

**ASSOCIATION OF JUVENILES OF FOUR FISH SPECIES  
WITH SANDBANKS IN DURBAN BAY, KWAZULU NATAL**

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## **PREFACE**

The work described in this thesis was carried out in the Department of Biology, University of Natal, Durban from January 1993 to December 1994, under the supervision of Prof. A. T. Forbes. It was co-supervised by Professor D.P. Cyrus, Department of Zoology, University of Zululand.

These studies represent original work by the author and have not been submitted in any form to another university. Where use was made of the work of others it has been duly acknowledged in the text.

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## ABSTRACT

Estuaries in South Africa are important nursery areas for the juveniles of many fish species. The condition of many of these systems has, however, deteriorated as a result of degradation caused by urban, industrial and agricultural development. An assessment of the role of harbours, particularly in KwaZulu Natal, as nursery grounds has therefore become an important issue. Durban Bay has undergone considerable changes since the mid-1800s and further developments are proposed. If these developments continue, they will result in the loss of large areas of the sandbanks, but Portnet has recognised the need to integrate environmental considerations into future port developments and operations.

It was the overall aim of this study to establish the nature of the association of the juveniles of four common fish species viz. *Pomadasys commersonnii*, *Gerres filamentosus*, *Liza dumerilii* and *Leiognathus equula* with these sandbanks and, thereby assess the impact of their removal.

It was found that all species were abundant on the sandbanks and that the diets of *P. commersonnii*, *G. filamentosus* and *L. equula* were very similar, consisting primarily of bivalve siphon tips, benthic crustaceans and polychaetes. The respective contributions of each food type to the diet varied with species. The diet of *L. dumerilii* differed from that of the other three species, consisting primarily of benthic floc, foraminiferans, ostracods and sponge spicules. Despite differences in selectivity, it was concluded, from studies of the benthos in the harbour, that all four species, irrespective of size, were feeding on these

sandbanks, as opposed to in the channels, throughout the year. Removal of the sandbanks for the construction of a new pier would, thus, result in the elimination of important feeding grounds for the juveniles of these four species.

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## CHAPTER 1

### GENERAL INTRODUCTION

Estuaries in South Africa provide an important, perhaps vital, habitat for the juveniles of many fish species (Whitfield, 1994), but they are becoming increasingly threatened and degraded by urban, industrial and agricultural development (Wiseman and Sowman, 1992). In KwaZulu Natal only 22 out of 62 estuaries were considered to be in good condition in 1993 (Cooper, Harrison, Ramm and Singh, 1993), and with the accelerating population growth in South Africa, and subsequent increasing development and demand for recreational facilities, the number of degraded estuarine ecosystems is likely to increase unless adequate conservation measures are taken.

Over the past 50 years, the most dramatic changes in southern African estuaries have been due to human interference (Reddering and Rust, 1990). The chemical components of water pollution generated by runoff from urban, agricultural, industrial and mining centres, and biological impacts, such as introduction of exotic aquatic plants and fish, both lead to disruption of the general functioning of estuarine ecosystems, and in particular their food chains (Cyrus, 1991). Physical impacts, such as dam construction in the catchment of an estuary or drainage of wetlands for agriculture, are related to reduced fresh water inflow into estuaries and may result in poor sediment scour, extended closed phases, increased siltation, hypersaline conditions and reduction of riverine input of organic material (Whitfield and Bruton, 1989). Most of these factors would impact on the estuarine fish fauna (Cyrus, 1991).

In KwaZulu Natal this degradation has led to a deterioration in the condition of estuarine nursery grounds for juvenile fish, creating a need to recognise and assess the role and significance of harbours as nursery areas. This may seem improbable since operations and developments in harbours appear to conflict with the maintenance of ecological processes in the port environment. World trends, however, seem to indicate greater environmental concern and a move towards the integration of these concerns into the management and development of harbours (Davis, MacKnight, IMO Staff and Others, 1990; Anon, 1992a).

Although the Port of Durban is Africa's busiest harbour with a cargo throughput of 25 million tons per annum (Pearson, 1993), recent research has shown that it was still functioning as a nursery area for juvenile fish (Cyrus and Forbes, 1994). Despite planned developments to cater for an envisaged increase in trade, Portnet, the harbour authority, recently adopted a policy of integrating environmental considerations into the proposed port developments and operations. Plans include urban waterfront development along the Victoria Embankment and in the Point area (Pearson, 1993), which will increase the human activity in and around the harbour, consequently increasing the potential for pollution and probably increasing fishing pressure. There are also plans for development and expansion of large areas of the Port of Durban to increase its cargo handling capacity. It has been estimated that the present tonnage handled in the port will double by the year 2015 (Pearson, 1993). No rigid time scale has been set, but it is anticipated that developments will occur when required and in whatever order circumstance dictates. Developments will include widening and deepening of the entrance channel, upgrading and remodelling of general cargo facilities, deepening of berths (Pearson, 1993) and realignment of channels (Anon, 1992b). The proposed development of the new Pier 3 in

Durban Bay will provide an additional 73 ha of land and five new berths with a total length of 1500 m (Anon, 1992b), resulting in the loss of large areas of the existing sandbanks. This could have serious effects on the juvenile fish fauna since sandbanks are important habitats within nursery areas, providing food for the growth of juvenile fish (Ayvazian, Deegan and Finn, 1992). Prior to this study, no work had been done on the significance of the sandbanks to the juvenile fish fauna in the Port of Durban.

The fish species that utilize southern African estuaries have been divided into five classes according to the extent of their dependence upon these systems (Whitfield, 1994):

Category I: Estuarine species which breed in southern African estuaries;

Ia. Resident species which have not been recorded spawning in the marine or freshwater environment.

Ib. Resident species which also have marine or freshwater breeding populations.

Category II: Euryhaline marine species which usually breed at sea with the juveniles showing varying degrees of dependence on southern African estuaries;

IIa. Juveniles dependent on estuaries as nursery areas.

IIb. Juveniles occur mainly in estuaries, but are also found at sea.

IIc. Juveniles occur in estuaries, but are usually more abundant at sea.

Category III: Marine species which occur in estuaries in small numbers but are not dependent on these systems.

Category IV: Euryhaline freshwater species, whose penetration into estuaries is determined primarily by salinity tolerance. This includes some species which may breed in both freshwater and estuarine systems.

Category V: Obligate catadromous species which use estuaries as transit routes between the marine and freshwater environments.

Species belonging to Categories I and II will clearly be most threatened by the accelerating degradation of estuaries (Cyrus, 1991), and would benefit most by the protection of nursery areas. Despite its intensive use and considerable development since the mid-1800s (Holden, 1855), research in Durban Bay indicated a significant nursery function in that the fish populations on the sandbanks were dominated by juveniles of marine species, belonging primarily to Category II (Cyrus and Forbes, 1994). These species generally spawn at sea where physical conditions are less variable than in estuaries, providing a more stable environment for the survival of egg and larval stages (Whitfield, 1990a). Spawning usually occurs close inshore, often in the immediate vicinity of estuary mouths, or even within the estuary mouth (Garratt, 1994), thereby reducing the distance between spawning and nursery grounds (Whitfield, 1990a). In permanently open estuaries, most immigration takes place when river outflow is at its lowest and at the start of the wet season, (Wallace and van der Elst, 1975), but the majority of species have an extended spawning season of four to eight months, enabling juveniles to utilise seasonally closed estuaries (Whitfield, 1990a).

Residence time of juveniles within estuaries varies amongst species, but most marine species which utilize South African estuaries as nursery grounds, spend between one and three years in the systems (Whitfield, 1990b). During this time, juveniles benefit from the abundance of food (Miller and Dunn, 1980), the low number of predators in calm, sheltered, shallow estuarine waters, and the protective isolation created by turbidity (Cyrus

and Blaber, 1987a). The estuarine environment is, however, subject to rapid and large fluctuations in salinity, temperature, turbidity and dissolved oxygen (Wallace, Kok, Beckley, Bennet, Blaber and Whitfield, 1984). The benefits of estuaries are only available to those species which can tolerate these physical extremes.

The juveniles of four Category II species, viz. *Pomadasys commersonnii* (Lacepède), *Gerres filamentosus* Cuvier, *Liza dumerilii* (Steindachner) and *Leiognathus equula* (Forsskål), which are common in KwaZulu Natal estuaries (Blaber, 1977; Blaber 1978; Cyrus and Blaber, 1982; Smith and Heemstra, 1986), were netted in large numbers on the sandbanks in Durban Bay in 1991. Previous work has shown that all four species are bottom feeders (Tiews, Divino, Ronquillo and Marquez, 1973; Blaber, 1977; Cyrus and Blaber, 1983a; Whitfield, 1990b), so it is probable that they were utilising the sandbanks as feeding grounds.

*P. commersonnii*, commonly known as the spotted grunter in KwaZulu Natal, is a Category IIa species (Whitfield, 1994) which occurs from False Bay along the African coast to India (Smith and Heemstra, 1986). It is a prime angling and table fish in tropical and temperate waters (van der Westhuizen and Marais, 1977; Smith and Heemstra, 1986) and constitutes about 30% of the catch of light-tackle recreational anglers in Durban Bay (Guastella, 1994). There is evidence of its decline in KwaZulu Natal (van der Elst and Adkin, 1991), which may be attributed to overfishing or to the fact that it is dependent on estuaries during the juvenile phase of its life cycle (Whitfield, 1994), or to a combination of both.

Spawning of *P. commersonnii* along the east African coast occurs in the shallow inshore zone (Wallace, 1975a) from August to December (Wallace, 1975a; Kyle, 1986). Fry (20-50 mm in length) enter KwaZulu Natal and eastern Cape estuaries between July and December (Whitfield, 1990b). The juveniles grow rapidly in the estuarine nursery grounds, where they remain for about a year, after which they return to the sea and reach maturity at about three years of age (Whitfield, 1990b). Adults often return to estuaries to feed (Whitfield, 1990b).

*G. filamentosus* and *L. dumerilii* are both Category IIb species (Whitfield, 1994). *G. filamentosus*, or pouter as it is known in KwaZulu Natal, is an Indo-Pacific species (Smith and Heemstra, 1986), which is used as a food source in India (Prabhakara Rao, 1968), and as bait (Smith and Heemstra, 1986). Spawning occurs during summer, autumn and winter in the marine environment along the east coast of southern Africa, and adults do not return to estuaries after spawning (Cyrus and Blaber, 1984a). Fry enter estuaries, throughout the year, at about 10 mm standard length (SL). They remain within the estuarine nursery area until attainment of sexual maturity, which occurs at about 70 mm SL, with no size difference between the sexes (Cyrus and Blaber, 1984a).

*L. dumerilii*, commonly known as the groovy mullet in KwaZulu Natal, has been recorded along the east and south-east coasts of southern Africa from southern Mozambique to the Breede River (Day, Blaber and Wallace, 1981) and it is widely used as food and bait (Smith and Heemstra, 1986). Spawning occurs in the immediate vicinity of estuary mouths (Wallace, 1975a; van der Horst and Erasmus, 1981) from June to November along the KwaZulu Natal coast (Wallace, 1975a) and from December to February along the

eastern Cape coast (van der Horst and Erasmus, 1981). Recruitment of juveniles less than 50 mm total length (TL) occurs mainly from August to February in KwaZulu Natal estuaries (Wallace and van der Elst, 1975) and throughout the year, but with peaks in April and May, in eastern Cape estuaries (Beckley, 1984). After spawning, adults often return to estuaries (Wallace, 1975a).

*L. equula*, known as the slimy or soapy in KwaZulu Natal, is a tropical Indo-Pacific species extending to Algoa Bay (Smith and Heemstra, 1986), and it belongs to Category IIc (Whitfield, 1994). Leiognathids constitute a very important fishery in India (James, 1975), being excellent bait fish and important food fish (Smith and Heemstra, 1986). Spawning has been recorded along the KwaZulu Natal coast, in the vicinity of river mouths, from September to April, but it is possibly more intense from October to March (Wallace, 1975a; van der Elst, 1990). Juveniles entered the temporarily open Mhlanga estuary in KwaZulu Natal in April (Whitfield, 1980a). Adults often return to estuaries after spawning (Wallace, 1975a).

It was the overall aim of this study to establish the nature of the association of the juveniles of *P. commersonnii*, *G. filamentosus*, *L. dumerilii* and *L. equula* with two of the sandbanks in Durban Bay, and thereby establish the impact of removal of these banks. The immediate objectives were to investigate the diets of these species as well as prey selectivity, and any seasonal changes or size-related differences in their feeding habits.

## CHAPTER 2

### PHYSICO-CHEMICAL CONDITIONS IN THE STUDY AREA

#### 2.1 INTRODUCTION

Durban Bay is a sub-tropical, landlocked estuarine bay situated on the coast of KwaZulu Natal, South Africa, between 29°51' to 29°54' South and 31°00' to 31°03' East (Figure 2.1). It has an axial length and maximum width of 8 km and 3.3 km, respectively (Begg, 1978). The Umbilo and Mhlatuzana Rivers, which are both canalized in their lower reaches, enter the bay from the south west (Begg, 1978) but provide little fresh water input except during floods. In the 1950s surface salinities in the bay ranged from 19.4‰ to 36.4‰ (Day and Morgans, 1956). In later studies, the range declined to from 27 to 35.5‰ (Joubert, 1965; Begg, 1978), while in two surveys conducted in June and October 1991, surface salinities throughout the bay were found to be marine (35‰) (Hay, 1993). These studies indicate that Durban Bay is essentially a marine-dominated tidal system. Minimum and maximum surface temperatures recorded in the 1950s were 21.3°C and 27°C, respectively (Day and Morgans, 1956). From July 1993 to June 1994, surface temperatures recorded during pollution surveys throughout the bay ranged from 19.8°C to 27.1°C (Waste Water Management Laboratory, pers. comm.). Turbidity levels were low during the two surveys conducted in 1991, ranging from 3 Nephelometric Turbidity Units (NTU) to 9.9 NTU (Hay, 1993).

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<sup>1</sup>Waste Water Management Laboratory, Durban Water and Waste, 3 Prior Road, Durban, 4001

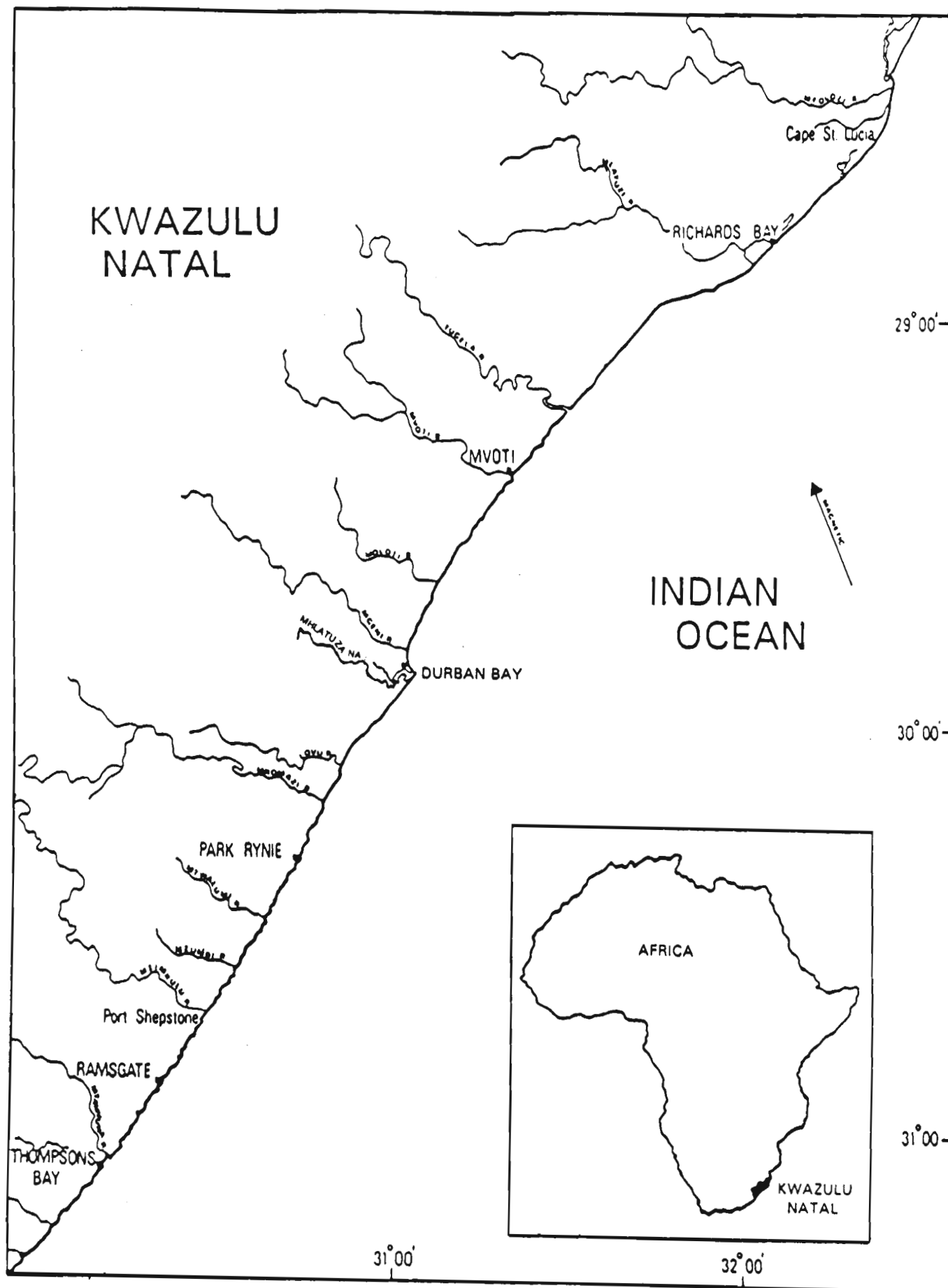


Figure 2.1: The position of Durban Bay on the KwaZulu Natal coast

The total high water area of the port is 892 ha while the low water area is 679 ha (O'Grady, 1993). There are six major sandbanks in Durban Bay (Figure 2.2), which are remnants of the original banks that existed before harbour development occurred (Holden, 1855). These include the large east and west central sandbanks (CE and CW) which are separated by a shallow channel and which slope steeply off on their south side; an area referred to as Boardsailor's bank (BS) for the purpose of the present study; the large North West (NW) and smaller North East (NE) sandbanks, both adjacent to the Victoria Embankment, and the South West (SW) bank, which supports 9 ha of mangroves. The mangroves and part of the SW bank are in the process of being declared a Natural Heritage Site by Portnet, which means that they will be excluded from any future port developments. Portnet has, however, proposed the removal of the central sandbanks and part of Boardsailor's bank for the construction of Pier 3 (Anon, 1992b) (Figure 2.2). The total area exposed on these two banks at low tide is approximately 50 ha and at high tide the water is approximately 2 m deep.

The objective of this part of the study was to investigate and compare the physico-chemical conditions on the BS and CW sandbanks, and investigate sediment distribution throughout the bay.

