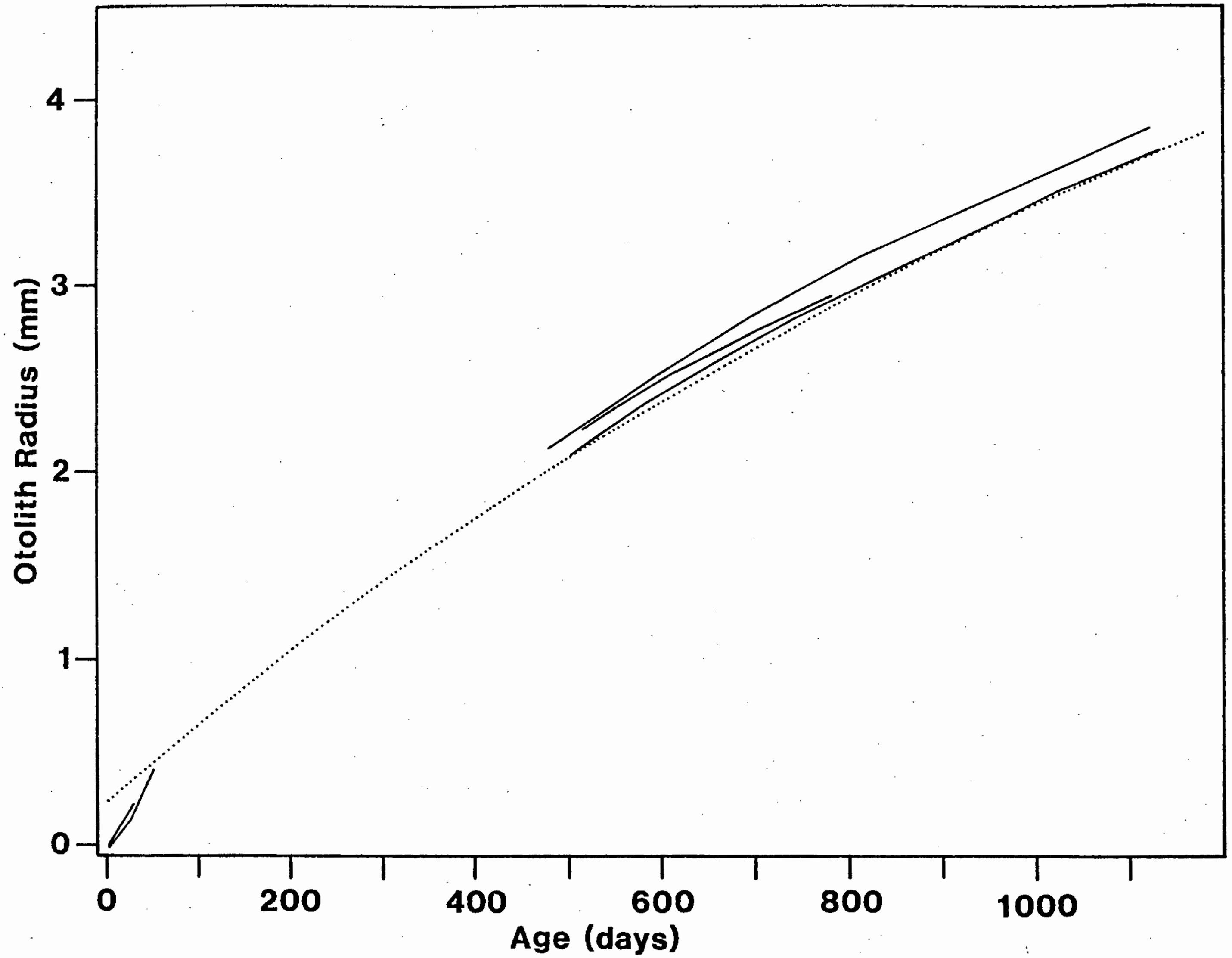


FIGURE 3.10 Comparison between predicted otolith radius at age as determined from otolith annulus measurements (....), and actual otolith radii at age measured from electron micrographs of daily growth increments on three otoliths (——).

As the difference in growth rate between the sexes was negligible, the data were combined to give an overall growth rate. Initial runs, using the full data set, described the growth as

$$Lf(mm) = 411.730 \, (1 - e^{-0.162 \, (t - 0.175)})$$

The resultant L_{∞} is however substantially smaller than the largest fish (425 mm and 433 mm fork length) measured in this study, and those reported for the South African angling and spearfishing records (470 mm and 457 mm fork length, respectively)(van der Elst 1981).

As initial growth may not conform to a von Bertalanffy-type relationship, inclusion of this data would have the effect of lowering the L_{∞} value. The data were thus re-run, omitting the one year old fish to give

$$Lf(mm) = 538.015 \, (1 - e^{-0.097 \, (t + 0.431)})$$

and this result was subsequently taken as representing the growth rate of hottentot.

Although this curve deviates from the observed values for ages where data are sparse (>9 years), the small degree of systematic error between ages 2 and 9 indicates a good fit to the data. Table 3.5 presents the standard errors and coefficients of variation calculated from these growth parameters, and the lengths at age, and Figure 3.11 compares the curve with those of Nepgen (1977) and

TABLE 3.5 Standard errors of the von Bertalanffy growth parameters and the lengths at age, calculated by the jackknife variance estimation method.

PARAMETER	JACKKNIFE ESTIMATE	STANDARD ERROR	COEFFICIENT OF VARIATION
L_∞	537.898	25.689	0.477
k	0.0969	0.0073	0.076
t_o	-0.430	0.0696	-0.162
AGE	FORK LENGTH		
1	69.601	1.568	0.023
2	112.844	0.749	0.007
3	152.093	0.473	0.003
4	187.718	0.523	0.003
5	220.054	0.548	0.003
6	249.403	0.574	0.002
7	276.043	0.793	0.003
8	300.223	1.252	0.004
9	322.169	1.870	0.006
10	342.090	2.588	0.008
11	360.171	3.387	0.009
12	376.582	4.232	0.011

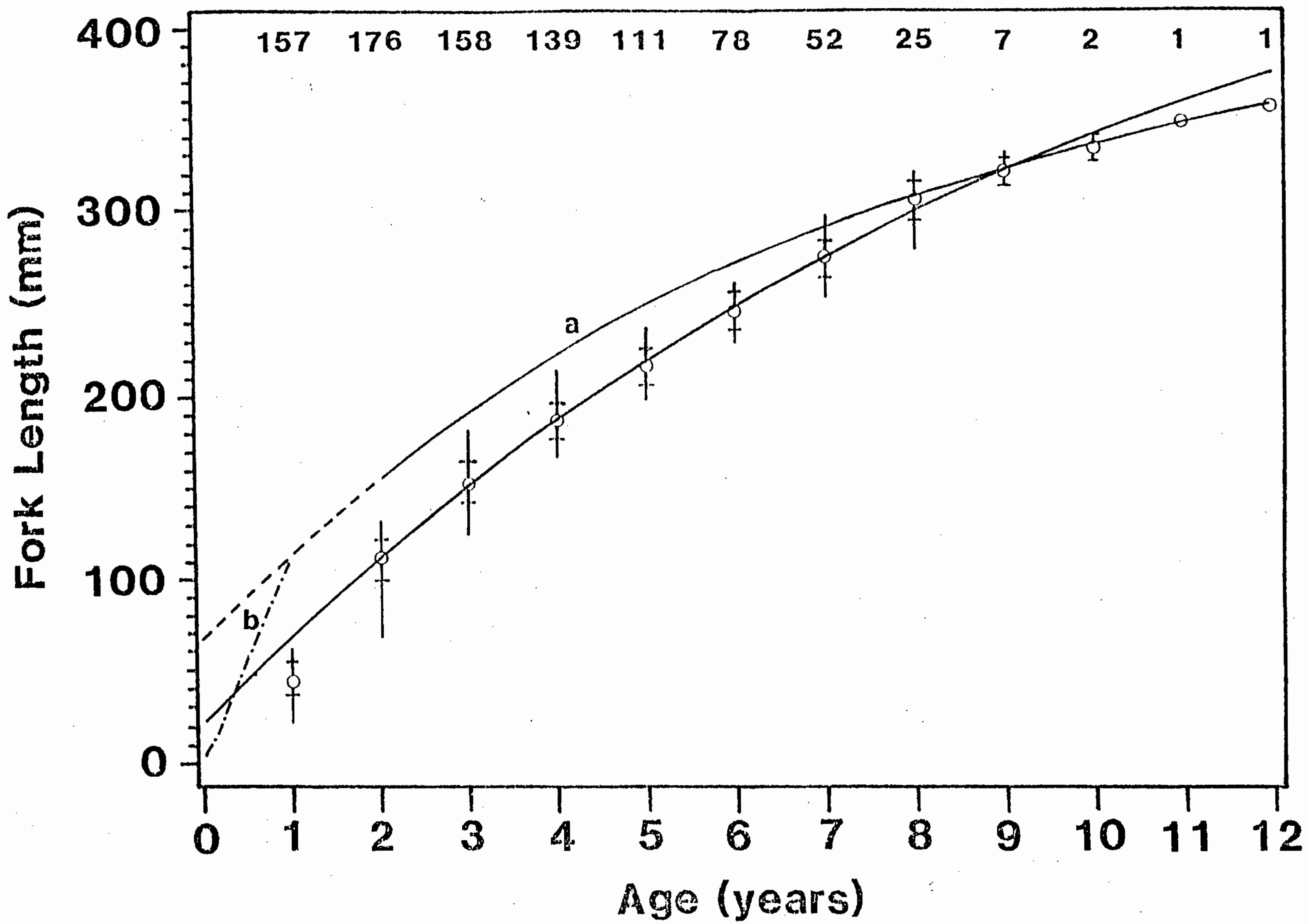


FIGURE 3.11 Growth curve of P. blochii, determined from back-calculted length at annulus formation. Mean back-calculated lengths at age are shown with one S.D. (horizontal lines) and range (vertical lines). Curve a) is that of Nepgen (1977), and b) that of Brownell (1979), for the same species.

Brownell (1979).

The percentage of opaque and hyaline edges of the otoliths follow a similar trend to that of Nepgen (1977), opaque edges predominating during summer and hyaline edges, indicating slower growth, predominating during autumn and winter.

The age key for P. blochii is presented in Table 3.6.

DISCUSSION

The total length-fork length relationship calculated in this study compares favourably with that of Nepgen (1977). The length-mass regressions for the separate sexes however differ in that they suggest the females of the larger length classes are slightly heavier than males of the same length. Although Nepgen (1977) does not comment on the significance of the regressions for the two sexes, no significant difference was found between the curves in this study. The present sample, although being smaller than Nepgen's, covers both a wider size range (67 - 433 mm Lf compared with 122 - 383 mm Lf), and area. The discrepancy in results may thus be the result of differences in sampling strategies. It is unlikely however, that the results of the two studies are statistically significantly different.

The mean size of the sample (233 mm Lf) is well in excess of the minimum legal size limit (199 mm Lf / 220 mm Lt), and the size at

TABLE 3.6 Age : length key for *Pachymetopon blochii*.

Lf (cm)	AGE 1	2	3	4	5	6	7	8	9	10	11	12	TOTAL
0													
1													
2	5												5
3	31												31
4	59												59
5	49												49
6	13	1											14
7													
8		3											3
9		28											28
10		34											34
11		86											86
12		20	2										22
13		4	12										16
14			50										50
15			36										36
16			53	9									62
17			4	22									26
18			1	38									39
19				62	5								67
20				7	23								30
21				1	24								25
22					33								33
23					26	29							55
24						23							23
25						15	1						16
26						11	12						23
27							12						12
28							25	3					28
29							2	6					8
30								6					6
31								5	2				7
32								5	3				8
33									2	1			3
34										1			1
35											1	1	2
TOTAL	157	176	158	139	111	78	52	25	7	2	1	1	907

which sexual maturity is reached (220 mm Lf). At the present size limit, however, a substantial portion of the landed catch will be immature.

At the 95 % confidence level, a significant difference from a 1 : 1 sex ratio, in both this and Nepgen's (1977) study is evident ($p < 0.001$ for both). Together with the seasonal oscillation of sex ratios, this has some interesting implications.

Although this oscillation may be an artefact of the sampling technique, it appears that females exhibit a greater catchability during the summer. This may be due to increased feeding activity at time of spawning. As feeding activity decreases at low temperatures (Fishermen:pers comms and own observations), this seems unlikely as upwelling is more frequent during the summer. This is further supported by the low condition factor evident during these months.

It therefore appears that females are more common in the catch and more readily caught during their summer spawning season. As a consequence one may expect the ratio to swing in favour of the males with time. This could however only be ascertained by sampling over an extended period. The higher catchability of females, as suggested by the data, makes it doubtful whether the observed sex ratio of 1 : 1.383 can be taken as representative of the population. To obtain a more realistic result, it may be necessary to investigate alternative sampling methods, such as gill netting.

The bi-annual spawning of *P. blochii* is a relatively unusual phenomenon amongst South African reef fish, most species having a single breeding peak during summer (Bennett & Griffiths 1986, Buxton & Clarke 1986, Garratt 1985, van der Elst 1976, Wallace 1975). Brownell (1979) reported that the eggs are pelagic. The young fish, which seek shelter in shallow water kelp beds, occur in the same range as the adults.

Using the fecundity estimates calculated by Nepgen (1977), a 220 mm fork length fish will thus produce approximately 118 300 eggs at each spawning. The extended spawning season apparent for this species, suggests that hottentot may be serial spawners. In the absence of such information, no estimate of the total numbers of eggs released annually can be made, but it appears to be substantial.

From the growth data it is evident that the hottentot is a relatively slow growing species, reaching reproductive maturity in its 5th year.

These results differ substantially from those of Nepgen (1977). Critical examination of the otoliths and back-calculation suggest that Nepgen (1977) over-aged his specimens by one year. The similarity in size between his one year olds and the two year olds in this study, support this conclusion. As no small fish were sampled, and thickening of the otolith, with age, results in the fading of the early rings, this possibly led to Nepgen (1977) failing to recognize the first annual growth zone.

Although the results of Brownell (1979) correspond with those of Nepgen (1977), for one year old fish, the juveniles reared in his study were fed mussels and/or pilchards daily (Brownell, pers. comm). The regularity of these high protein food sources, unlikely to be encountered by juveniles in the environment, would have a marked influence on their growth rate.

The abrupt change in growth rate from 112 mm in the first year (Brownell 1979), to a subsequent mean annual rate of 26 mm (Nepgen 1977), further suggests that these results are erroneous. Al-thought the back-calculated size of a one year old P. blochii (69 mm) corresponds well with that of P. aeneum (56 mm) (Buxton and Clarke 1986), the non-conformity of the one year old hottentot suggests that the growth rate of young fish (<2 years) differs from that predicted by the von Bertalanffy equation.

The deviation from 0 of t_0, for the predicted otolith growth curve, illustrates the inability of a von Bertalanffy-type equation to handle the initial rapid growth exhibited by the fish, after hatching. The observed values for this early period appear sig-moidal, meeting the theoretical curve at $\pm$ 50 days. The growth rate of the fish can be expected to follow a similar trend. The similarity between the otolith growth rate predicted from the data, and the rate calculated from the micrographs, however, strongly supports the growth curve for P. blochii determined in this study.

Although subdaily increments have been reported (Taubert and Coble 1977, Brothers 1981, Methot 1981, Campana and Neilson 1982, Thomas 1985), these are usually only recognizable in young fish (<100 days). The portion of the hottentot otoliths in which subdaily rings might be expected, was however obscured by an opaque zone, in which rings were poorly etched and indistinguishable. The increments observed were thus interpreted as daily, representing growth from between 1 to 3 years.

The variation in patterns of increment deposition, and the sharp lines which cut the previous layers unconformably, indicating interupted growth (Pannella 1971), are attributable to short-term temperature fluctuations (Brothers 1981). The frequent recurrence of these patterns suggests that the growth rate of hottentot is strongly influenced by upwelling.

The exact timing of initiation of ring formation varies between species, some fish forming rings in the embryo, whilst others only after yolk-sac absorption (Brothers et al 1976, Tanaka et al 1981). As this is unknown for the hottentot, and periodic cessations of growth may occur, the birth dates could not be accurately assessed from the micrographs. Back-calculation of daily rings, GSI's and the reduced condition factor, suggests that annulus deposition occurs during/after the summer spawning. Although the secondary spawning peak, apparent in autumn/winter, suggests the cause for the false rings, these were most noticeable towards the centre of the otolith and would thus have been formed before the fish reached sexual maturity. For convenience therefore, the birth date of *P. blochii* can be taken as 1 January.

