Variation in diet of the West coast rock lobster (*Jasus lalandii*): influence of rock-lobster sex, size and food environment.

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Abstract

Few studies of rock-lobster diet have included analyses of mature females or juveniles of either sex. This study focused on the diet of male and female West Coast rock lobsters (*Jasus lalandii*) in three size classes (*viz.*: 10 - 35 mm CL (carapace length) - small, 40 - 59 mm CL - medium and 70 - 85 mm CL - large), using visual analyses of stomach contents. The principle aims were to examine potential differences in diet between: (1) male and female rock lobsters; (2) changes in diet with size and (3) a comparison of rock-lobster diet between areas of known fast- and slow-growth rates.

The primary prey items of rock lobsters are shown to be the black mussel (*Choromytilus meridionalis*), ribbed mussel (*Aulacomya ater*), barnacle (*Notomegabalanus algicola*), sea urchin (*Parechinus angulosus*), sponge and crustacean remains. There was no difference in diet between male and female rock lobsters within any size class. Bray-Curtis similarity dendograms and Multi-Dimensional scaling plots revealed differences between small, medium and large rock-lobster diets. Small rock lobsters consumed mainly ribbed and black mussels, whereas medium rock lobsters consumed higher percentages of barnacle and sponge. Sea urchins comprised a substantial percentage of large rock-lobster diet. ANOSIM (Primer v 4.0) established significant differences ($p < 0.05$) amoung diets of the three size classes. Differences in diet were also observed between areas of fast- and slow-growth rates, but these were limited to the small and medium size classes. Key prey items responsible for this difference in diet were black mussel and rock-lobster remains. The gut fullness index decreased with increasing rock-lobster size.

In conclusion, there appears to be no difference in diet between male and female rock lobsters, regardless of their size. However, rock-lobster diet does appear to vary with size. The inverse relationship between gut fullness indices and size, suggests that small rock lobsters, which have a higher moult frequency, feed relatively more frequently than larger rock lobsters. Diet composition plays a role in determining the growth rate of rock lobsters from different areas.

1. Introduction

The West Coast rock lobster, *Jasus lalandii,* is closely related to six other species of the genus *Jasus* all of which are found in cool temperate waters of the southern hemisphere (Pollock 1989). South Africa has a large, intensive rock-lobster fishery with *J. lalandii* being the most important commercial species in southern Africa, yielding the highest current annual tonnage of approximately 2000 tons (SFRI unpubl. data). The total annual catch of rock lobster in South Africa is valued at over R100 million (Pollock 1989) and sustainable utilization of these species will benefit several sectors of this country. Only a comprehensive understanding of these species and strict enforcement of regulations can ensure this.

Numerous studies on the diet of lobsters from around the world have been conducted (Ennis 1973, Carter and Steele, 1982, Joll and Phillips, 1984, Lawton and Lavalli, 1995). Lawton and Lavalli (1995) conducted a thorough study of the postlarval, juvenile, adolescent and adult ecology of the American lobster, *Homarus americanus.* The diet of this species in Bonavista Bay, Newfoundland (Ennis 1973) and it's reproductive cycle (Quackenbush 1994) have also been extensively examined. The primary prey items established were that of the rock crab, *Cancer irroratus,* and the spider crab, *Hyas araneus*. Carter and Steele (1982) conducted a similar study on the diet of immature lobsters this species from Placentia Bay, Newfoundland and found mussels and brittlestars to further contribute to the diet. Both these studies showed the diet to be calcium-rich during the moulting season. Joll and Phillips (1984) compared the diet of juvenile western rock lobsters, *Palinurus cygnus*, at sites of slow- and fast-growth rate, in Western Australia. Few international studies have concentrated on the diet of female lobsters.

Several studies relating to the moult increment and growth rate of *J. lalandii* have been conducted on the West Coast of southern Africa (Goosen and Cockcroft 1995, Melville-Smith *et al* 1995). Further studies concerning the energy requirements for reproduction, comparing that of male and female *J. lalandii* have been carried out by Beyers and Goosen (1987) and Barkai and Branch (1988). The influence of prey size on selection by this species and the related energy expenditure *versus* energy gain have also been examined (Griffiths and Seiderer 1980, Mayfield 1998, Van Zyl *et al.* 1998).

It has been established that there are areas of fast (high) growth and slow (low) growth of *J. lalandii* along the West Coast of southern Africa (Goosen and Cockcroft 1995). The content of the diet influences the energy input and thus the amount of energy available for respiration, reproduction and growth. The importance of the diet in rock lobster populations has led to numerous studies which include investigations of the benthic community in the areas of large rock-lobster populations (Newman and Pollock 1974, Pollock 1979, Griffiths and Siederer 1980, Barkai and Branch 1988, Barkai *et al.* 1996, Mayfield 1998).

The production of eggs requires a greater energy output than reproduction by males and this is why adult males grow faster and larger than females (Barkai and Branch 1988). No study, to my knowledge, has examined the potential change in diet that may accompany this shift in energy channelling.

Juvenile rock lobsters have a higher moult frequency than adults (Heydorn 1969, Pollock 1973) and thus, needing a high energy input, may have different dietary requirements. The size of prey specimens (particularly mussels) influences selection by rock lobsters. Small rock lobsters forage on small mussels thereby reducing energy expenditure and increasing the net gain (Griffiths and Seiderer 1980). The strength and shape of the mussel restricts predation by rock lobsters and limits the type of prey available to juveniles (Pollock 1979, Griffiths and Seiderer 1980).

Dietary studies of rock lobsters are best conducted by analysing the stomach content as described by Berg (1979) and Williams (1981). Combined reports of dietary analyses on *J. lalandii* show that adult rock lobster feed predominantly on ribbed and black mussels (*Aulacomya ater* and *Choromytilus meridionalis*), barnacles (*Notomegabalanus algicola*) and sea urchins (*Parechinus angulosus*, Barkai and Branch 1988, Pollock 1989, Mayfield 1998). Crustacean remains, especially those of *J. lalandii,* also form a significant component of the diet (Barkai *et al.* 1996). Under high-density laboratory conditions, cannibalism of freshly moulted rock lobsters has been observed (Barkai and Branch 1988) and, in their natural environment, rock lobsters have often been observed feeding on exuvia during moulting periods. This may be related to the need to replenish inorganic substances (probably calcium and lime) following ecdysis (Heydorn 1969). Other organisms which supplement the diet of *J. lalandii* include small crustaceans and molluscs, bryozoans, hydrozoans, sponges, polychaetes and small fragments of foliar and coralline algae (Barkai and Branch 1988, Pollock 1989, Mayfield 1998).

A decline in the mean growth increments of *J. lalandii* since the 1989/90 season (Goosen and Cockcroft 1995, Mayfield 1998) has seriously affected the annual catch. The cause of this slow growth is poorly understood and two theories have been postulated to explain it. The first theory suggests that the difference in growth rate amoung areas is due to a reduction in the quantity and quality of the benthic prey species (Newman and Pollock 1974, Pollock 1979, Beyers and Goosen 1987). Pollock *et al* (1997) postulates this change in benthos to be predominantly due to the prevailing environmental conditions of the 1990/1991 *El Niño.* Studies by Newman and Pollock (1974), Beyers and Goosen (1987) and Mayfield (1998) suggest that the availability of food influences the length of foraging time and thus restricts the overall energy gain. This, in turn, limits the growth rate.

The second theory is based on the increased occurrence of oxygen-deficient waters which induce negative physiological effects, hence reducing growth rate of *J. lalandii* (Pollock and Shannon 1987, Tomalin 1993). When exposed to water low in dissolved oxygen *J. lalandii* aggregates at shallow depths where the oxygen content is higher due to increased mixing and wave action (Pollock and Shannon 1987). This forces a greater number of rock lobsters to forage in a smaller area, leading to less food intake per capita, and hence, reduced growth. It is also possible that under conditions of low oxygen, *J. lalandii* simply stops feeding and dies of starvation rather than dying because of a lack of oxygen (Mayfield 1998). Although this theory has prodominantly been observed in *J. lalandii* from Namibia, it may have some relevance to the reduced growth rate of *J. lalandii* in South African waters (S. Mayfield pers. comm.). Consistent decrease in mean annual growth has led to reassessment of all these factors and their effects on rock-lobster growth.

Considerable knowledge has been accumulated on the diet, feeding habits, energy requirements and growth of male *Jasus lalandii* of carapace length 70 - 80 mm (Mayfield 1998). However, information is lacking on the diet of female rock lobsters, juveniles of both sexes and potential size-related changes in diet.

Based on local and international published information on other lobster species, I predict that:

(1) The diet between male and female rock lobsters would differ once sexual maturity is reached due to females requiring more energy for the costly process of egg production.

(2) The diet would differ between juvenile and adult rock lobsters due to the shorter intermoult period and, thus, higher growth rate of juvenile rock lobsters. Therefore might anticipate that juveniles need a higher energy diet.

(3) Both diet and gut fullness indices would be different between rock lobsters at sites of slow- *versus* fast-growth rates.

2. Methods

When possible, 40 male and 40 female rock lobsters in each of three size classes (*viz.*: 10 – 30 mm CL (small); 40 – 59 mm CL (medium) and 70 – 85 mm CL (large)), were collected from five sample sites along the Cape West Coast of South Africa. The large size class incorporates reproductively active individuals. The sites, (*viz.*: Dassen Island, Robben Island, Cape Town Harbour wall, Mouille Point and Olifantsbos; Figure 1) were selected because the growth rate of rock lobsters was known for each. Dassen Island and Mouille Point are fast-growth (FG) sites whereas the three remaining sites are slow-growth (SG, Goosen & Cockcroft 1995, Hazell *et al.* in prep.).

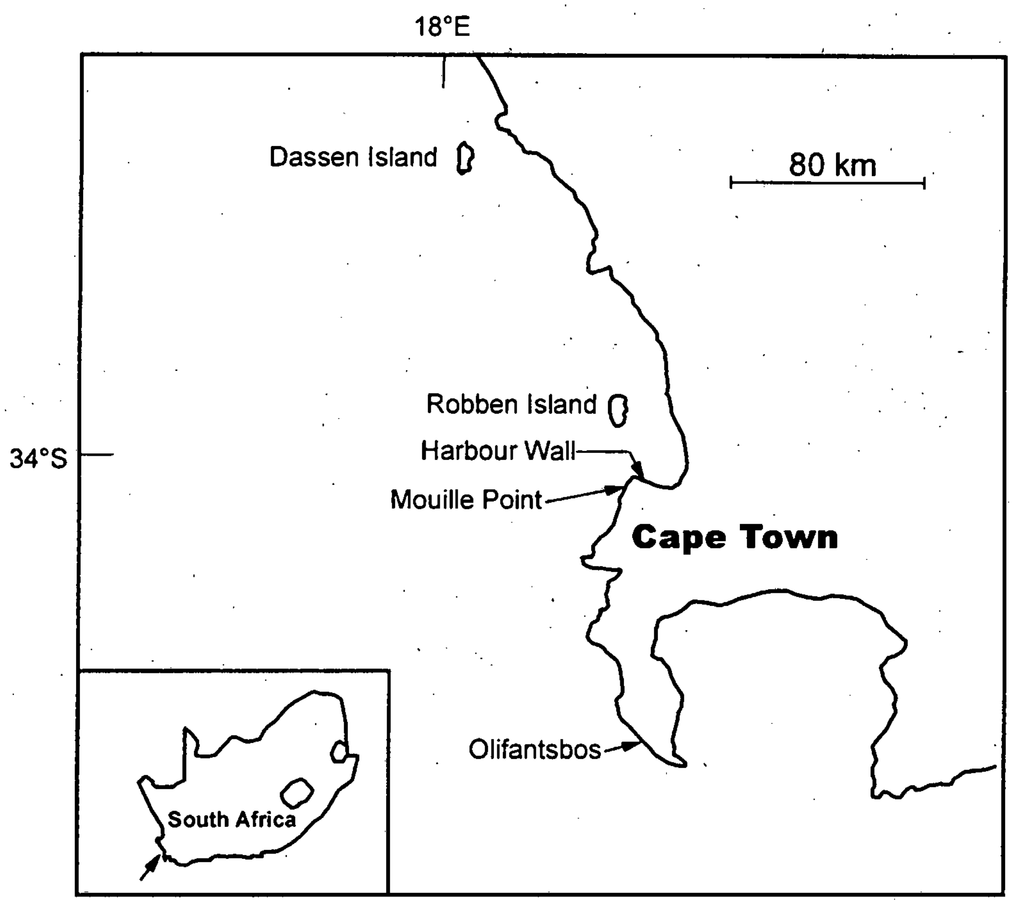

Figure 1: Map of the West Coast of South Africa indicating location of the study sites.