## 2.2 MATERIALS AND METHODS

Physical conditions were recorded on the BS and CW sandbanks every three months from May 1993 (autumn) to February 1994 (summer), and August 1993 (winter) to February 1994 (summer), respectively. Surface salinities were measured using a temperature

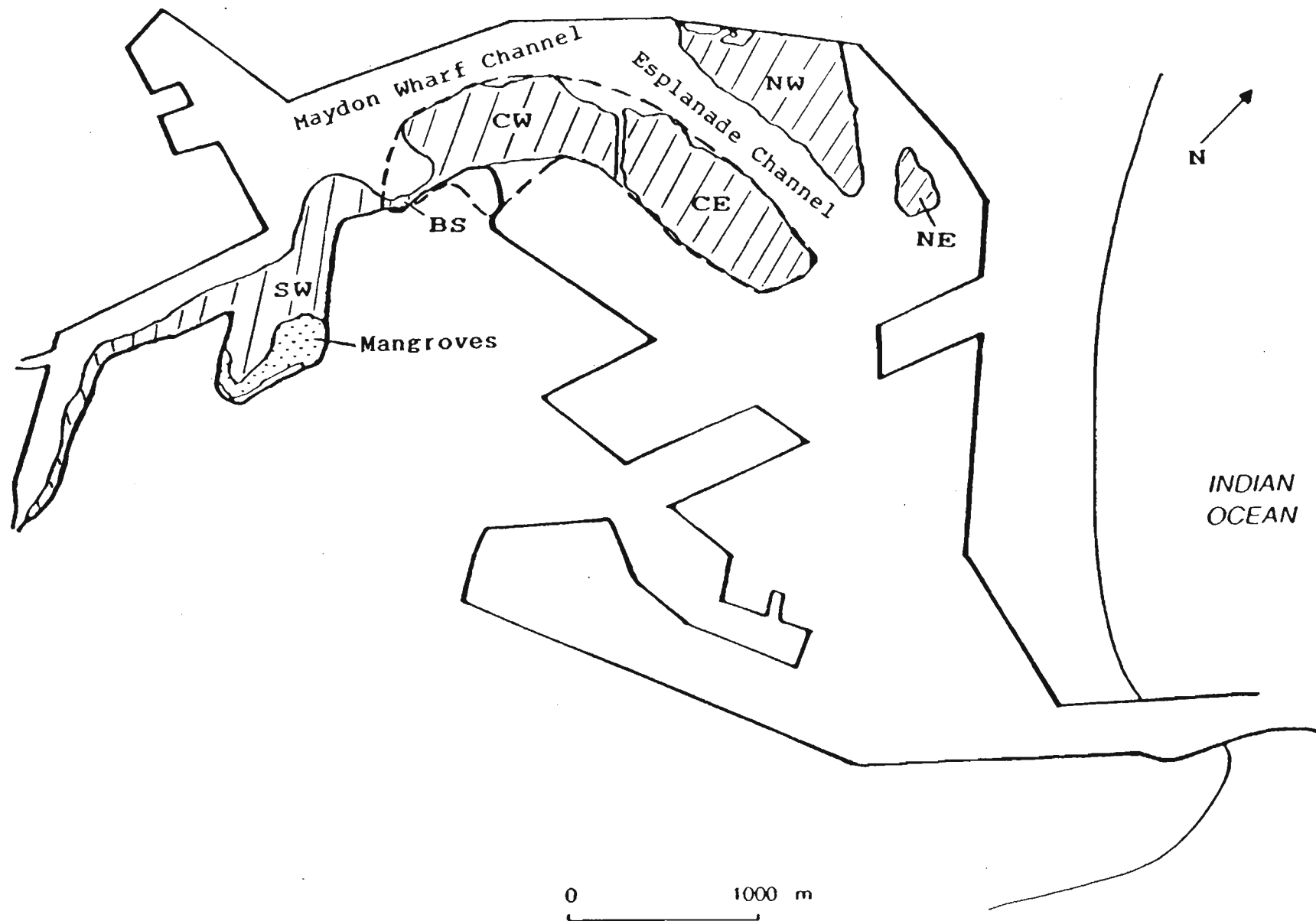


Figure 2.2: Durban Bay. Straight lines represent developed areas and dashed lines show the proposed position of Pier 3

compensated calibrated refractometer (American Optics Corporation) while surface water temperature was measured on each sampling trip using a standard mercury thermometer. Water samples were collected on each sampling trip and turbidities were measured in the laboratory using a Hach 2100A turbidimeter.

On each sampling trip sediment samples were collected from the BS and CW sandbanks from the top 2 cm of substratum. The sediments were analysed and the median phi values calculated. Sediment samples were wet sieved through a graded series of sieves, the mesh apertures of which decreased geometrically from 2 mm to 0,063 mm (Gray, 1981). Dry weight (80°C, 24 hours) was determined for the fraction retained in each sieve. The dry weight (80°C, 24 hours) of the subsieve fraction was determined using a 25 ml aliquot of the wash water which had been made up to three litres. The median phi value of each sediment sample was determined from a plot of cumulative dry weight of the sediment fractions against phi values ( $-\log_2$  of the sieve apertures). The subsieve component was plotted against a phi value of five. Sediments were classified according to Gray (1981). Percentage shell matter was calculated for each sample, by expressing the dry weight of the 2 mm fraction, which contained only shell matter, as a percentage of the total dry weight of the sediment sample.

A set of five replicate sediment samples was also collected from each of the other four sandbanks (CE, NW, NE and SW) to determine sediment distribution within Durban Bay. They were analysed using the same method.

2.3 RESULTS

Surface salinities were essentially marine throughout the study period on both banks, ranging from 28 to 35‰ while surface temperatures varied between 21 and 27°C (Table 2.1). Turbidities on the CW sandbank ranged from 19 to 22 NTU, but showed greater extremes (13.5 to 46 NTU) on the BS bank (Table 2.1). Median phi values of sediments on both sandbanks corresponded to medium to fine sand (Gray, 1981) (Table 2.1).

Table 2.1: Physical conditions recorded on the BS and CW sandbanks during the study period

	MAY 1993		AUG 1993		NOV 1993		FEB 1994	
	BS	CW	BS	CW	BS	CW	BS	CW
Salinity (‰)	28.0	-	34.0	35.0	34.0	35.0	35.0	34.0
Temperature (°C)	21.0	-	21.5	22.0	26.0	26.5	26.0	27.0
Turbidity (NTU)	13.5	-	31.0	22.0	46.0	19.0	23.0	21.0
Median phi	2.5	-	2.3	2.0	2.2	2.3	2.2	2.0
% Shell content	1.9	-	0	3.9	0.2	21.8	0.2	34.2

It was found that the sediment of the four other sandbanks could also be classified as medium to fine sand, but that the percentage shell content varied (Table 2.2). The highest percentage shell content (34.2%) was recorded on the CW sandbank (Table 2.1). Percentage shell matter on the SW sandbank was also relatively high, while the mean percentage shell content recorded on the other sandbanks was considerably lower (Tables 2.1 and 2.2).

Table 2.2: Sediment characteristics of the CE, NW, NE and SW sandbanks

	Median phi (Mean $\pm$ SD)	% Shell content (Mean $\pm$ SD)
CE (n=5)	2.02 $\pm$ 0.27	0.18 $\pm$ 0.08
NW (n=5)	2.23 $\pm$ 0.15	0.20 $\pm$ 0.16
NE (n=5)	2.31 $\pm$ 0.09	0.04 $\pm$ 0.04
SW (n=5)	2.15 $\pm$ 0.29	5.51 $\pm$ 10.8

## 2.4 DISCUSSION

Durban Bay has been defined as an embayment (Begg, 1978) since it is subjected to tidal influences and the salinity is essentially marine. This was confirmed by this study and other surveys in which salinities recorded were close to that of sea water (Day and Morgans, 1956; Joubert, 1965; Begg, 1978; Hay, 1993).

Surface salinities as well as temperatures were very similar on the BS and CW sandbanks throughout the study. Seasonal trends in temperature were evident, similar to those recorded in other studies (Hay, 1993; <sup>2</sup>Waste Water Management Laboratory, pers. comm.).

Although turbidities recorded on both sandbanks during this study indicated that the water was clear to partially turbid (Cyrus and Blaber, 1987a), greater extremes in turbidity were recorded on the BS bank. The BS sandbank is situated closer to the incoming rivers and the mangroves which may both act as a source of sediment input into the system, raising

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<sup>2</sup>Waste Water Management Laboratory, Durban Water and Waste, 3 Prior Road, Durban, 4001

turbidities in this region of the bay. Day and Morgans (1956) found that the south western part of the bay, near the incoming rivers, was very muddy while the water at the western end near Maydon Wharf was discoloured.

It was found that the sediment distribution on the sandbanks within the harbour was uniform, with all the major sandbanks being classified as medium to fine sand (Gray, 1981). The amount of shell matter, however, varied. The percentage shell content of the CW bank sediments was consistently higher than that recorded on the BS bank. These results were very similar to those obtained by van der Walt (1993).

Durban Bay may be described as a "sheltered arm of the sea", with salinities being essentially marine and water temperatures slightly higher than the open sea in summer and slightly lower in winter (Begg, 1978). It, thus, provides a habitat suitable for estuarine and marine fish species (Guastella, 1994).

## CHAPTER 3

### THE CATCH COMPOSITION

#### 3.1 INTRODUCTION

Durban Bay is essentially a human-modified marine system, but it supports a fish biota typical of KwaZulu Natal estuaries (Beckley, van der Elst, Chater and Birnie, 1994). Although the stenohaline marine component is better represented than in other KwaZulu Natal estuaries, the fish fauna in the port consists to a large extent of typically euryhaline species which include juveniles of many species which utilise the bay as a nursery ground (Wallace, 1975b).

In a preliminary study by Cyrus and Forbes (1994) of the fish populations in Durban Bay, the BS sandbank was found to support the highest abundances of juvenile fish compared with all other sandbanks in the bay. The CW sandbank also supported a high number of juvenile fish but had a lower species diversity. The fish populations on these sandbanks were dominated by juveniles of marine species, belonging primarily to Category II (Whitfield, 1994), with the juveniles of *P. commersonnii*, *G. filamentosus*, *L. dumerilii* and *L. equula* being especially common (Cyrus and Forbes, 1994).

It was the aim of this aspect of the study to analyse the catches on the two sandbanks (BS and CW) over a one year period and assess the importance of the respective contributions of the juveniles of *P. commersonnii*, *G. filamentosus*, *L. dumerilii* and *L. equula* to the total catch.

### 3.2 MATERIALS AND METHODS

The BS sandbank (Figure 2.2) was sampled quarterly from May 1993 to February 1994, and the CW bank (Figure 2.2) from August 1993 to February 1994 at low tide. Fish were collected using a 70 m x 2 m x 13 mm bar mesh seine net, which swept an area of approximately 1500 m<sup>2</sup>. The number of individuals of each species and standard length (SL), to the nearest 10 mm, of each specimen caught, were recorded.

### 3.3 RESULTS

Thirty four species were netted on the BS sandbank and 13 on the CW sandbank during the study period (Tables 3.1 and 3.2). *G. filamentosus*, *L. dumerilii* and *L. equula* were common throughout the year. Although common in autumn and winter, *P. commersonnii* disappeared from the catch in spring and summer (Tables 3.1 and 3.2).

In autumn and winter, over 75% of the catches on the BS bank were made up of *P. commersonnii*, *G. filamentosus*, *L. dumerilii* and *L. equula*, whereas in spring and summer, the latter three species contributed more than 75% to the catches (Figure 3.1). On the CW bank, *L. dumerilii* was dominant in winter (55%) and summer (91.9%) (Figure 3.2).

Table 3.1: Mean catch per unit effort (CPUE) (no. of fish per seine net haul) on the BS sandbank during autumn (May 1993), winter (August 1993), spring (November 1993) and summer (February 1994) (study species in bold type)

Species	Autumn (n=4)	Winter (n=2)	Spring (n=3)	Summer (n=3)
Elopidae				
<i>Elops machnata</i>	-	-	-	0.3
Clupeidae				
<i>Hilsa kelee</i>	0.5	-	16.7	-
Plotosidae				
<i>Plotosus lineatus</i>	-	-	23.0	-
Platycephalidae				
<i>Platycephalus indicus</i>	0.5	3.0	1.7	1.7
Ambassidae				
<i>Ambassis</i> spp.	-	-	6.0	29.3
Serranidae				
<i>Epinephelus malabaricus</i>	-	-	-	1.0
Pomatomidae				
<i>Pomatomus saltatrix</i>	2.3	-	-	0.3
Haemulidae				
<b><i>Pomadasys commersonnii</i></b>	<b>16.0</b>	<b>11.0</b>	-	-
<i>Pomadasys kaakan</i>	-	1.5	0.7	-
<i>Pomadasys multimaculatum</i>	-	-	-	0.7
Sparidae				
<i>Acanthopagrus berda</i>	0.5	1.0	-	1.0
<i>Crenidens crenidens</i>	0.5	9.0	7.0	-
<i>Rhabdosargus holubi</i>	0.5	0.5	3.0	-
<i>Rhabdosargus sarba</i>	3.0	3.5	2.3	0.7
<i>Rhabdosargus thorpei</i>	-	-	-	0.3
Gerreidae				
<i>Gerres acinaces</i>	0.5	3.5	0.3	4.3
<b><i>Gerres filamentosus</i></b>	<b>14.8</b>	<b>134.5</b>	<b>84.7</b>	<b>44.0</b>
<i>Gerres rappi</i>	0.3	-	-	-
Sillaginidae				
<i>Sillago sihama</i>	1.0	2.0	0.3	4.3
Leiognathidae				
<b><i>Leiognathus equula</i></b>	<b>75.5</b>	<b>109.0</b>	<b>113.7</b>	<b>652.7</b>
Carangidae				
<i>Caranx sexfasciatus</i>	0.5	6.5	-	3.3
<i>Caranx</i> sp.	3.3	-	-	-
<i>Scomberoides</i> spp.	0.8	3.5	0.7	0.7
<i>Trachinotus</i> sp.	0.3	-	-	-
Mugilidae				
<b><i>Liza dumerilii</i></b>	<b>47.5</b>	<b>20.0</b>	<b>9.7</b>	<b>12.7</b>
<i>Liza macrolepis</i>	-	7.5	2.0	6.3
<i>Liza tricuspidens</i>	-	-	0.3	-
<i>Mugil cephalus</i>	0.3	0.5	-	-
<i>Valamugil buechanani</i>	0.5	-	-	-
<i>Valamugil seheli</i>	0.3	-	-	-
Sphyrinaeidae				
<i>Sphyræna jello</i>	3.3	7.5	1.3	-
Soleidae				
<i>Solea</i> sp.	-	1.0	-	0.3
Tetraodontidae				
<i>Amblyrhynchotes honckenii</i>	0.3	-	0.7	-
<i>Arothron immaculatus</i>	0.5	2.0	0.2	2.7

Table 3.2: Mean catch per unit effort (CPUE) (no. of fish per seine net haul) on the CW sandbank during winter (August 1993), spring (November 1993) and summer (February 1994) (study species in bold type)

Species	Winter (n=3)	Spring (n=2)	Summer (n=2)
Belonidae			
<i>Strongylura leiura</i>	0.3	3.5	-
Platycephalidae			
<i>Platycephalus indicus</i>	2.3	0.5	1.5
Haemulidae			
<i>Pomadasys commersonnii</i>	-	0.5	-
Sparidae			
<i>Crenidens crenidens</i>	-	0.5	-
Gerreidae			
<i>Gerres acinaces</i>	-	0.5	2.5
<i>Gerres filamentosus</i>	-	0.5	-
Sillaginidae			
<i>Sillago sihama</i>	-	1.5	4.5
Carangidae			
<i>Scomberoides</i> spp.	2.3	1.5	1.5
Mugilidae			
<i>Liza dumerilii</i>	12.3	1.0	118.5
<i>Liza macrolepis</i>	-	1.5	-
Soleidae			
<i>Solea</i> sp.	-	-	0.5
Tetraodontidae			
<i>Amblyrhynchotes honckenii</i>	0.7	-	-
<i>Arothron immaculatus</i>	0.3	4.0	-

The catch per unit effort (CPUE) data for *P. commersonnii*, *G. filamentosus*, *L. dumerilii* and *L. equula* on the BS and CW sandbanks are shown in Figures 3.3 and 3.4, respectively. The CPUE figures for *P. commersonnii* and *L. dumerilii* on the BS bank showed the same trend, declining over the year, whereas the CPUE for *L. equula* increased. An exceptionally high CPUE was recorded for this species in summer. *G. filamentosus* was common throughout the year, with a peak in CPUE in winter (Figure 3.3). On the CW bank, the CPUE for *L. dumerilii* was low in winter and spring, but increased considerably in summer (Figure 3.4).