Although sources of error are recognized in using the scanning electron microscope method for validation (Thomas 1985), these are negligible. This form of validation may thus prove highly effective for linefish species, where the mark-recapture or Peterson's methods may be difficult to apply. As the number of increments deposited annually decreases with age, due to changes in the efficiency and continuity of the growth process (Pannella 1971), this technique will produce more reliable results if practiced on juveniles.

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4. TRENDS IN CATCHES AND EFFORT FROM COMMERCIAL CATCH STATISTICS

Since as early as 1940, attempts have been made to determine the species composition and size of the linefish catches on the Cape coast. As the importance of maintaining catch and effort records for the effective and efficient management of stocks had not been realized at that time, irregularities in these data are common. In tracing the development of the linefishery through trends in the annual catches, it was therefore necessary to evaluate the validity of existing data. In order to determine the degree of exploitation of a fish stock, trends in the catch per unit effort must also be monitored. If the CPUE falls below 50 % of its pristine level, the resouce is considered to be overexploited.

METHODS

An in depth review of the available literature and data on catch records was conducted, in an attempt to reconstruct the development of the linefishery in the Cape.

The first consistent monthly records of linefish landings and effort, made at the various fishing stations, between 1897 and 1906, served as a reliable data source for comparison with the more modern statistics. Where the catch records were incomplete, they were scaled up accordingly, assuming a constant catch for each month. In later years, where total catches included landings by trawlers, the figures were adjusted by subtracting the mean percentage contributed by these vessels to the total catch. This mean was calculated from data where trawler and line caught landings were recorded separately. If more than one value was found in the records for a specific year, the total catch was taken as the mean of the values.

In evaluating the more recent catch statistics, the validity of the method of estimation used in establishing the annual catch figures, for 1981 - 1983, was investigated. These estimates take into account the numbers and types of boats operational, numbers of trips per year, and the catch per outing. These scaling factors were adjusted each year to allow for increases or decreases in effort and/or catch. With the improvement in harbour, commercial and dealer returns, this method was discontinued in 1984. Annual catches were subsequently obtained by scaling the existing data for missing returns.

As it is not possible to assess what proportion of the boats present at the fishing stations between 1897 and 1906 were actively in use in the industry, or how many were involved in fisheries other than that for the hottentot, the assumption made is that all the small sailing craft were in some way connected to the line-fishery. The catch per small boat was thus calculated to give an indication of the CPUE.

Due to the paucity of modern effort data, the results of the 1985 survey offer the only reliable comparison for the historical records.

Although the small dinghies used in the industry today, are little different from the sailing craft employed in the past, larger and more powerful vessels are presently involved. Power factors were thus introduced to convert the data to catch per small boat year, making them comparable with early figures. In appointing these factors, the size of boat and crew, as well as its range, were taken into consideration.

RESULTS AND DISCUSSION

Records of the species and numbers of fish landed at the fishing stations on the Cape coast date back to 1840. The inconsistency and irregularity of these data, however, prohibit their use in evaluating annual catches. In some cases only the species caught were recorded and not the mass or quantities, or the information collected for one year was simply repeated in subsequent reports. Although reliable records exist for the Saldahna and St Helena Bay area for 1857 - 1876, quantities are frequently recorded as mass of the dried product, or in volumes of pickled fish, thereby making an accurate estimate of the catch difficult (Legislative Council 1840 - 1885).

The appointment of the Government biologist in 1896, for "the purpose of obtaining definite and reliable information as to the resources of the South African seas, and to advise as to what steps should be taken to place the industry on a more satisfactory basis, both with regards to its development and its conservation" (Official Year Book 1927), saw the initiation of a decade of regular collection of catch statistics. The remarkably complete records of species composition, quantities and values of fish landed, as well as the effort employed, collected under his supervision, are rather an indictment of the poor catch statistics available from more recent times.

Annual trends in the total linefish landings, and the catch of hottentot, are illustrated in Figure 4.1. Noteworthy trends are the increase in the fishery after the Boer War(1899 - 1902) and World War 1 (1914 - 1918). Catches for the years 1950 - 1980 were estimated as 10 - 15 thousand tons.

Of further interest is the consistency of the hottentot catch over the period for which data are available. Although being the staple species of the industry on the west coast, their percentage contribution to the total catch seldom exceeds 5 percent (Table 4.1).

Figure 4.2 presents the total catch and hottentot catch recorded at the different fishing harbours. Of interest is that the landings of _P_._blochii_, on the west coast, have since the start of the century, contributed far more substantially to the total catch than they do east of Cape Point.

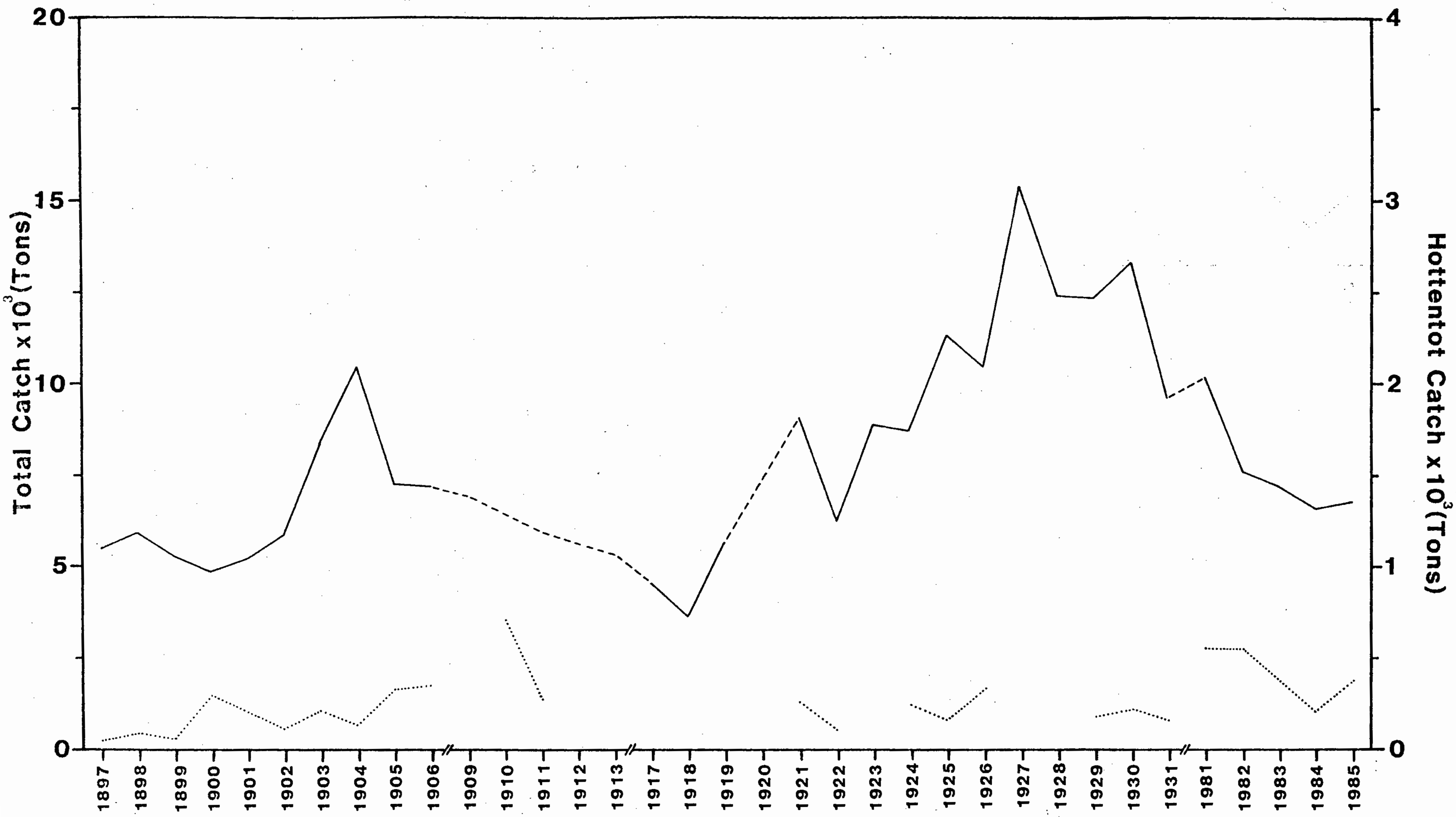


FIGURE 4.1 Total linefish catch (——) and landings of hottentot (.....) recorded from 1897 to 1985. (- - - - represents periods for which no data are available.

TABLE 4.1 Percentage contribution to the total linefish catch of _P. blochii_

YEAR	%	YEAR	%	YEAR	%
1897	0.8	1911	4.7	*1936	3.3
1898	1.5	1921	5.9	*1937	2.4
1899	0.9	1922	3.7	*1938	6.2
1900	6.1	1924	7.5	1981	5.5
1901	3.9	1925	9.1	1982	7.3
1902	1.9	1926	3.7	1983	5.3
1903	2.5	1929	1.4	1984	3.1
1904	1.3	1930	1.6	1985	5.3
1905	4.5	1931	1.6		
1906	4.8	*1935	1.0		

* Data for Cape Town only.

The decline in the fishery due to the Boer War, apparent at all localities, is more noticeable at those stations further from Cape Town. Many of the fishermen took up duties connected with the war, resulting in a decline in effort. On the west coast, fishing was seriously interupted owing to invation of the area (Gilchrist 1902). Harbour and community development has however resulted in the more recent increase in the linefishery at the 'outstations'. This is particularly evident at Struis Bay where, since the commencement of exploitation of the Agulhas Bank fishing grounds, the linefishing industry has undergone a marked development. Catches reported from this station are now an order of

REFERENCES for Figures 4.1 & 4.2

1860 - 1863	Legislative Council (1838 - 1885)
1897 - 1906	Gilchrist (1897 - 1905, 1907)
1909 - 1911	Williams (1913)
1913	Unpublished Internal Reports, Cape Archives
1917 - 1919	Unpublished Internal Reports, Cape Archives
1921	Anon.
1922 - 1928	Unpublished Internal Reports, Cape Archives
1929 - 1931	Department of Mines and Industries (1933)
1935 - 1939	Department of Mines and Industries (1937a, 1937b, 1938, 1939, 1940)
1953 - 1960	Department of Commerce and Industries (1954 - 1964)
1961 - 1972	Department of Industries (1966 - 1973)
1973 - 1979	Department of Industries (1974 - 1980)
1980 - 1981	Department of Agriculture and Fisheries (1981 - 1982)
1982 - 1985	Department of Environment Affairs (1983 - 1985)

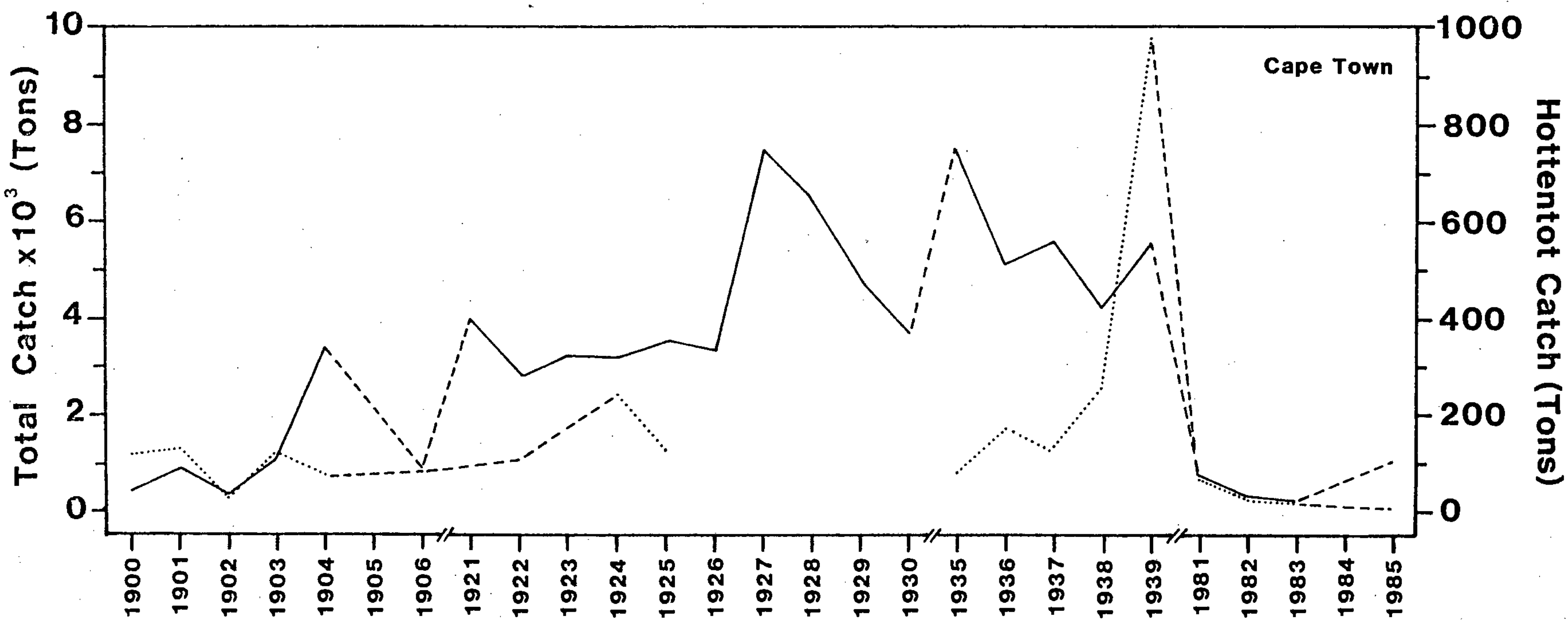
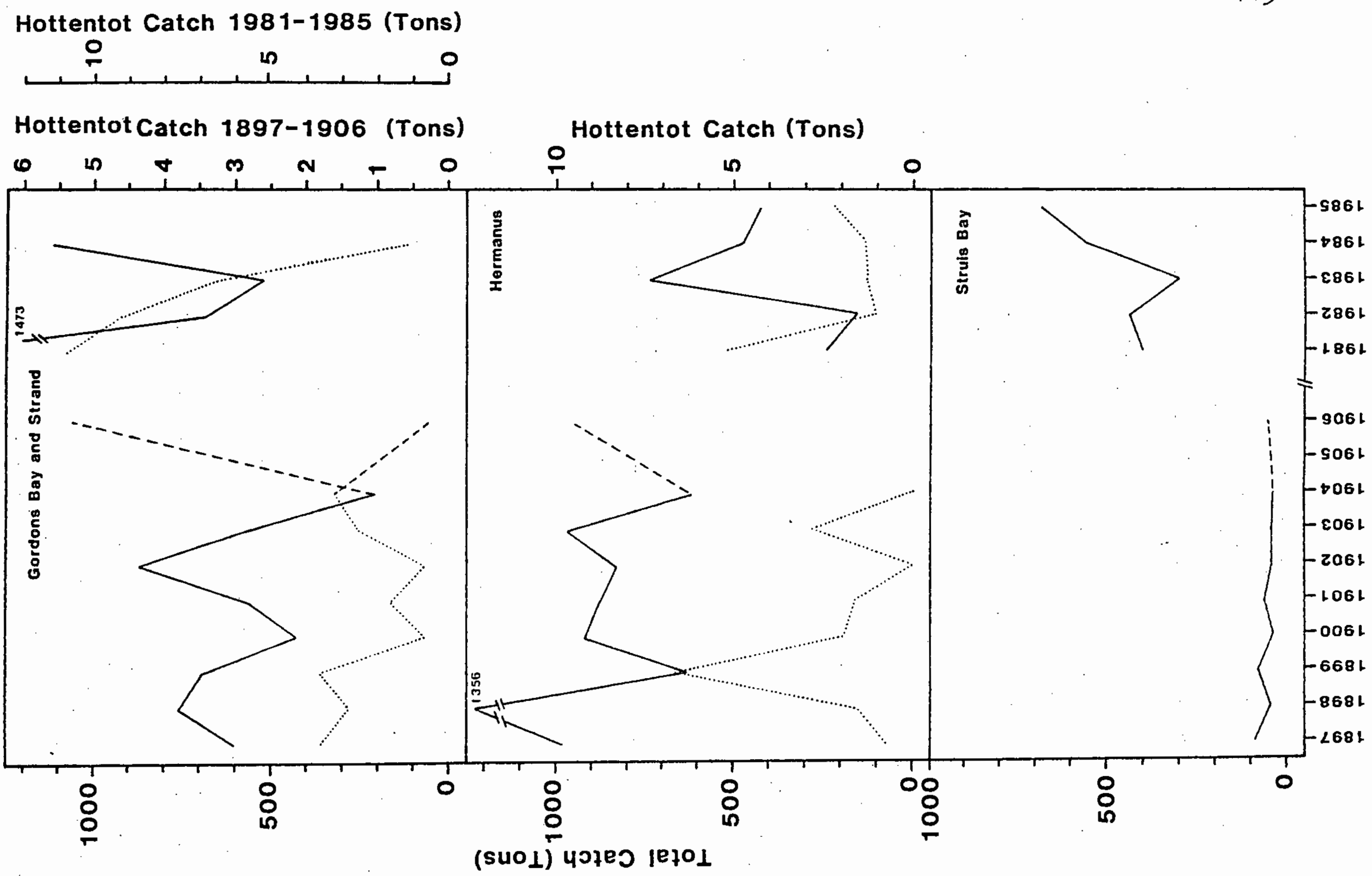
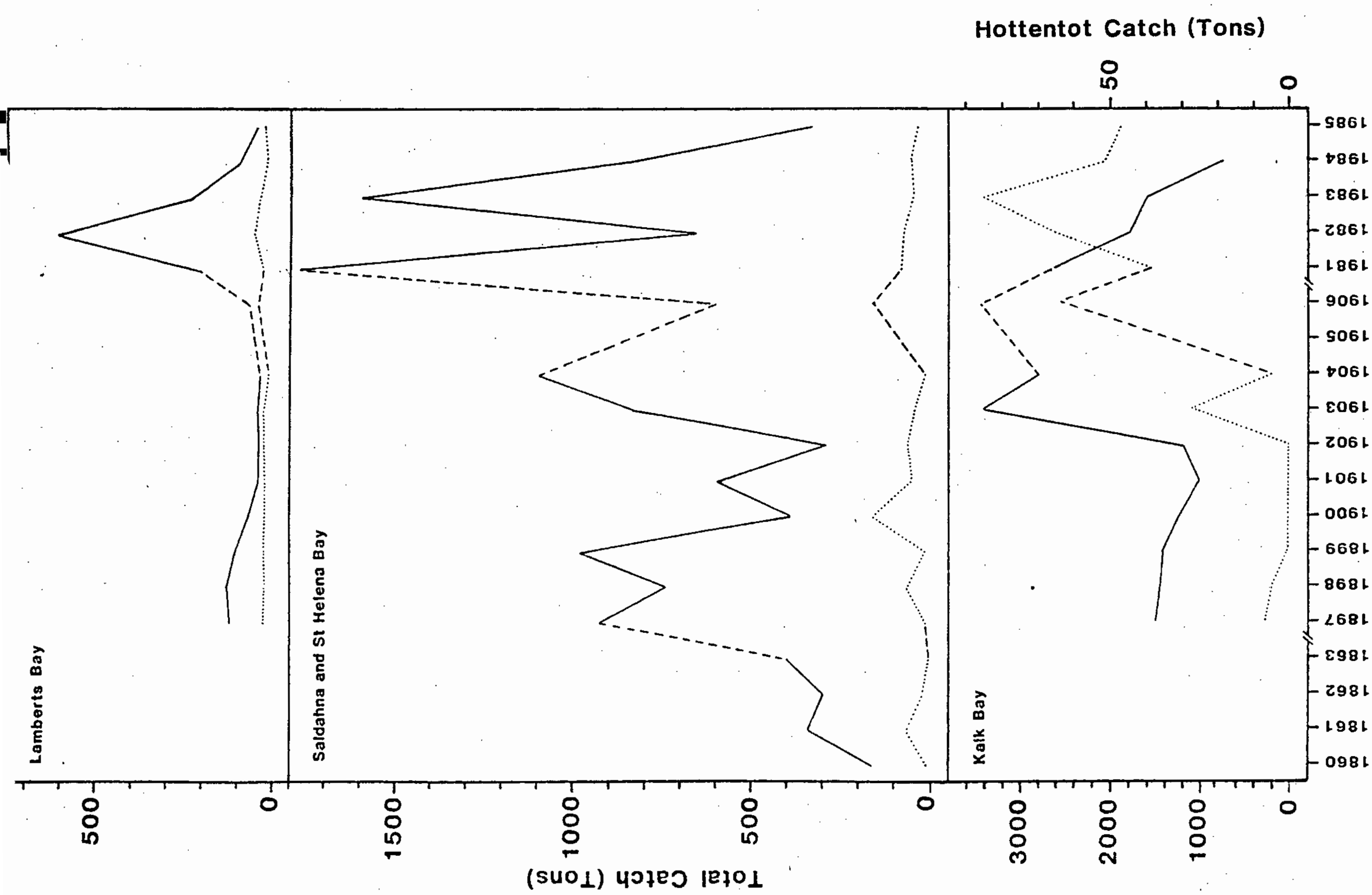