All sites were sampled during May 1998, except Dassen Island which, due to weather constraints, was sampled in August. However, all rock lobsters collected were in the same stage of moult cycle, *i.e.*, intermoult period. All rock lobsters, except for large males from Dassen Island, were collected at dawn using SCUBA in a depth range of between 7 and 15 m. Large male rock lobsters were collected from traps at Dassen Island. The only significant difference in the diet of trap *vs.* SCUBA-caught rock lobsters is that of fish and isopods occurring more frequently in the diet of trap caught rock lobsters (Griffiths 1996). These prey items were absent from the diet of rock lobsters collected from traps. Rock lobsters were anaesthetised by immersion in a water-ice slush, exsanguinated and their stomachs removed. All full stomach samples (defined as > 0.2 g for small, > 1.0 g for medium and > 2.0 g for large) were frozen at –20°C for further analysis. From the sample, the proportion of rock lobsters feeding was calculated by:

inconsistency here.

$$\frac{\text{number of full stomachs obtained}}{\text{number of rock lobsters sampled}} \times 100$$

2.1. Laboratory Analyses:

Stomachs were defrosted, blotted dry and weighed to 0.001g using an electronic balance (Mettler AE 100). The stomach contents were then flushed into a petri dish, the stomach membrane re-weighed and a gut fullness index calculated using the equation:

$$\frac{\text{total stomach weight (g)} - \text{stomach membrane weight (g)}}{\text{total stomach weight (g)}} \times 100$$

Stomach contents were viewed under a Nikon binocular dissecting microscope (8 X magnification). Diagnostic fragments were used to identify prey and each stomach was subjectively assessed in order to estimate the percentage contribution of each prey species relative to the total gut volume (after Hyslop 1980, Williams 1981).

2.2 Statistical Analyses:

Data were analysed primarily using Primer, v4.0 (Plymouth Marine Laboratory, 1994). Bray-Curtis similarity dendograms (following root-root data transformation) and Multi-Dimensional scaling (MDS) plots, based on the percentage contribution to stomach volume, provided an analysis of (1) all size classes for each site, (2) the diet of rock lobsters from different size classes and (3) the diet of rock lobsters at sites of fast- *versus* slow-growth.

The *a priori* hypotheses (H_0: no difference in diet between male and female rock lobsters, between different size-classes or between sites of contrasting growth rates) were tested using Analysis of Similarity (ANOSIM, Primer v4.0, Plymouth Marine Laboratory, 1994). Parallel comparisons could not always be made due to the absence of either male or female rock lobsters in particular size classes at various sites. The specific comparisons conducted are shown in Table 2. ANOSIM provided an indication of the percentage of similarity between grouped classes. SIMPER analysis (Primer v4.0, Plymouth Marine Laboratory, 1994) was used to identify those prey items responsible for the grouping observed in dendograms, MDS plots and ANOSIM.

3. Results

A variety of prey items were found in the stomach of rock lobsters feeding at the study sites. Table 1 concisely summarises the percentage prey items contributed to the stomach volume. Several prey items (polychaete, chiton, brittle star, plastic, string and tar) comprised less than 5 % of the stomach content in any size class of rock lobster and were excluded from any analyses.

Several "rubbish prey" items were consumed at the Harbour wall and Olifantsbos. These items, observed in the stomachs of four individual rock lobsters, included string, plastic and tar. The tar was found in the stomach of a large male rock lobster, while the other "rubbish prey" were found in medium rock lobsters from the Harbour wall. When these items were

Table 1: Summary of all prey items found in all rock-lobster stomachs represented as % frequency of occurrence, with scientific and common name when appropriate.

Species		Size class:			
Scientific name	Common name	small	medium	large	
Parechinus angulosus	sea urchin	2	22	17	
Aulacomya ater	ribbed mussel	78	74	41	‖*
Choromytilus meridionalis	black mussel	77	40	19	
Notomegabalanus algicola	barnacle	49	39	16	
Jasus lalandii remains	rock-lobster remains	4	15	33	
Sponge		40	49	22	
Coralline algae		13	4	10	
Foliose algae		6	21	5	
Crustacean remains		26	28	27	
Mollusc		13	15	8	
Polychaete		2	3	5	
Chiton		1	0	2	
Brittle star		0	0	2	
Plastic		0	1	0	
String		0	0	0	
Tar		0	0	2	

* This is interesting!

The "crushability" of ribbed mussel shells (5g & 12g) was 202 N & 263 N respectively while that for black mussel shells (5g & 12g) was 101 N & 174 N respectively; meaning that ribbed mussels are tougher to crack. (Emma de Beer Hons Project)

Handling times for ribbed mussels were also 2-4 times longer, presumably reflecting this stronger shells.

Calorific content per 2 g dry wt. was insignificantly different between the two mussel species (44.2 & 44.4 kJ/2 g) (Emma's project)

Yet — your table shows that the % frequency occurrence in the diet for medium & large black mussel is significantly lower than that of the ribbed mussel.

Why?

observed, they comprised between 80 and 100% of the stomach contents of the individuals involved.

3.1. Effects of sex on rock-lobster diet: Influence of rock lobster gender on diet ~ a less ambiguous alternative.

The influence of sex on prey composition was negligible with no significant difference being observed between males and females in all three size groups (ANOSIM, $p>0.05$, Table 2). Comparisons between the sexes were limited to particular size-classes at some sites due to low sample numbers in some size catergories. There was clearly no difference in diet between male and female rock lobsters for the three size classes examined.

3.2. Effects of size on rock-lobster diet:

Statistical analyses (ANOSIM) between the various size classes, namely, small *versus* medium and medium *versus* large, showed significant differences ($p<0.05$) in the diet. All comparisons made (Table 2) had high Global R values and a significance level below 0.05, except for the comparison of medium males and large males at Olifantsbos.

Rock lobsters of different sizes had different diets. SIMPER analysis was used to determine the prey species responsible for the dissimilarity between the various size classes. The dietary difference between small and medium individuals at Dassen Island was due to the occurrence of barnacle (*Notomegabalanus algicola)* and sponge contributing a greater percentage to the diet of medium individuals than to that of small individuals. The black mussel (*Choromytilus meridionalis)* and ribbed mussel (*Aulacomya ater)* were more prevalent in the diet of small rock lobsters. Species responsible for the dissimilarity between medium and large male diets at Dassen Island were barnacle (greater prevalence in medium rock-lobster diet) and crustacean remains (greater prevalence in large rock-lobster diet).

The dietary dissimilarity between small and medium rock lobsters at Mouille Point (MP) and the Harbour wall (HW), was due to black mussel being more prevalent in the diet of small individuals (9% medium, 43% small - MP, 10%

Table 2: Comparison of rock-lobster diet between male and female and across three size classes.
H0 = no difference in diet between comparison
H1=difference in diet occurring between comparison made
small = 10 - 35 mm CL, medium = 40 - 59 mm CL, large = 70 - 85 mm CL

Site	Sex Comparison	Global R	p	Reject H0
Dassen Island	small male vs small female	-0.14	> 0.05	No
Mouille Point	small male vs small female	-0.02	> 0.05	No
Harbour wall	small male vs small female	-0.02	> 0.05	No
Dassen Island	medium male vs medium female	0.047	> 0.05	No
Mouille Point	medium male vs medium female	0.06	> 0.05	No
Olifantsbos	medium male vs medium female	-0.026	> 0.05	No
Harbour wall	medium male vs medium female	-0.003	> 0.05	No
Robben Island	medium male vs medium female	0.088	> 0.05	No
Robben Island	large male vs large female	-0.052	> 0.05	No

Site	Size Comparison	Global R	p	Reject H0
Dassen Island	small vs medium	0.547	< 0.01	Yes
Mouille Point	small vs medium	0.215	< 0.01	Yes
Harbour wall	small vs medium	0.081	< 0.01	Yes
Dassen Island	medium male vs large male	0.542	< 0.01	Yes
Olifantsbos	medium male vs large male	0.0133	> 0.05	No
Robben Island	medium female vs large female	0.568	< 0.01	Yes
Robben Island	medium male vs large male	0.307	< 0.01	Yes

Table 3: Shannon-Wiener Index of Diversity for diet of *Jasus lalandii*.
small = 10 - 35 mm CL, medium = 40 - 59 mm CL, large = 70 - 85 mm CL

Site	Growth rate	small	medium	large
Dassen Island	fast growth	0.83	1.29	0.49
Mouille Point	fast growth	0.87	0.95	0.33
Olifantsbos	slow growth	2.71	0.36	0.11
Harbour Wall	slow growth	0.58	0.62	0.11
Robben Island	slow growth	0.37	0.85	0.35

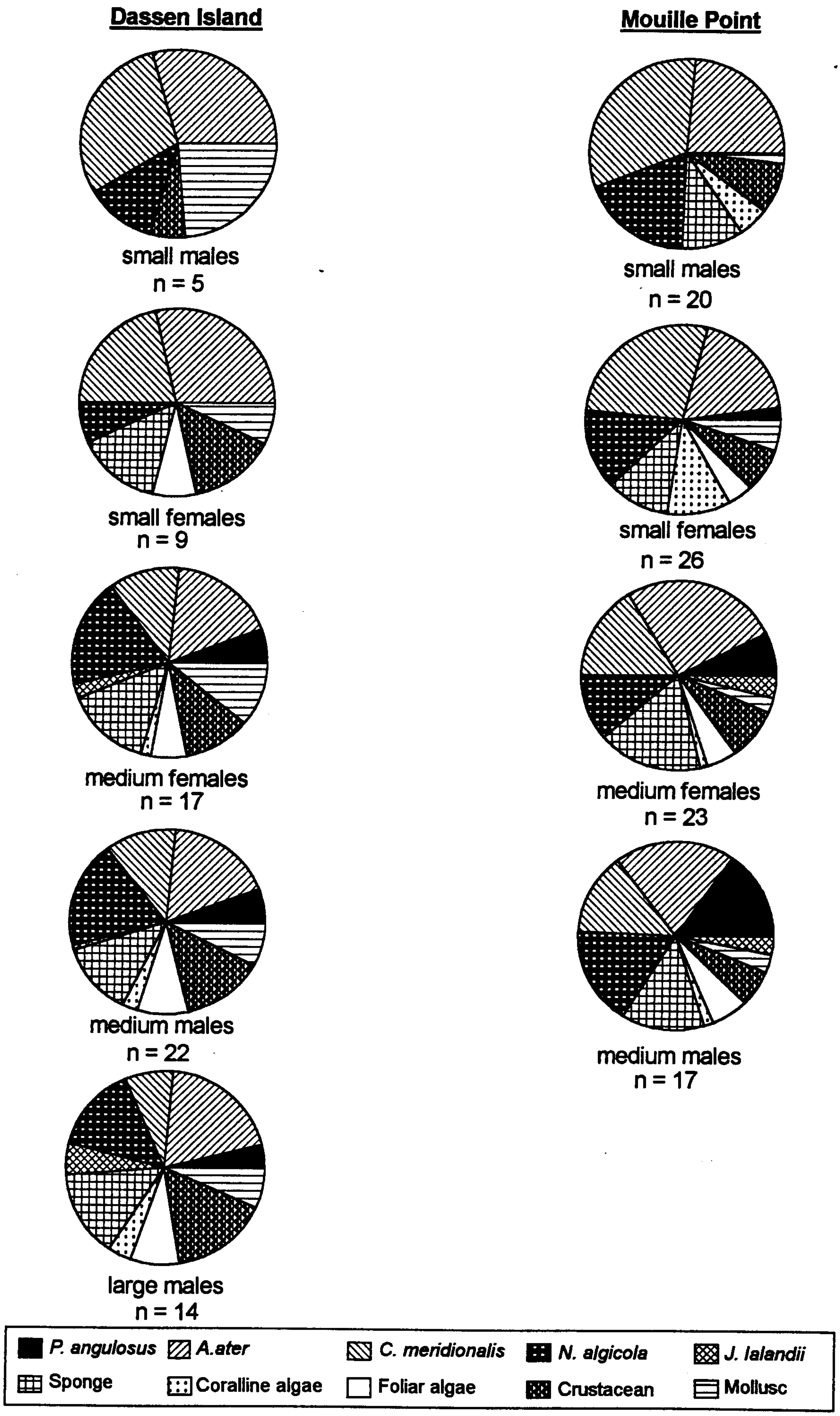

Figure 2: Diet, by frequency of occurrence, of *J. lalandii* sampled at fast-growth sites of Dassen Island and Mouille Point (n = sample size).