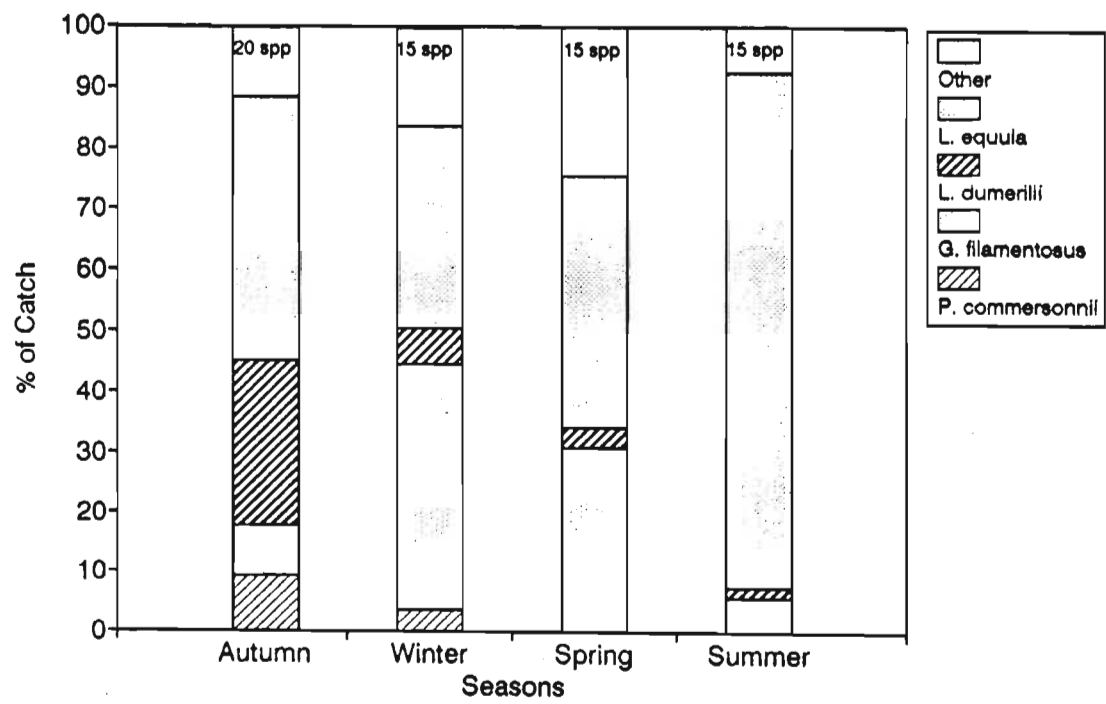


Figure 3.1: Catch composition on the BS sandbank

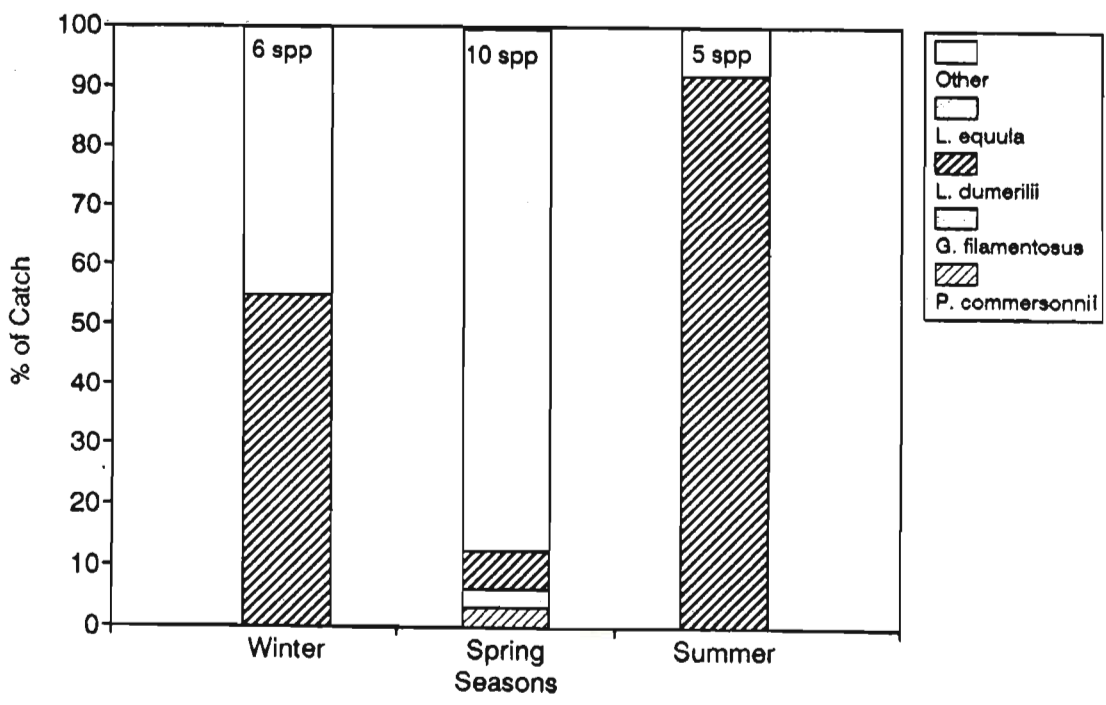


Figure 3.2: Catch composition on the CW sandbank

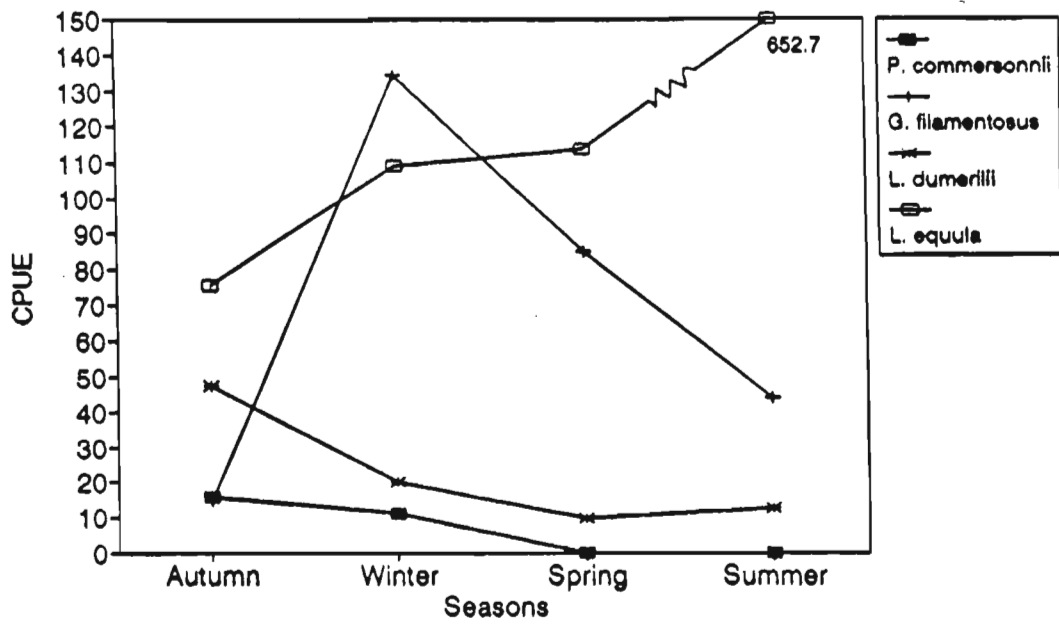


Figure 3.3: CPUE (no. of fish per seine net haul) on the BS sandbank

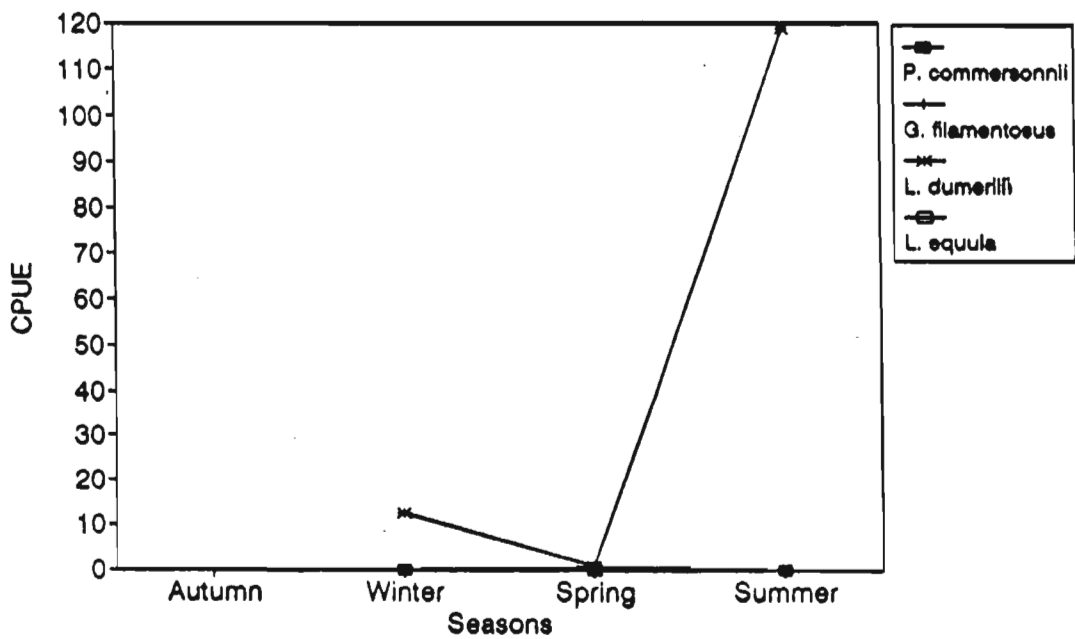


Figure 3.4: CPUE (no. of fish per seine net haul) on the CW sandbank

The length-frequency histograms for *P. commersonnii*, *L. dumerilii*, *G. filamentosus* and *L. equula* caught during the different seasons are shown in Figures 3.5 to 3.9. Seasonal shifts in size class structure were evident for all species caught on the BS bank. No such trends were evident in Figure 3.8 due to the low number of *L. dumerilii* caught on the CW bank in November 1993. All *P. commersonnii*, *L. dumerilii* and *L. equula*, and 48% of *G. filamentosus* specimens caught were juveniles, measuring less than the lengths at sexual maturity given for each species by Wallace (1975a), Day *et al.* (1981) and Cyrus and Blaber (1984a).

### 3.4 DISCUSSION

Despite considerable developments since the mid-1800s (Holden, 1855) it was found that Durban Bay is still functioning as a nursery ground for the juveniles of many fish species. The catch on both sandbanks consisted predominantly of Category II species, the juveniles of which are dependent on southern African estuaries as nursery grounds (Whitfield, 1994). The juveniles of *P. commersonnii*, *G. filamentosus*, *L. dumerilii* and *L. equula* were major components of the catch on the BS bank throughout the year, while *L. dumerilii* dominated catches on the CW bank in winter and summer. These four species also dominated seine net catches on the BS bank in June and October 1991, constituting 84% and 90% of the catch, respectively, while *L. dumerilii* dominated catches on the CW bank during both periods (<sup>3</sup>D.P. Cyrus, pers. comm.).

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<sup>3</sup>Prof. D.P. Cyrus, Coastal Research Unit, Department of Zoology, Private Bag X1001, Kwadlangezwa, 3886

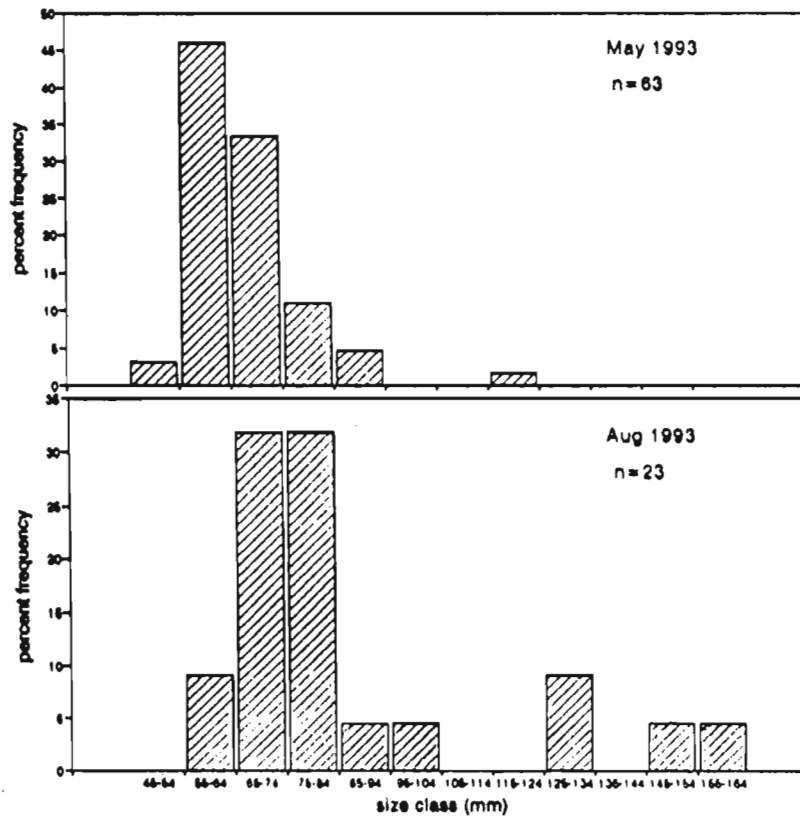


Figure 3.5: Length-frequency histograms for *P. commersonnii* caught on the BS sandbank

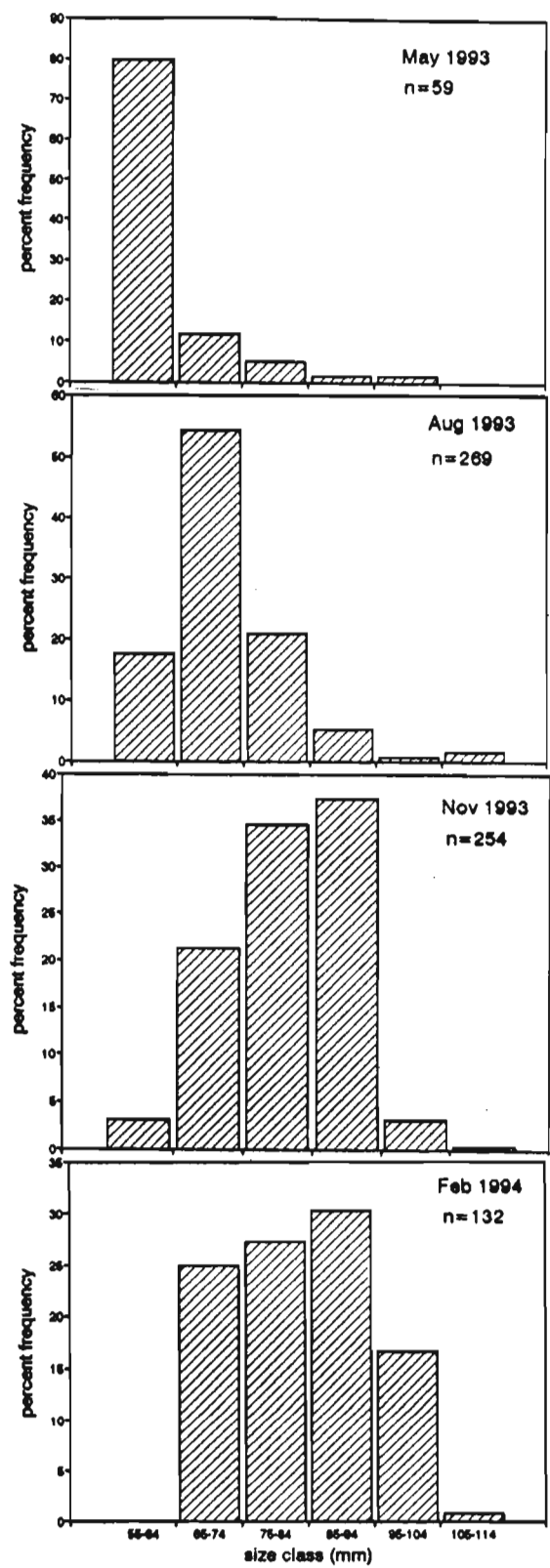


Figure 3.6: Length-frequency histograms for *G. filamentosus* caught on the BS sandbank

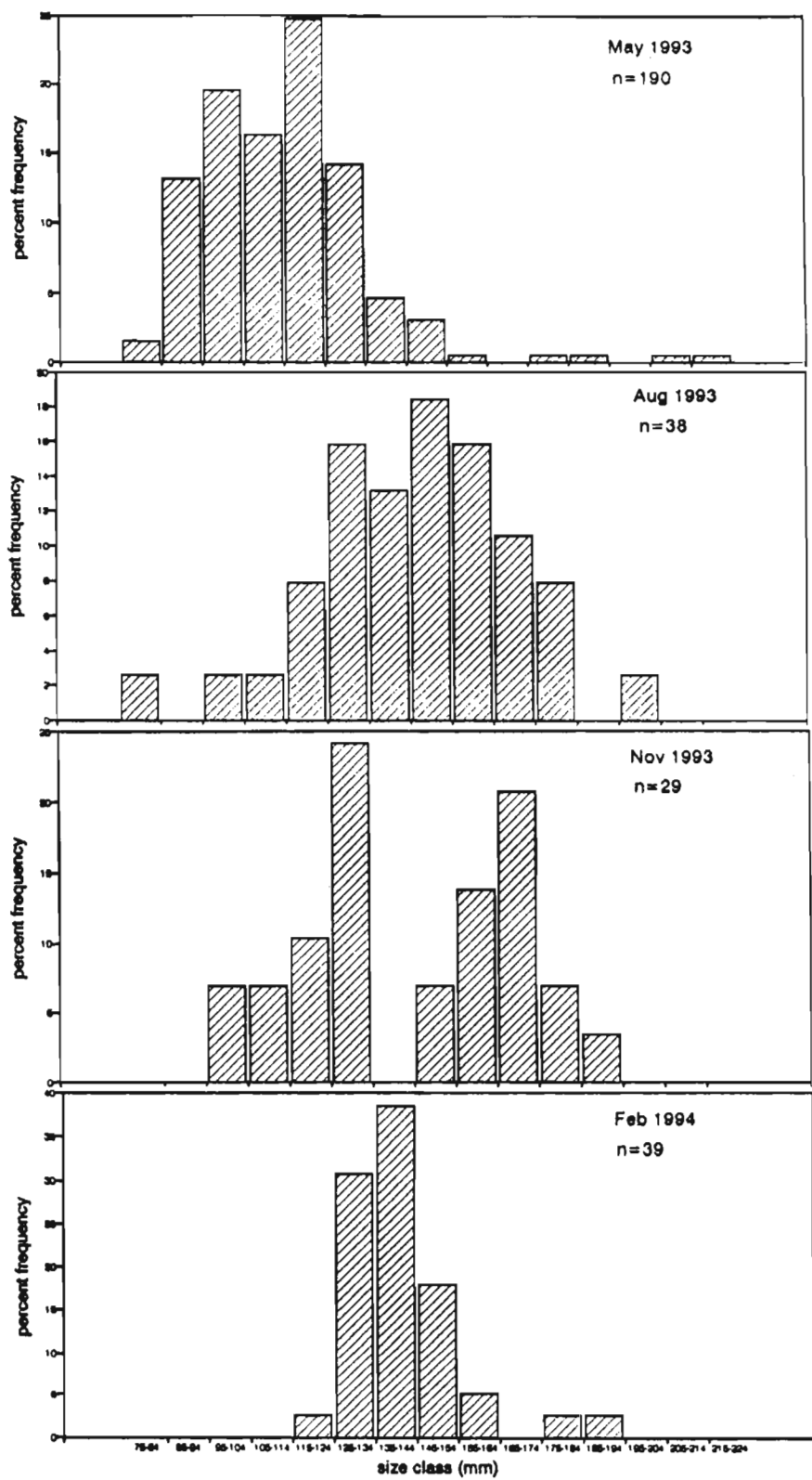


Figure 3.7: Length-frequency histograms for *L. dumerilii* caught on the BS sandbank

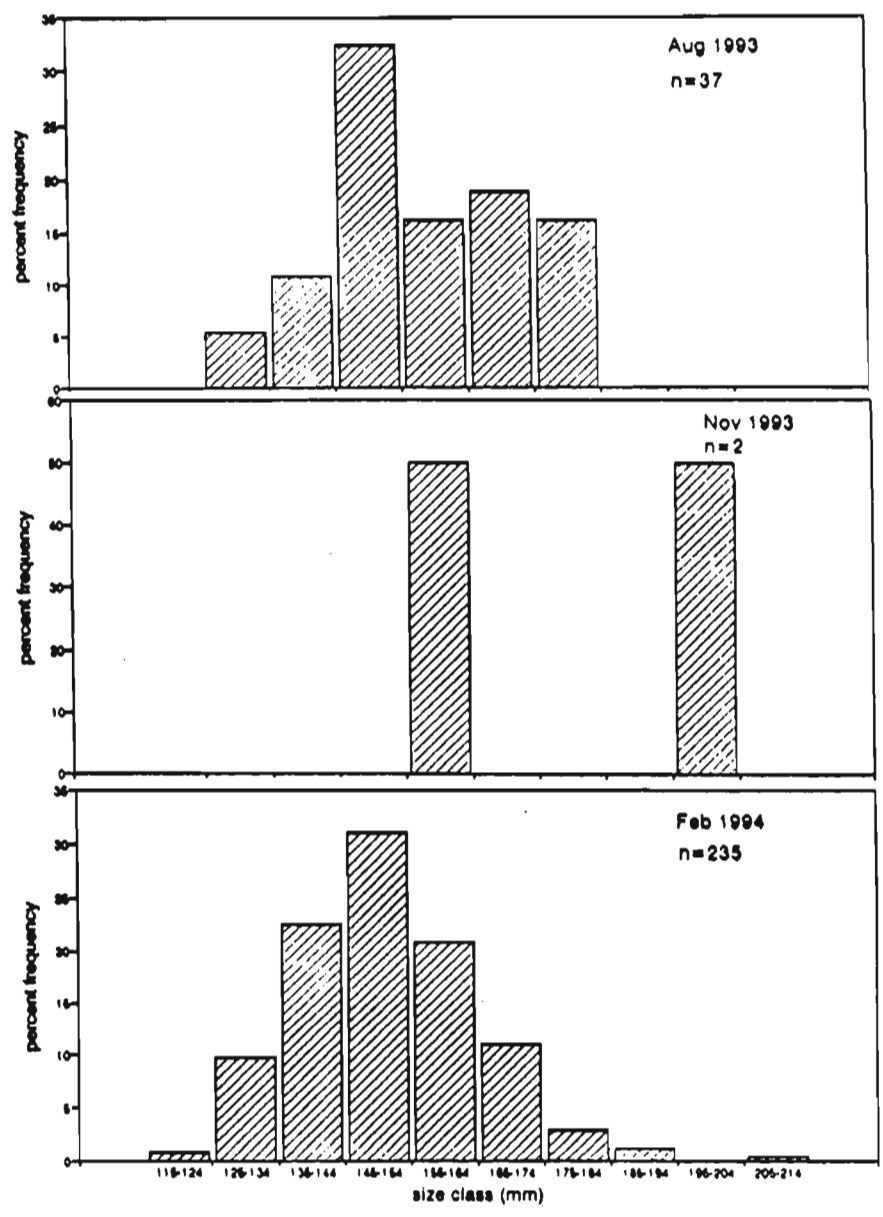


Figure 3.8: Length-frequency histograms for *L. dumerilii* caught on the CW sandbank