FIGURE 4.2 Total linefish catch (——) and landings of hottentot (.....) at major landing sites on the Cape coast, 1897 - 1985. (- - - - represents periods for which no data are available).


Hottentot Catch 1981-1985 (Tons)
Hottentot Catch 1897-1906 (Tons)
Hottentot Catch (Tons)
Gordons Bay and Strand
Hermanus
Struis Bay
1473
1356
Total Catch (Tons)
1897
1898
1899
1900
1901
1902
1903
1904
1905
1906
1981
1982
1983
1984
1985


Hottentot Catch (Tons)
Lamberts Bay
Saldahna and St Helena Bay
Kalk Bay
Total Catch (Tons)
1860
1861
1862
1863
1897
1898
1899
1900
1901
1902
1903
1904
1905
1906
1981
1982
1983
1984
1985

magnitude higher than those recorded at the start of the century. Although hottentot do constitute part of the catch at this station, the quantities are negligible, and thus seldom reflected on the catch returns, the fishermen usually keeping the fish for personal consumption (Fishermen: pers. comm.). The shift in effort to Struis Bay is also the most probable explanation for the decline in total catch at Hermanus.

Although the early records from Cape Town and False Bay suggest that hottentot were not a significant part of the catch, total landings for these areas include net caught species. The exceptionally high total catch figures for Cape Town (two orders of magnitude higher than recent figures) indicate that Table Bay supported a substantial net fishery in the past. The inshore fishery now no longer dominates in the area, harbour developments resulting in the establishment of the larger demersal and pelagic industries. Modern records indicate, however, that when snoek catches are poor, linefish landing, at this port, are dominated by hottentot.

In contrast, the total catch at the False Bay stations has remained much the same, indicating a transition from a net to a line dominated fishery. Although the hottentot catches have remained relatively constant in other areas, landings of this species have **increased** in False Bay. Due to poor landing of snoek, the total catch for 1985, of 634 tons, represents only 35 % of the catch for the area in 1984. The hottentot catch however increased from 61 tons in 1984 to 98 tons the following year, thereby illustrating the increased targeting for this species in the event of poor availability of other linefish species.

The principal fishery for hottentot, however, remains confined to the west coast, Figure 4.3 illustrating that the majority of the total hottentot catch, throughout 1985, was made west of Cape Point.

Although scaled up where possible, some comments are necessary on these data. The total catch recorded for 1899 and 1906, are underestimates as no data was received from a number of east coast stations. In 1901, only one monthly return was recorded from Algoa Bay. Although the figure was scaled up, it amounted to only 50 % of the expected catch for that area. Similarly, in 1903 and 1905, no returns were received from Port Elizabeth. The total catch figures for the Cape were thus calculated by including a mean for that station (calculated from the previous 6 years of data). During 1904, data were collected for the first 6 months only. For this period, exceptionally good catches of snoek were made. Although the figures were scaled up to 12 months, the total catch of 10 500 tons may be a gross overestimate, should the snoek catches not have remained at the same level.

Estimates, derived from the data in this fashion will be reasonably accurate. What must be kept in mind, however, is that the total catches, recorded by Gilchrist, are indicative of trawler, net and line caught fish. Trawling was practiced on a small scale only, mainly on the east coast. With the exception of St Helena

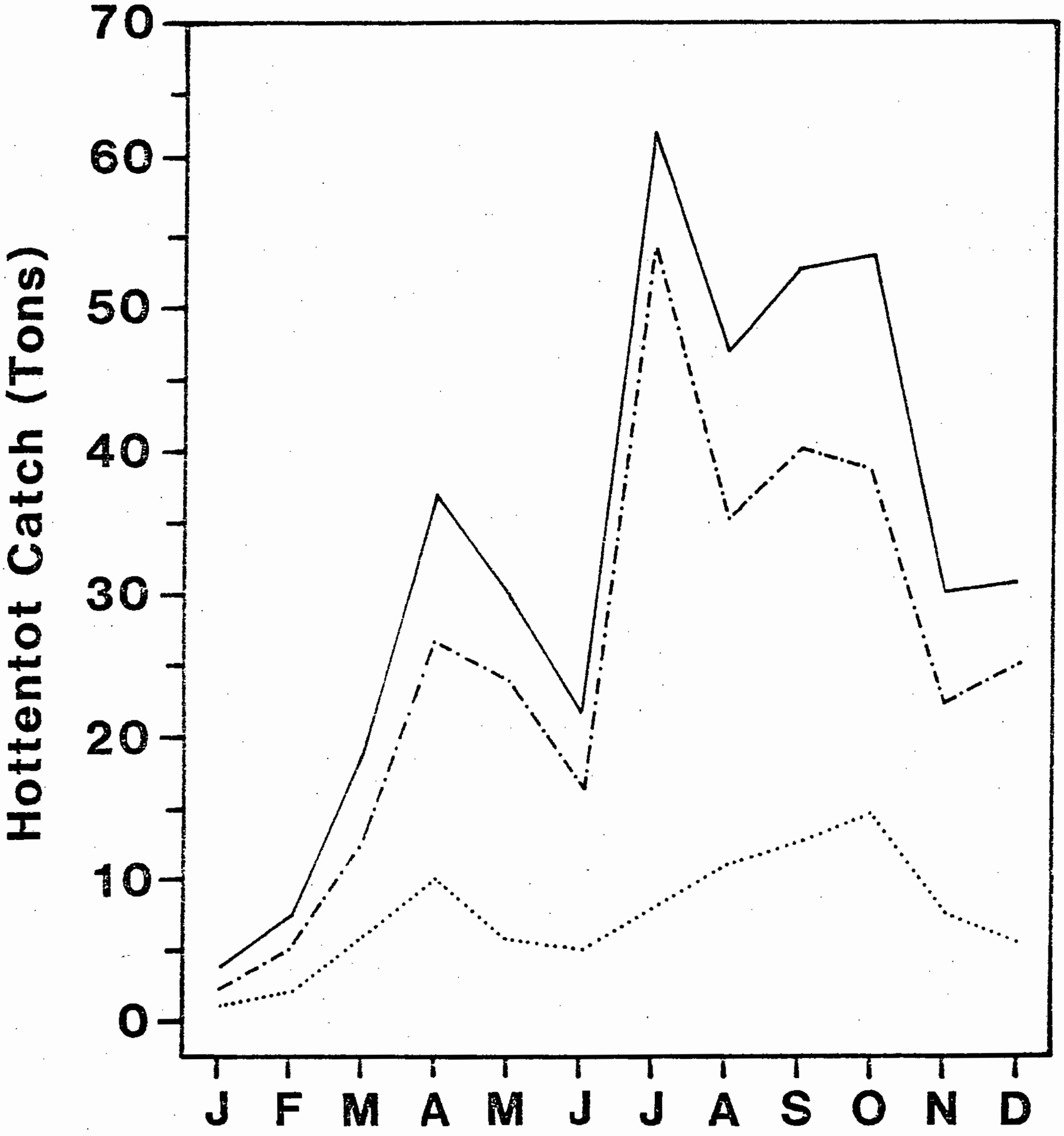


FIGURE 4.3 Monthly commercial catches of hottentot during 1985. Solid line represents total catch, -·-·- the catch west of Cape Point, and ..... the catch east of Cape Point.

Bay, Saldahna, Table Bay and False Bay, which supported substantial net fisheries, the netfish catches from other stations are negligible. As some species can be caught by more than one fishing method, it was not possible to separate the trawler and net landings from the linefish catch, thus resulting in an overestimate of the total catch.

Although records exist on the export of dried and cured fish (mainly snoek), for 1907 - 1911, no information as to linefish catches were traced for this period, other than Gilchrist's report for 1909. With the transfer of fisheries matters from the Department of Agriculture to the Cape Provincial Administration in 1910 (Williams 1913), contrary to Gilchrist's urgency for the continuation of the collection of catch statistics, attention was focussed on establishing a boat registration system. The catch figures provided for the census of 1911 are therefore approximations only (Census 1911).

With the perseverence of Gilchrist, the collection of fisheries statistics was re-introduced in 1914, and became governed by the regulations promulgated under the Statistics Act of that year. Due to lack of funds and the commencement of World War 1, collection of catch records was, however, only 50 % efficient. Government funding was again made available in 1920, but due to discontent with the methods of data collection funding was discontinued once sufficient information had been gathered for the 1021 census (Unpublished Internal Reports, Cape Archives).

As the early 1920's saw the rapid development of both the rock-lobster and trawling industries, attention was diverted from the linefishery. Although data were collected concerning the particulars of boats used, persons employed and the value of fish landed, for the purpose of the census, no information exists pertaining to species composition and the contributing quantities to the catch. The apparent growth of the linefishery during this period may thus be an artefact of the data, as records were derived from total catches which included trawler landings.

In 1935, such information was again recorded, but as complete statistics were not available for all stations, only those figures for Cape Town were published (Department of Commerce and Industries 1937).

The Second World War resulted in the rapid and considerable expansion of the fishing industry. Fisheries statistics, however, suffered seven years of stagnation during and after the War (Department of Commerce and Industries 1949). The birth of the pilchard industry in 1947, succeeded in further neglect of the linefishery. From that period onwards, data are available only as annual catches of the inshore fishery, no distinction being made between trawler, net and line caught fish.

Recorded annual catches since 1906 must therefore be considered as rough approximations only, this being particularly applicable to the period 1950 - 1980.

The situation remained such until 1983, when a stringent system of catch returns was re-introduced (Department of Environment Affairs 1984). Monthly returns are now received from all harbours, registered commercial fishing boats, spearfishermen and a few of the major fish dealers (SFRI Unpublished Records).

An evaluation of the methods used to derive the estimates for 1981, 1982 and 1983 (using the indication of effort determined during the survey of the fishing centres), concluded that the predicted number of craft operational on the west coast, had been overestimated, thereby resulting in higher predicted catches.

As regards the catches of hottentot for this period, some confusion exists regarding the category of "doppies". Traditionally describing bunches of small silverfish (Argyrozona argyrozona Val.) and panga (Pterogymnus laniarius Cuvier), this category now includes small roman (Chrysoblephus laticeps Cuvier), fransmadam (Boosoidea inornata Castelnau), steentjies (Spondyliosoma emarginatum Cuvier) and hottentot. Visual assessments of catches, determined that at Kalk Bay, Gordons Bay and Hermanus, hottentot constitute approximately 70 %, 50 % and 5 %, respectively, of the doppies category. In calculating the annual hottentot catch, these proportions were thus added to the figures from the doppies catch.

The observed decrease in catches over the 1981 - 1985 period is thus thought to reflect an increased accuracy in the estimate of annual catches, due primarily to more efficient statistics collection.

Certain errors are, however, still inherent to the most recent data. Inaccuracies in the harbour returns include : not every landing site being covered; the absence of the data collector at the time of landing, or them not being fully aware of the extent of the catch. In addition, not all commercial vessels submit returns, and may purposefully under-report their catches (A.J. Penney SFRI, Pers. comm.). This is reflected in the total linefish catch presented in Table 4.2. Unlike the Annual Report figures (Department of Environment Affairs 1986), these returns do not take the recreational catches made by skiboats, shore anglers and spearfishermen into consideration and thus provide for an under-estimate of the total catch. It appears. however, that the total hottentot catch has been underestimated, as the figure obtained from commercial returns is higher than the estimate given in the annual report. From the tabulated figures, the hottentot catch for 1985 is predicted at around 400 tons.