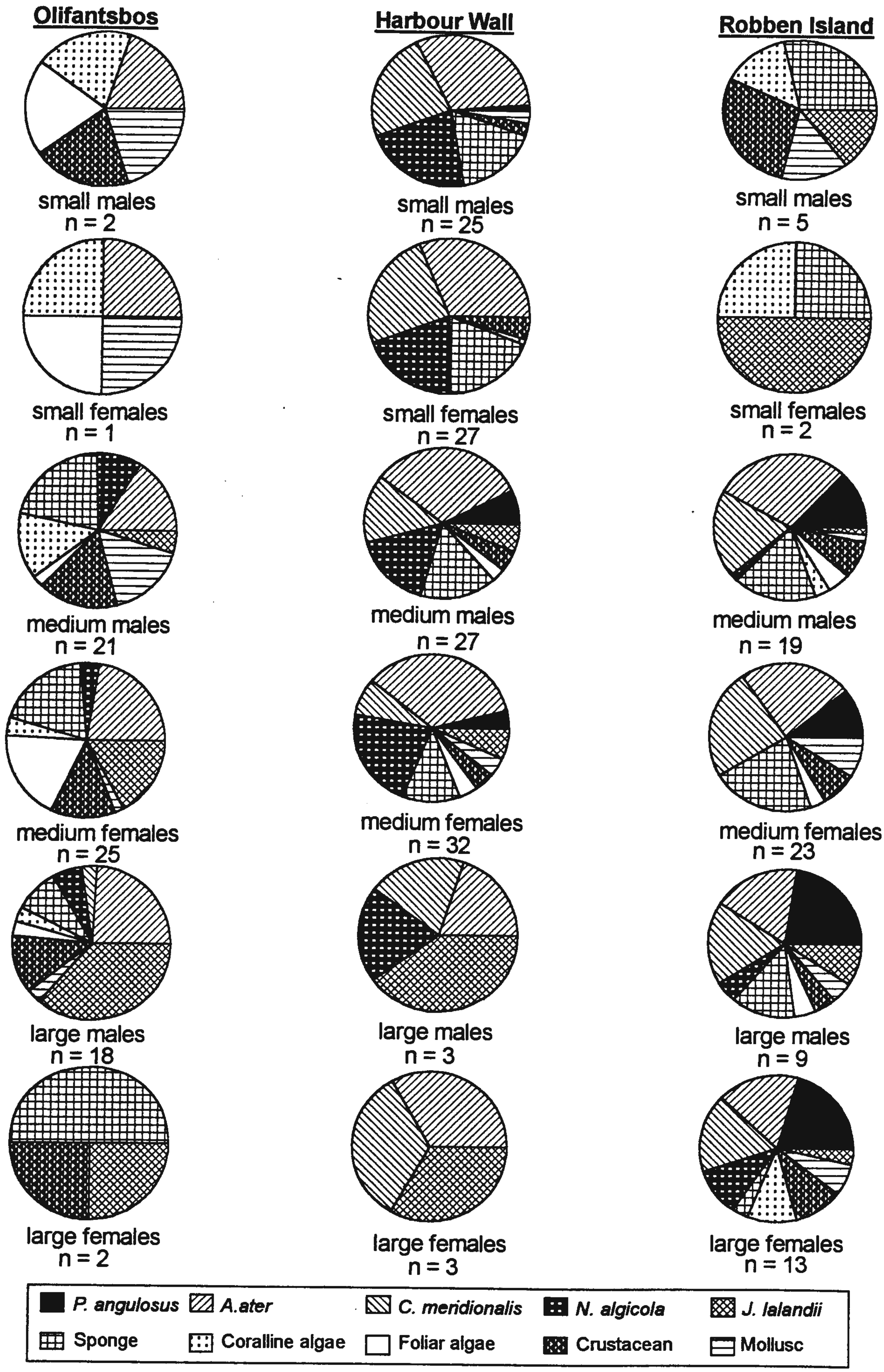

Figure 3: Diet, by frequency of occurrence, of *J. lalandii* sampled at slow-growth sites of Olifantsbos, Cape Town harbour wall and Robben Island (n = sample size).

Too many to take in.

medium, 19% small - HW). Sponge occurred more frequently in the diet of medium individuals (20% medium, 8% small - MP, 16% medium, 12% small - HW).

The dietary difference between large and medium rock lobsters at Robben Island was due to ribbed mussel, black mussel and sponge being more prevalent in the diet of medium individuals while sea urchin (Parechinus angulosus) were more abundant in large rock lobster diet.

Data analyses, however, had high stress levels associated with the two-dimensional MDS plots (0.18 to 0.24) and are potentially dangerous to interpret (Clarke and Warwick 1994). The high stress level prevents much emphasis being placed on these two dimentional groupings and the groupings observed can be considered loose or weak (Figures 6 to 13). The stress levels associated with potential three dimentional MDS plots were also observed to be high and for simplicity, only two dimentional plots were presented. The most obvious pattern was displayed by rock lobsters at Dassen Island (Figures 4 & 5), for which there were relatively clearly defined clusters of small, medium and large rock lobsters.

At all sites sampled, except for Olifantsbos, the diversity of diet (Shannon-Wiener Index of Diversity) increased from small to medium size class of rock lobster, and decreased from medium to large (Table 3). Small rock lobster sample numbers at Olifantsbos were low (n = 2, n = 1), which may be responsible for this anomaly. At all sites examined, sea urchin and rock-lobster remains were minimal in the diet of small individuals, increasing in occurrence from medium to large individuals (Figures 2 & 3).

3.3. Gut fullness index and percentage feeding:

The gut fullness index of rock lobsters sampled, decreased with increasing size at four of the fives sites studied (Table 4, excluding n = 1). At Robben Island the medium size class had a higher gut fullness index than either the small or large classes.

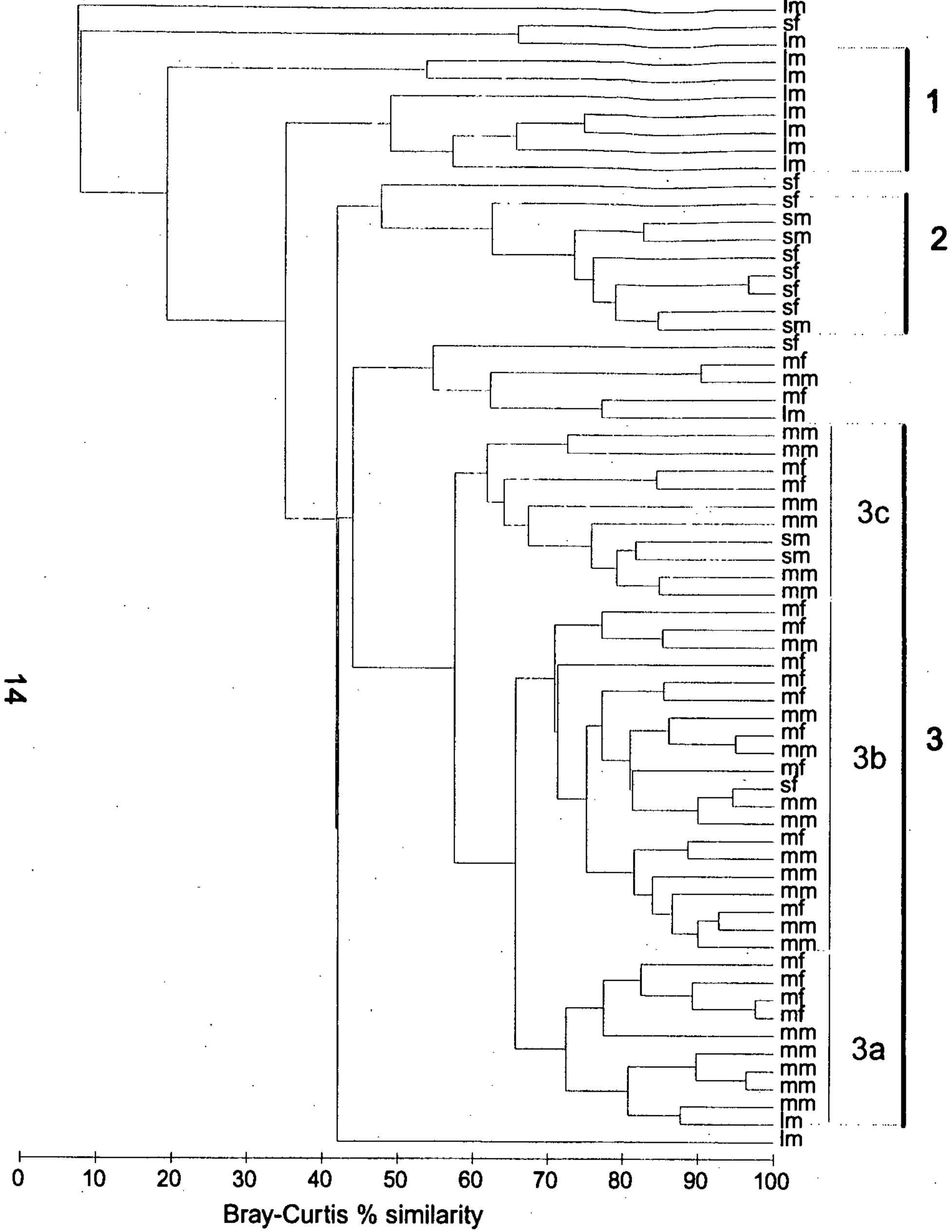

Figure 4: Bray-Curtis similarity dendogram based on the percentage prey items observed in the stomach contents of rock lobsters collected from Dassen Island. Coding :sm = small males; sf = small females; mm = medium males; mf = medium females; lm = large males; lf = large females.

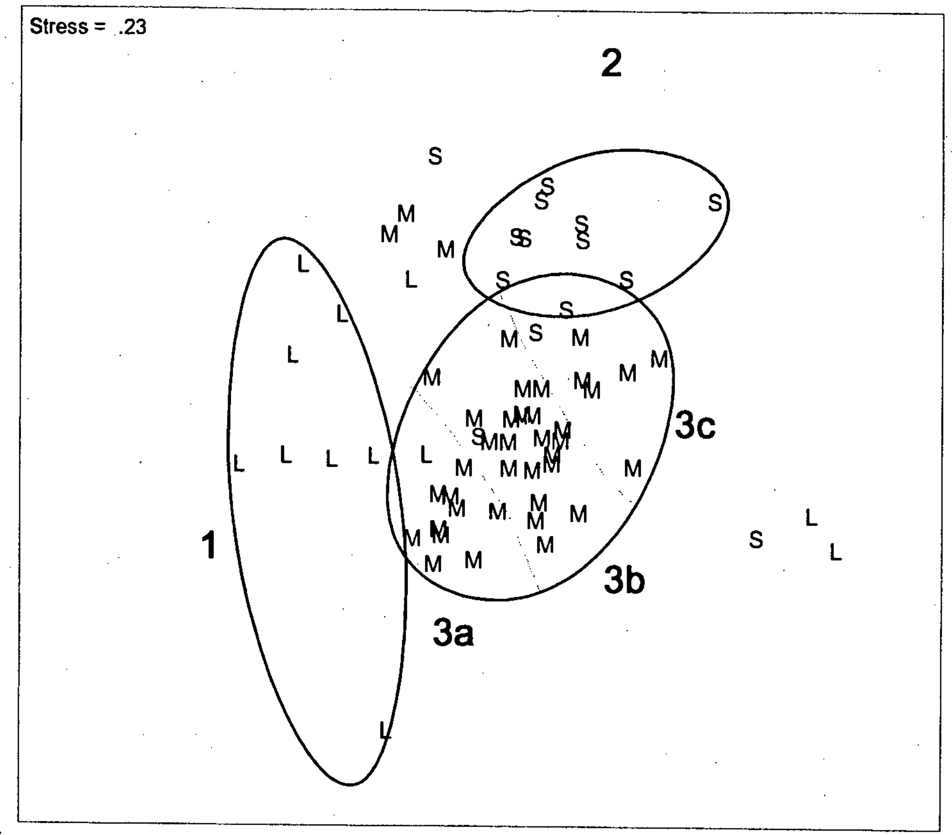

Figure 5: Multi-Dimentional scaling plot to show groupings of rock-lobster stomach contents from rock lobsters collected at Dassen Island.
Group numbers correspond to Figure 4.