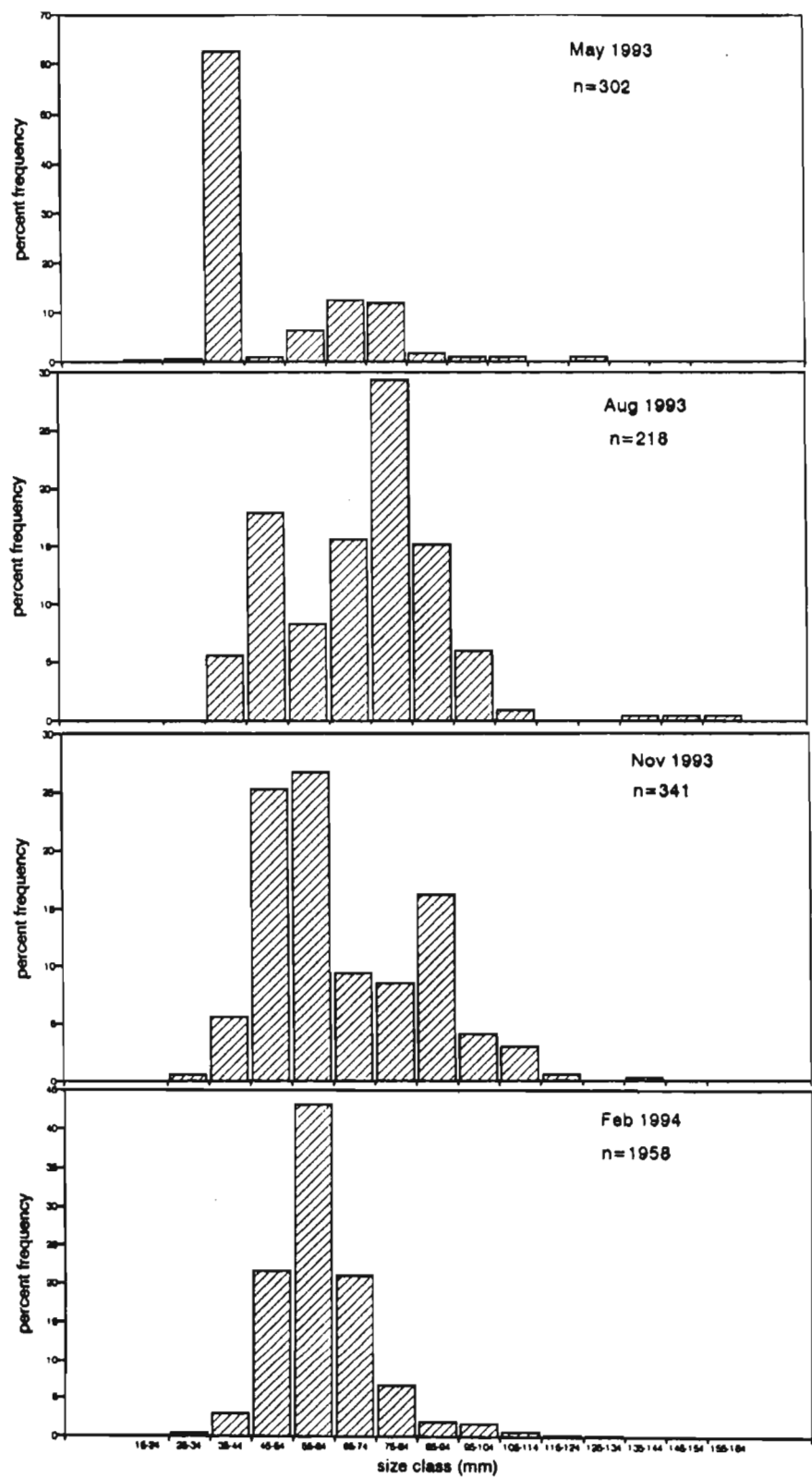


Figure 3.9: Length-frequency histograms for *L. equula* caught on the BS sandbank

Compared with other KwaZulu Natal estuaries (Blaber, 1977; Cyrus and Blaber, 1984b; Harrison, 1993) very high abundances of these four species were recorded in Durban Bay. *G. filamentosus* was abundant throughout the year, especially in winter and spring, whereas in the Kosi system this species was present throughout the year but was most common in summer (January) and autumn (October) (Cyrus and Blaber, 1984b). The highest CPUE recorded for *G. filamentosus* at five sites in the Kosi system over one year using the same seine net was only 22.0 (Cyrus and Blaber, 1984b), whereas a maximum CPUE of 134.5 was recorded during this study. In 1991 high CPUE figures, similar to those recorded in the present study, were recorded for this species on the BS bank in Durban Bay (Cyrus and Forbes, 1994).

*G. filamentosus* was the most common *Gerres* species caught throughout the study period. The dominant *Gerres* species in a specific locality depends on the salinity, with *G. filamentosus* being most common in areas with salinities of approximately 20-35‰ (Cyrus and Blaber, 1982). It was, therefore, not surprising that it dominated in Durban Bay, where salinities throughout the year ranged from 28-35‰.

CPUE figures for *L. equula* on the BS bank were high throughout the year, but especially so in summer. Large shoals of small juveniles have been netted in other estuarine nursery areas in KwaZulu Natal during late summer (van der Elst, 1990).

*L. dumerilii* was present throughout the year, with a peak in abundance on the CW sandbank in summer. The maximum CPUE (measured as number of fish per seine net haul) recorded was 118.5, whereas the highest CPUE for *L. dumerilii* in six other

KwaZulu Natal estuaries was 4.5 (Blaber, 1977). The dimensions of the seine net were, however, not given. Seasonal trends in the abundance of *L. dumerilii* have been found in other KwaZulu Natal estuaries. In St Lucia its abundance was shown to be markedly seasonal (Wallace, 1975b), with a decrease in abundance from October to February (Whitfield and Blaber, 1978).

Compared with June 1991, however, when a CPUE of 268 was recorded for *P. commersonnii* on the BS bank (Cyrus and Forbes, 1994), low CPUE figures were recorded for *P. commersonnii* on the BS bank in this study (Table 3.1) and it also disappeared from the catch in spring and summer. In the Kosi system, however, this species was common in summer and winter (Blaber, 1978).

The use of only one method of sampling may bias results in a study such as this, but in a comparison of the effectiveness of four methods of sampling fish (seine net, gill net, beam trawl and otter trawl) it was found that seine net collections (30m) most closely resembled the total assemblage in each system (Ramm, Cooper, Harrison and Singh, 1991). Obviously for a more detailed description of the assemblage, a number of sampling techniques should be used (Ramm *et al.*, 1991).

The low species diversity on the CW bank, low number of *P. commersonnii* and *G. filamentosus* and the absence of *L. equula* in comparison with the BS bank, may have occurred as a result of fish having escaped from the net as it was pulled over the edge of the slope on the south side of the CW sandbank. It may, however, have been a consequence of differing abiotic or biotic conditions on the two banks or a combination

of all of these factors. Water temperature and salinity on the two banks was very similar throughout the study period as were the median phi values of the sediment. Percentage shell content on the two sandbanks was very different, but this is not likely to have directly affected the catch composition. The major difference between the two banks in terms of physical conditions was turbidity. On the CW bank turbidities ranged from 19 to 22 NTU, whereas greater extremes in turbidity were recorded on the BS bank (13.5 to 46 NTU).

It has been found that turbidity is the most important physical factor in determining the distribution of juvenile marine fish in KwaZulu Natal estuaries (Cyrus and Blaber, 1987b). Although the turbidity preferences of these four species are different (Cyrus and Blaber, 1987b), it does not seem likely that the relatively low turbidities and relatively small variation in turbidities between the two sandbanks would have influenced the distribution of the juveniles of these four species. However, the differences in turbidity may have been important in influencing the vulnerability of these fishes to capture by the seine net.

The benthos of the two sandbanks was different. In two unpublished benthic surveys of Durban Bay conducted in August 1991 and 1992 fewer benthic species and considerably lower densities of polychaetes and molluscs were recorded on the CW bank than on the BS bank during both surveys (<sup>4</sup>A.T. Forbes, pers. comm.).

It has been found that food availability does influence the distribution of juveniles of certain species of marine fish in KwaZulu Natal estuaries (Cyrus and Blaber, 1987b). In South Lake, St. Lucia, *L. equula* was most abundant in areas where its favoured food was

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<sup>4</sup>Prof. A.T. Forbes, Department of Biology, University of Natal, King George V Avenue, Durban, 4001

at its greatest density, although *P. commersonnii* and *G. filamentosus* did not show this trend (Cyrus and Blaber, 1987b). However, it is possible that food availability could be influencing the distribution of these species in Durban Bay.

## CHAPTER 4

### DIET AND SELECTIVITY

#### 4.1 INTRODUCTION

Studies of the diets of fish based on stomach content analysis have become standard practice in fish ecology (Hyslop, 1980), and the diets of many fish species have been extensively researched. The feeding habits of particular species, however, vary according to locality, season and/or age (Wootton, 1990), providing unique results for each area or population studied.

Size-related changes in diet have been recorded in many fish species (for example Tyler, 1978; Smale and Kok, 1983; Gunn and Milward, 1985; Weerts, 1992). In their first year, fish generally grow very quickly, and during this period diet often changes rapidly (Wootton, 1990). In juvenile *L. dumerilii*, for example, a change in feeding habits, from consuming zooplankton through a sequence of changes to the adult diet of benthos and associated sand particles, occurs within a few weeks (Blaber and Whitfield, 1977).

Changes in diet may occur gradually across a predator's size range or abruptly at a specific length (Wootton, 1990). A complete switch in prey items may occur (Tyler, 1978) or there may be a change in the relative contribution of each food item to the diet (Wahbeh and Ajiad, 1985).

Seasonal changes in feeding habits may occur as a result of changes in the habitats available for foraging, changes due to the life-history patterns of the food organisms or changes in the feeding activity of the fish themselves (Wootton, 1990). The latter may be related to the breeding cycle of the fish (Cau, Deiana and Rattu, 1986).

The diets of *P. commersonnii*, *G. filamentosus*, *L. dumerilii* and *L. equula* have been previously investigated in South Africa and other parts of the world (Prabhakara Rao, 1968; Tiews *et al.*, 1973; Masson and Marais, 1975; Blaber, 1977; van der Westhuizen and Marais, 1977; Whitfield, 1980b; Cyrus and Blaber, 1983a, 1984b) and, for each species, differences in diet have been recorded at different localities. Size-related changes and seasonal changes in diet have also been recorded in some of these species.

To obtain comprehensive information about the feeding habits of a species and about its role in the community, it is important to examine its potential food sources as well as its stomach contents. "Potentially available food" may be defined as those food items which occur in the particular habitat and are judged to be available to the fish, based on considerations of its morphology and feeding behaviour (Berg, 1979). Numerous electivity indices have been used to measure selective predation (Lechowicz, 1982). Selective predation occurs when the relative frequencies of prey types in a predator's diet differ from the relative frequencies in the environment (Chesson, 1978). Food items that constitute a larger proportion of the diet than of the available food items are considered to be preferred while those that are proportionately under-represented in the diet are considered to be avoided (Lechowicz, 1982).

Work has been published on selective predation by *G. filamentosus* in the Kosi system (Cyrus and Blaber, 1983a) and *P. commersonnii* in St Lucia (Blaber, 1983), but no research has been undertaken on the selectivity of *L. equula*. It has been suggested that the diets of *L. dumerilii* and other mullet species are probably determined largely by the occurrence of particular food items on the preferred substratum of each species (Blaber, 1977), rather than by selection for specific prey items. For this reason, studies on the diet of mullet have usually included an analysis of the size of the sand grains ingested rather than the determination of electivity indices.

The objectives of this study were to investigate and compare the diets of the juveniles of *P. commersonnii*, *G. filamentosus*, *L. dumerilii* and *L. equula* netted on the BS and CW sandbanks in Durban Bay. Seasonal changes and size-related differences in their feeding habits, as well as prey selectivity, were investigated in order to establish the nature of their association with these sandbanks.

## 4.2 MATERIALS AND METHODS

### 4.2.1 Field sampling

Fish were collected using the method described previously (Chapter 3, Section 3.2, p 17). In order to minimise deaths, only approximately 40 juveniles each of *P. commersonnii*, *G. filamentosus*, *L. dumerilii* and *L. equula* were retained for stomach content analysis while the remaining specimens were measured and returned to the water. The specimens were preserved in 4% formaldehyde and transferred to 70% alcohol after 24 hours.

Three benthic grab samples were collected from the BS and CW sandbanks during each sampling period, using a Zabalocki-type Eckman Grab, which samples an area of 0.0236 m<sup>2</sup>. The samples were emptied separately into buckets, sieved through a 0.5 mm mesh sieve and preserved in 250 ml plastic honey jars with 4% formaldehyde and Phloxine-B. This dye selectively stains animal tissue pink, facilitating sorting.

#### 4.2.2 Laboratory procedures

Standard length of each fish specimen was measured to the nearest millimetre. An incision was then made from the cloaca to between the opercula, and percentage fullness of the stomach was estimated by eye to the nearest 10%. The alimentary tract was removed and stomach contents were washed into a petri dish using a wash bottle, and examined using a Kyowa binocular microscope (45x magnification). Food items were identified to the lowest possible taxon and counted. Keys and identification guides used were Day (1967a), Day (1967b), Day (1969), Griffiths (1976) and Kilburn and Rippey (1982). All food items not identifiable as belonging to a specific taxonomic group were classified as unidentified remains (UR).

The amount of each food type in individual stomachs was measured as the volume flattened between two microscope slides 1 mm apart, the bottom one of which had a 1 mm x 1 mm graph paper grid stuck to its underside. By counting the number of 1 mm<sup>2</sup> squares obscured by each prey item, volume could be extrapolated directly. This method was modified by Weerts (1992) from Hellawell and Abel (1971). The volumes of benthic floc, defined as the mixture of detritus and microorganisms found on benthic substrates (Whitfield, 1980b), and sand grains from the *L. dumerilii* stomachs were measured

separately in a 1 ml measuring cylinder.

After sorting and identifying prey items, *L. dumerilii* specimens from each sampling trip were grouped into two size classes (86-150 mm SL and >150 mm SL), which were comparable with other studies (Masson and Marais, 1975; Marais, 1980), and the stomach sediment of each size class pooled. The median phi values and shell content of the stomach sediment samples were determined using the same method as for sandbank sediment samples (Chapter 2, Section 2.2, p 12).

Benthic samples were sorted in the laboratory using a Kyowa binocular microscope, and organisms were identified to the lowest possible taxon and counted. Keys and identification guides used were Day (1967a), Day (1967b), Day (1969), Griffiths (1976) and Kilburn and Rippey (1982).

#### 4.2.3 Data analyses

Numerical and occurrence methods of stomach content analysis tend to overemphasize the importance of numerous small prey items, and numerical methods cannot be used effectively for plant material or benthic floc. Volumetric methods have the opposite bias and tend to overestimate the importance of larger, yet less frequently eaten, food items, but they may be applied to all food items (Hellawell and Abel, 1971). In this study, a multi-method approach was used to investigate the diet of each species.

Size-related and seasonal changes in the feeding habits were also investigated. Individuals of each species were divided into arbitrary size classes, depending on length range and sample size. For each species, similarity between the diets of fish in different size classes and fish caught in different seasons was analysed using the Bray-Curtis measure of similarity with the computer programme, PRIMER 3.1b (Clarke and Warwick, 1994). Volumetric percentage contribution was used so that all food categories could be included in the analysis. For *L. dumerilii*, however, frequency of occurrence was used. If diets of different size classes were more than 50% similar the seasonal samples were not divided into size classes.

- (i) Frequency of occurrence (%F): The number of stomachs in which each food item occurred was counted and expressed as a percentage of the total number of stomachs containing food.
- (ii) Numerical occurrence (%N): The number of individuals of each prey type in all stomachs was expressed as a percentage of the total number of individuals recorded.
- (iii) The "points" method of Ricker (1968) (%V): Points were allocated to each food category according to the volume it represented in relation to all food groups in each stomach and the estimated percentage fullness of the stomach. The maximum total points which could be allocated was 100 for a full stomach. This method gives an approximate volumetric analysis of diet.

$$\text{Points} = \text{Volume 1} / \text{Volume 2} \times \% \text{ fullness}$$

where: Vol. 1 = volume of food group in stomach

Vol. 2 = volume of total stomach contents

The index of relative importance (IRI) (Pinkas, Oliphant and Iverson, 1971) incorporates numerical, volumetric and frequency of occurrence percentages. This gives an overall representation of diet (Windell, 1971). The IRI was calculated for major food categories (those contributing more than 4% by any two methods of analysis) of each fish species.

$$IRI = (N + V)F$$

where: IRI = Index of relative importance

N = Numerical percentage

V = Volumetric percentage

F = Frequency of occurrence percentage

It is acknowledged that a combination of different methods, such as the IRI, compound sources of error (Hyslop, 1980), but this was taken into account when the results were interpreted.

Similarities between the three benthic samples collected each season were analysed using the Bray-Curtis measure of similarity and multi-dimensional scaling with the computer programme, PRIMER 3.1b (Clarke and Warwick, 1994)

It has been suggested that the diets of *L. dumerilii* and other mullet species are probably determined largely by the occurrence of particular food items on the preferred substrate of each species (Blaber, 1977), rather than by selection for specific prey items. For this reason, selectivity was only determined for *P. commersonnii*, *G. filamentosus* and *L.*

*equula*. The assumption was made that the fish were feeding where they were caught. Results were obtained using calculated densities of benthic animals and numbers of animals consumed by each species. Selectivity for principal benthic prey items was calculated using Ivlev's electivity index (1961).

$$E = \frac{r - p}{r + p}$$

where 'r' is the proportion of a species in a food sample and 'p' is the proportion of a species available in the benthos, both expressed as percentages. Positive electivity is expressed by values between +1 and 0, absence of electivity by a value of 0 and negative electivity by an index value between 0 and -1.

Although Ivlev's (1961) electivity index has been criticised by various authors (Berg, 1979; Strauss, 1979), a review of several electivity indices, highlighting their respective strengths and weaknesses, did not find one index which ideally satisfied all the considered criteria (Lechowicz, 1982). It was found that, apart from one index, the indices differed in the absolute values calculated for a particular data set, but gave essentially identical rank order preferences. It was concluded that, apart from the *L* index (Strauss, 1979), all indices, including Ivlev's (1961) electivity index, provided useful measures of feeding preference (Lechowicz, 1982). Ivlev's (1961) electivity index has been used successfully by Cyrus and Blaber (1983a), Blaber (1986) and Harrison (1991) for South African fish diets.

## 4.3 RESULTS

### 4.3.1 *Pomadasys commersonnii*

The stomach contents of 43 *P. commersonnii* specimens ranging in length from 55 to 160 mm SL were analysed (Figure 4.1). Bivalve siphon tips were numerically dominant while crustaceans (Table 4.1) were volumetrically the most important food category. Although unidentified remains (UR) were volumetrically important in the diet, they consisted of partly digested gut components no longer identifiable as belonging to a specific taxonomic group and were, therefore, of little relevance to the dietary analysis. In terms of the index of relative importance for each food category (Table 4.2), bivalve siphon tips were most important in the diet, followed by crustaceans.

Although most of the siphons consumed by *P. commersonnii* were those of *Dosinia hepatica*, the large *Solen cylindraceus* siphon tips contributed most to the volume of siphons found in the stomachs of these fish (Table 4.1).

Crustaceans consisted primarily of brachyurans and unidentifiable crustacean remains by volume, but harpacticoid copepods and amphipods, particularly *Corophium triaenonyx*, were numerically dominant (Table 4.1).