Trends in the total CPUE, and that for the various fishing stations, are presented in Figure 4.4. With the exception of Lamberts Bay, where a marked decline is evident for the 1985 data, modern CPUE levels appear to be little different from those at the start of the century. Although some stations exhibit an horizontal or slightly downward trend, between 1897 and 1906, the total figures show a slight increase in CPUE during that period.

TABLE 4.2 Hottentot catches (kg) in various areas, extracted from commercial returns, harbour returns and published data for 1985 (Department of Environmental Affairs 1985). The total reported hottentot catch is also compared with the total catch of all linefish species.

AREA	DATA SOURCE		
	Commercial Returns	Harbour Returns	Annual Report
Port Nolloth	429	554	1 300
Hondeklip Bay	6 478	-	-
Doorn Bay	11 965	18 701	18 700
Lamberts Bay	18 583	18 258	18 300
Elands Bay	27 332	15 660	15 700
St Helena Bay	79 691	6 226	7 800
Saldahna	40 940	25 810	25 800
Yzerfontein	-	104 236	104 200
Cape Town	24 825	10 196	11 100
Hout Bay	3 241	30 589	30 600
Simonstown	43 950	9 284	27 900
Kalk Bay	46 715	87 466	97 500
Gordons Bay	32 349	8 329	-
Hermanus	31 903	2 474	2 700
Gans Bay	26 906	883	7 200
Struis Bay	1 273	-	-
TOTAL CATCH	396 677	338 729	368 800
TOTAL CATCH (All Species)	4 001 036	5 933 777	6 781 300

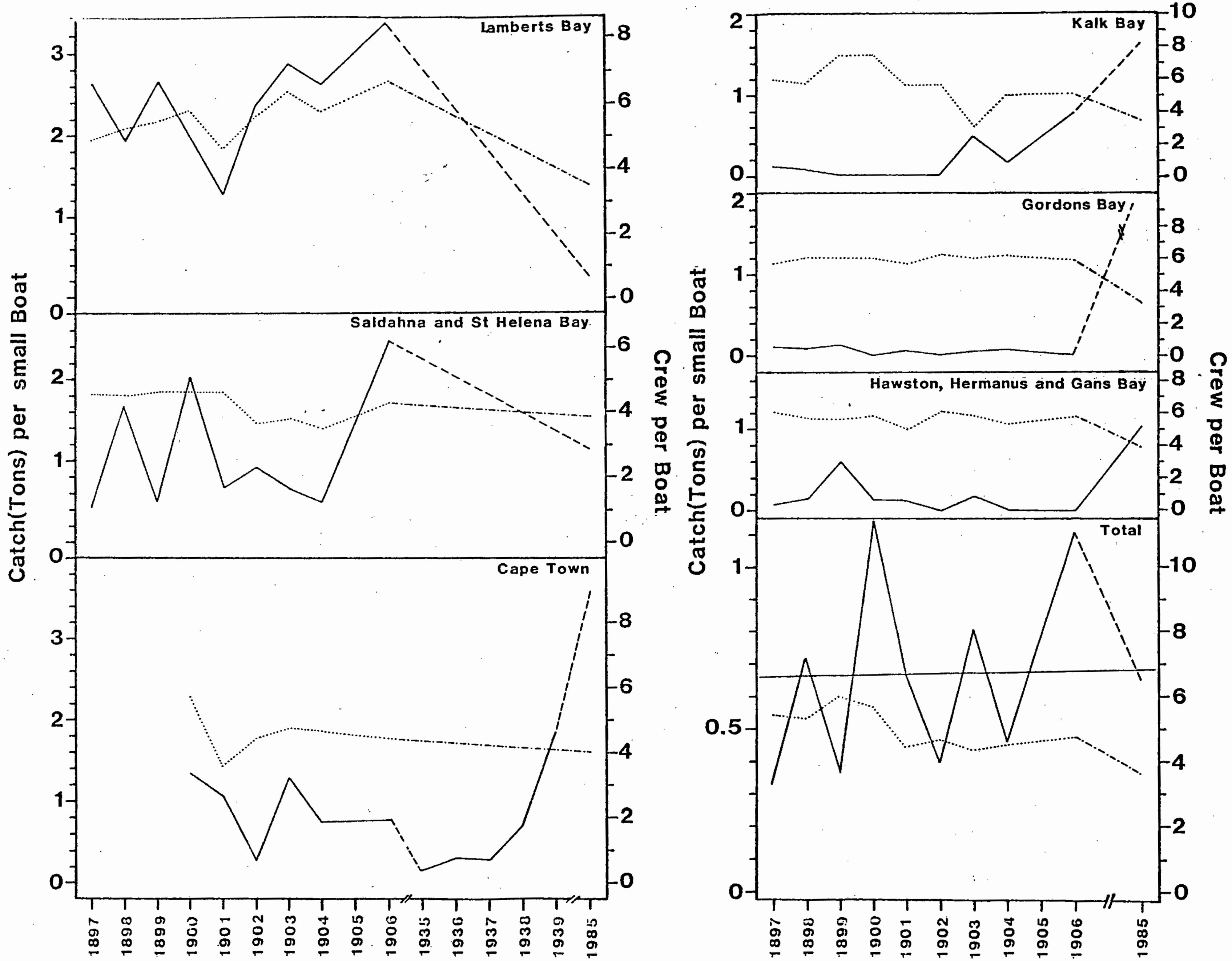


FIGURE 4.4 Catch per unit effort trends at major fishing centres on the south western Cape coast from 1897 to 1985.

The recent decline in effort at Lamberts Bay is attributable to the dominance of the rocklobster and pelagic industries in the area. It also reflects the general decline in fishing effort on the west coast in recent years, due to increased running costs and low returns per catch. The marked increase evident in the Cape Town, Kalk Bay, Gordons Bay and Hermanus areas, since 1906, illustrates the change in these areas from a net to a line dominated fishery.

As the net fishery has an obvious direction of effort to other species, this presents a serious bias in the results. A further bias to be considered is that the modern fishery is influenced by restrictive legislations. Although Gilchrist (1900) gives the average mass of hottentot landed as 680g (300 mm Lf), small fish were included in the catches for the making of "bokkoms" (salted, sun-dried fish). The present bag limit of 10 fish/man/day, is not applicable to the commercial fishery, and would thus not influence the results.

Of interest is the general decline in the numbers of crew per boat. The corresponding increase in CPUE suggests that the intensity of directed effort is improving. As the basic handline tackle has not changed since the start of the century, this is not the result of improved fishing gear, but may be attributable to the presence, in the modern fishery, of larger and more far ranging vessels.

In conclusion therefore, the records of the hottentot catch and the effort employed, kept by Gilchrist, can be compared with some confidence to the more recent data. Intermediate catch figures should, however, be viewed with some caution. Although catch statistics are becoming increasingly accurate, it appears that there has been little change in the mass/quantities of hottentot landed since the start of the century. Historical records of the total catch of all species, are less reliable however, as they include net and trawler caught fish.

Furthermore, there has been little change in the CPUE, environmental variables thus being a key factor affecting fluctuations in the fishery.

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5. LENGTH COMPOSITION OF COMMERCIAL CATCHES AND THE EFFECT OF HOOK SIZE ON SIZE OF FISH CAUGHT

Analysis of catch composition can serve as a method of detecting overutilization of a fish stock (Low et al 1985). Preliminary observations made in the field, suggested that the mean size of hottentot in the catches varies between sampling stations. The survey of the fishing centres revealed that the range of hooks used in the fishery differs from area to area.

As previous studies on hook selectivity (Fry 1949, McCracken 1963, Koike et al 1968, Kanda et al 1978, Koike & Kanda 1978, amongst others), have suggested that the size of the hook used has a bearing on the size of fish landed, it was decided to investigate this aspect of the hottentot fishery and to determine whether the spacial variations in length compositions are attributable to hook size.

METHODS

In investigating the exploited population structure, length frequency measures made during this study, and by the SFRI, were used. Temporal and spatial variations in the data were investigated. The Student's t-test (Zar 1974) was used to test if differences in the mean size of fish caught at the four sampling areas were significant, and size distributions were compared using the Kolmogorov-Smirnov test (Sokal & Rohlf 1981).

The length at first capture (L_c) was determined by fitting a straight line to the increasing portion of the length frequency distribution (Gulland 1963). The length corresponding to half the maximum frequency, was taken as L_c.

Intensive handline fishing for hottentot was conducted from dinghies over a two day period at Robben Island, using the size range of hooks illustrated in Figure 5.1. The traditional two-hooked trace was used and equal periods of fishing were undertaken with each hooksize. To overcome differences in fishing skills, the hooks were rotated amongst the fishermen at half-hourly intervals. Fish caught on a particular hook were stored in sacs, marked with the corresponding hook size. All fish caught were kept and their fork lengths recorded. A size index was calculated for each hook by obtaining the product of the length and width if the hook (Ralston 1982). The mouth gape size of a sample of fish was measured, and its relationship to fish length was determined.

Analysis of variance was conducted on the mean size caught on each hook. As these results suggested that differences between hooks were significant, the relationship between hook size and fish length was modeled.

In applying the length frequency data to the model, the fork lengths were grouped into 16 size categories.

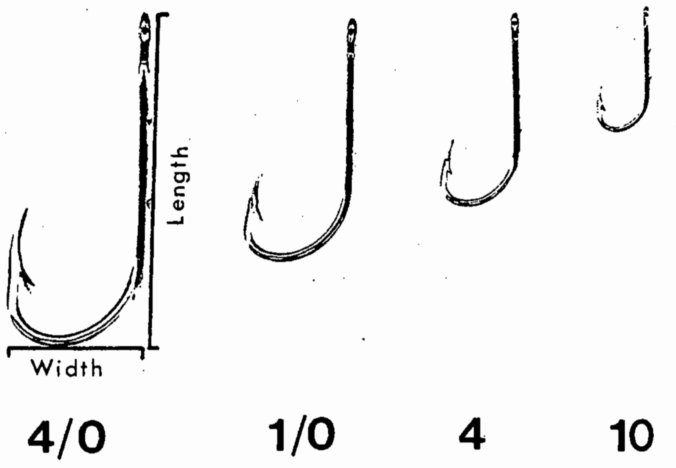

FIGURE 5.1 The four hook sizes used in this study.

The assumptions of the model are that the length of fish caught is related to the size of hook used, and, therefore, as the size of hook is increased, the mean size in the catch will increase accordingly. A further assumption is that the fish is fully recruited into the fishery at between 184 and 200 mm fork length (L_{crit}).

For the observed length (L) and variance (v):

$$L = L_1 + hL_2$$

and

$$v = v_1 + hv_2$$

respectively, where L_n is the length giving the highest selectivity for hook n, and v_n is the variance of the hook (h) (Fig 5.2).

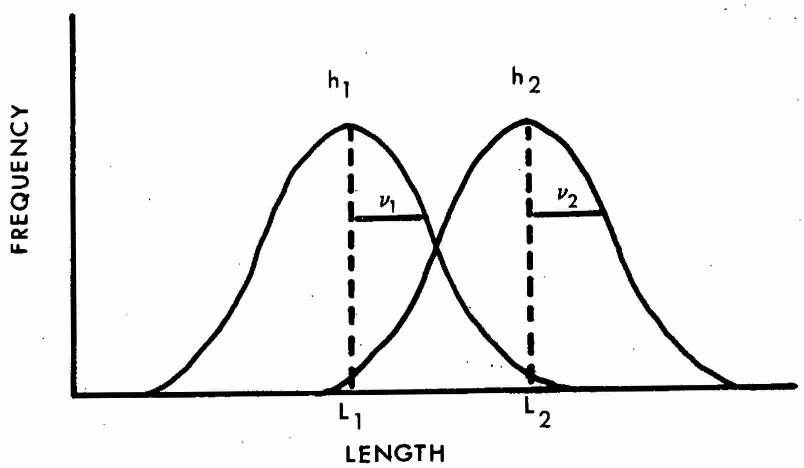

Figure 5.2 Diagramatic representation of the size distribution caught on different hooks, illustrating the variables discussed in the text.

The index of selectivity will thus be

$$e^{-\frac{(L - (L_1 + hL_2))^2}{2(v_1 + hv_2)^2}}$$

As the abundance of fish in a population decreases with increase in length, if $L < L_{crit}$ then

$$N = L/\ L_{crit} \times e^{-ML}$$

where M is the natural mortality. Alternatively, if $L > L_{crit}$, then

$$N = e^{-ML}$$

By including a factor of relative abundance (λ), the model can thus be described by

$$N_{Lh} = \lambda\, L/L_{crit}\, e^{-ML}\, e^{-\frac{(L - (L_1 + hL_2))^2}{2\,(v_1 + hv_2)^2}} \qquad L < L_{crit}$$

or

$$N_{Lh} = \lambda\, e^{-ML}\, e^{-\frac{(L - (L_1 + hL_2))^2}{2\,(v_1 + hv_2)^2}} \qquad L > L_{crit}$$

In the case of the hottentot, $L > L_{crit}$ and thus only the latter relationship was applicable.

In developing the model, certain variations were investigated, namely that the size of hook had no influence on 1) the size of fish caught (L_2 excluded), b) the size of fish and the variance

(L_2 and v_2 excluded), and c) the variance only (v_2 excluded).

After calculating the residual sum of squares for each hook, the F-test was applied in testing them against each other.

RESULTS

The size composition and mean size in the catches, made at the fishing station on the south western Cape, are presented in Table 5.1 and 5.2, respectively. From the statistical parameters it appears that, with the exception of Struis Bay, the mean size of fish caught follows a decreasing trend from west to east. The decline apparent in the mean size at Kalk Bay from 1984 to 1985, was attributed to the natural population fluctuations in False Bay. Such natural variations will tend to obscure the less marked, short term changes in population structure due to fishing pressure, particularly in view of the long lifespan of the species. The high mean size recorded for Saldahna in 1985, results from an exceptional sample measured in February ($\bar{x}$ = 338 mm Lf). The unusually large mean size recorded from Struis Bay is, on the other hand, due to only the very biggest fish being kept at this station.

The length frequency distributions recorded at the four sampling sites, are illustrated in Figure 5.3. Comparisons of the mean size of fish from these stations reveals that differences among the west coast stations are not significant. Similarly, for Kalk Bay and Gans Bay. There was however a difference between catches

TABLE 5.1 Overall length-frequency composition of hottentot catches landed in various major fishing areas.

Lf	LAMBERTS BAY	YZERFONTEIN	SALDAHNA 84	SALDAHNA 85	CAPE TOWN	HOUT BAY	KOMMETJIE	KALK BAY 84	KALK BAY 85	GORDONS BAY	GANS BAY 84	GANS BAY 85	STRUIS BAY	TOTAL
14														
15					1			1						2
16					1	2		4	2		5			14
17	1		1		3			16	7		8			36
18	8		2	4	9		1	38	45	5	19			131
19	12		7	4	10	4	3	114	143	14	30	2		343
20	11	32	56	9	17	26	9	209	243	22	20	19		673
21	8	66	101	23	16	60	35	263	294	28	14	37		945
22	21	86	166	53	22	55	54	269	247	17	24	38		1052
23	19	114	153	86	27	70	36	244	248	15	34	49		1095
24	31	91	168	72	22	60	35	225	200	18	33	25		980
25	39	45	135	68	13	41	27	151	128	34	27	22		730
26	22	48	111	77	23	29	25	163	126	23	25	26	2	700
27	13	35	70	57	20	26	13	109	97	18	17	12		487
28	7	30	38	36	12	27	14	94	54	13	12	12	4	353
29	11	18	37	25	6	22	12	76	63	10	10	8	2	300
30	11	14	10	28	4	11	7	60	39	3	8	3	4	202
31	4	11	9	28	1	10	4	44	21	3	5	2	3	145
32	1	11	8	22	1	10	6	35	13		5		1	113
33	3	9	1	12	1	6	1	21	10		3		1	68
34	1	8		8		3	3	19	19		1			62
35	1	4	1	13		6	1	14	10					50
36		3	1	11		1		8	8					32
37	1			3			1	9	1					15
38		1	1	3				6	3	1				15
39				3		1		6	2					12
40								5						5
41						1	1	2						4
42	1							1						2
43	1							3						4
44								1						1

TABLE 5.2 Mean length of hottentot landed at various major landing sites during 1984 and 1985.