1 = Diet of large rock lobsters
2 = Diet of small rock lobsters
3 = Diet of medium rock lobsters, **a**,**b** and **c** = subgroups of **3**
S = small rock lobsters; M = medium rock lobsters; L = large rock lobsters.

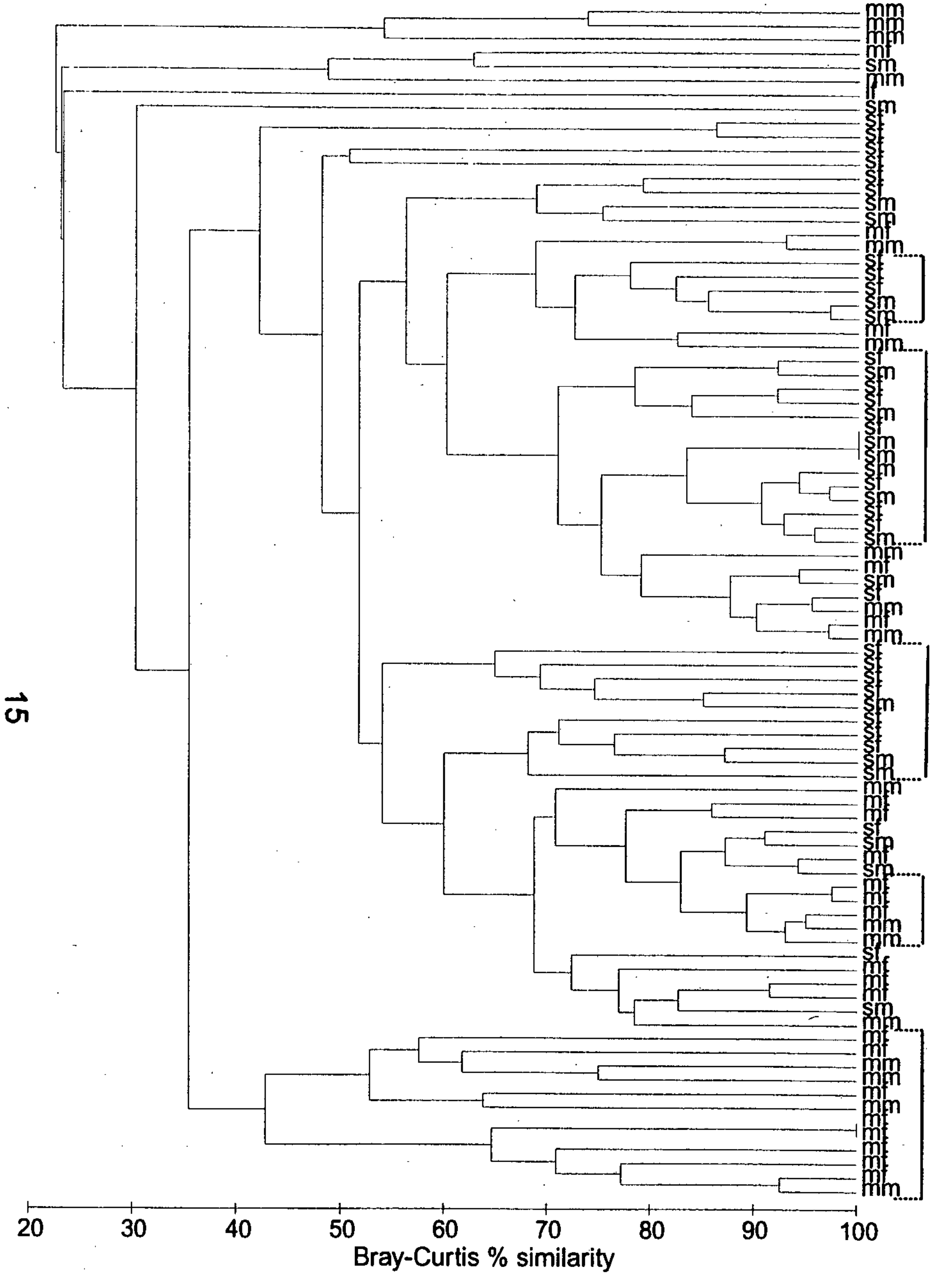

Figure 6: Bray-Curtis similarity dendogram based on the percentage prey items observed in the stomach contents of rock lobsters collected from Mouille Point. Coding: sm = small males; sf = small females; mm = medium males; mf = medium females; lm = large males; lf = large females.

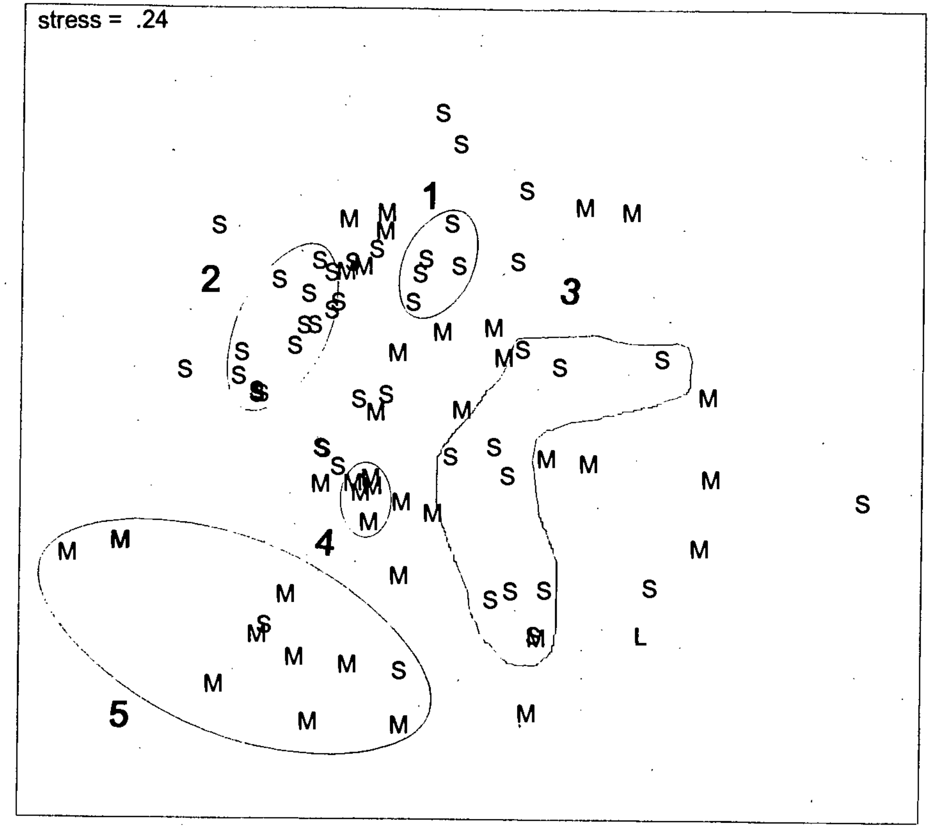

Figure 7: Multi-Dimentional scaling plot to show groupings of rock-lobster stomach contents from rock lobsters collected as Mouille Point.
Group numbers correspond to Figure 6.
1, **2** and **3** = Diet of small rock lobsters
4 and **5** = Diet of medium rock lobsters
S= small rock lobsters; M = medium rock lobsters; L = large rock lobsters.

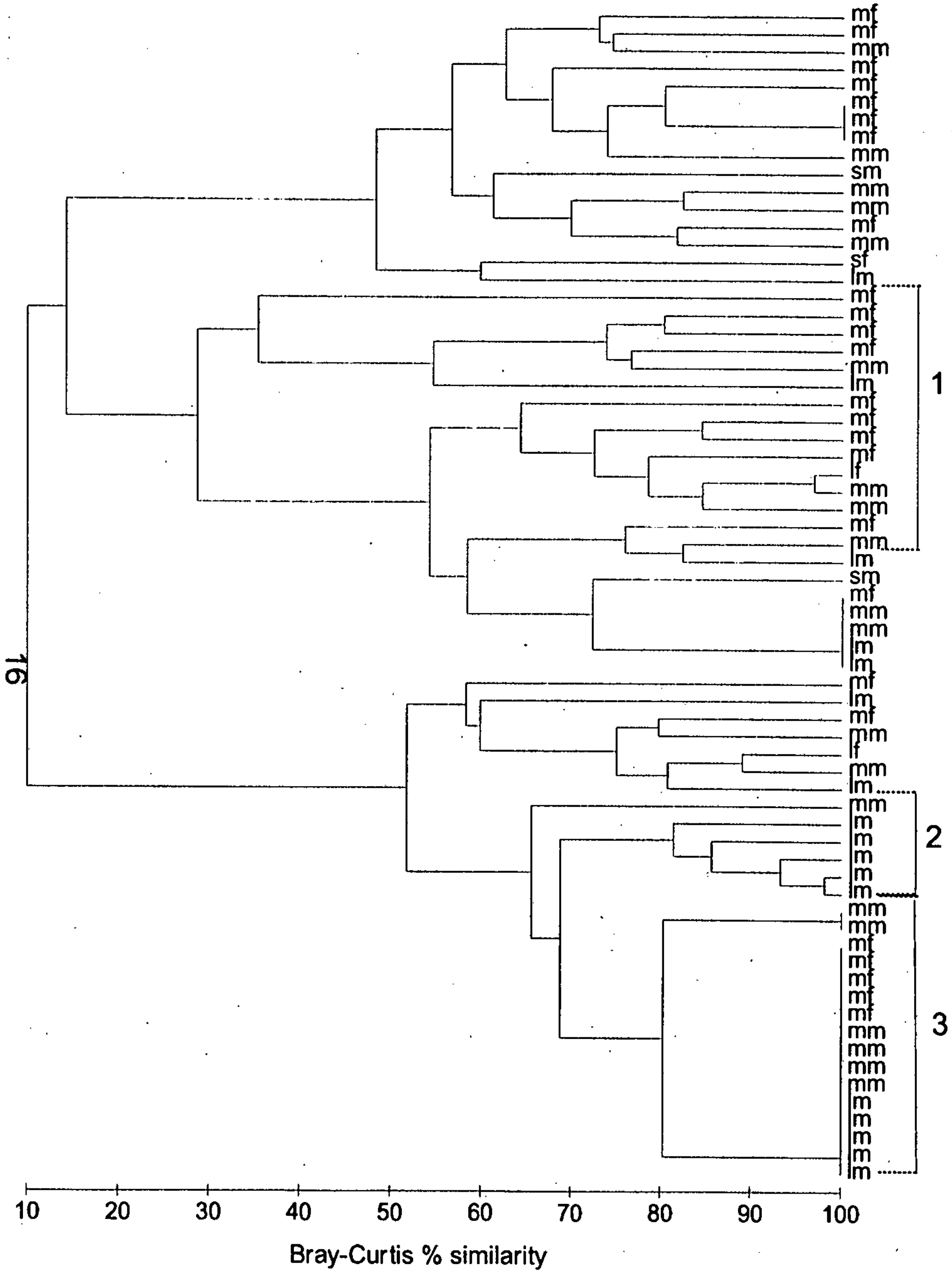

Figure 8: Bray-Curtis similarity dendogram based on the percentage prey items observed in the stomach contents of rock lobsters collected from Olifantsbos. Coding: sm = small males; sf = small females; mm = medium males; mf = medium females; lm = large males; lf = large females.