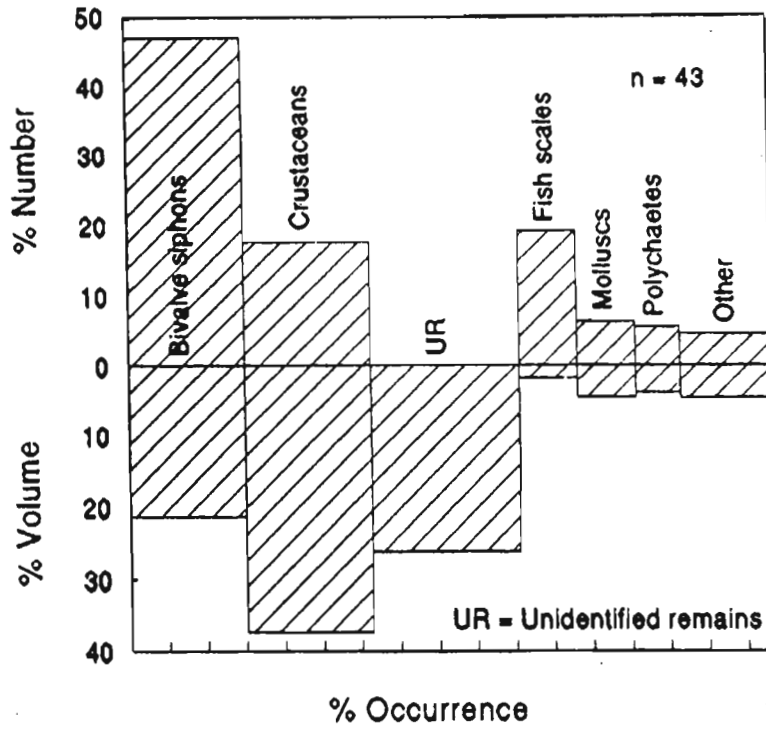


Figure 4.1: Major food categories in the diet of *P. commersonii*  
(x axis tick marks at 20% intervals)

Table 4.1: Numeric and volumetric percentage contributions of different food items to the diet of *P. commersonnii* (n=43)

Food Items	% N	% V
<b>Bivalve siphons:</b>		
<i>Dosinia hepatica</i>	23.30	6.04
<i>Eumarcia paupercula</i>	2.91	0.60
<i>Solen cylindraceus</i>	14.89	13.60
<i>Tellina prismatica</i>	5.83	1.07
<b>Crustaceans:</b>		
Harpacticoid copepods	8.41	0.91
<i>Aora kergueleni</i>	0.32	0.23
<i>Corophium triaenonyx</i>	3.56	1.09
Unidentifiable amphipods	2.59	1.37
<i>Apseudes digitalis</i>	0.65	0.17
Penaeids	0.32	2.07
Brachyurans	1.94	14.39
Crustacean remains	*	17.11
<b>Fish scales</b>	19.09	1.93
<b>Molluscs:</b>		
<i>Brachidontes variabilis</i>	0.65	1.55
<i>Dosinia hepatica</i>	0.97	1.12
Bivalve remains	2.59	1.32
<i>Finella natalensis</i>	0.32	0.34
Gastropod eggs	1.62	0.30
<b>Polychaetes:</b>		
<i>Prionospio sexoculata</i>	0.32	0.25
Polychaete remains	5.18	3.79
<b>Unidentified remains</b>	*	26.10
<b>Other:</b>		
Nematodes	2.59	0.59
Sponge spicules	0.32	0.06
Bryozoans	0.32	0.21
Larvaceans	1.29	0.08
Plant material	*	1.77
Filamentous algae	*	1.42
Sand grains	*	0.55

\* Numeric percentages could not be calculated

Table 4.2: Index of relative importance (IRI) of major food categories in the diet of *P. commersonnii*

Food Categories	IRI
Bivalve siphons	4126
Crustaceans	3587
Fish scales	634
Molluscs	323
Polychaetes	221

Size-related changes in diet:

The 43 specimens were divided into two size classes (I: 55-74 mm SL and II: 75-160 mm SL). The frequency of occurrence, and numeric and volumetric contributions of major food categories to the diets of the fish in the two size classes are shown in Figure 4.2. In both size groups, bivalve siphon tips were numerically dominant. In terms of volume, bivalve siphons were dominant in the stomachs of fish in the smaller size class, followed by crustaceans, while in the larger size class, crustaceans were clearly volumetrically dominant (Figure 4.2). In the smaller fish, bivalve siphons had the highest relative importance in the diet but as fish size increased crustaceans became the dominant prey (Table 4.3).

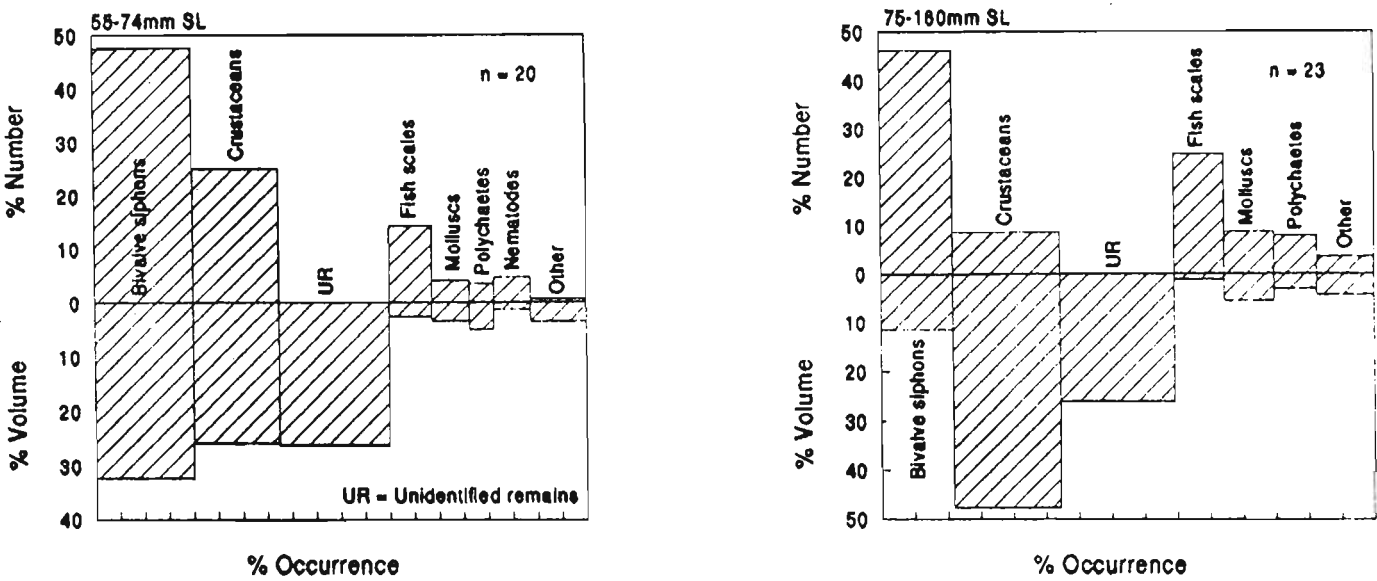


Figure 4.2: Major food categories in the diet of *P. commersonnii* from different size classes (x axis tick marks at 20% intervals)

Table 4.3: Index of relative importance (IRI) of major food categories in the diet of *P. commersonnii* from different size classes

Food Categories	55-74mm SL	75-160mm SL
Bivalve siphons	6400	2506
Crustaceans	3549	3671
Fish scales	599	793
Molluscs	225	441
Polychaetes	170	295
Nematodes	180	0

*S. cylindraceus* siphons were generally consumed by the smaller fish, while the larger fish ate mainly *D. hepatica* siphon tips (Table 4.4).

The crustaceans in both size classes were dominated volumetrically by brachyurans and unidentifiable crustacean remains. Smaller fish consumed large numbers of harpacticoid copepods, but small prey viz. copepods or nematodes were not taken by the larger fish. Instead, amphipods (*C. triaenonyx*, *A. kergueleni* and unidentifiable amphipods) were dominant (Table 4.4).

According to the Bray-Curtis measure of similarity (Field, Clarke and Warwick, 1982), the diets, in terms of volume, of fish from the two size classes were 54.24% similar. They were, therefore, not divided into size classes for the seasonal diet analysis.

#### Seasonal changes in diet:

The stomach contents of 24 specimens caught in autumn (May) and 19 specimens in winter (August), were analysed and compared. The diets of fish caught in both seasons were similar (50.12%) (Figure 4.3), with bivalve siphon tips being relatively the most important prey items, followed by crustaceans (Table 4.5).

Table 4.4: Numeric and volumetric percentage contributions of different food items to the diet of *P. commersonnii* from size classes I (55-74 mm SL) and II (75-160 mm SL)

Food Items	I (n=20)		II (n=23)	
	%N	%V	%N	%V
<b>Bivalve siphons:</b>				
<i>Dosinia hepatica</i>	14.53	5.20	34.31	6.79
<i>Eumarcia paupercula</i>	2.33	0.96	3.65	0.28
<i>Solen cylindraceus</i>	23.84	24.60	3.65	3.84
<i>Tellina prismatica</i>	6.98	1.62	4.38	0.59
<b>Crustaceans:</b>				
<b>Harpacticoid copepods</b>	15.12	1.93	0	0
<i>Aora kergueleni</i>	0	0	0.73	0.43
<i>Corophium triaenonyx</i>	2.91	0.72	4.38	1.42
Unidentifiable amphipods	2.91	0.79	2.19	1.88
<i>Apseudes digitalis</i>	1.16	0.37	0	0
Penaeids	0.58	4.40	0	0
<b>Brachyurans</b>	2.33	12.11	1.46	16.41
<b>Crustacean remains</b>	*	5.43	*	27.47
<b>Fish scales</b>	14.53	2.62	24.82	1.32
<b>Molluscs:</b>				
<i>Brachidontes variabilis</i>	0	0	1.46	2.92
<i>Dosinia hepatica</i>	0	0	2.19	2.11
Bivalve remains	3.49	2.48	1.46	0.29
<i>Finella natalensis</i>	0.58	0.72	0	0
Gastropod eggs	0	0.23	3.65	0.35
<b>Polychaetes:</b>				
<i>Prionospio sexoculata</i>	0	0	0.73	0.47
Polychaete remains	3.49	4.96	7.30	2.75
<b>Nematodes</b>	4.65	1.25	0	0
<b>Unidentified remains</b>	*	26.06	*	26.13
<b>Other:</b>				
Sponge spicules	0	0	0.73	0.11
Bryozoans	0.58	0.46	0	0
Larvaceans	0	0	2.92	0.14
Plant material	*	1.73	*	1.81
Filamentous algae	*	0.21	*	2.49
Sand grains	*	1.17	*	0

\* Numeric percentages could not be calculated

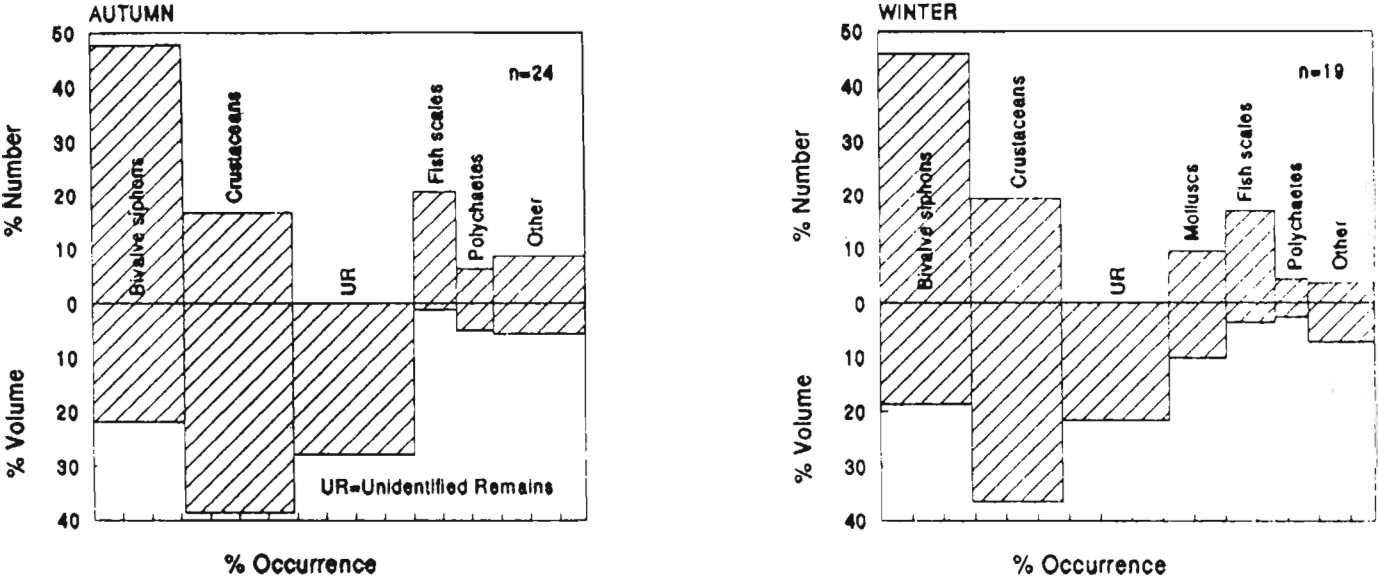


Figure 4.3: Major food categories in the diet of *P. commersonnii* caught in autumn and winter  
(x axis tick marks at 20% intervals)

Table 4.5: Index of relative importance (IRI) of major food categories in the diet of *P. commersonnii* caught in different seasons

Food Categories	AUTUMN	WINTER
Bivalve siphons	4338	3729
Crustaceans	4148	3225
Fish scales	639	651
Molluscs	138	725
Polychaetes	283	148

This species consumed mainly *S. cylindraceus* siphons in autumn but in winter switched to eating predominantly *D. hepatica* siphon tips. Harpacticoid copepods and amphipods dominated the crustacean category numerically, and unidentifiable remains and brachyurans dominated volumetrically, in both seasons (Table 4.6).

Table 4.6: Numeric and volumetric percentage contributions of different food items to the diet of *P. commersonnii* caught in autumn and winter

Food Items	AUTUMN (n = 24)		WINTER (n = 19)	
	% N	% V	% N	% V
<b>Bivalve siphons:</b>				
<i>Dosinia hepatica</i>	10.34	4.12	40.00	10.37
<i>Eumarcia paupercula</i>	4.60	0.65	0.74	0.52
<i>Solen cylindraceus</i>	24.14	15.98	2.96	7.10
<i>Tellina prismatica</i>	8.62	1.11	2.22	0.50
<b>Crustaceans:</b>				
<b>Harpacticoid copepods</b>				
<i>Aora kergueleni</i>	5.75	0.45	11.85	1.97
<i>Corophium triaenonyx</i>	0.63	0.32	0	0
Unidentifiable amphipods	5.04	0.95	2.22	0.62
<i>Apseudes digitalis</i>	1.26	0.32	4.44	4.19
Penaeids	0.57	0.13	0	0
<b>Brachyurans</b>	0.57	3.13	0	0
<b>Crustacean remains</b>	2.87	11.63	0.74	20.94
	*	21.69	*	8.65
<b>Fish scales</b>	20.69	1.15	17.04	3.65
<b>Molluscs:</b>				
<i>Brachidontes variabilis</i>	0	0	1.48	4.84
<i>Dosinia hepatica</i>	0	0	2.22	3.49
Bivalve remains	2.87	1.50	2.22	0.92
<i>Finella natalensis</i>	0.57	0.51	0	0
Gastropod eggs	0	0	3.70	0.92
<b>Polychaetes:</b>				
<i>Prionospio sexoculata</i>	0.57	0.38	0	0
Polychaete remains	5.75	4.63	4.44	2.57
<b>Unidentified remains</b>	*	27.78	*	21.62
<b>Other:</b>				
Nematodes	2.87	0.47	2.22	0.67
Sponge spicules	0	0	0.74	0.19
Bryozoans	0	0	0.74	0.67
Larvaceans	2.30	0.11	0	0
Plant material	*	0.90	*	3.67
Filamentous algae	*	2.05	*	0.19
Sand grains	*	0	*	1.71

\* Numeric percentages could not be calculated

### Selectivity:

Bivalve siphons, crustaceans, fish scales, molluscs and polychaetes were numerically the most important food categories in the diet of *P. commersonnii* throughout the study period (Figure 4.1). Selectivity for fish scales and molluscs could not be calculated as fish scales and gastropod eggs, which formed part of the mollusc category, in the benthos were not counted. Electivity indices, which are a measure of selectivity, were calculated for bivalve siphons, polychaetes and crustaceans.

*P. commersonnii* took bivalve siphon tips in proportion to their availability, while crustaceans were positively selected and a negative electivity value was recorded for polychaetes (Figure 4.4A). The positive selection for crustaceans may have been over-estimated because harpacticoid copepods, which made an important numeric contribution to the diet of *P. commersonnii*, may have passed through the net used to sieve benthic samples and would, therefore, not have been sampled accurately in the benthos (Appendix 1). Selectivity of the fish in the two size classes for the major prey categories was very similar (Figure 4.4B). Selectivity for major prey categories during successive seasons was also calculated and compared, but little variation was found (Figure 4.4C).

Selectivity for major prey species, excluding harpacticoid copepods, was also calculated (Figure 4.5). *D. hepatica* siphons were taken in proportion to their availability, *E. paupercula* siphons had a negative electivity index, and *T. prismatica* and *S. cylindraceus* were positively selected. *P. commersonnii* also showed a strong positive selection for amphipods (Figure 4.5A). There was little difference between the two size classes, except that for smaller fish slightly negative electivity values were recorded for *D. hepatica*

siphon tips, while these siphons were marginally positively selected by fish in the larger size class (Figure 4.5B). From autumn to winter, little change in selectivity was found, except that for larger fish slightly negative electivity values were recorded for *E. paupercula* siphon tips, while these siphons were marginally positively selected by smaller fish (Figure 4.5C).

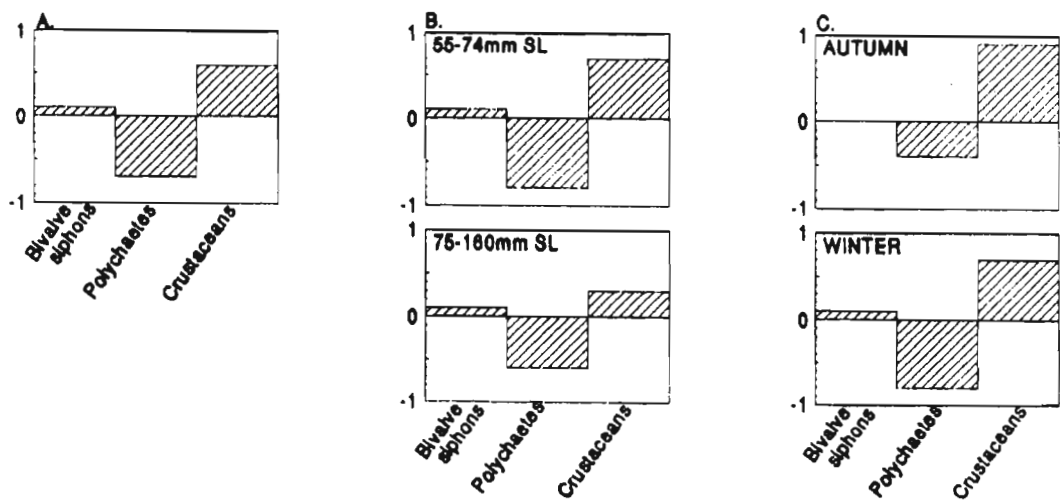


Figure 4.4: Selectivity of *P. commersonnii* for major prey categories A) from the total study period, B) from different size classes and C) during different seasons

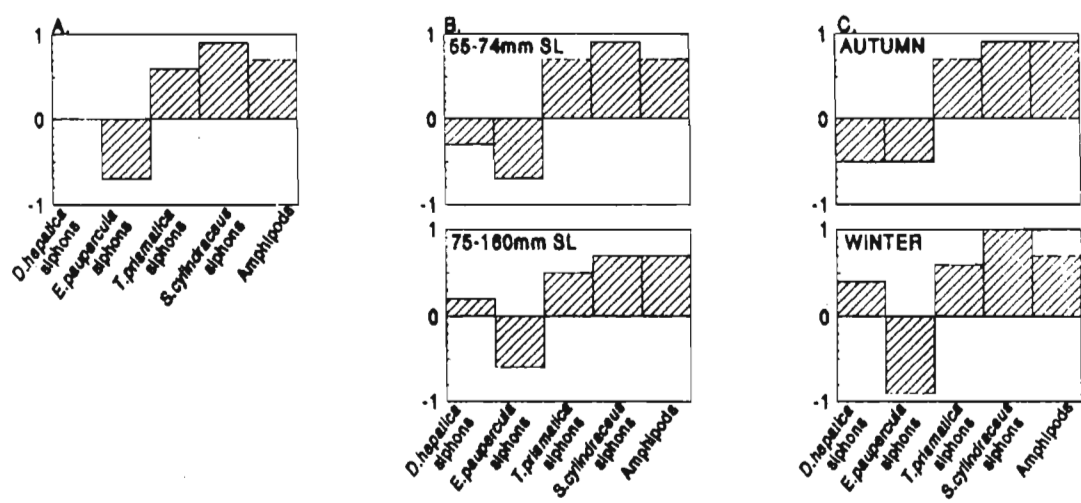


Figure 4.5: Selectivity of *P. commersonnii* for major prey species A) from the total study period, B) from different size classes and C) during different seasons

4.3.2 *Gerres filamentosus*

The stomach contents of 129 *G. filamentosus* specimens ranging in length from 58 to 80 mm SL were analysed. *G. filamentosus* become sexually mature from around 70 mm SL (Cyrus and Blaber, 1984a), but specimens measuring up to 80 mm SL, which were used for stomach content analysis, appeared to be sexually immature.