AREA	MEAN	S.D.	S.E.	MIN	MAX	N	L_c
LAMBERTS BAY	25.1	3.98	0.26	18	43	227	21.7
SALDAHNA 84	24.1	2.64	0.08	17	38	1076	
85	26.3	3.98	0.16	18	39	645	
Combined	24.9	3.38	0.08	17	39	1721	20.7
YZERFONTEIN	24.6	3.40	0.14	20	38	626	
CAPE TOWN	23.6	3.34	0.23	15	33	209	
HOUT BAY	24.6	3.74	0.17	13	41	473	
KOMMETJIE	24.4	3.41	0.20	19	41	288	
KALK BAY 84	24.1	4.16	0.09	15	44	2210	
85	23.3	3.58	0.08	16	39	2023	
Combined	23.7	3.92	0.06	15	44	4233	18.9
GORDONS BAY	23.8	3.29	0.22	18	38	224	
GANS BAY 84	23.4	3.89	0.22	16	34	300	
85	23.6	2.58	0.16	19	31	255	
Combined	23.5	3.35	0.14	16	34	555	19.9
STRUIS BAY	29.4	1.94	0.47	26	33	17	

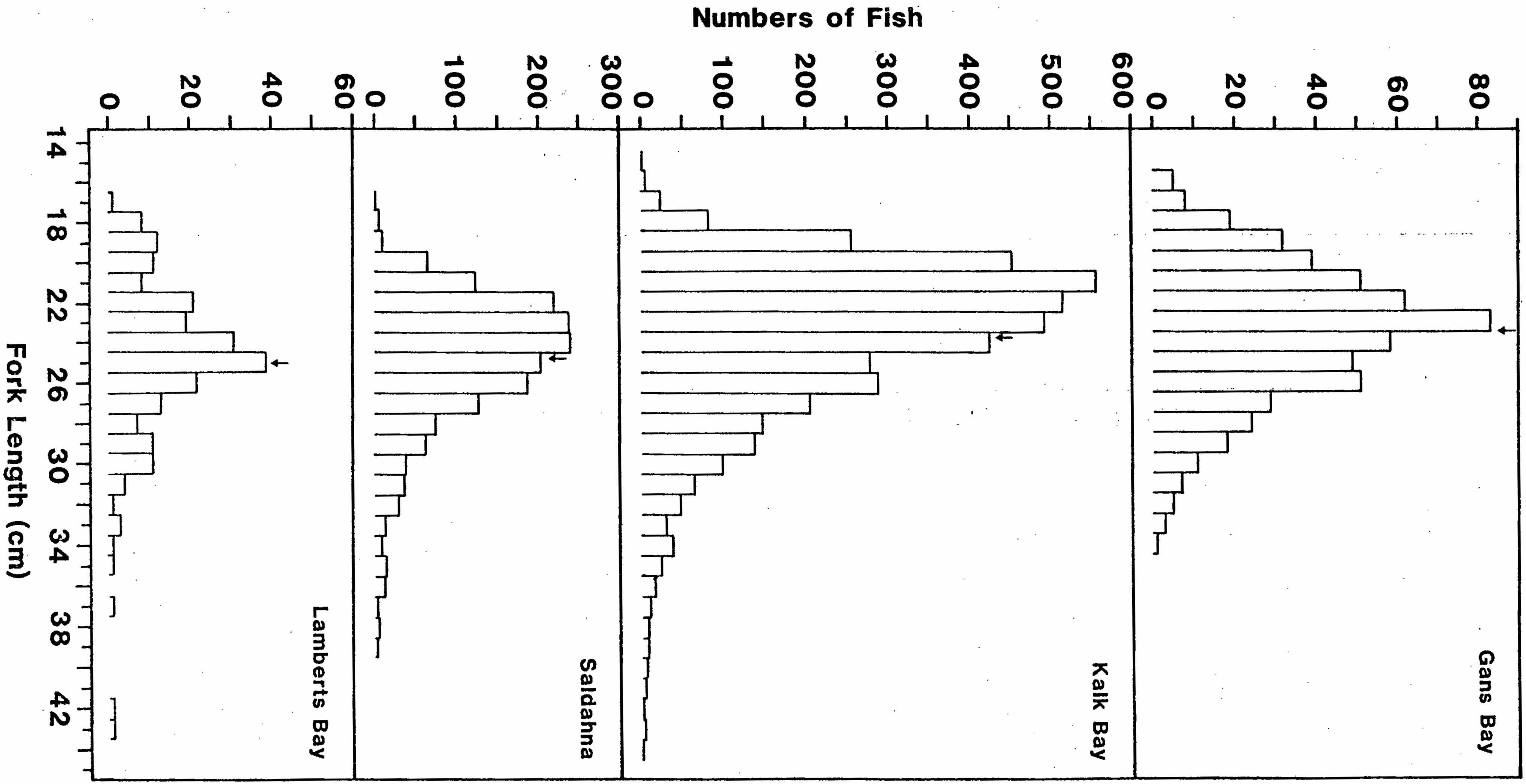

FIGURE 5.3 Length frequency distributions of hottentot catches from Lamberts Bay, Saldahna Bay, Kalk Bay and Gans Bay.

from the west and south coasts, at the 5 % level. The mean size of fish landed at the west coast sites were significantly larger than those east of Cape Point.

Comparing size distributions further identified that (although not different from Gans Bay), the composition of the Kalk Bay catch differed significantly from those of the west coast (95 % confidence). The apparent skewing to the left, of the Kalk Bay catch, is attributable mainly to a decline in the mean size of fish caught (over and above the decreasing west to east trend), due to heavier fishing effort in this area, and to the available market in Cape Town for smaller, often undersized fish. At the other stations however, where small hottentot are no longer used for "bokkoms", the market for the small size classes is poor, and they are thus not included as frequently in the landed catch.

Temporal variations in the size freqency composition of catches from Kalk Bay are illustrated in Figure 5.4. Although the monthly mean size of fish varied by up to 36 mm, there appears to be no consistant annual cycle to these changes.

Figure 5.5 illustrates the linear relationship between the lengths and widths of the four hooks. Of these, the hook most commonly (with the exception of False Bay) used is the 1/0. Using the hook size index, the smallest hook was 25.6 % the size of the 1/0, and the largest was 170 % of its size.

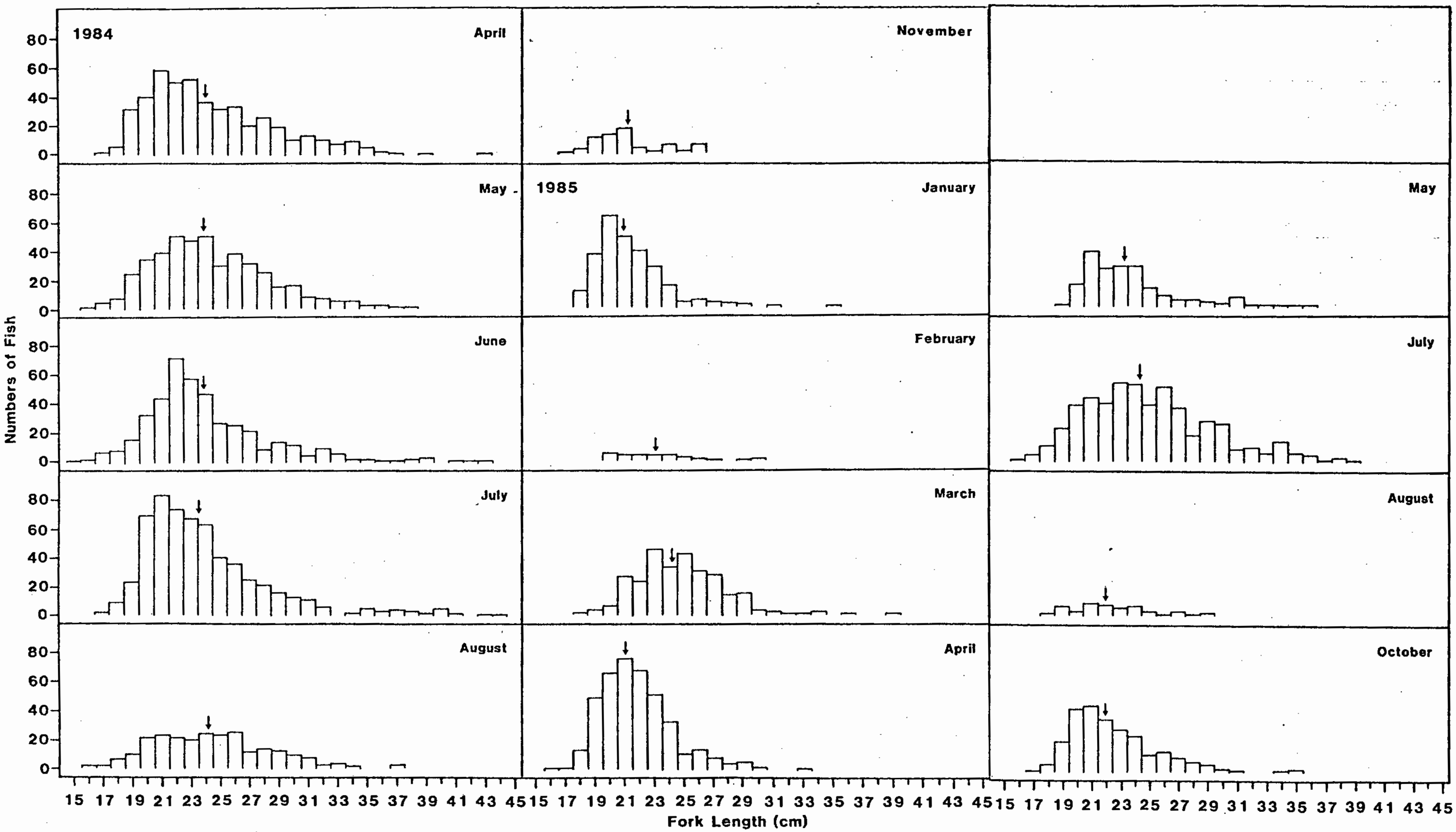

FIGURE 5.4 Seasonal variation in the length-frequency composition of hottentot catches landed at Kalk Bay during 1984 and 1985. Arrows represent the means.

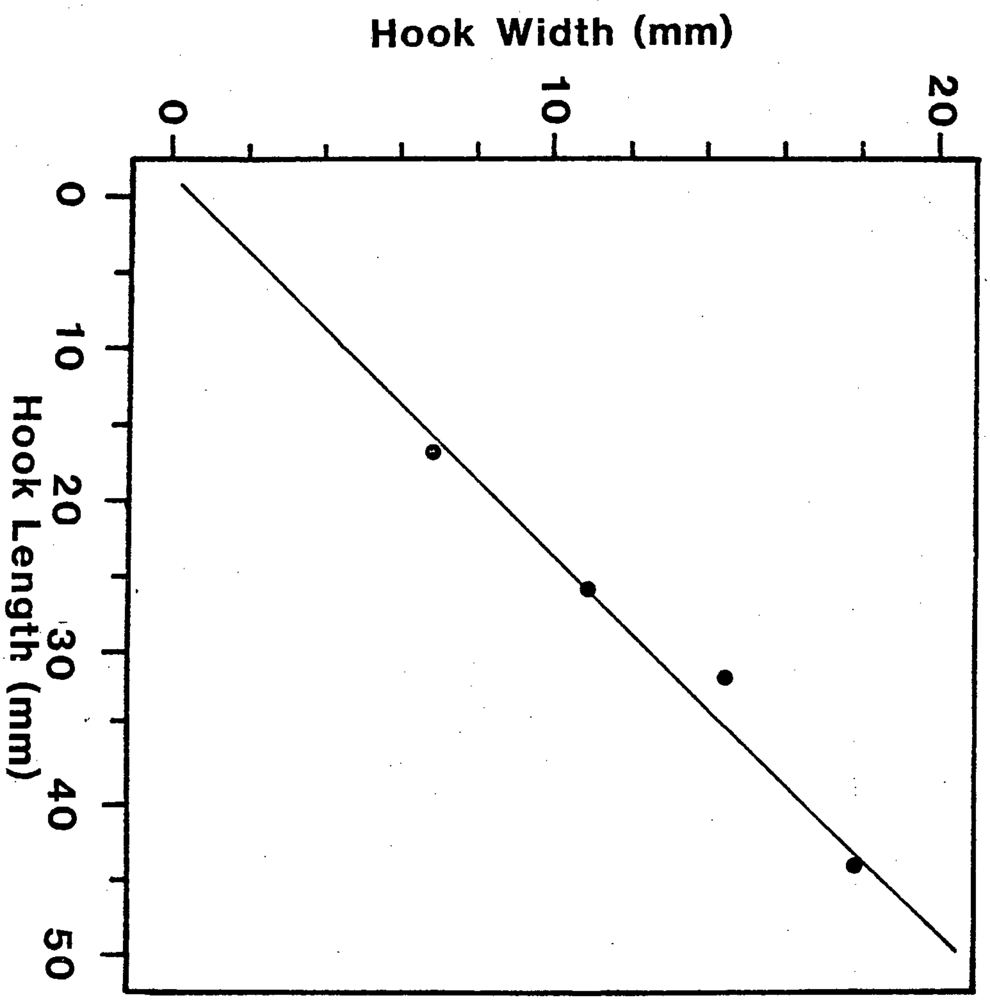

FIGURE 5.5 Relationship between the length and width of the hooks used during the experimental hook size selectivity study.

The relationship of gape size to fork length (Fig 5.6), was described by

$$\text{Gape(mm)} = 1.557 + 0.085 \times \text{Lf(mm)} \quad (r^2=0.95,\ SE=6.27)$$

The size distributions of fish caught on the four hooks are presented in Figure 5.7, and the parameters of these length compositions are contained in Table 5.3.

Table 5.3 Mean length of P. blochii caught using four different hook sizes (sizes 10, 4, 1/0 and 4/0) during the experimental hook size selectivity study.

PARAMETER	HOOK 10	HOOK 4	HOOK 1/0	HOOK 4/0
MEAN Lf	22.9	24.8	25.8	26.1
S.D.	31.6	33.5	33.4	35.3
S.E.	1.7	1.7	1.7	3.0
MAX	314.0	352.0	390.0	371.0
MIN	152.0	137.0	164.0	168.0
N	359	395	377	139
L_c	186.0	211.0	215.0	216.0

The analysis of variance identified that the mean size of fish caught on the hooks was significantly different ($p < 0.001$). With the exception of hoks 1/0 and 4/0, pairwise comparisons similarly found significant differences between the means.

In developing the model, it was found that the predicted values derived when assuming equal variances differed little from the full model (Table 5.4). Results obtained making other assumptions were, however, unsatisfactory.

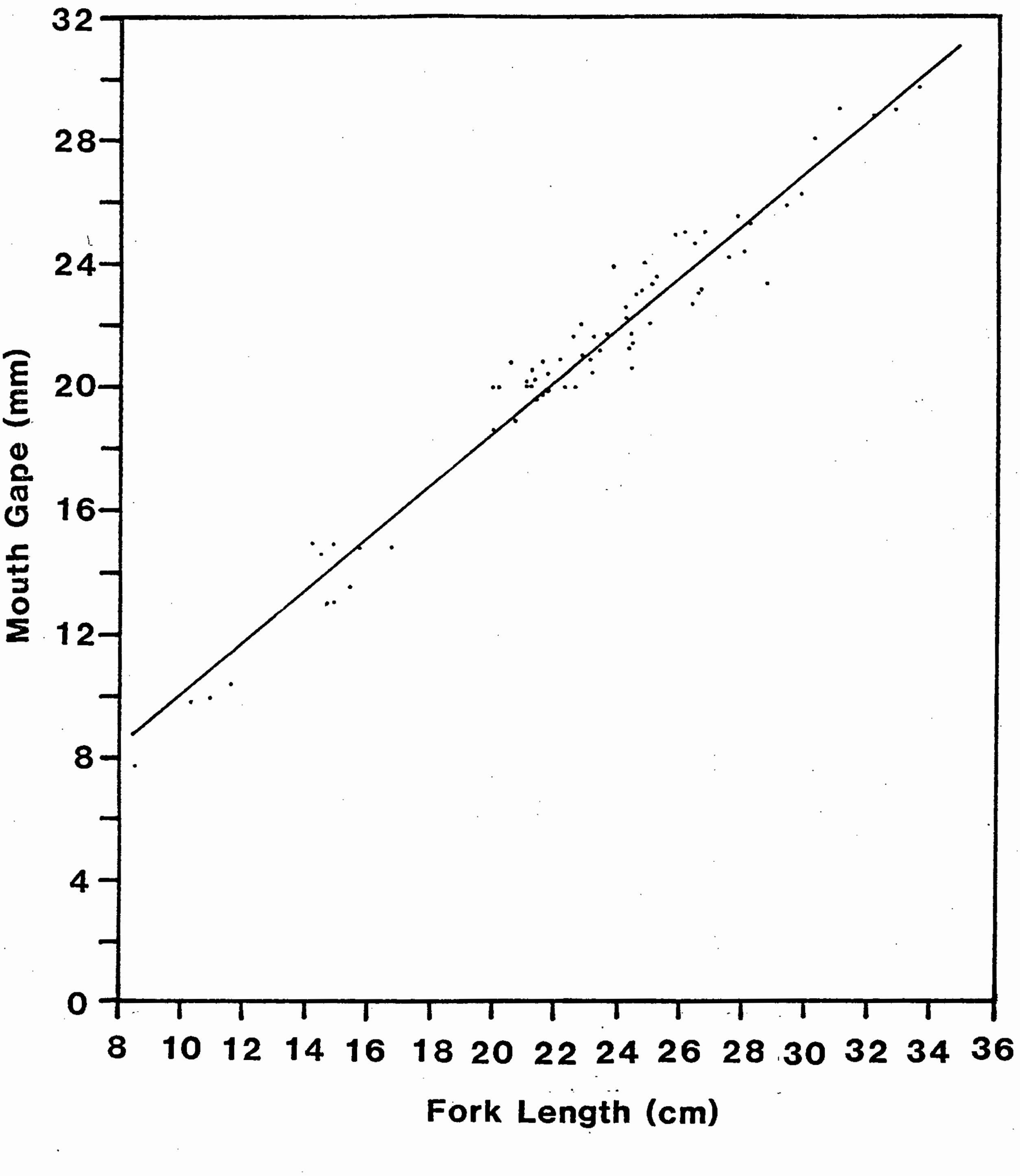

FIGURE 5.6 Relationship of mouth gape size to fork length for *P. blochii*.