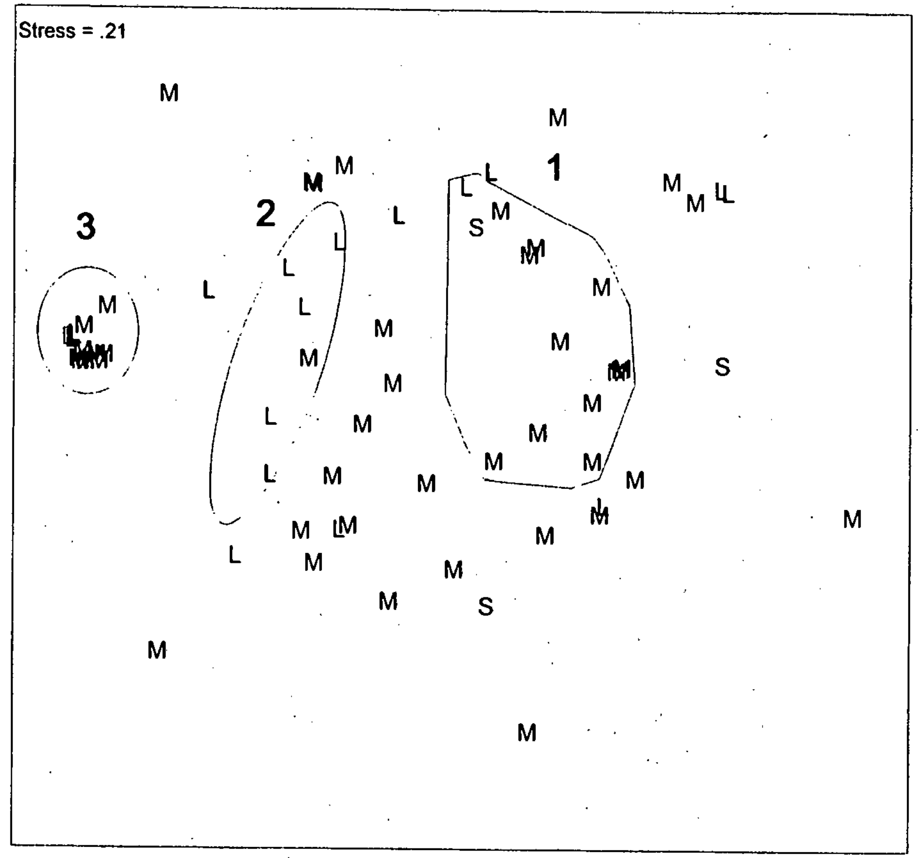

Figure 9: Multi-Dimentional scaling plot to show groupings of rock-lobster stomach contents from rock lobsters collected at Olifantsbos.
Group numbers correspond to Figure 8.
1 = Diet of medium rock lobsters
2 = Diet of large rock lobsters
3 = Diet of predominantly medium rock lobsters
S = small rock lobsters; M = medium rock lobsters; L = large rock lobsters.

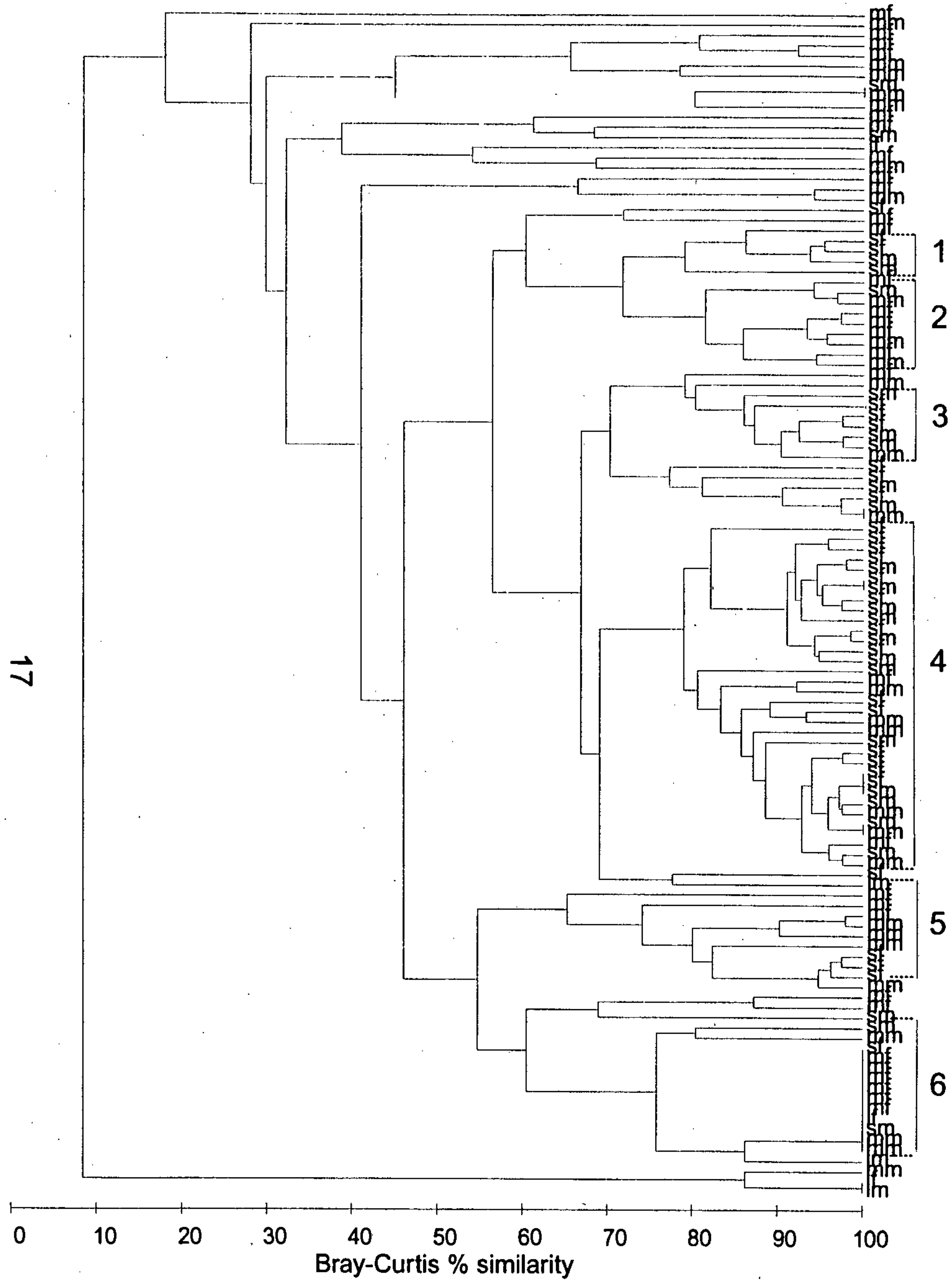

Figure 10: Bray-Curtis similarity dendogram based on the percentage prey items observed in the stomach contents of rock lobsters collected from Cape Town Harbour wall. Coding: sm = small males, sf=small females; mm = medium males; mf = medium females; lm = large males; lf = large females.

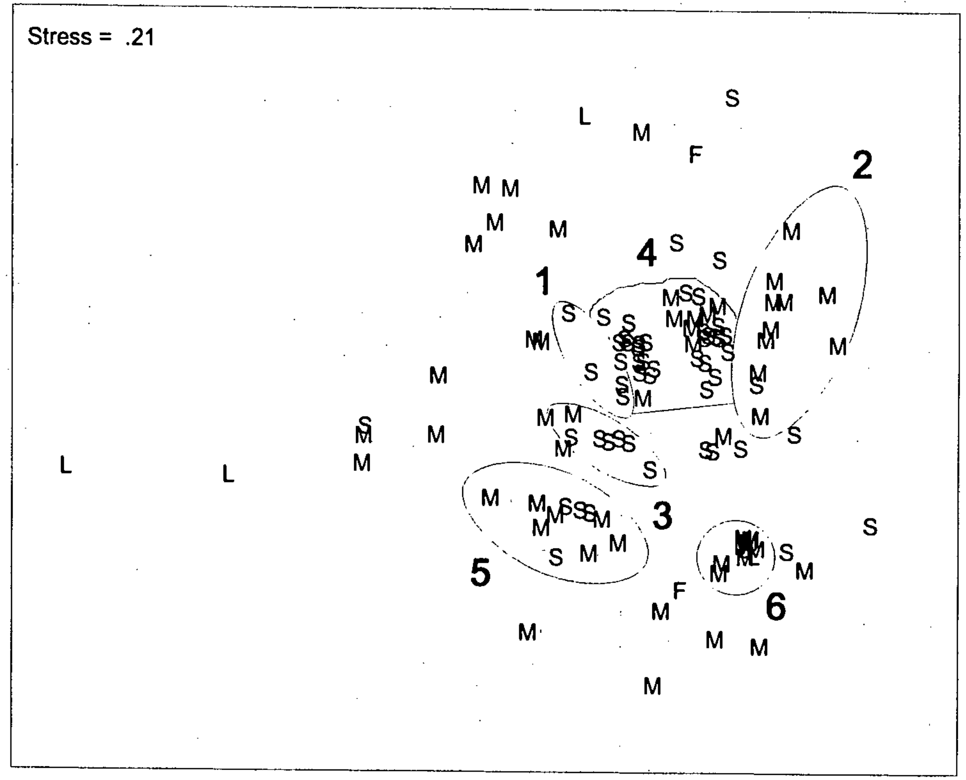

Figure 11: Multi-Dimentional scaling plot to show groupings of rock-lobster stomach contents from rock lobsters caught at Cape Town Harbour wall. Group numbers correspond to Figure 10.

1, **3** and **4** = Diet of small rock lobsters

2, **5** and **6** = Diet of medium rock lobsters

S = small rock lobsters; M = medium rock lobsters; L = large rock lobsters.

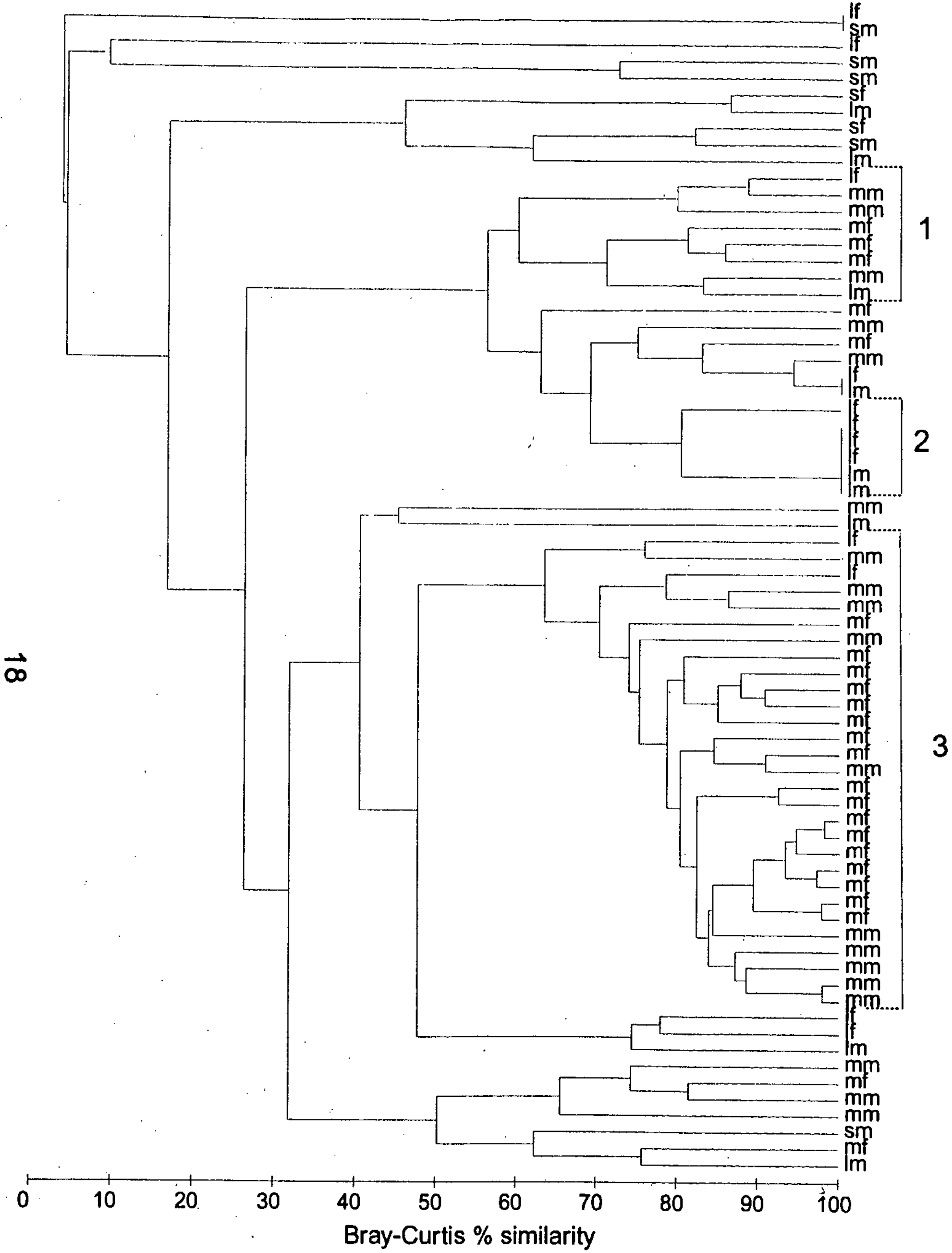

Figure 12: Bray-Curtis similarity dendogram based on the percentage prey items observed in the stomach contents or rock lobsters collected from Robben Island. Coding: sm = small males; sf = small females; mm = medium males; mf = medium females; lm = large males; lf = large females.