Bivalve siphon tips completely dominated the diet of *G. filamentosus* in terms of the three methods of stomach content analysis (Figure 4.6) and the index of relative importance (Table 4.7). Crustaceans, polychaetes and molluscs (Table 4.8) were also consumed, but their relative importance in the diet was considerably lower than that of the siphon tips (Table 4.7).

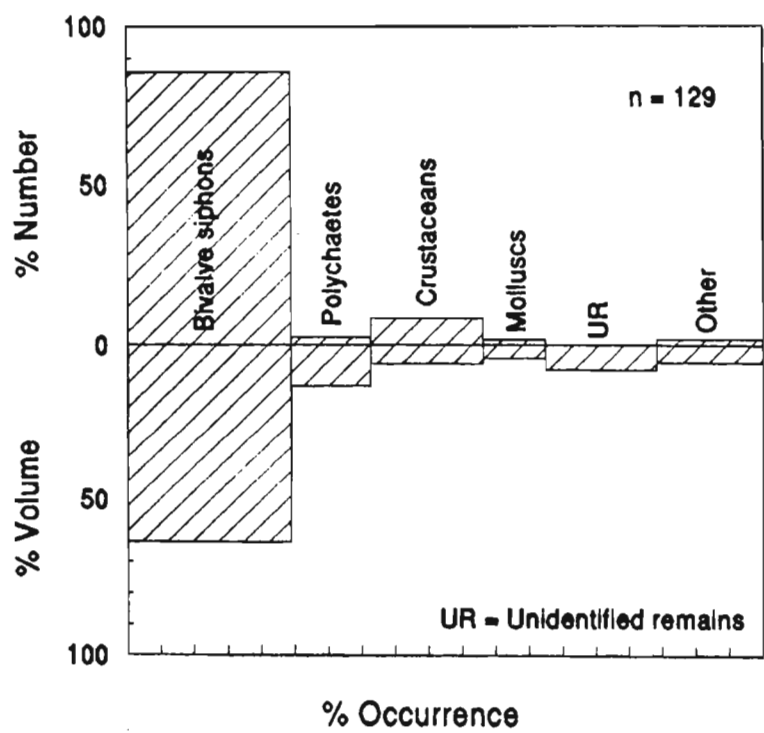


Figure 4.6: Major food categories in the diet of *G. filamentosus* (x axis tick marks at 20% intervals)

Table 4.7: Index of relative importance (IRI) of major food categories in the diet of *G. filamentosus*

Food Categories	IRI
Bivalve siphons	14567
Crustaceans	964
Polychaetes	724
Molluscs	220

*G. filamentosus* consumed primarily *D. hepatica* siphon tips, although the siphons of three other species were also eaten (Table 4.8).

Size-related changes in diet:

The *G. filamentosus* specimens were divided into two size classes (I: 58-70 mm SL and II: 71-80 mm SL). Bivalve siphon tips, primarily those of *D. hepatica*, completely dominated the diet of fish from both size classes (Figure 4.7 and Tables 4.9 and 4.10). In both size groups crustaceans were second most important in terms of the IRI, followed by polychaetes (Table 4.9). The importance of these two food types, however, decreased with increasing fish size. In the crustacean category this was reflected by a decrease in the amount of harpacticoid copepods consumed (Table 4.10).

Table 4.8: Numeric and volumetric percentage contributions of different food items to the diet of *G. filamentosus* (n=129)

Food Items	%N	%V
<b>Bivalve siphons:</b>		
<i>Dosinia hepatica</i>	60.60	43.15
<i>Eumarcia paupercula</i>	15.41	8.14
<i>Solen cylindraceus</i>	3.09	8.46
<i>Tellina prismatica</i>	6.36	3.83
<b>Crustaceans:</b>		
Harpacticoid copepods	6.14	2.72
Cyclopoid copepods	0.20	0.24
<i>Apseudes digitalis</i>	0.39	0.46
Unidentifiable tanaids	1.64	1.91
<i>Corophium triaenonyx</i>	0.02	0.03
Unidentifiable amphipods	0.02	0.03
Cumaceans	0.06	0.11
Crustacean remains	*	0.52
<b>Polychaetes:</b>		
<i>Glycera convoluta</i>	0.04	2.40
<i>Glycera natalensis</i>	0.35	2.90
<i>Glycera</i> sp.	0.10	0.51
<i>Prionospio sexoculata</i>	0.29	1.30
<i>Prionospio</i> sp.	0.27	0.50
<i>Nereis</i> sp.	0.02	1.32
<i>Cirriformia</i> sp.	0.08	0.45
<i>Phyllodoce castanea</i>	0.06	0.37
<i>Epidiopatra</i> sp.	0.02	0.21
Eunicidae	0.08	0.45
Polychaete remains	1.04	2.68
<b>Molluscs:</b>		
<i>Brachidontes variabilis</i>	0.12	1.51
<i>Dosinia hepatica</i>	0.04	0.15
Bivalve remains	0.49	1.29
<i>Atys cylindrica</i>	0.08	0.13
Gastropod remains	0.06	0.16
Gastropod eggs	0.90	0.96
<b>Unidentified remains</b>	*	7.65
<b>Other:</b>		
Foraminiferans	0.08	0.13
Nematodes	1.51	1.44
Sponge spicules	0.02	0.03
Larvaceans	0.04	0.04
Fish scales	0.35	0.69
Plant material	*	2.05
Filamentous algae	*	0.03
Sand grains	*	0.99

\* Numeric percentages could not be calculated

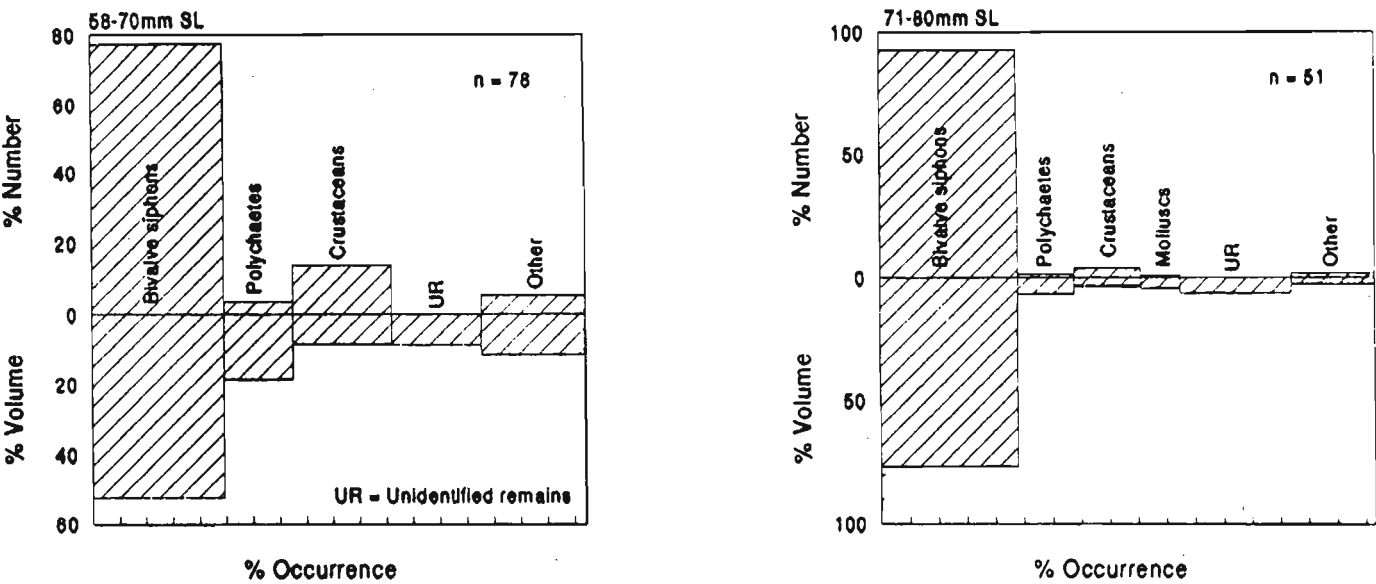


Figure 4.7: Major food categories in the diet of *G. filamentosus* from different size classes (x axis tick marks at 20% intervals)

Table 4.9: Index of relative importance (IRI) of major food categories in the diet of *G. filamentosus* from different size classes

Food Categories	58-70mm SL	71-80mm SL
Bivalve siphons	12840	16270
Crustaceans	1667	330
Polychaetes	1139	310
Molluscs	118	143

The similarity of the diets of fish from the two size classes is reflected in the Bray-Curtis measure of similarity (Field, Clarke and Warwick, 1982) (61.28%). Seasonal catches were, therefore, not divided into size classes.

Table 4.10: Numeric and volumetric percentage contributions of different food items to the diet of *G. filamentosus* from size classes I (58-70 mm SL) and II (71-80 mm SL)

Food Items	I (n=78)		II (n=51)	
	%N	%V	%N	%V
<b>Bivalve siphons:</b>				
<i>Dosinia hepatica</i>	42.24	29.63	76.61	58.95
<i>Eumarcia paupercula</i>	21.47	10.66	10.11	5.20
<i>Solen cylindraceus</i>	2.72	6.28	3.41	11.01
<i>Tellina prismatica</i>	10.76	5.91	2.53	1.39
<b>Crustaceans:</b>				
<b>Harpacticoid copepods</b>	10.89	4.08	1.99	1.14
Cyclopoid copepods	0.18	0.29	0.23	0.19
<i>Apseudes digitalis</i>	0.44	0.56	0.34	0.34
Unidentifiable tanaids	2.20	2.33	1.19	1.42
<i>Corophium triaenonyx</i>	0.04	0.06	0	0
Unidentifiable amphipods	0.04	0.06	0	0
Cumaceans	0.13	0.21	0	0
Crustacean remains	*	0.92	*	0.13
<b>Polychaetes:</b>				
<i>Glycera convoluta</i>	0.09	4.46	0	0
<i>Glycera natalensis</i>	0.61	5.02	0.11	0.44
<i>Glycera</i> sp.	0.18	0.82	0.04	0.16
<i>Prionospio sexoculata</i>	0.61	2.42	0	0
<i>Prionospio</i> sp.	0.57	0.93	0	0
<i>Nereis</i> sp.	0	0	0.04	2.86
<i>Cirriformia</i> sp.	0.18	0.83	0	0
<i>Phyllodoce castanea</i>	0.13	0.69	0	0
<i>Epidiopatra</i> sp.	0	0	0.04	0.46
Eunicidae	0.13	0.68	0.04	0.17
Polychaete remains	1.14	2.77	0.96	2.58
<b>Molluscs:</b>				
<i>Brachidontes variabilis</i>	0.13	1.14	0.11	1.94
<i>Dosinia hepatica</i>	0	0	0.08	0.32
Bivalve remains	0.57	1.28	0.42	1.30
<i>Alys cylindrica</i>	0.04	0.13	0.11	0.12
Gastropod remains	0.09	0.21	0.04	0.10
Gastropod eggs	1.32	1.29	0.54	0.58
<b>Unidentified remains</b>	*	8.75	*	6.37
<b>Other:</b>				
Foraminiferans	0.04	0.09	0.11	0.17
Nematodes	2.37	1.99	0.77	0.79
Sponge spicules	0	0	0.04	0.07
Larvaceans	0.09	0.08	0	0
Fish scales	0.59	1.11	0.13	0.19
Plant material	*	2.97	*	0.97
Filamentous algae	*	0.06	*	0
Sand grains	*	1.28	*	0.65

\* Numeric percentages could not be calculated

### Seasonal changes in diet:

The stomach contents of 32 specimens caught in autumn (May), 32 specimens in winter (August), 33 specimens caught in spring (November) and 32 specimens caught in summer (February) were analysed and compared.

Results from all three methods of stomach content analysis and the IRI revealed that bivalve siphon tips dominated the diet of *G. filamentosus* in all four seasons (Figure 4.8 and Table 4.11). In autumn and spring polychaetes were the second most important prey consumed, but in winter crustaceans became relatively more important in the diet than polychaetes (Table 4.11). In summer the diet of this species consisted almost exclusively of bivalve siphon tips (Figures 4.8 and Tables 4.11 and 4.12). The similarity of diets of fish caught in different seasons is reflected in the Bray-Curtis measure of similarity (Field, Clarke and Warwick, 1982) shown in Table 4.13.

Table 4.11: Index of relative importance (IRI) of major food categories in the diet of *G. filamentosus* caught in different seasons

Food Categories	AUTUMN	WINTER	SPRING	SUMMER
Bivalve siphons	14640	8324	8949	18870
Polychaetes	900	1265	2687	28
Crustaceans	488	4887	1968	70
Molluscs	39	416	1584	8

The siphons of all four bivalve species were important prey throughout the year. *D. hepatica* siphons were consistently dominant by volume, but the dominant siphons, in terms of numeric contribution, varied (Table 4.12). No apparent trend was evident in the seasonal intake of crustaceans or polychaete species by *G. filamentosus* (Table 4.12).

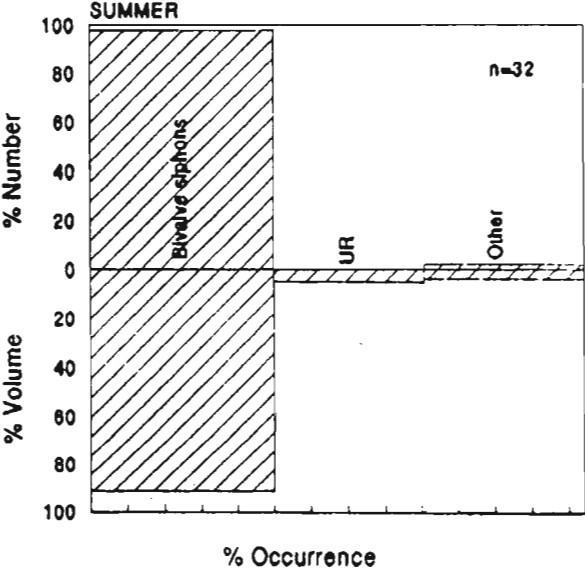
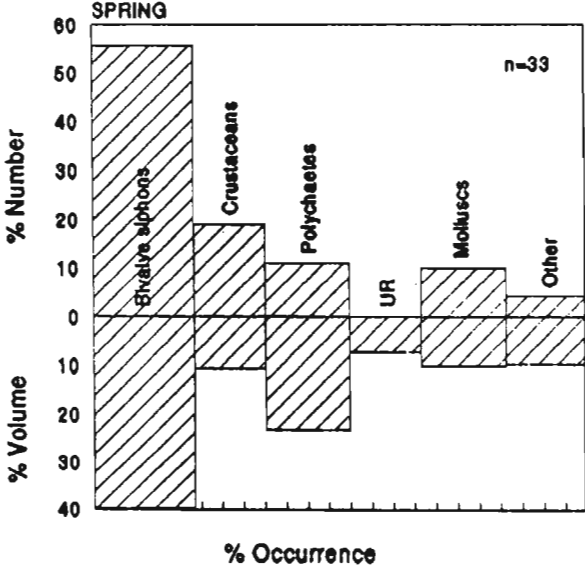
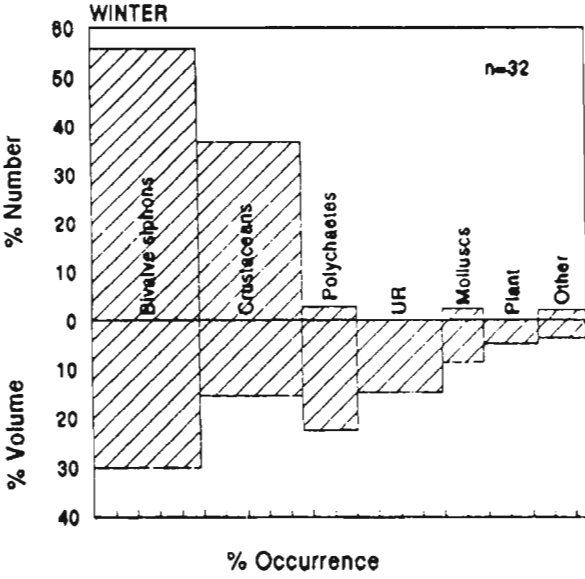
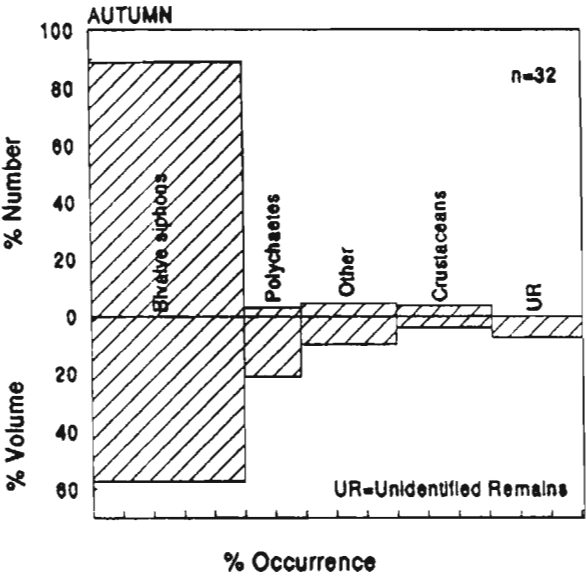


Figure 4.8: Major food categories in the diet of *G. filamentosus* caught in different seasons (x axis tick marks at 20% intervals)

Table 4.12: Numeric and volumetric percentage contributions of different food items to the diet of *G. filamentosus* caught in different seasons