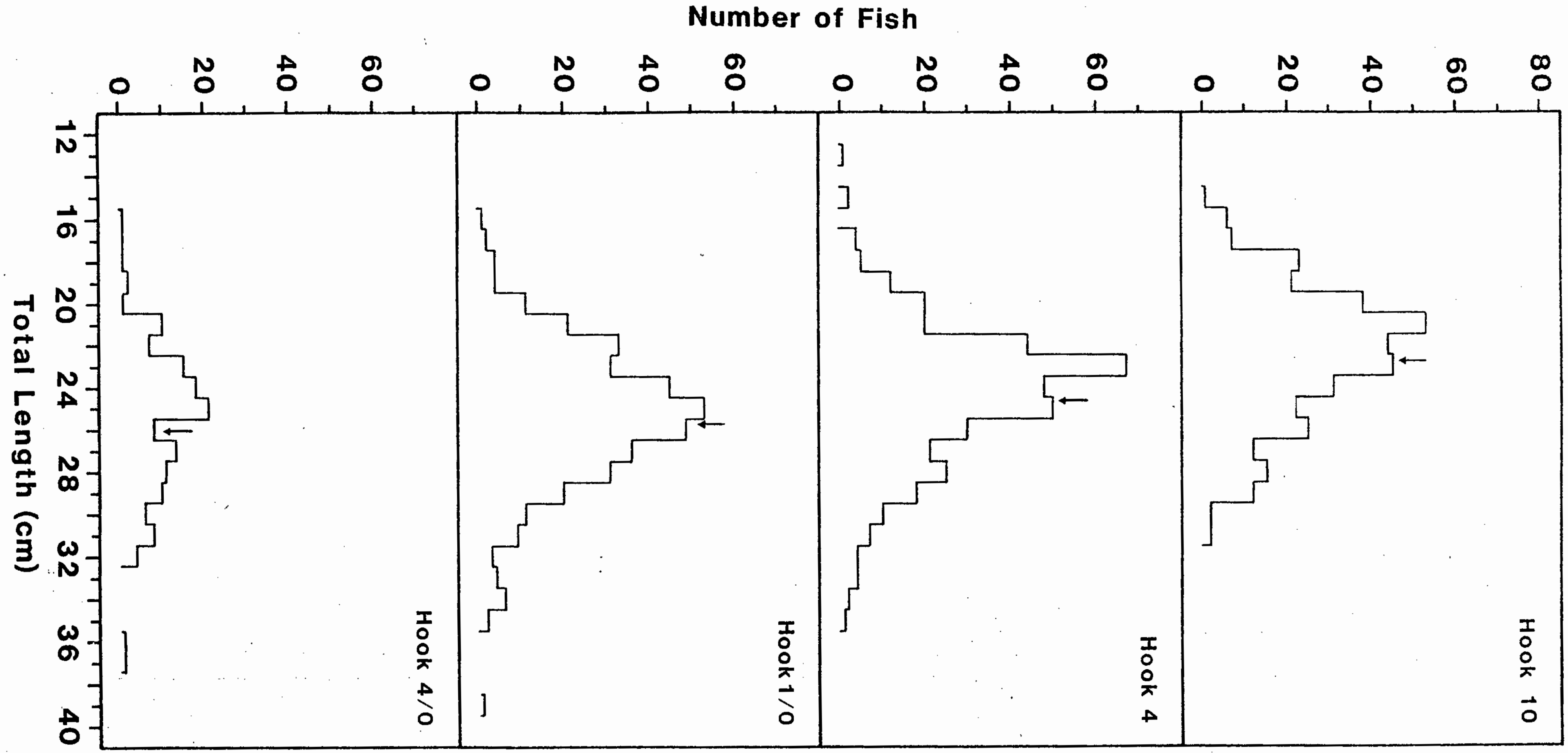

FIGURE 5.7 Size composition of catches made on four hook sizes (10, 4, 1/0 and 4/0). Arrows represent the means.

Comparisons between hooks subsequently revealed that, with the exception of hook 1/0 and 4/0, differences were all significant at the 1 % level.

DISCUSSION AND CONCLUSIONS

As hottentot do not undergo large-scale migrations (Nepgen 1977), it was concluded that the southern African stock represents one population. Although constituting a major component of the west coast linefish catch, the hottentot is not a prime target species east of False Bay. The observed decrease in mean size around the coast is thus probably a consequence of the natural population structure.

As the hooks used in the fishery differ between areas, the variation in L_c will, however, be partly attributable to a hook selectivity effect.

Although the minimum size of fish landed commercially is controlled by the imposed size limit, the hook size study showed that very small fish (<120 mm Lf) were absent in the catch. The reason for this is the difference in behaviour patterns exhibited by the juveniles.

The probability of a fish being hooked is therefore dependent on its size (Saeterdal 1963). Furthermore, Koike _et al_ (1968), Kanda _et al_ (1978) and Koike and Kanda (1978) found that, when

TABLE 5.4 Length-frequency distribution of hottentot caught using various hook sizes, compared with length-frequency distributions predicted by the hook-size selection simulation model developed in the text. Predicted distributions are shown for both the full model and the simplified version which assumes equal variances.

SIZE RANGE (mm)	ACTUAL VALUES				PREDICTED VALUES							
					FULL MODEL				EQUAL VARIANCES			
	10	4	1/0	4/0	10	4	1/0	4/0	10	4	1/0	4/0
< 152	0.0	1.0	0.0	0.0	0.7	0.2	0.0	0.0	0.6	0.2	0.0	0.0
153 - 168	5.0	2.0	1.0	0.0	4.3	1.3	0.3	0.1	4.2	1.3	0.4	0.1
169 - 184	19.0	6.0	2.0	2.0	16.5	6.3	2.0	0.5	16.3	6.3	2.1	0.6
185 - 200	34.0	15.0	8.0	3.0	43.7	20.8	8.2	2.7	43.5	20.7	8.3	2.8
201 - 216	73.0	30.0	20.0	9.0	67.5	39.7	19.5	7.9	67.6	39.6	19.6	8.2
217 - 232	69.0	67.0	53.0	12.0	81.2	58.8	35.8	18.2	81.5	58.9	35.8	18.4
233 - 248	64.0	92.0	60.0	24.0	76.3	67.9	51.0	32.1	76.4	67.9	50.9	32.1
249 - 264	40.0	66.0	85.0	31.0	55.8	60.9	56.3	43.8	55.7	60.9	56.1	43.6
265 - 280	24.0	45.0	61.0	17.0	31.8	42.4	48.1	46.2	31.5	42.4	48.1	46.0
281 - 296	24.0	40.0	46.0	17.0	14.2	23.0	31.9	37.7	13.9	22.9	32.0	37.7
297 - 312	5.0	14.0	18.0	11.0	4.9	9.7	16.4	23.8	4.7	9.6	16.6	24.0
313 - 328	2.0	9.0	10.0	10.0	1.3	3.2	6.5	11.6	1.3	3.2	6.7	11.9
329 - 344	0.0	5.0	8.0	1.0	0.3	0.8	2.0	4.4	0.3	0.8	2.1	4.6
345 - 360	0.0	3.0	4.0	0.0	0.0	0.2	0.5	1.3	0.0	0.2	0.5	1.4
361 - 376	0.0	0.0	0.0	2.0	0.0	0.0	0.1	0.3	0.0	0.0	0.1	0.3
377 - 392	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1

fishing with hooks and lines, samples were biased towards an optimum catchable length, this in turn being dependent on hook size. This is clearly demonstrated by this study, the mean size of fish caught being closely related to the size of hook used.

The variation in the size at firstcapture between hooks similarly shows that the L_c can be altered by changing the hook size. This complies with the results of Holt (1963) and McCracken (1963).

Of interest is that both the model and the ANOVA found that hooks 1/0 and 4/0 were not significantly different. This suggests that, of the four hooks, the 1/0 may be the optimum sized hook if fishermen are targeting for big fish, an increase in hook size not yielding substantially larger mean sizes. The number of fish caught on the large hook is also less than that captured, over the same time period, on the 1/0. Should the fishermen be satisfied with a smaller mean size and opt rather for higher catches, as is tha case in Kalk Bay, smaller hooks would be utilized.

The survey of the fishing centres revealed that the hooks used in the hottentot fishery range from 2/0 to No. 3. At Lamberts Bay, where 2/0 and 1/0 hooks are employed, a higher mean size and L_c are evident in the catch. As larger fish are still readily available, the fishermen have not had to resort to smaller hooks to maintain catches, as is evident at Kalk Bay. Although the mean size of fish landed at Gans Bay is lower than that for Kalk Bay, the use of larger hooks, and the higher L_c suggests that this is not soley the result of gear selectivity. This confirms that the mean size in the population decreases from west to east.

In conclusion, therefore, there is a direct relationship between hook size and the length of fish caught. The mean size in the catch will thus be influenced by the size of hook used in a particular area as well as the natural variations in the population structure.

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6. STOCK ASSESSMENT, POPULATION DYNAMICS AND IMPLICATIONS FOR MANAGEMENT OF THE HOTTENTOT RESOURCE

The nature of management of the South African linefishery has, in most instances, been one of a crisis situation. In the case of the hottentot however, although commercially exploited, this species has apparently remained abundant as the total annual catches have changed little since the start of the century. Effective management actions can thus be investigated and introduced timeously, as part of an allover plan, before the fishery reaches a post-mortem situation. Being the major linefish species besides snoek, on the west coast, this report documents and evaluates the current state of the fishery and investigates the applicability of various management options.

METHODS

By converting the length frequency data of the total catch to age composition using the growth curve, the total mortality (Z) for the sample, and for each of the sampling areas, was established according to the method discussed in Hughes (1986). The logarithm of the frequency is plotted against age, and the gradient of the resultant straight line regression represents Z.

As the fish are fully recruited into the fishery at 6 years, and the sample sizes of fish older than 10 years are so small, only the data for 6 to 10 year olds was used. The age-length key, which is not an unbiased sample of the total catch length distribution, proved unsatisfactory after age 8. Deterministic age at lengths up to age 10 were thus used.

The natural mortality (M) was determined using the relationship of Pauly (1980)

$$\text{Ln } M = -0.0066 - 0.279\text{Ln } L_{\infty} + 0.6543\text{Ln } k + 0.4634\text{Ln } T_o$$

where L_{∞} and k are the von Bertalanffy parameters and T_o is the average environmental temperature. This was taken as 17° C.

The method of Rikhter and Efanov (1977)

$$M = \frac{1.521}{t_m^{07}} - 0.155$$

where t_m is the age at 50 % maturity, was also used.

As Z = F + M, estimates of the instantaneous fishing mortality (F), were subsequently calculated.

Age at first capture (t_c), corresponding to half the maximum frequency, was determined by fitting a straight line to the increasing portion of the age frequency distribution (Gulland 1963).

Finally, to establish the maximum sustainable yield, and to determine the impact of the fishery on the hottentot stock, these parameters were applied to the Beverton and Holt (1957) yield per recruit model.

RESULTS

Figure 6.1 presents the length composition of the hottentot catch for 1984 and 1985.

In applying the two methods for calculating M, the result using the relationship of Rikhter and Efanov (1977) ($M = 0.338\ year^{-1}$), was preferred to the unreasonably low value of 0.138 $year^{-1}$ obtained from the Pauly (1980) technique. The values of Z, and their corresponding fishing mortalities are contained in Table 6.1. For comparison, the F parameter was calculated using both values of M.

Table 6.1 Total mortality (Z), fishing mortality (F) and age at first capture (t_c) of the hottentot catch.

PARAMETER	TOTAL	LAMBERTS BAY	SALDAHNA BAY	KALK BAY	GANS BAY
Z	0.733	1.217	0.756	0.698	1.391
v	0.026	0.201	0.081	0.028	0.221
t_c	4.25	4.93	4.60	4.05	4.35
M=0.1375					
F	0.596	1.080	0.619	0.554	1.254
M=0.338					
F	0.395	0.879	0.418	0.353	1.053

Taking into account the variance around Z, the observed fishing mortalities are unexpected. Considering that the effort is much greater at Kalk Bay and Saldahna, the fishing mortalities in these

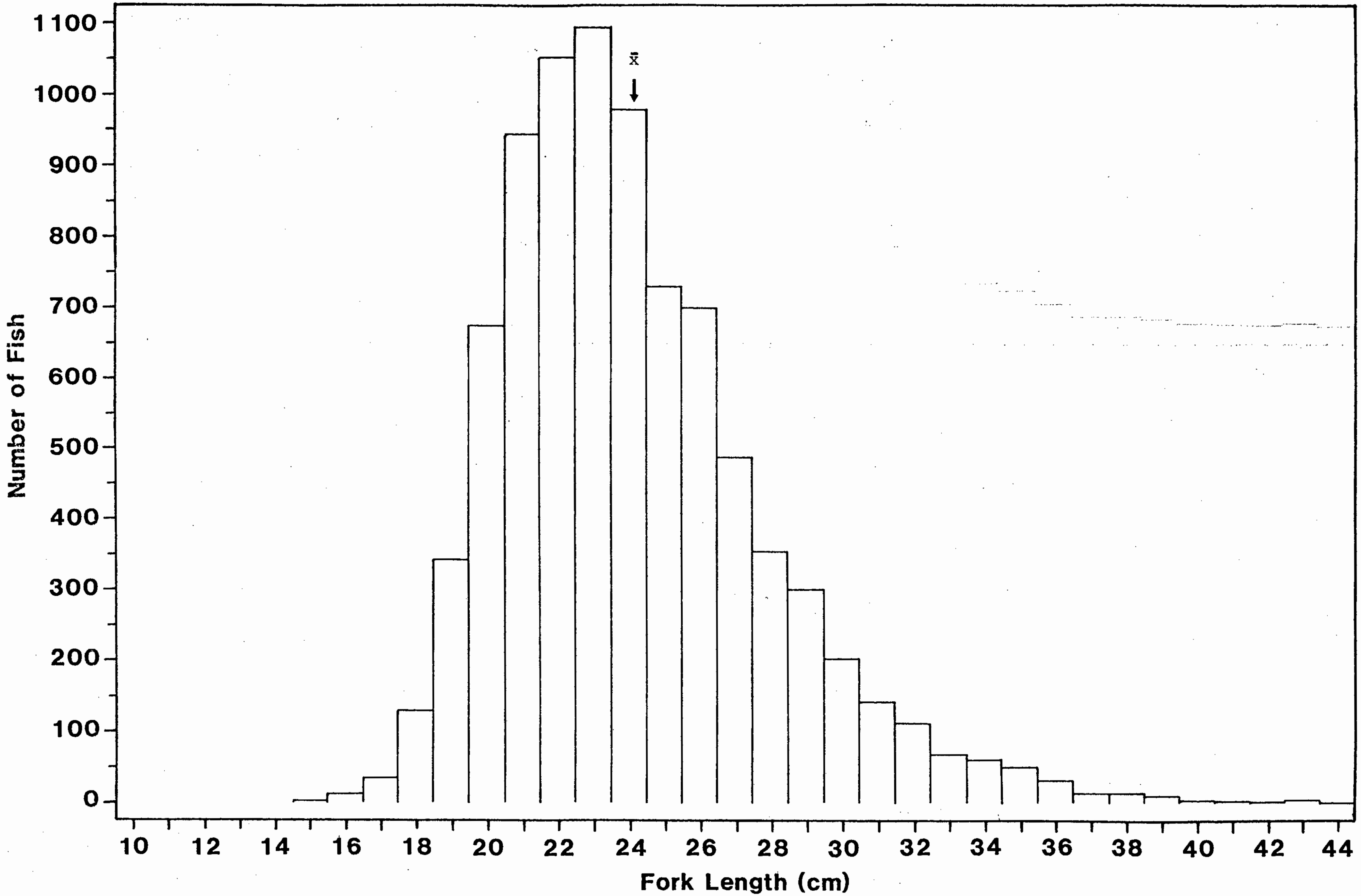

FIGURE 6.1 Overall length-frequency composition of hottentot landed at major fishing harbours during 1984 and 1985.

areas were predicted to be higher. The longer tails in the size frequency distributions (Fig 5.3) likewise suggest higher F values, as the presence of larger numbers of big fish, reflects a greater fishing effort. Irregularities of the results are thought to be attributable to the lack of robustness in the methods available for calculating the total and natural mortality.