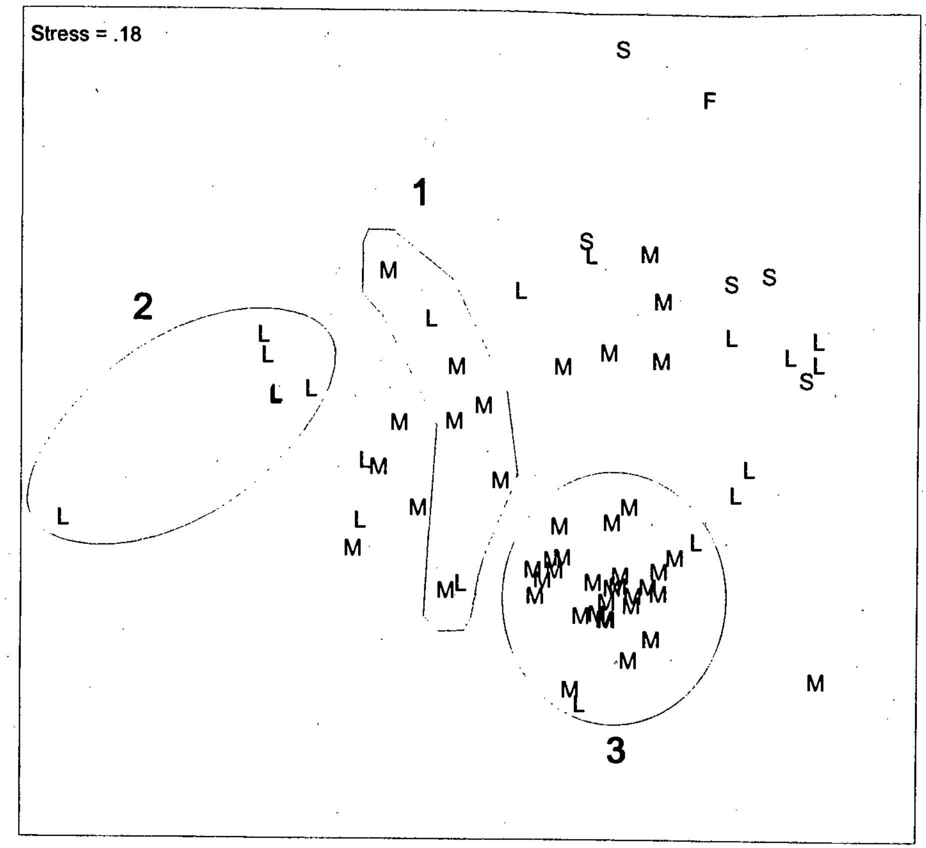

Figure 13: Multi-Dimentional scaling plot to show groupings of rock-lobster stomach contents from rock lobsters collected at Robben Island.
Group numbers correspond to Figure 12.
1 and **3** = Diet of medium rock lobsters.
2 = Diet of large rock lobsters.
S = small rock lobsters; M = medium rock lobsters; L = large rock lobsters.

The percentage of lobsters feeding at each site did not show any distinct trends and the average percentage feeding in each size class was similar (Table 4).

3.4. Dietary differences in relation to growth rate of small rock lobsters:

The diet of small individuals from Mouille Point (FG) and Harbour wall (SG) were compared to assess possible diet dissimilarity between rock lobsters from fast and slow-growth areas. The dendogram and associated MDS plot (Figures 14 & 15) showed limited grouping of fast- or slow-growth diet samples, suggesting that there was little difference in diet of small rock lobsters in fast-, compared to slow-growth areas.

Nevertheless, there was a significant difference in diet between small individuals at the fast-growth and slow-growth site (ANOSIM, Global $R = 0.168$, $p<0.05$). The difference in diet between rock lobsters at the two sites was shown to be primarily due to a higher abundance of ribbed mussels occurring in the diet of individuals from the fast growth Mouille Point site (50%) compared with that at the slow-growth Harbour wall site (21%). The black mussel occurred more frequently in individuals found at the Harbour wall (43%) relative to those at Mouille Point (18%).

There was no difference in the gut fullness index observed at the two sites for the small individuals (Table 4). Diet diversity (Shannon-Wiener index) was higher at Mouille Point (0.87) than at the Harbour wall (0.58, Table 3).

3.5. Dietary differences in relation to growth rate of medium rock lobsters:

Due to a significant difference between the diets of medium-sized rock-lobsters at the two slow-growth sites, Harbour wall and Olifantsbos (ANOSIM, Global $R = 0.38$ $p < 0.05$), dietary comparisons between sites of fast- and slow-growth rates were conducted between Harbour wall (SG) and Mouille Point (FG) and, separately between Olifantsbos (SG) and Dassen Island (FG). The Harbour wall *versus* Mouille Point dendogram and MDS

Table 4: Dietary summary of *Jasus lalandii* from five selected sites.
FG = fast growth, SG = slow growth
small = 10 - 35 mm CL, medium = 40 - 59 mm CL, large = 70 - 85 mm CL

				Gut Fullness Index			
Site	Growth Rate	Size	Sex	Mean	SE	sample size	% feeding
Dassen Island	FG	small	male	43.76	5.84	5	35.7
		small	female	39.05	6.10	9	45.0
		medium	male	41.03	2.42	22	51.2
		medium	female	37.00	2.87	17	39.5
		large	male	31.37	5.21	14	35.0
		large	female	All in berry	-	-	-
Mouille Point	FG	small	male	56.02	3.21	20	69.0
		small	female	57.07	3.16	26	65.0
		medium	male	49.81	4.31	17	42.5
		medium	female	42.53	3.64	23	57.5
		large	female	41.28	-	1	33.3
Olifantsbos	SG	small	male	68.49	1.56	2	50.0
		small	female	24.09	-	1	25.0
		medium	male	38.62	4.09	21	52.5
		medium	female	31.60	3.48	25	62.5
		large	male	40.83	5.62	18	40.9
		large	female	26.22	9.03	2	40.0
Harbour Wall	SG	small	male	53.45	3.35	25	62.5
		small	female	61.01	2.88	27	62.8
		medium	male	37.10	4.71	27	64.3
		medium	female	40.31	3.85	32	80.0
		large	male	50.69	23.42	3	60.0
		large	female	21.93	12.49	3	75.0
Robben Island	SG	small	male	33.70	7.46	5	50.0
		small	female	36.46	15.70	2	40.0
		medium	male	45.54	3.88	19	47.5
		medium	female	45.73	2.44	23	57.5
		large	male	40.04	7.84	9	60.0
		large	female	38.33	4.64	13	29.5

Total # sampled:		779
Total full stomachs:		411
Average % feeding	small	50.5
Average % feeding	medium	55.5
Average % feeding	large	45.9
	Average	51.2

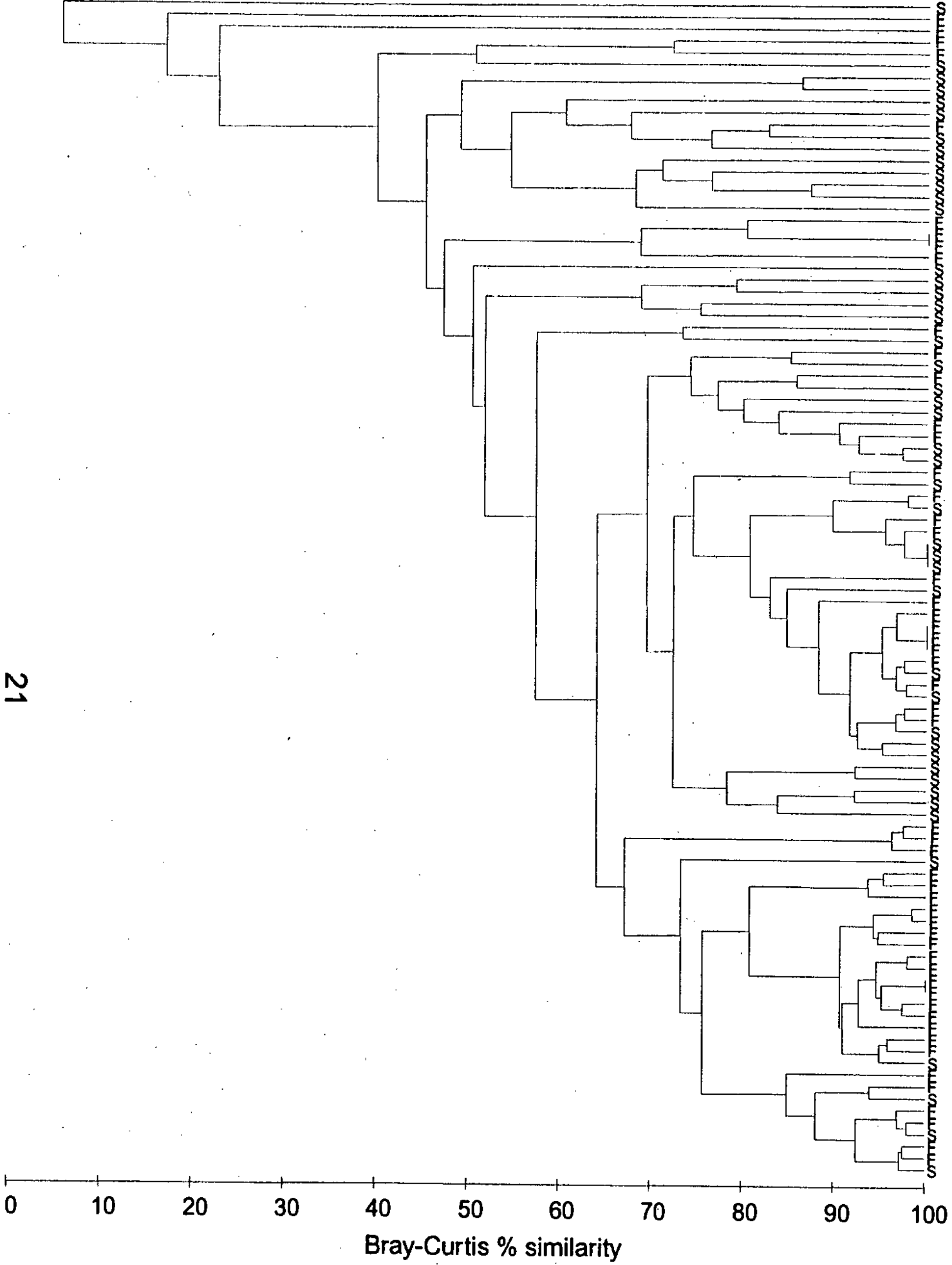

Figure 14: Bray-Curtis similarity dendogram based on the percentage of prey items observed in the stomach contents of small rock lobsters collected from Mouille Point (F - fast growth) and Cape Town harbour wall (S - slow growth).