	AUTUMN (n=32)		WINTER (n=32)		SPRING (n=33)		SUMMER (n=32)	
Food Items	% N	% V	% N	% V	% N	% V	% N	% V
<b>Bivalve siphons:</b>								
<i>Dosinia hepatica</i>	34.88	29.04	20.06	11.55	35.21	21.33	83.95	73.41
<i>Eumarcia paupercula</i>	43.26	19.24	7.85	4.31	10.16	4.86	9.44	4.41
<i>Solen cylindraceus</i>	0.23	1.77	4.22	5.10	4.17	10.89	3.51	12.83
<i>Tellina prismatica</i>	10.53	7.55	23.84	8.95	5.99	2.64	0.76	0.50
<b>Crustaceans:</b>								
Harpacticoid copepods	3.62	3.04	26.31	6.07	12.52	4.24	0.69	0.57
Cyclopoid copepods	0	0	0.58	0.96	0	0	0.22	0.15
<i>Apeudes digitalis</i>	0	0	2.26	1.91	0.54	0.61	0	0
Unidentifiable tanaids	0	0	7.34	5.29	5.06	4.89	0.04	0.02
<i>Corophium triaenonyx</i>	0	0	0	0	0.20	0.10	0	0
Unidentifiable amphipods	0	0	0	0	0.20	0.10	0	0
Cumaceans	0	0	0	0	0.54	0.63	0	0
Crustacean remains	*	1.25	*	1.20	*	0	*	0.15
<b>Polychaetes:</b>								
<i>Glycera convoluta</i>	0.23	11.18	0	0	0	0	0	0
<i>Glycera natalensis</i>	0.68	5.23	1.56	11.10	0	0	0	0
<i>Glycera</i> sp.	0.11	1.15	0	0	0.73	1.37	0	0
<i>Prionospio sexoculata</i>	0	0	0	0	2.54	6.20	0	0
<i>Prionospio</i> sp.	1.47	2.32	0	0	0	0	0	0
<i>Nereis</i> sp.	0	0	0.15	8.10	0	0	0	0
<i>Cirriformia</i> sp.	0.11	0.38	0	0	0.54	1.90	0	0
<i>Phyllodoce castanea</i>	0	0	0	0	0.54	2.00	0	0
<i>Epidiopatra</i> sp.	0	0	0	0	0	0	0.04	0.52
Eunicidae	0	0	0.14	0.94	0.54	1.60	0	0
Polychaete remains	0.34	0.78	0.99	2.36	6.17	9.80	0.25	0.66
<b>Molluscs:</b>								
<i>Brachidontes variabilis</i>	0.11	1.57	0.44	4.70	0.36	2.10	0	0
<i>Dosinia hepatica</i>	0	0	0.15	0.07	0.18	0.70	0	0
Bivalve remains	0.23	0.47	1.16	2.94	2.00	2.91	0.11	0.16
<i>Alys cylindrica</i>	0.11	0.33	0	0	0	0	0.11	0.14
Gastropod remains	0	0	0.29	0.53	0.18	0.39	0	0
Gastropod eggs	0.11	0.22	0.44	0.50	7.26	3.94	0	0
<b>Unidentified remains</b>	*	7.45	*	14.91	*	7.11	*	5.02
<b>Other:</b>								
Foraminiferans	0	0	0.29	0.45	0.18	0.21	0.04	0.04
Nematodes	3.40	3.18	0.73	1.16	3.45	1.71	0.72	0.63
Sponge spicules	0	0	0	0	0.18	0.16	0	0
Larvaceans	0	0	0.29	0.27	0	0	0	0
Fish scales	0.57	1.15	0.73	1.49	0.54	0.66	0.14	0.19
Plant material	*	2.30	*	4.92	*	3.60	*	0.18
Filamentous algae	*	0	*	0.21	*	0	*	0
Sand grains	*	0.39	*	0	*	3.24	*	0.43

\* Numeric percentages could not be calculated

Table 4.13: Bray-Curtis percentage similarity of the diets of *G. filamentosus* caught in different seasons (in terms of %V)

	AUTUMN	WINTER	SPRING
WINTER	49.76		
SPRING	50.65	55.86	
SUMMER	43.81	29.23	45.44

#### Selectivity:

Electivity indices were calculated for bivalve siphons, crustaceans and polychaetes, which together numerically constituted 96% of the diet of *G. filamentosus* throughout the study period (Figure 4.6). Bivalve siphons tips and crustaceans were positively selected by *G. filamentosus*, while polychaetes had a negative electivity (Figure 4.9A). The positive selection for crustaceans may, however, have again been biased because harpacticoid copepods, which made an important numeric contribution to the crustacean component of the diet of *G. filamentosus*, may not have been sampled accurately in the benthos. Little variation occurred in the selectivity of the fish in the two size classes for the major prey categories, except that crustaceans were more positively selected by smaller fish (Figure 4.9B). Selectivity for major food categories was also calculated over the four seasons. Selectivity in autumn, winter and spring was similar, but in summer, 90% negative electivity was recorded for crustaceans (Figure 4.9C). This was probably influenced by the fact that the population structure of the fish sampled in the first three months was dominated by fish in the smaller size class, which showed a greater positive selection for crustaceans. In summer, fish of the larger size class were dominant in the sample.

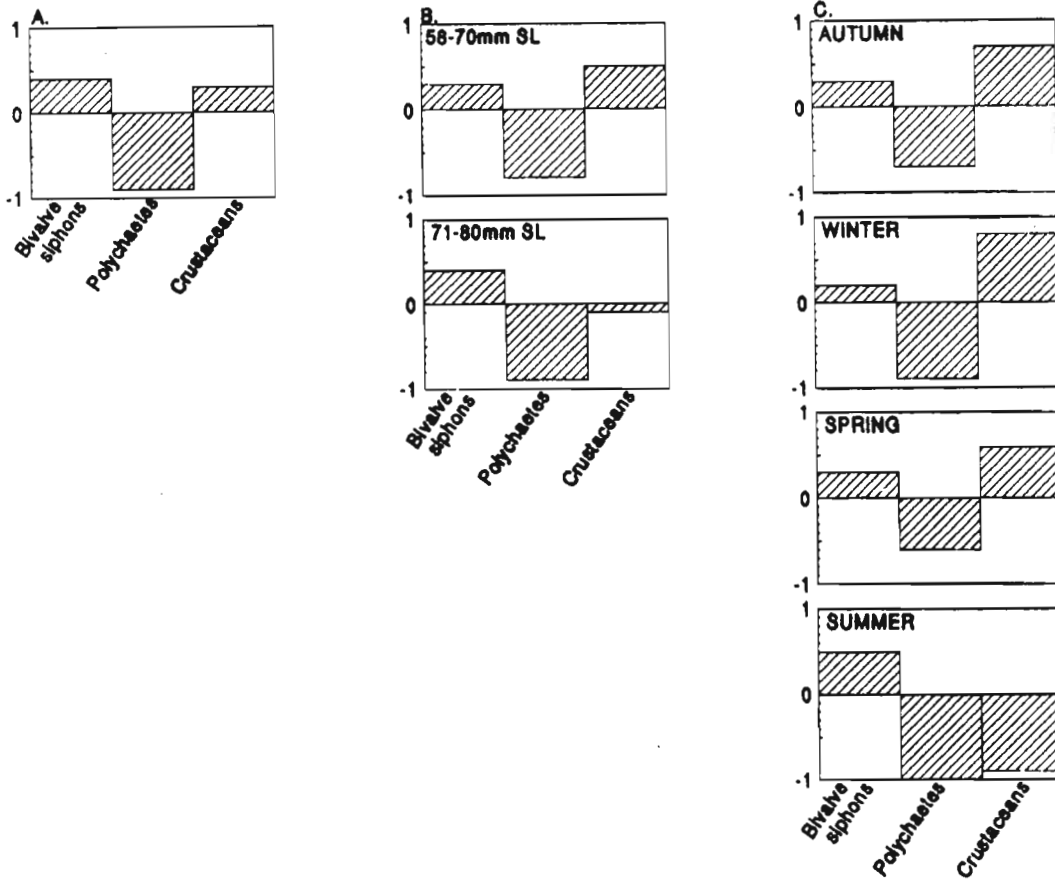


Figure 4.9: Selectivity of *G. filamentosus* for major prey categories A) from the total study period, B) from different size classes and C) during different seasons

Selectivity for major prey species was also calculated (Figure 4.10). *D. hepatica*, *T. prismatica* and *S. cylindraceus* siphons were positively selected, while *E. paupercula* siphons were taken in proportion to their availability (Figure 4.10A). Little variation occurred in the selectivity of the fish in the two size classes, except that for fish in the larger size class a slightly negative electivity index was recorded for *E. paupercula* siphon

tips, while these siphons were slightly positively selected by fish in the smaller size class (Figure 4.10B). Selectivity for the siphon tips of the four species varied considerably across the four seasons (Figure 4.10C). Although this may indicate a change in selectivity, it may also be an artefact of the small number (three) of benthic samples taken in each season.

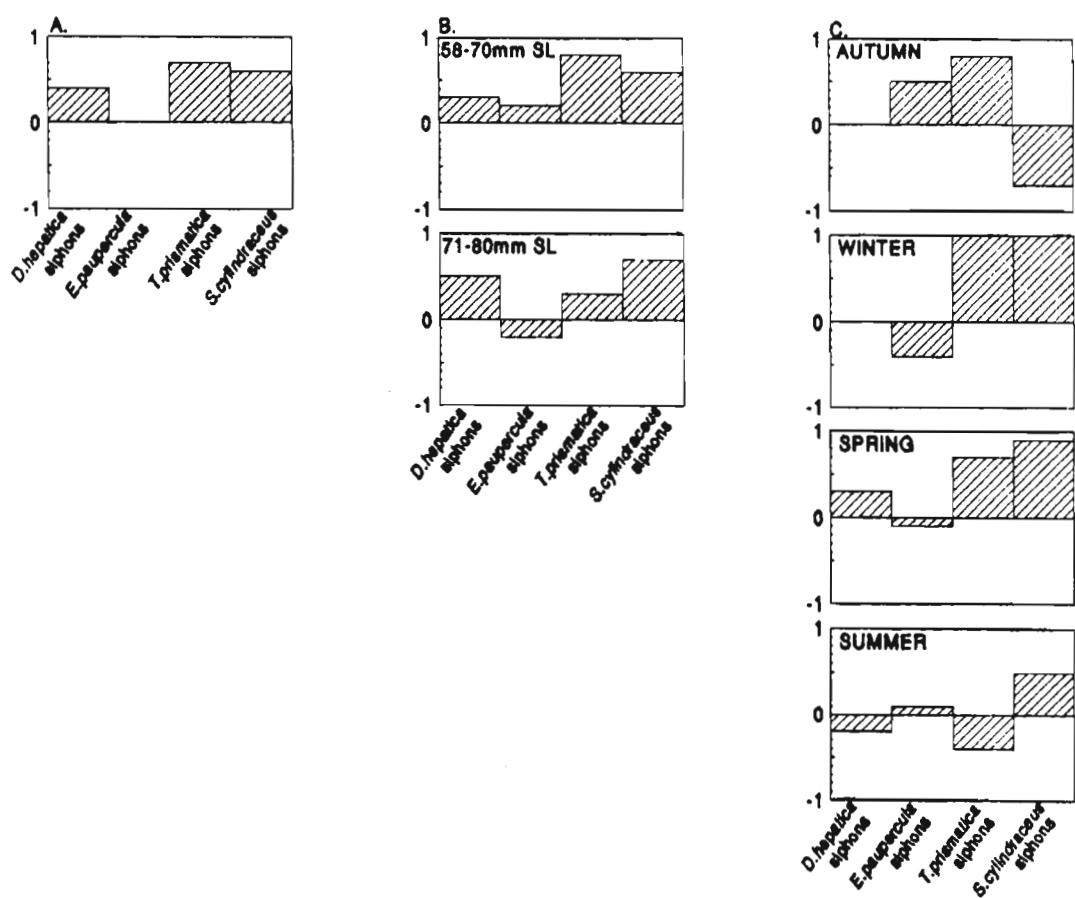


Figure 4.10: Selectivity of *G. filamentosus* for major prey species A) from the total study period, B) from different size classes and C) during different seasons

4.3.3 *Leiognathus equula*

The stomach contents of 130 *L. equula* specimens ranging in length from 42 to 115 mm SL were analysed. The diet was not completely dominated by any one food type, but crustaceans, polychaetes, bivalve siphon tips and nematodes were the major food items (Figure 4.11 and Table 4.14).

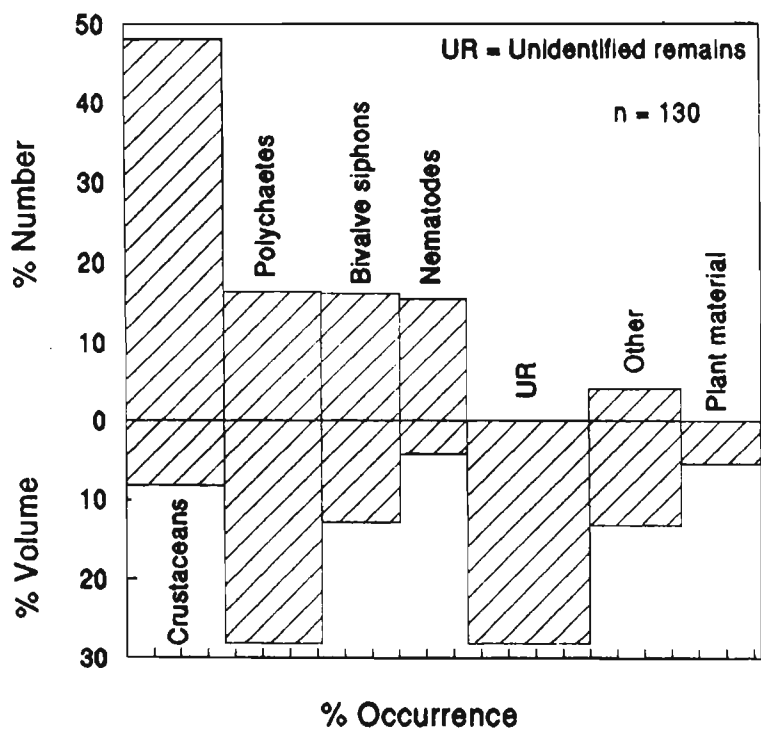


Figure 4.11: Major food categories in the diet of *L. equula* (x axis tick marks at 20% intervals)

Table 4.14: Index of relative importance (IRI) of major food categories in the diet of *L. equula*

Food Categories	IRI
Crustaceans	4071
Polychaetes	3144
Bivalve siphons	1679
Nematodes	964

Harpacticoid copepods were the dominant crustaceans consumed by this species. Two genera viz. *Cossura* and *Prionospio* species dominated the polychaete component of the diet numerically, while *Cirriformia* sp. were volumetrically most important. The most important siphons consumed were those of *D. hepatica* and *T. prismatica* (Table 4.15)

#### Size-related changes in diet:

Due to the large sample size and wide size range, *L. equula* specimens were divided into three size classes (I: 42-59 mm SL; II: 60-79 mm SL and III: 80-115 mm SL). The frequency of occurrence as well as numeric and volumetric contributions of food items to the diets of the fish in the three size classes are shown in Figure 4.12. Crustaceans were clearly the most important prey item by number in size class I, but bivalve siphons and polychaetes increased in importance in size class II, and in size class III higher numbers of polychaetes than bivalve siphons or crustaceans, were consumed. This trend was also reflected in the IRI for each food category (Table 4.16). Nematodes were relatively important in all size classes but their importance decreased with increasing fish size, whereas the importance of molluscs increased (Table 4.16).

Table 4.15: Numeric and volumetric percentage contributions of different food items to the diet of *L. equula* (n=130)

Food Items	%N	%V
<b>Crustaceans:</b>		
<b>Harpacticoid copepods</b>	<b>46.02</b>	<b>6.33</b>
Cyclopoid copepods	0.15	0.10
<i>Apseudes digitalis</i>	0.15	0.19
Unidentifiable tanaids	1.53	1.30
Unidentifiable amphipods	0.12	0.15
Cumaceans	0.03	0.04
Ostracods	0.06	0.17
Crustacean remains	*	0.77
<b>Polychaetes:</b>		
<b><i>Cirriformia</i> sp.</b>	<b>1.28</b>	<b>8.09</b>
<b><i>Cossura coasta</i></b>	<b>4.52</b>	<b>1.48</b>
<b><i>Prionospio sexoculata</i></b>	<b>2.17</b>	<b>3.47</b>
<b><i>Prionospio</i> sp.</b>	<b>2.56</b>	<b>3.75</b>
<i>Glycera convoluta</i>	0.03	1.30
<i>Glycera natalensis</i>	0.15	0.51
<i>Glycera</i> sp.	0.09	0.16
<i>Phyllodoce castanea</i>	0.09	0.14
Polychaete remains	5.40	8.96
<b>Bivalve siphons:</b>		
<b><i>Dosinia hepatica</i></b>	<b>8.18</b>	<b>7.38</b>
<i>Eumarcia paupercula</i>	1.07	1.03
<i>Solen cylindraceus</i>	0.40	1.34
<b><i>Tellina prismatica</i></b>	<b>6.47</b>	<b>3.17</b>
<b>Nematodes</b>	<b>15.36</b>	<b>4.18</b>
<b>Unidentified remains</b>	<b>*</b>	<b>28.29</b>
<b>Other:</b>		
<i>Brachidontes variabilis</i>	0.06	0.18
<i>Dosinia hepatica</i>	0.24	0.38
Bivalve remains	0.52	2.19
<i>Arys cylindrica</i>	0.03	0.13
<i>Bullia laevissima</i>	0.06	0.32
Gastropod remains	0.03	0.04
Gastropod eggs	0.67	0.46
Foraminiferans	0.24	0.29
Sponge spicules	0.03	0.02
Fish scales	1.89	2.15
Fish eggs	0.09	0.07
Plant material	*	5.40
Filamentous algae	*	1.33
Diatoms	0.27	0.26
Sand grains	*	4.49

\* Numeric percentages could not be calculated

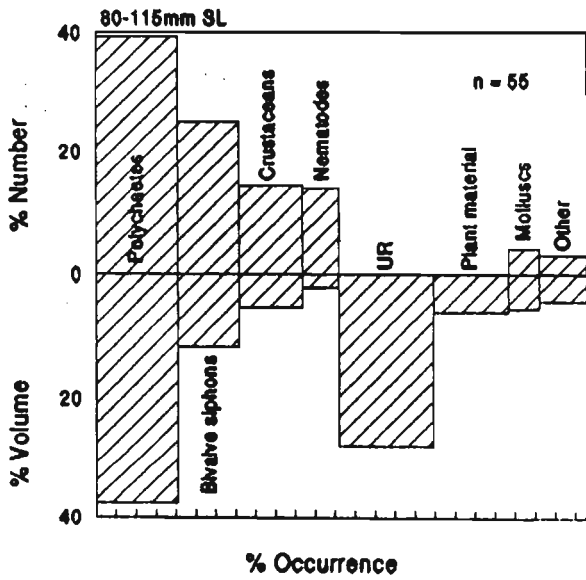
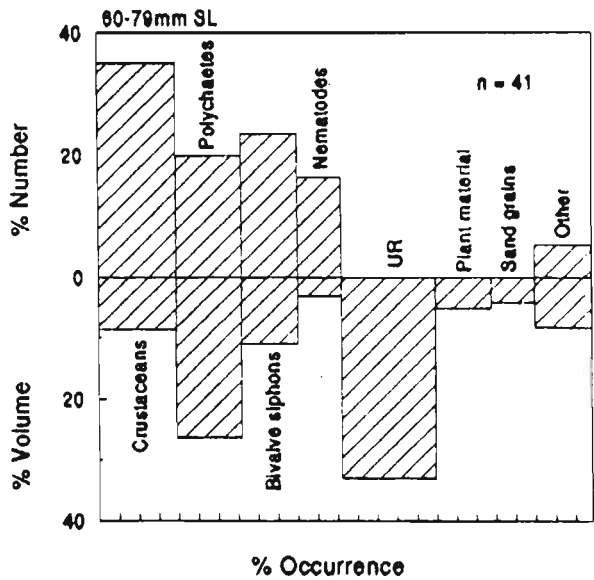
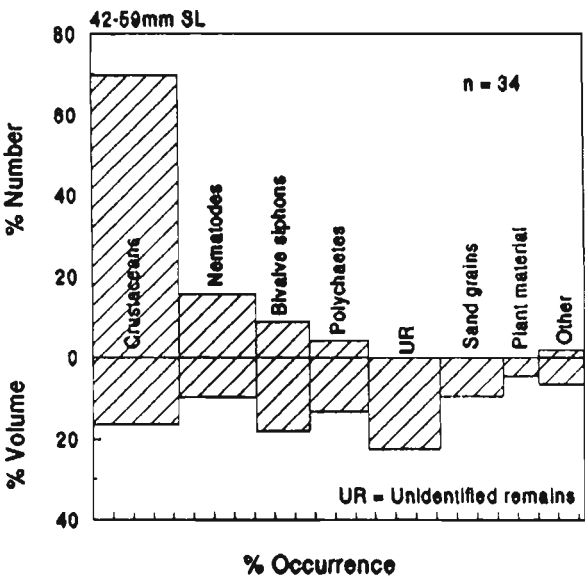


Figure 4.12: Major food categories in the diet of *L. equula* from different size classes (x axis tick marks at 20% intervals)

Table 4.16: Index of relative importance (IRI) of major food categories in the diet of *L. equula* from different size classes

Food Categories	42-59 mm SL	60-79 mm SL	80-115 mm SL
Crustaceans	7344	3416	1253
Polychaetes	1011	3038	6282
Bivalve siphons	1412	1935	2268
Nematodes	1920	852	586
Molluscs	7	131	300

Harpacticoid copepods dominated the crustacean category of all three size classes by number and volume, but their overall importance in the diet declined with increasing fish size. This decrease was accompanied by an increase in the number of crustacean species consumed. Although the same species of polychaete remained dominant in both groups, the number of species consumed also increased with increasing fish size (Table 4.17).