The age at first capture for the entire sample (4.24 years), differs substantially from that calculated , by Hughes (1986) (2 years), from the results of Nepgen (1977). The erroneous growth curve of Nepgen (1977) will be primarily responsible for this. Fish are therefore recruited into the fishery at an earlier age than that at the minimum legal size limit (198 mm Lf, 4.33 years) and at 50 % sexual maturity (220 mm Lf, 5 years).

Application of these parameters to the Beverton and Holt (1957) model, using the M of 0.338 $year^{-1}$, reveals that the predicted numbers and biomass at age of the exploited stock (Fig 6.2 and 6.3, respectively), do not differ dramatically from those of the unfished population, the maximum expected biomass being at only two years younger than that for the unexploited population. With F = 0.396 the yield per recruit curve (Fig 6.4), gives $F < F_{MSY}$ for all the values of t_c greater than 4.25 years, indicating that the current level of fishing effort is appropriate for utilization of this resource. The $F_{0.1}$ value was calculated as 0.28. Therefore, although 30 % more effort is currently devoted to the fishery, this results in a less than 10 % increase in the yield per recruit, to that achieved at $F_{0.1}$.

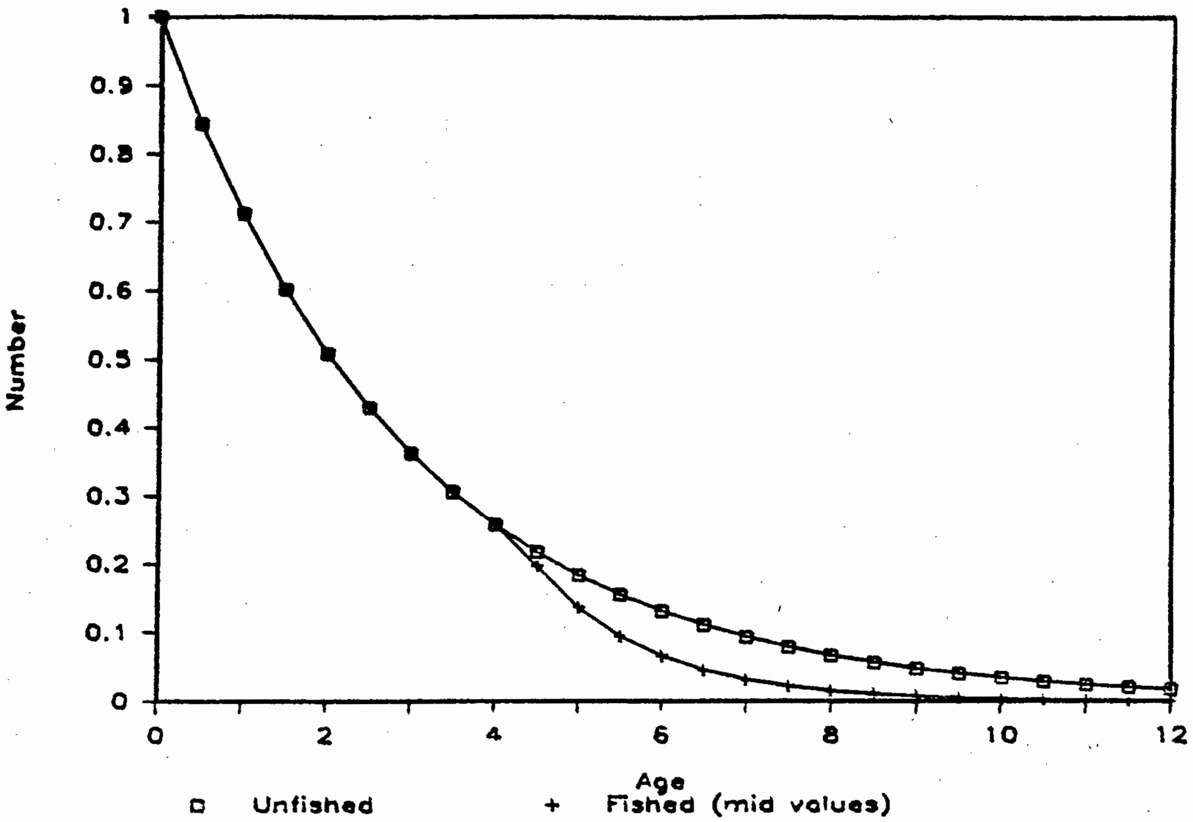

FIGURE 6.2 Simulation model showing predicted number of hottentot at age in a fished and unfished population.

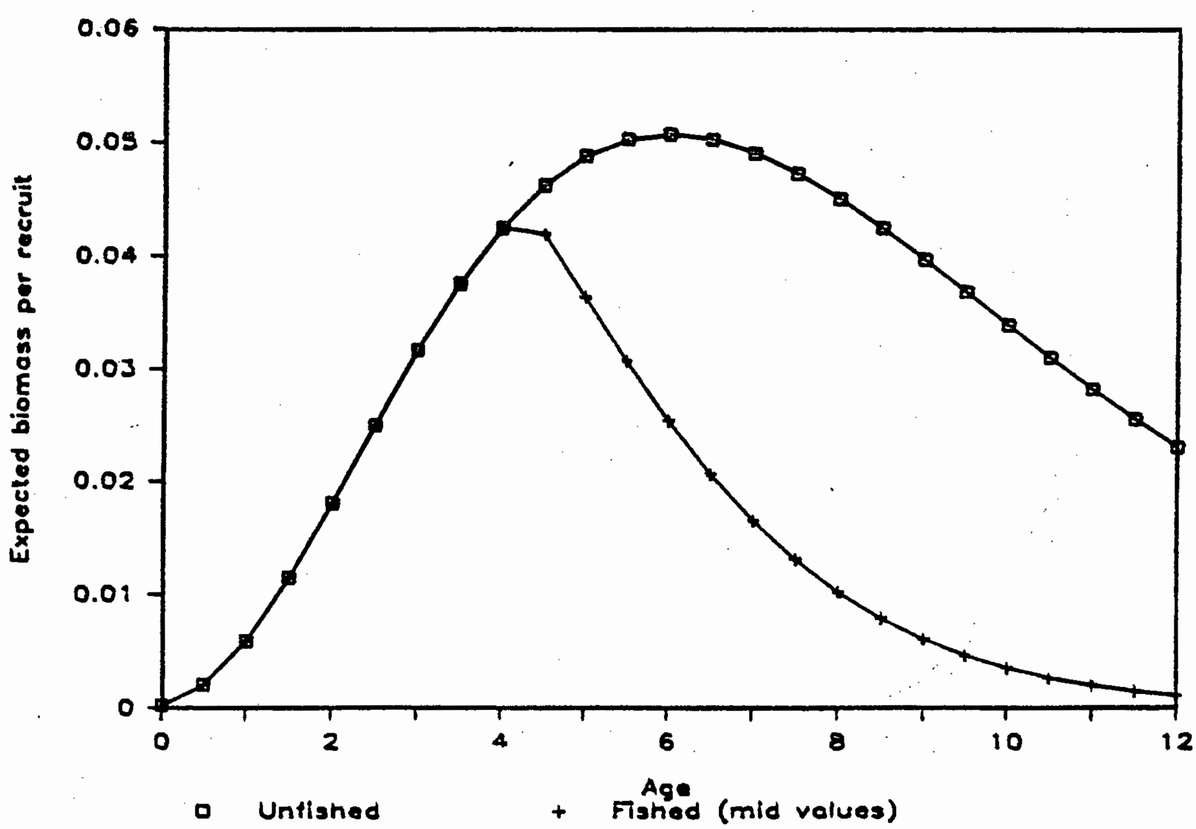

FIGURE 6.3 Simulation model showing predicted biomass of hottentot at age in a fished and unfished population.

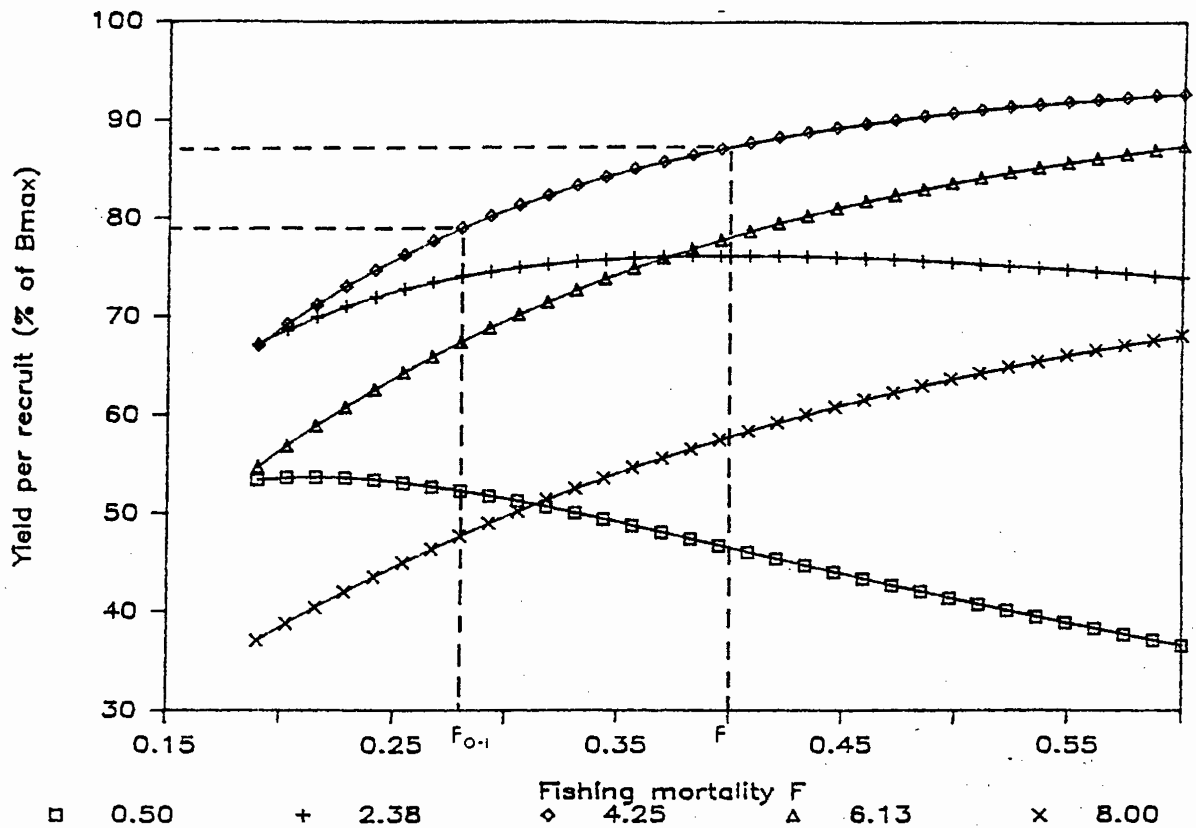

FIGURE 6.4 The relationship between yield per recruit and fishing mortality (F) for P. blochii for five ages at first capture.

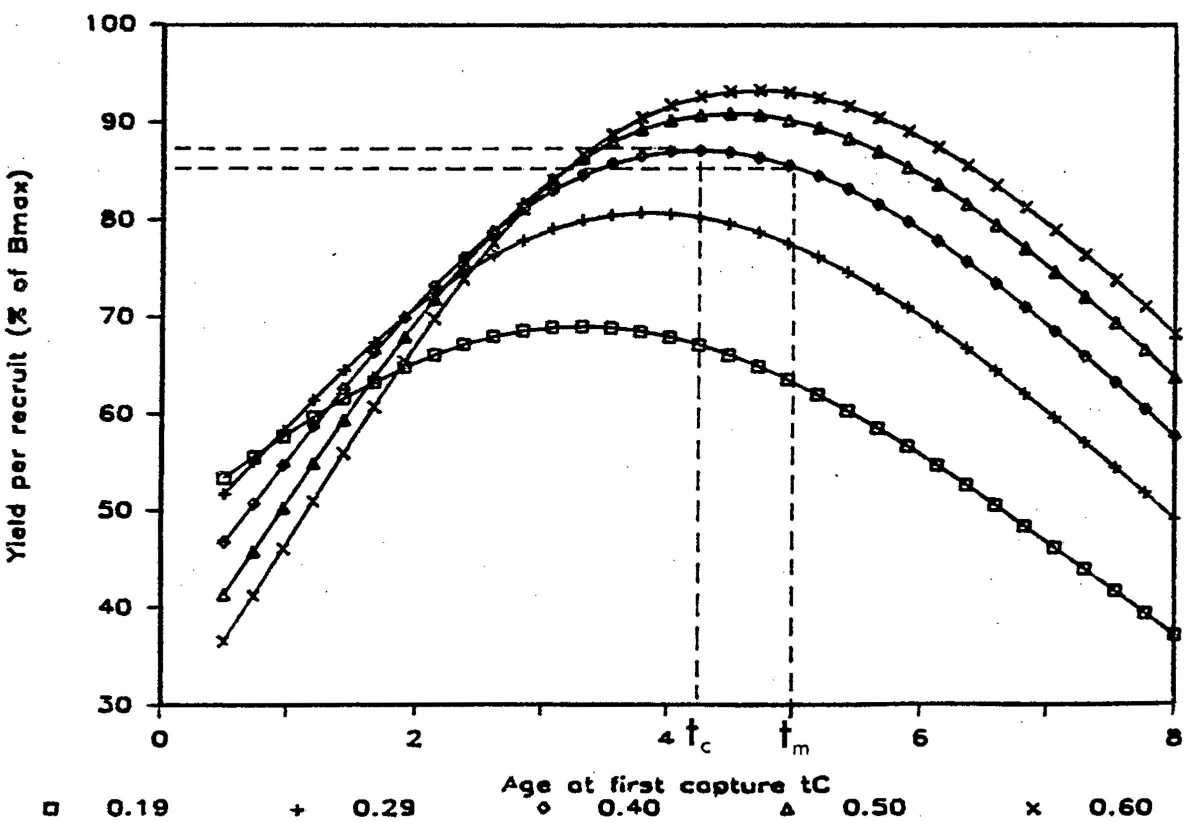

FIGURE 6.5 The relationship between yield per recruit and age at first capture for P. blochii for five levels of fishing mortality (F).

Furthermore, at the current fishing pressure, yield per recruit is at its maximum, for the age at first capture (4.25 years) and age at minimum legal size (4.33 years) (Fig 6.5), indicating that, although $t_c < t_m$, yield per recruit would not benefit from an increase in the size limit to the length at 50 % maturity. Similarly, although it appears that yield per recruit could be improved by increasing the fishing pressure, an increase in effort would provide minimal additional return.

Although considered inappropriate for the stock, the M of 0.138, derived from the Pauly method (1980), implies F = 0.596, which from the Y/R curves (Appendix 6.1) gives $F > F_{MSY}$ for most of the t_c values considered, indicating that the resource is overexploited. The difference in these conclusions emphasizes how important it is to have reliable data, thus supporting Hughes (1986), who made similar observations using the data of Nepgen (1977).