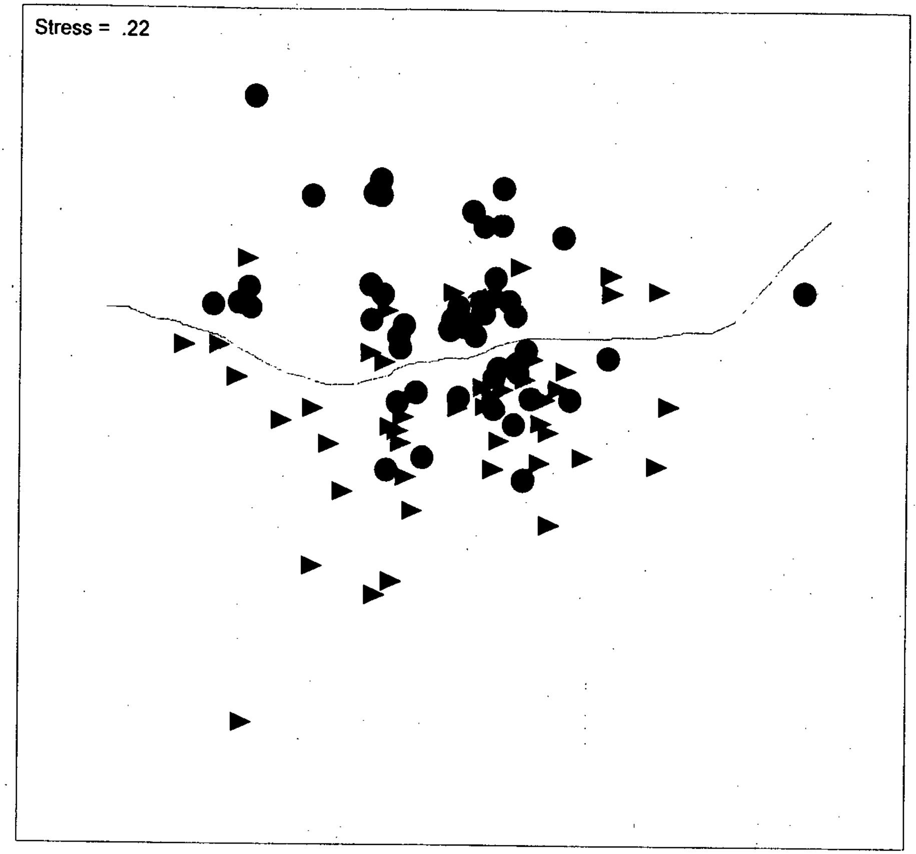

Figure 15: Multi-Dimentional scaling plot indicating small rock-lobster stomach contents from rock lobsters collected from Mouille Point (FG) and Cape Town harbour wall (SG).

● = Diet of rock lobsters from fast growth site.

► = Diet of rock lobsters from slow growth site.

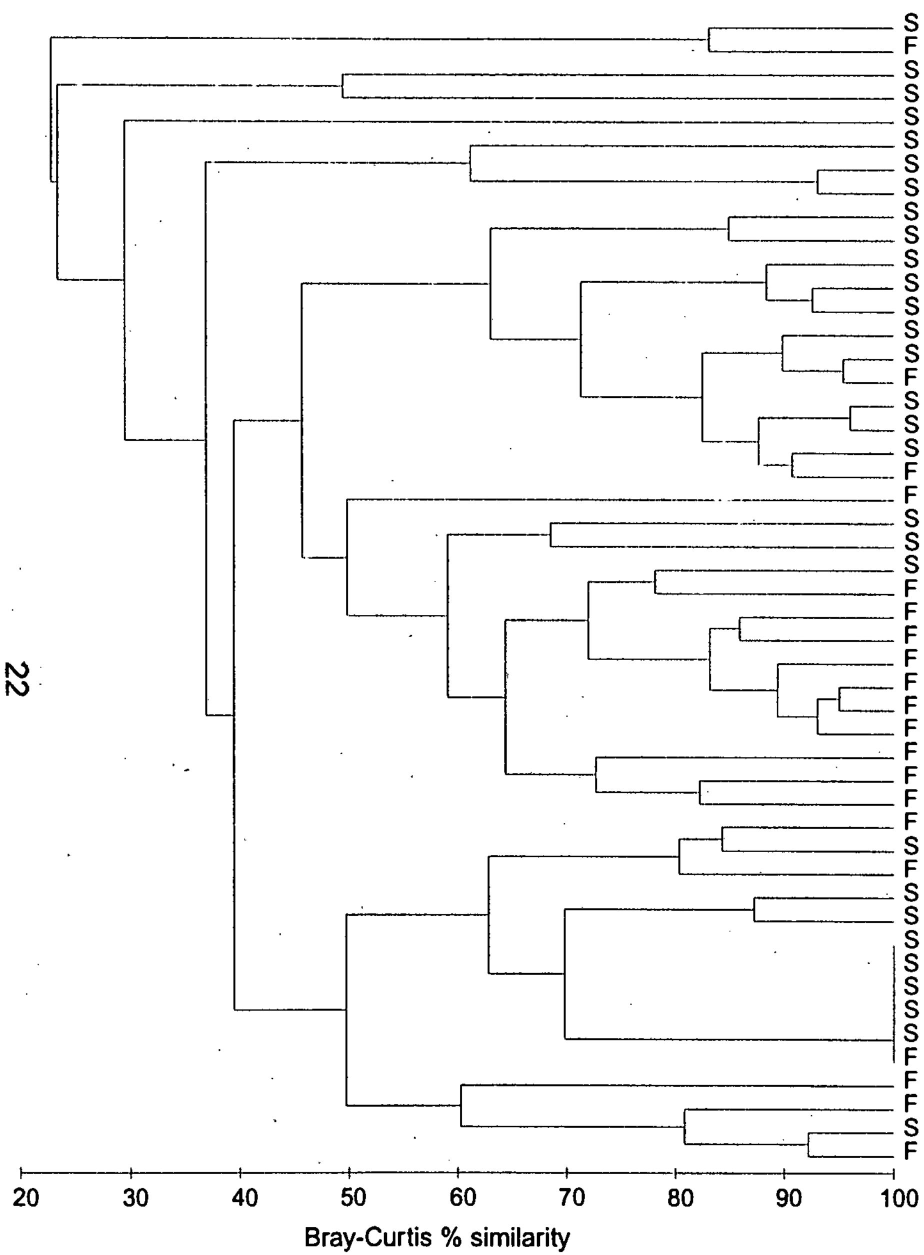

Figure 16: Bray-Curtis similarity dendogram based on the percentageprey items observed in the stomach contents of medium rock lobsters collected from Mouille Point (F - fast growth) and Cape Town harbour wall (S -slow growth).

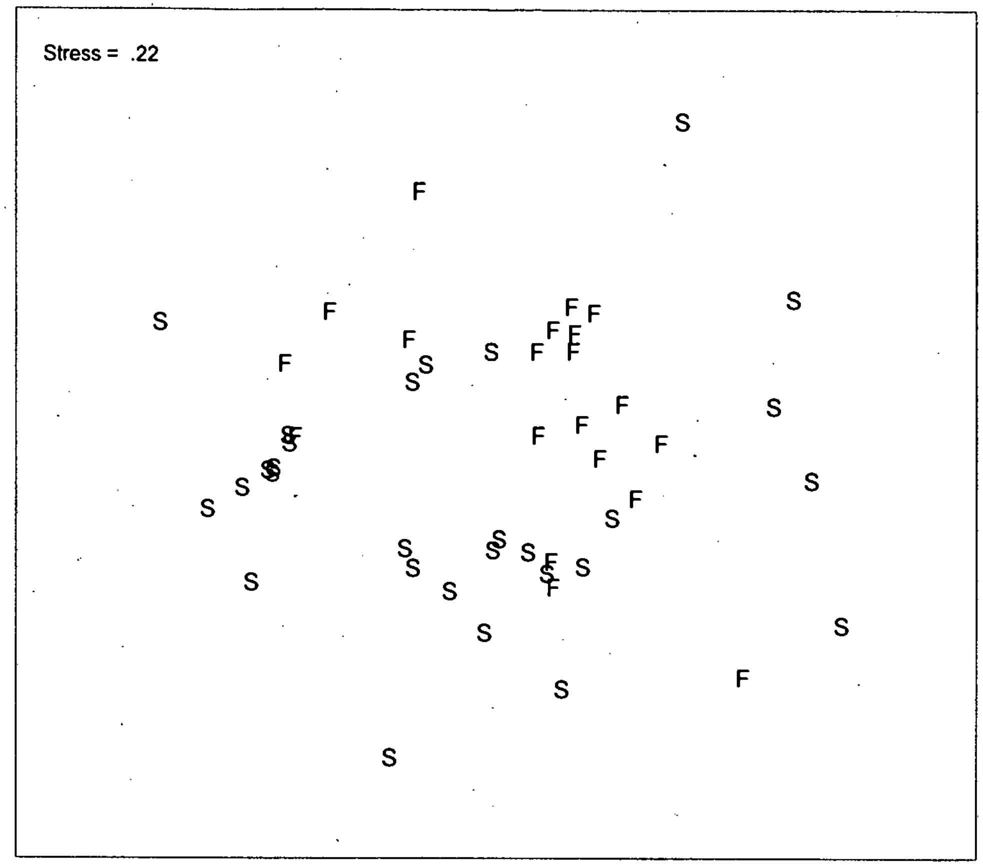

Figure 17: Multi-Dimentional scaling plot indicating medium rock-lobster stomach contents from rock lobsters collected from Mouille Point (F) and Cape Town harbour wall (S).

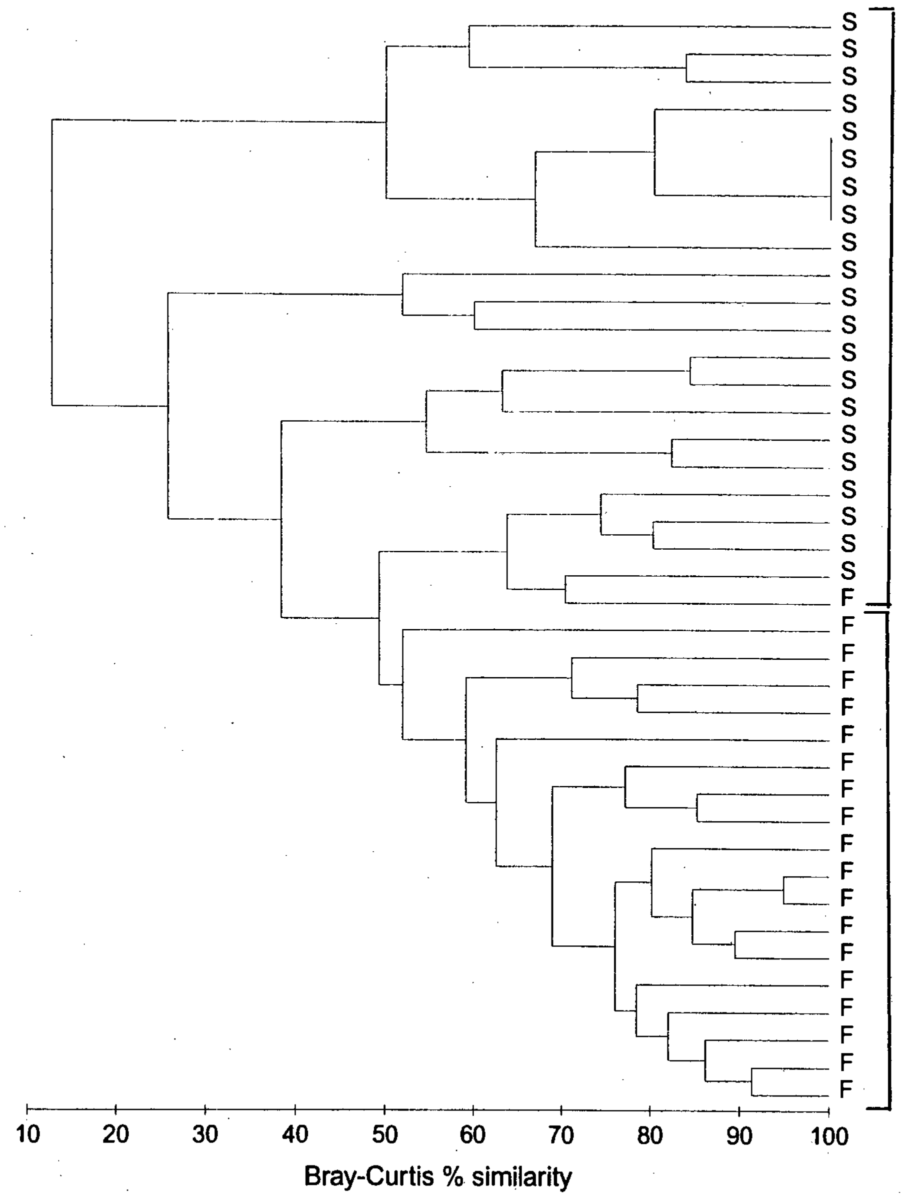

Figure 18: Bray-Curtis similarity dendogram based on the percentage prey items observed in the stomach contents of medium rock lobsters collected from Dassen Island (F - fast growth) and Olifantsbos (S - slow growth).