DISCUSSION AND CONCLUSIONS

Available evidence indicates that the hottentot is a slow growing species and may thus be readily susceptible to overexploitation.

In considering the available management options, it appears that, although the present minimum size limit is below the length at 50 % maturity, the Y/R relationship indicates that, at the current level of exploitation, this is appropriate for utilization of the resource. An increase of the restriction would not, in fact, benefit the stock. With the exception of Kalk Bay, the market for under-sized fish is poor and the size limit is therefore effectively self imposed.

Increasing consumer demands for an inexpensive protein source may however result in the small size classes of fish becoming acceptable, as in the case of the hake. In the event of such a swing in the market, should the age at first capture drop much below 4 years, the stock would tend towards overexploitation at the current fishing pressure.

Results of the hook selectivity study indicated that, if the fishermen continue to utilize the size of hooks presently in use, the size of fish at first recruitment into the fishery, will remain at an acceptable level (t_c > 4 years). In considering the available potential of regulating the size of fish landed by imposing restrictions on the sizes of hooks permissible in the industry, the complexity of the multispecies fishery must be kept in mind. As there is no direct control over which species the fishermen target for, a regulation governing the sizes of hooks would prove to be highly impractical and extremely difficult to enforce.

As hottentot do not exhibit marked migrational behaviour (Nepgen 1977), resident populations would benefit from marine sanctuaries. These serve as areas in which localized populations can recover from the effects of exploitation, and from which fish can subsequently move to restock adjacent regions.

Although the species constitutes an important component of the west coast commercial linefishery, it is also captured, to a much smaller extent, by recreational skiboat fishermen, spearfishermen and shore anglers. This makes it difficult and impractical to enforce an overall quota on the fishery. By imposing a bag limit, it is however possible to control the catch. Being the subsistance fishery on the west coast, however, such a restriction could only be applied to the recreational fishery. Although it is the only species potentially available to the recreational fisherman throughout the year, it is not a major target species. Pressure from this sector is thus low. The enforced bag limit of 10 fish per man per day is therefore considered adequate for the non-commercial fishery.

Further options, which aim at reducing the effort levelled at the fishery, include limiting the access to the fishery, closed seasons and reserves aimed at population control. As hottentot do not exhibit major spawning aggregations, the latter option is not applicable.

Although providing employment for a number of experienced people, the hottentot fishery does not rank as a major industry in terms of manpower. Most of the fishermen are involved in other fisheries, the hottentot catches serving merely to supplement their incomes and see them through the "off seasons". Economic benefits are minimal in comparison with other linefish species, or with the large-scale demersal and pelagic fisheries, poor returns for effort having the effect of further decreasing the pressure on the fishery.

Reproductive activity is maintained throughout the year with spawning peaking during late autumn and summer. This makes the application of a closed season problematic. It appears, however, that the diversion of effort to the snoek and rocklobster fisheries during the major spawning periods effectively serves as a "closed season" for the hottentot. Although fish are still landed during these times, directed effort at the fishery is considerably reduced.

In the light of available information, the observed decline in the annual catches over recent years is thus thought to reflect a decline in effort rather than in the stock itself. The stock therefore does not show signs of overexploitation at the current fishing level. The present regulations will however, be advantageous in maintaining it at its present stable state.

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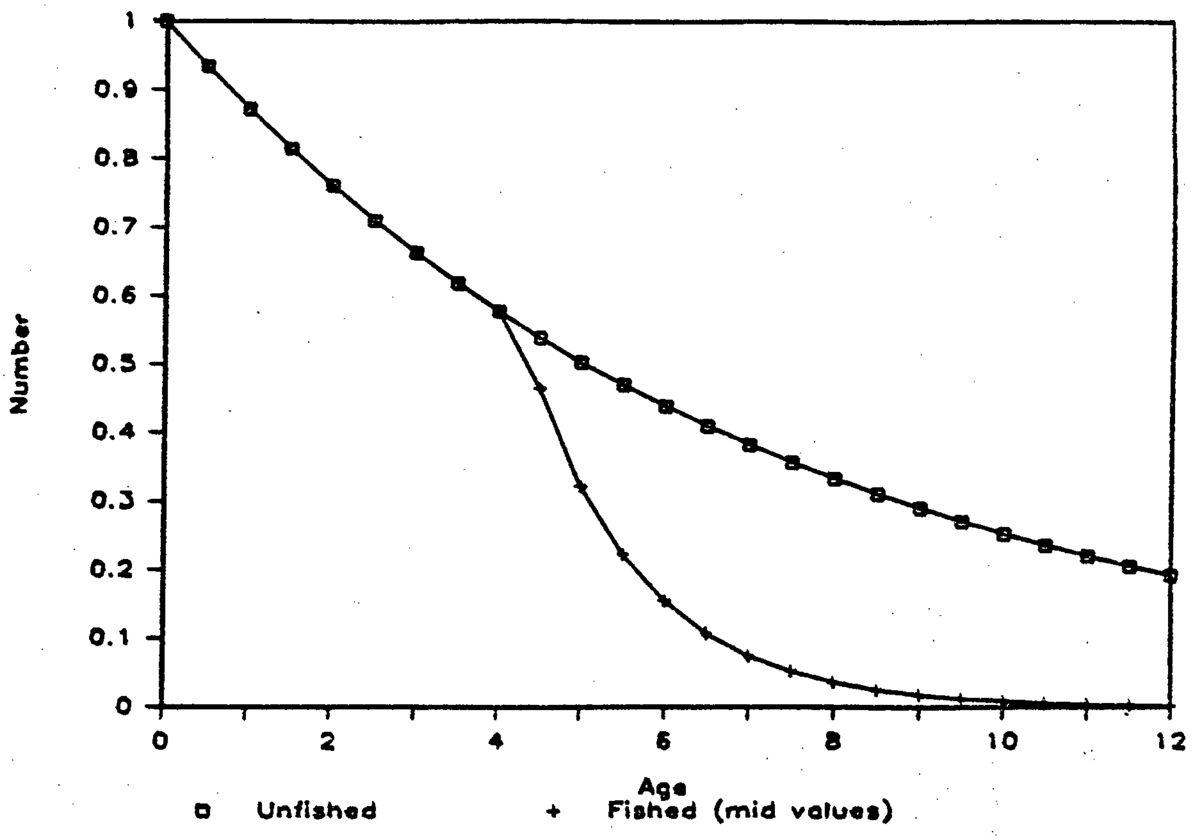
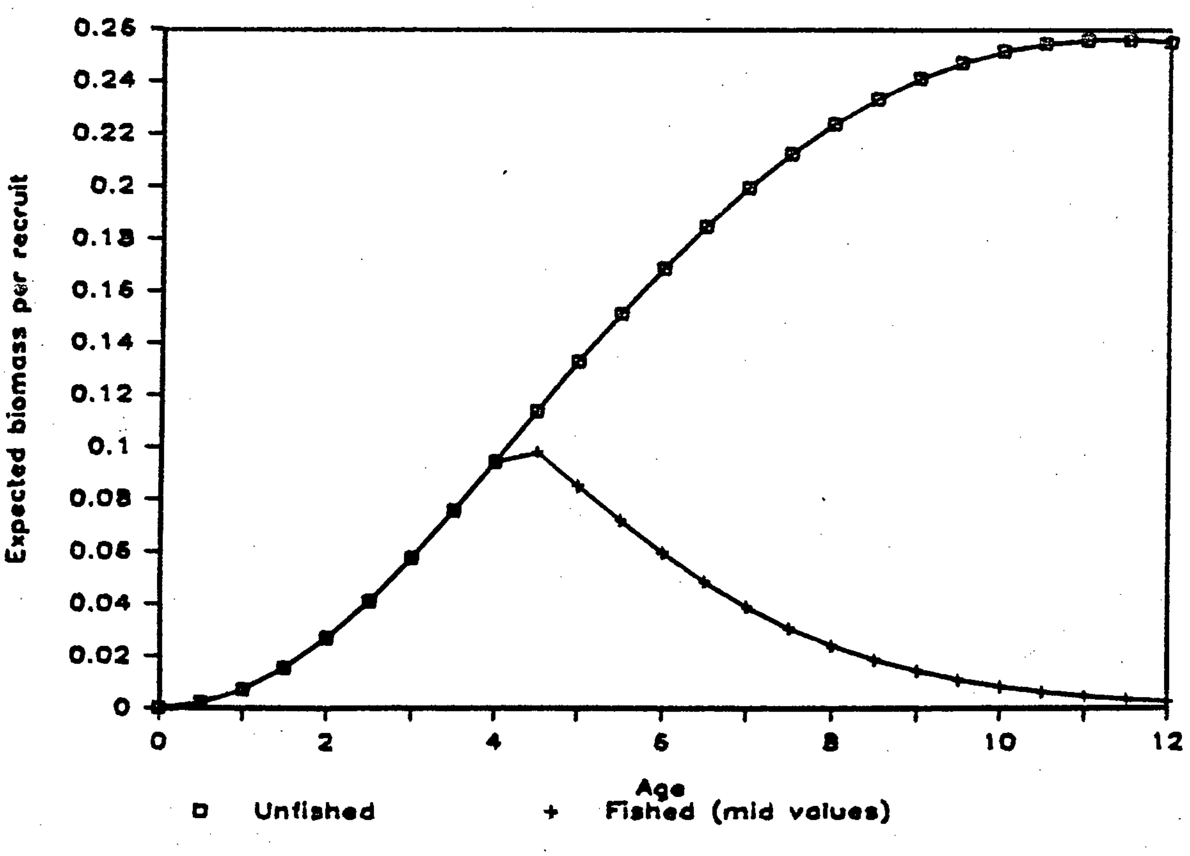
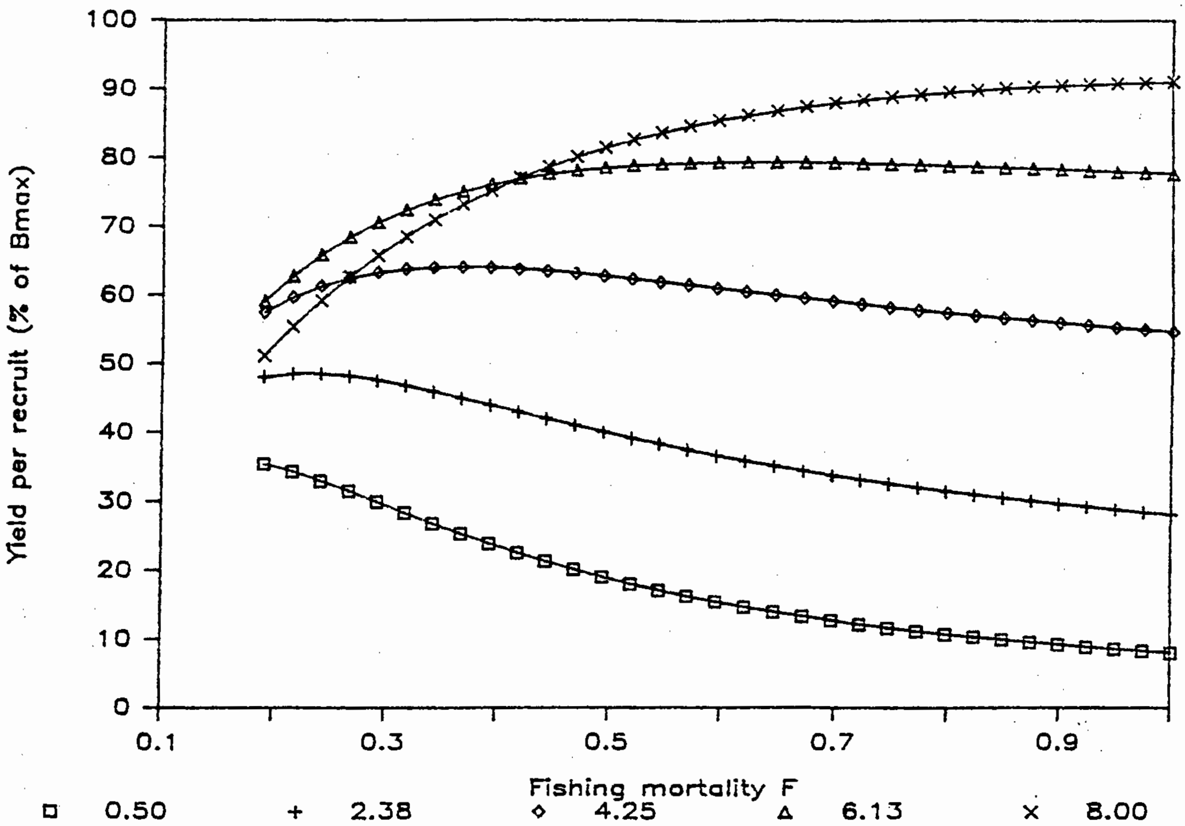
Appendix 6.1 - Mathematical yield per recruit simulation for *P. blochii*



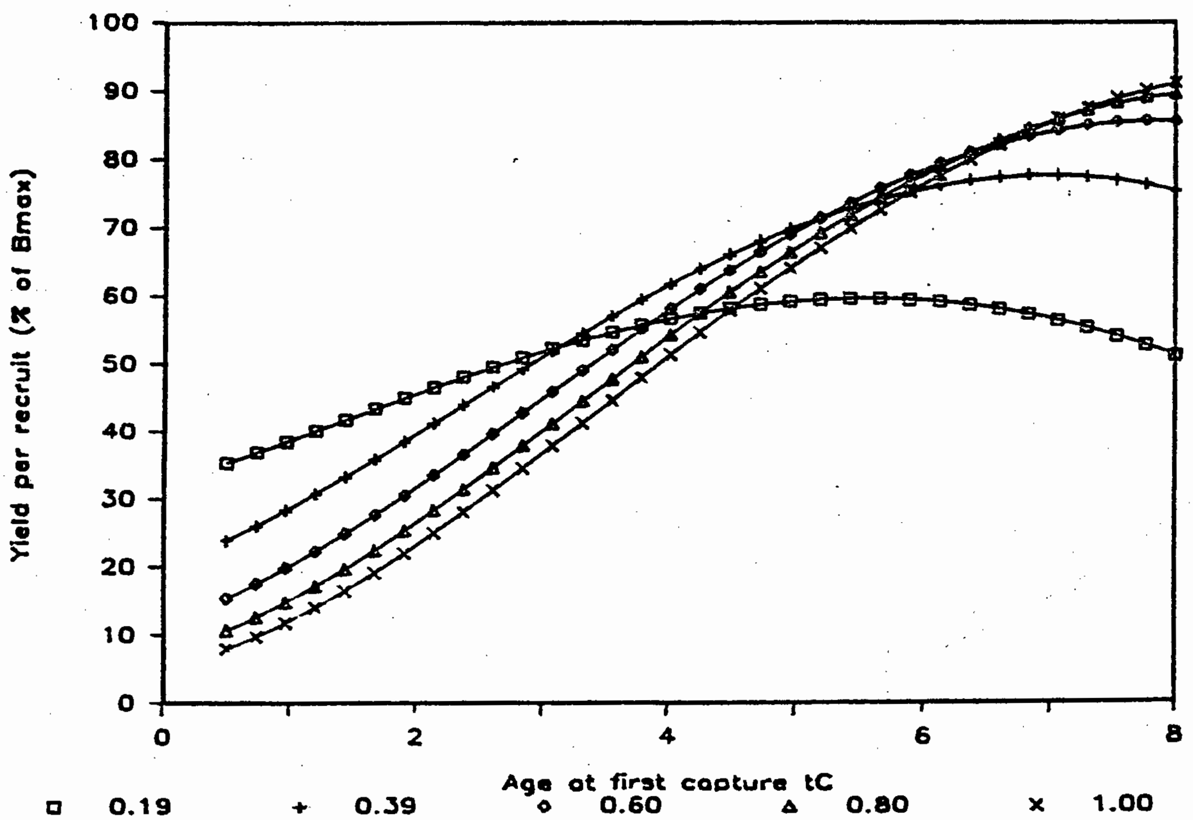
Simulation model showing predicted number of hottentot at age in a fished and unfished population.



Simulation model showing predicted biomass of hottentot at age in a fished and unfished population.



The relationship between yield per recruit and fishing mortality (F) for P. blochii for five ages at first capture.



The relationship between yield per recruit and age at first capture for P. blochii for five levels of fishing mortality (F).

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