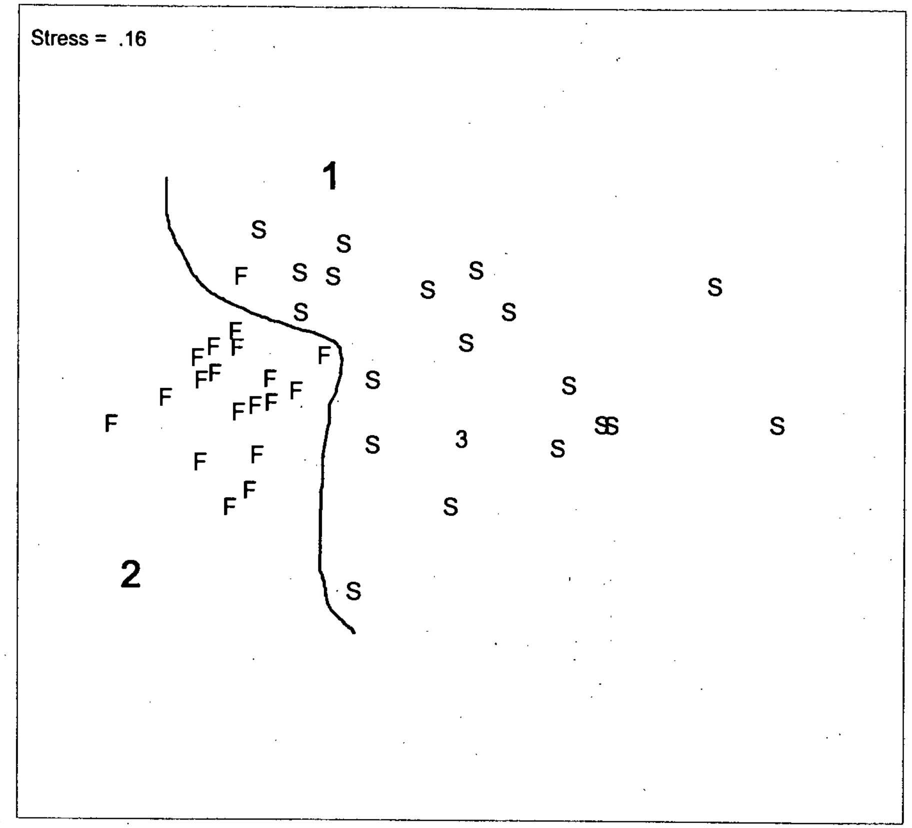

Figure 19: Multi-Dimentional scaling plot indicating medium rock-lobster stomach contents from rock lobsters collected from Dassen Island (F) and Olifantsbos (S).

comparison yielded no clear groupings of FG and SG individuals (Figure 16 & 17). ANOSIM analyses further showed no significant difference in diet at these two sites (Global R = 0.09, p> 0.5).

The comparison of diet between medium-sized rock lobsters at Olifantsbos (SG) *versus* Dassen Island (FG) showed a distinct grouping of individuals into the two sites (Figures 18 & 19). Both the dendogram and MDS plot of this comparison showed that except for one individual, group **1** consisted entirely of individuals from the slow-growth site while all individuals from the fast-growth site were in group **2**. The stress level of this plot is low (0.16) providing reliable interpretation. ANOSIM analyses showed a statistical difference between the diet of rock lobsters at these two sites (Global R = 0.418, p<0.05). SIMPER analyses showed this difference to be due to substantially more rock-lobster remains being found at the slow-growth site, 33%, *versus* 1% at the fast-growth site. Barnacle (21% FG, 1% SG), and mussels (ribbed mussel - 10% FG, 0% SG and black mussel - 17% FG, 4% SG) were found to be more prevalent in the diet of medium rock lobsters at the fast-growth site.

The gut fullness index of medium rock lobsters at the four sites, showed no substantial difference between fast- (42% ± 3.3) and slow-growth (36% ± 4.0) sites (derived from Table 4). The index of diversity (Shannon-Wiener index) shows a higher diversity of prey items at fast-growth sites (1.29 and 0.95) compared to that of slow-growth sites (0.36 and 0.62, Table 3).

4. Discussion

Results from the dietary analyses of *Jasus lalandii* in the current study were similar to that of previous similar investigations (Heydorn 1969, Newman and Pollock 1974, Pollock 1979, Barkai *et al.* 1996). The diet was dominated by mussels (both species of mussel) with substantial contributions of barnacle, sponge and crustacean remains (Table 1). Coralline algae, as a prey species for *J. lalandii*, plays a less dominant role in this study than that observed by Mayfield (1998). The low abundance of sea urchin remains in the rock-lobster diet, observed in this study, was similar to that of previous studies (Pollock 1979, Barkai *et al.* 1996). Mayfield (1998) however, observed a comparitively high preference for sea urchin.

The data collected in this study can be used to answer several questions relating to the diet of rock lobsters and the influence on growth rates. The conclusions drawn from the results may be limited by small sample numbers which, on occasion, were unavoidable. The hypotheses investigated were that: (1) A change in diet should occur between males and females once they are sexually mature (large size class). (2) The diet should differ between juvenile and adult rock lobsters. (3) Both diet and gut fullness indices would be different between rock lobsters at sites of slow- versus fast-growth rates.

Influence of Sex on rock-lobster diet.

The results obtained from this study clearly indicate that there are no significant differences (ANOSIM, $p > 0.05$) in diet between male and female rock lobsters of the same size within all the size-classes and sites studied (Table 2). These data fail to support the initial hypothesis, that a change in diet will occur between male and female rock lobsters upon reaching sexual maturity. There is no noticeable increase in higher energy foods in the diet of sexually mature female rock lobsters. This further supports the findings of Beyers and Goosen (1987) and Barkai and Branch (1988) who established that female rock lobsters allocate less energy to growth when they start producing eggs. Thus mature females probably continue to have similar overall energy and food requirements to mature males, simply channelling relatively more energy into reproduction rather than into growth. ✓

For a given age, female rock lobsters should therefore be smaller?

Influence of Size on rock-lobster diet.

At three of the five sites studied (Dassen Island, Mouille Point and Harbour wall), ribbed mussel, black mussel and barnacle made up approximately 75% of the diet of small rock lobsters. The absence of mussels (both species) from the diet of small rock lobsters at Robben Island may provide an explanation for the increase in rock-lobster exuvia consumed at this site.

Juvenile rock lobsters have a faster growth rate than adults (Pollock 1979) and moult more frequently (Pollock 1973, Beyers *et al.* 1994, Mayfield 1998). A high energy input would be required for rapid growth along with higher inorganic constituents (calcium and lime) in order to facilitate moulting (Heydorn 1969, Barkai *et al.* 1996, Mayfield 1998). At other sites, this can be provided by the mussel and barnacle component of the diet, while at Robben Island, lobster exuvia may serve this purpose.

The data support the second hypothesis of a change in diet occurring with increasing size. The results clearly show that with an increase in size, there is a significant change in rock-lobster diet (ANOSIM, $p<0.05$, Table 2). Small individuals consume a greater percentage of ribbed and black mussels while the diet of medium-sized rock lobster contained greater percentages of barnacle and sponge (SIMPER).

The medium *versus* large comparisons also show a distinct difference in diet at the sites where comparisons were possible. Medium individuals at Dassen Island fed on barnacle and sponge more frequently than large individuals. A similar comparison at Robben Island showed medium individuals to consume more sponges, ribbed and black mussels while sea urchins were more heavily preyed upon by larger individuals (SIMPER).

It is known that large rock lobsters consume larger prey items and rock lobsters select prey requiring the least energy expenditure and yielding the highest gain. Smaller rock lobsters are unable to handle large prey items (Griffiths and Seiderer 1980) and in this way, small rock-lobster diet is limited. This may provide an explaination for the difference in rock-lobster diet observed with an increase from small to large size classes.

At all represented sites, there was an increase in the amount of rock-lobster remains consumed from the medium to large size class. This could be due to exuvia being consumed or, in the case of larger individuals, more likely, due to cannibalism of freshly moulted rock lobsters (Carter and Steele 1982).

Juvenile rock lobsters at four of the five sites examined had a higher gut fullness index than medium and large rock lobsters. This conforms to Mayfield's (1998) predictions and may be explained by the fact that small rock lobsters have a higher moult frequency and thus faster growth rate (Pollock 1973, Pollock 1979) and would need to consume relatively larger amounts of food, more regularly. As the size of the rock lobster increased, so the average gut fullness index decreased (Table 4).

The diet diversity of small rock lobsters was lower at all sites than that of medium and large rock lobsters. Medium and large individuals have a similar prey diversity index. This contrasts to the finding of Mayfield (1998) who found, diversity of prey items, to decrease with an increase in size. Small rock-lobsters, being unable to process certain types or sizes of prey items, are possibly restricted to forage on a lower diversity of prey items.

Fast *versus* Slow-growth.

There was a significant difference in rock-lobster diet at sites of slow- and fast-growth rates ($p < 0.05$). This is contradictory to what Mayfield (1998) found in comparing the diets of rock lobsters collected at fast- and slow-growth sites. Mayfield (1998) established that, irrespective of the growth rate of rock lobsters in different areas, they consume similar prey in approximately the same proportions. The current study established key prey items (black mussel and lobster remains) that differentiate the diets of rock lobsters at sites of slow- and fast-growth. These differences however, appear to be due to the lack of 'preferred' prey at some of the sites. Alternatively, this study, having narrower size ranges than that of Mayfield (1998), was perhaps able to detect the size-related variation between sites of different growth rates.

Analyses of these results reveal several interesting trends. The first trend, the absence of black mussels from the diet of rock lobsters at sites characteristic of slow-growth (Harbour wall and Olifantsbos), suggests one of two options. If black mussels are present in low abundance at the SG sites and the rock lobsters are not consuming them, it can be assumed that the energy gained is not greater than that expended in foraging for black mussels at these sites. The more likely option is that black mussels are absent from the benthos at SG sites. This option is further supported by Mayfield (1998) where both *A. ater* and *C. meridionalis* were less dominant in the benthos at the slow-growth sites of Olifantsbos and Cape Town Harbour wall and thus less frequent in the diet of rock lobsters at these sites.

Secondly, there is a dominance of lobster remains in the diet of medium individuals at the slow-growth site of Olifantsbos. This could be explained by the absence of mussels (*A. ater* and *C. meridionalis*) from the benthos (Mayfield 1998), and thus from the rock-lobster diet, at this site. Some of the inorganic calcium component, which could otherwise have been obtained in the diet from mussel shell, may now have been supplemented from lobster exuvia. A constituent in mussel shells (probably lime) is proposed to be essential in the diet of the rock lobster due to it's 'partly calcareous exoskeleton' and the need for inorganic replenishment after ecdysis (Heydorn 1969, Barkai *et al.* 1996).

Similar gut fullness percentages were recorded at sites of differing growth rates. Assuming there is less edible food available at the SG sites (a fact that has been verified for some of the sites - Mayfield 1998), then rock lobsters here have to forage for a longer period of time in order to reach the same gut fullness percent as those at FG sites. Joll and Phillips (1984) observed this in their study on *Panulirus cygnus*. This may result in more energy being expended on foraging and thus fewer energy reserves remain to be allocated to growth (Mayfield 1998).

The higher prey diversity found in the diet at fast-growth sites (Table 3) suggests that there is a greater selection of prey items at these sites and that the rock lobsters are able to select prey items that incur the least energy expenditure and yield the highest energy gain. This would allow rock lobsters to optimise their rate of growth by prey selection. In areas where the choice of prey is limited (slow-growth areas) the rock lobsters would be forced to forage on whatever prey was available, preventing them from optimising their net energy gain. It thus appears evident that a longer foraging time (at slow-growth sites) could be a key factor responsible for the slow growth rate observed in the West Coast rock lobster.

5. Conclusion

This study, on the dietary components of the West Coast rock lobster, *Jasus lalandii*, answers several questions. The data collected addressed all the hypotheses posed and it can be concluded that:

(1) There are no differences in diet between male and female rock lobsters for any of the size classes studied;

(2) There is a difference in diet with an increase in rock-lobster size; and

(3) There is a difference in rock-lobster diet between sites of known slow- and fast-growth rate.

The later is particularly important because it may be associated with an increase in foraging time at slow-growth sites where the benthos has few edible prey, leading to a reduction of growth rate.

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