Changes in the diet with an increase in fish size are reflected in the Bray-Curtis measure of similarity (Field, Clarke and Warwick, 1982) shown in Table 4.18. The diets of fish in size classes I and III were least similar while those in size classes II and III were very similar.

Table 4.17: Numeric and volumetric percentage contributions of different food items to the diet of *L. equula* from size classes I (42-59 mm SL), II (60-79 mm SL) and III (80-115 mm SL)

Food Items	I (n=34)		II (n=41)		III(n=55)	
	%N	%V	%N	%V	%N	%V
<b>Crustaceans:</b>						
<b>Harpacticoid copepods</b>	<b>69.36</b>	<b>13.61</b>	<b>32.68</b>	<b>5.70</b>	<b>9.18</b>	<b>2.78</b>
Cyclopoid copepods	0	0	0.66	0.30	0	0
<i>Apsudes digitalis</i>	0	0	0.13	0.24	0.50	0.26
Unidentifiable tanaids	0.29	0.89	1.31	1.01	4.34	1.76
Unidentifiable amphipods	0	0	0.26	0.30	0.25	0.10
Cumaceans	0	0	0	0	0.12	0.10
Ostracods	0.12	0.71	0	0	0	0
Crustacean remains	*	1.08	*	1.22	*	0.23
<b>Polychaetes:</b>						
<i>Cirriiformia</i> sp.	0.12	2.70	3.15	11.30	1.99	8.45
<i>Cossura coasta</i>	2.05	2.51	5.25	0.99	9.06	1.30
<i>Prionospio sexoculata</i>	0	0	2.49	3.59	6.45	5.32
<i>Prionospio</i> sp.	0.12	0.99	4.33	4.37	6.08	4.79
<i>Glycera convoluta</i>	0	0	0	0	0.12	3.09
<i>Glycera natalensis</i>	0.06	1.22	0.26	0.35	0.25	0.25
<i>Glycera</i> sp.	0.06	0.26	0.26	0.28	0	0
<i>Phyllodoce castanea</i>	0	0	0	0	0.37	0.34
Polychaete remains	1.64	5.39	3.94	5.35	14.76	13.94
<b>Bivalve siphons:</b>						
<i>Dosinia hepatica</i>	3.75	6.83	8.27	6.17	17.49	8.68
<i>Eumarcia paupercula</i>	1.17	2.77	1.57	0.74	0.37	0.31
<i>Solen cylindraceus</i>	0.41	4.11	0.13	0.17	0.62	0.75
<i>Tellina prismatica</i>	3.34	4.27	13.52	3.91	6.45	1.94
<b>Nematodes</b>	<b>15.58</b>	<b>9.54</b>	<b>16.27</b>	<b>3.06</b>	<b>14.02</b>	<b>2.10</b>
<b>Molluscs:</b>						
<i>Brachidontes variabilis</i>	0.06	0.57	0	0	0.12	0.10
<i>Dosinia hepatica</i>	0.06	0.51	0.39	0.37	0.50	0.31
Bivalve remains	0	0	0.52	0.97	1.61	4.42
<i>Atrys cylindrica</i>	0	0	0.13	0.38	0	0
<i>Bullia laevissima</i>	0	0	0.26	0.92	0	0
Gastropod remains	0	0	0	0	0.12	0.10
Gastropod eggs	0	0	0.79	0.62	1.99	0.58
<b>Unidentified remains</b>	<b>*</b>	<b>22.41</b>	<b>*</b>	<b>33.13</b>	<b>*</b>	<b>27.60</b>
<b>Other:</b>						
Foraminiferans	0.23	0.63	0	0	0.50	0.35
Sponge spicules	0	0	0	0	0.12	0.05
Fish scales	1.17	3.29	3.15	3.06	2.23	0.77
Fish eggs	0.18	0.29	0	0	0	0
Plant material	*	4.64	*	5.16	*	6.01
Filamentous algae	*	0.98	*	1.99	*	0.99
Diatoms	0.23	0.34	0.26	0.21	0.37	0.27
Sand grains	*	9.47	*	4.15	*	1.99

\* Numeric percentages could not be calculated

Table 4.18: Bray-Curtis percentage similarity of the diets of *L. equula* from different size classes (in terms of %V)

	I (42-59 mm SL)	II (60-79 mm SL)
II (60-79 mm SL)	68.17	
III (80-115 mm SL)	58.27	76.62

The similarity coefficients were all above 50%, therefore fish were not divided into size classes for the seasonal diet analysis.

Seasonal changes in diet:

The stomach contents of 32 specimens caught in autumn (May), 37 specimens in winter (August), 33 specimens caught in spring (November) and 28 specimens caught in summer (February) were analysed and compared.

Numerically, and in terms of the IRI, crustaceans dominated the diet of *L. equula* throughout the year (Figure 4.13 and Table 4.19). The important prey, in terms of volume, varied seasonally (Figure 4.13). Despite this variation, the overall diet was similar in autumn, winter and spring (Table 4.20).

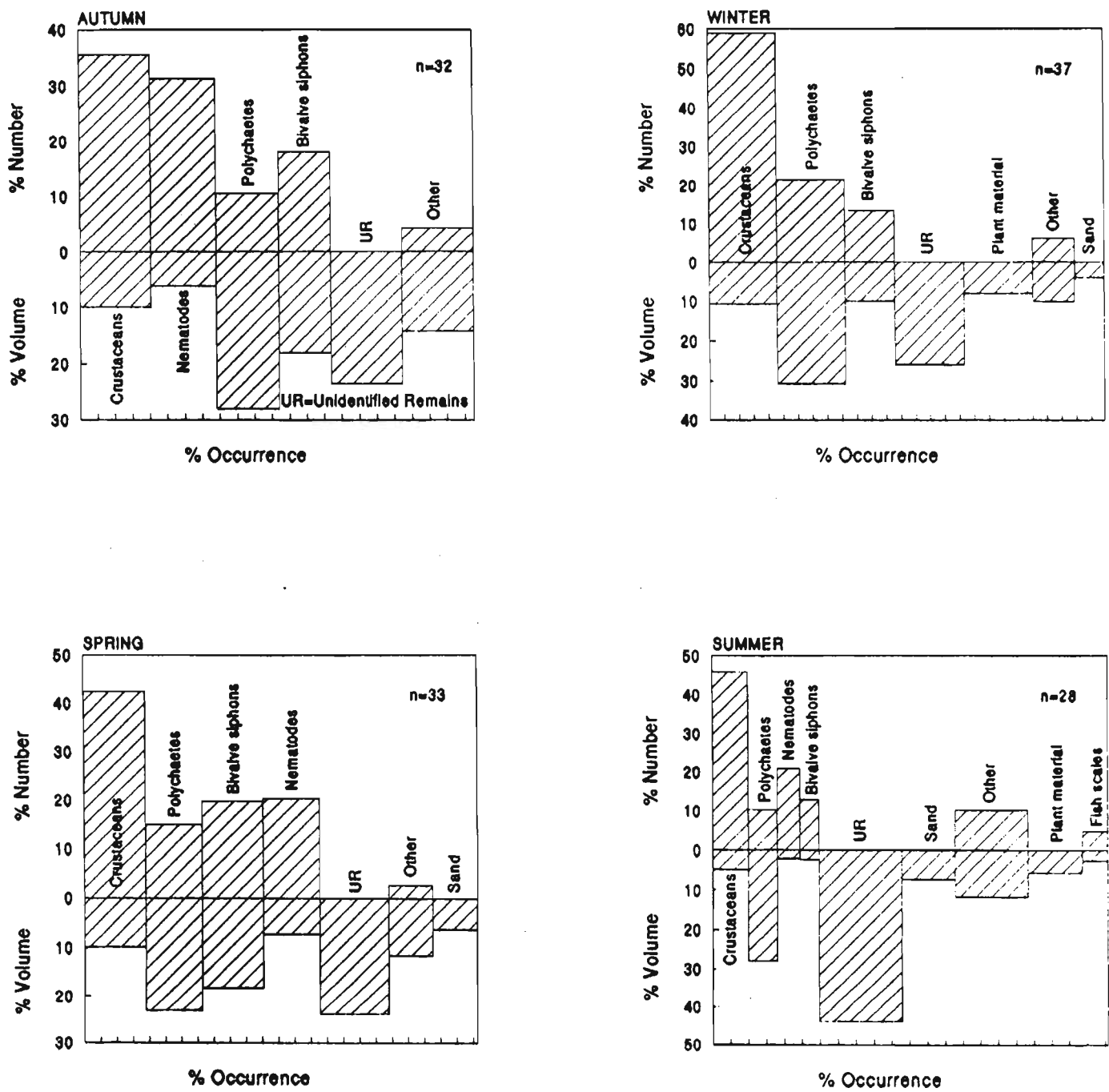


Figure 4.13: Major food categories in the diet of *L. equula* caught in different seasons (x axis tick marks at 20% intervals)

Table 4.19: Index of relative importance (IRI) of major food categories in the diet of *L. equula* caught in different seasons

Food Categories	AUTUMN	WINTER	SPRING	SUMMER
Crustaceans	3707	6396	3964	1993
Polychaetes	2783	4797	2656	1635
Nematodes	2805	119	1917	575
Bivalve siphons	2150	1595	2880	323
Fish scales	108	53	91	212

Table 4.20: Bray-Curtis percentage similarity of the diets of *L. equula* caught in different seasons (in terms of % V)

	AUTUMN	WINTER	SPRING
WINTER	66.19		
SPRING	71.45	71.47	
SUMMER	48.33	53.08	46.88

Harpacticoid copepods dominated the crustacean category numerically and volumetrically throughout the year. The importance of different species of polychaete in the diet of *L. equula*, however, varied seasonally, while the siphon tips of *D. hepatica* and *T. prismatica* were consumed by this species throughout the year (Table 4.21).

Table 4.21: Numeric and volumetric percentage contributions of different food items to the diet of *L. equula* caught in different seasons

	AUTUMN (n=32)		WINTER (n=37)		SPRING (n=33)		SUMMER (n=28)	
Food Items	% N	% V	% N	% V	% N	% V	% N	% V
<b>Crustaceans:</b>								
<b>Harpacticoid copepods</b>	<b>34.44</b>	<b>6.43</b>	<b>55.60</b>	<b>7.14</b>	<b>42.08</b>	<b>8.53</b>	<b>42.12</b>	<b>3.23</b>
Cyclopoid copepods	0.53	0.13	0.07	0.22	0	0	0	0
<i>Apeudes digitalis</i>	0	0	0.37	0.61	0	0	0	0
Unidentifiable tanaids	0.26	0.18	2.68	2.42	0.23	0.47	3.66	1.71
Unidentifiable amphipods	0.26	0.55	0.15	0.15	0	0	0	0
Cumaceans	0.13	0.18	0	0	0	0	0	0
Ostracods	0	0	0	0	0.23	0.80	0	0
Crustacean remains	*	2.61	*	0.22	*	0	*	0
<b>Polychaetes:</b>								
<i>Cirriiformia</i> sp.	1.99	6.07	0.36	2.46	0	0	8.06	26.26
<i>Cossura coasta</i>	0	0	7.86	2.65	4.56	3.26	0	0
<i>Prionospio sexoculata</i>	2.26	3.09	2.77	5.60	1.82	2.67	0	0
<i>Prionospio</i> sp.	3.19	5.54	4.29	7.61	0.11	0.43	0	0
<i>Glycera convoluta</i>	0.13	5.34	0	0	0	0	0	0
<i>Glycera natalensis</i>	0.27	1.35	0.22	0.29	0	0	0	0
<i>Glycera</i> sp.	0.40	0.64	0	0	0	0	0	0
<i>Phyllodoce castanea</i>	0	0	0.15	0.29	0.11	0.20	0	0
Polychaete remains	2.39	5.97	5.90	11.77	8.20	16.63	2.20	1.51
<b>Bivalve siphons:</b>								
<i>Dosinia hepatica</i>	<b>12.23</b>	<b>13.39</b>	<b>3.57</b>	<b>4.21</b>	<b>14.25</b>	<b>11.76</b>	<b>0.73</b>	<b>0.25</b>
<i>Eumarcia paupercula</i>	3.06	2.44	0	0	1.37	1.92	0	0
<i>Solen cylindraceus</i>	0.27	0.66	0.29	0.71	0.80	1.24	0	0
<i>Tellina prismatica</i>	<b>2.53</b>	<b>1.59</b>	<b>9.61</b>	<b>5.22</b>	<b>3.19</b>	<b>3.39</b>	<b>12.09</b>	<b>1.98</b>
<b>Nematodes</b>	<b>31.25</b>	<b>6.14</b>	<b>2.40</b>	<b>2.03</b>	<b>20.30</b>	<b>7.21</b>	<b>20.88</b>	<b>2.14</b>
<b>Fish Scales</b>	<b>1.99</b>	<b>2.27</b>	<b>1.16</b>	<b>1.68</b>	<b>2.05</b>	<b>2.23</b>	<b>4.76</b>	<b>2.27</b>
<b>Unidentified remains</b>	<b>*</b>	<b>23.46</b>	<b>*</b>	<b>25.90</b>	<b>*</b>	<b>23.80</b>	<b>*</b>	<b>43.94</b>
<b>Other:</b>								
<i>Brachidontes variabilis</i>	0	0	0.15	0.59	0	0	0	0
<i>Dosinia hepatica</i>	1.06	1.56	0	0	0	0	0	0
Bivalve remains	0.66	1.63	0.29	1.80	0.46	4.30	1.47	1.62
<i>Arys cylindrica</i>	0	0	0.07	0.30	0	0	0	0
<i>Bullia laevissima</i>	0	0	0.15	1.07	0	0	0	0
Gastropod remains	0.13	0.17	0	0	0	0	0	0
Gastropod eggs	0.13	0.22	1.31	0.88	0.11	0.16	0.73	0.48
Foraminiferans	0.40	0.44	0	0	0	0	1.83	0.86
Sponge spicules	0	0	0	0	0.11	0.10	0	0
Fish eggs	0	0	0.22	0.22	0	0	0	0
Plant material	*	3.87	*	8.18	*	3.33	*	5.73
Filamentous algae	*	2.59	*	0.90	*	1.41	*	0
Diatoms	0	0	0.36	0.62	0	0	1.47	0.37
Sand grains	*	1.47	*	4.13	*	6.16	*	7.32

\* Numeric percentages could not be calculated

#### 4.3.4 *Liza dumerilii*

The stomach contents of 125 *L. dumerilii* specimens ranging in length from 86 to 215 mm SL, from both the BS and CW sandbanks, were analysed. Volumetrically, the stomach contents of *L. dumerilii* were dominated by sand grains and benthic floc (Figure 4.16). Numerically, foraminiferans dominated the stomach contents (Figure 4.16), but very small food items, not distinguishable under 45x magnification, may have been overlooked. For this reason and for the purpose of comparison with other studies on *L. dumerilii*, the majority of which use only the frequency of occurrence method, the frequency of occurrence of all components of the stomach contents are shown in Table 4.22.

Sand grains were ingested by all the specimens examined (Table 4.22). The diet of this species consisted primarily of benthic floc, sponge spicules and small benthic organisms, viz. foraminiferans and ostracods, each of which occurred in over 80% of the specimens. Fish eggs, nematodes, plant material, filamentous algae and diatoms were also relatively important in the diet of *L. dumerilii*.

The median phi values for the *L. dumerilii* stomach sediment ranged from 2.14 to 2.36 on both banks throughout the study period (Table 4.23). This matches the sandbank sediment (Tables 2.1 and 2.2) and can be classified as medium to fine sand (Gray, 1981). No shell material was found irrespective of whether the specimens were caught on the CW or BS bank.

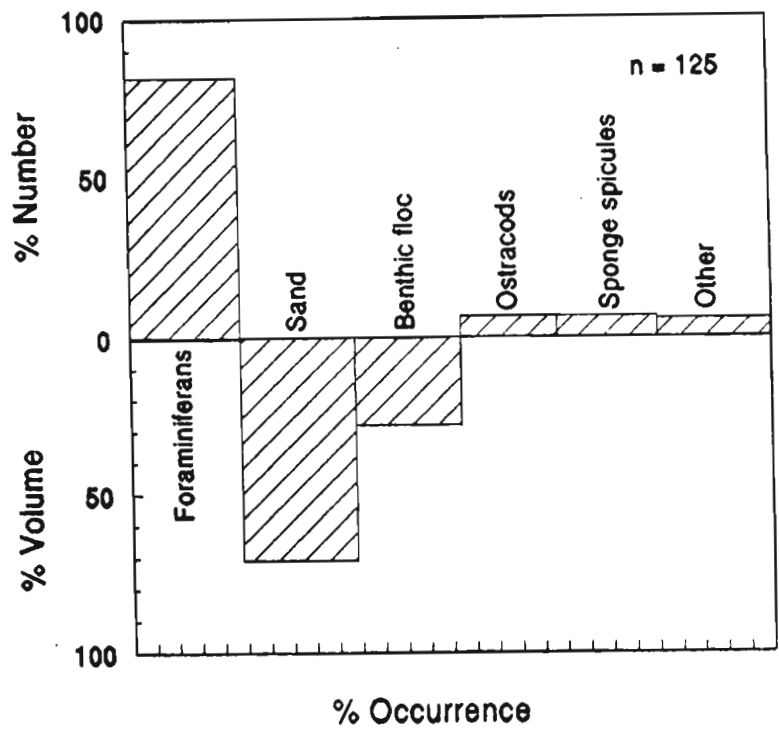


Figure 4.16: Principal components of the stomach contents of *L. dumerilii* (x axis tick marks at 20% intervals)

Table 4.22: Percentage frequency of occurrence (%F) of stomach contents of *L. dumerilii* (n=125)

Stomach Contents	% F
<b>Foraminiferans</b>	<b>96.8</b>
<b>Sponge spicules</b>	<b>88.0</b>
<b>Nematodes</b>	<b>60.8</b>
Bivalves	
<i>Dosinia hepatica</i>	39.2
<i>Eumarcia paupercula</i>	8.0
<i>Brachidontes variabilis</i>	8.0
Bivalve remains	4.8
Gastropods	
<i>Assimineia ovata</i>	24.0
<i>Atys cylindrica</i>	0.8
<i>Finella natalensis</i>	0.8
Gastropod remains	8.8
Gastropod eggs	8.8
Polychaete remains	3.2
Copepods	
Harpacticoids	44.0
Cyclopoids	0.8
Cumaceans	0.8
<b>Ostracods</b>	<b>82.4</b>
Crustacean remains	3.2
Insect remains	6.4
<b>Fish eggs</b>	<b>77.6</b>
Fish scales	18.4
<b>Plant material</b>	<b>64.8</b>
<b>Diatoms</b>	<b>47.2</b>
<b>Filamentous algae</b>	<b>52.0</b>
<b>Benthic floc</b>	<b>92.0</b>
<b>Sand grains</b>	<b>100.0</b>

Table 4.23: Median phi values of the stomach sediment of *L. dumerilii* caught on the BS and CW sandbanks

	AUTUMN	WINTER	SPRING	SUMMER
Size class I	2.36	2.36	2.27	2.18
Size class II	-	2.14	2.27	2.27

Size-related changes in diet:

The 125 specimens were divided into two size classes (I: 86-150 mm SL and II: 151-215 mm SL) for comparison with other size-related dietary studies on *L. dumerilii* (Masson and Marais, 1975; Marais, 1980).

The stomach contents of the fish from the two size classes were very similar in terms of numeric and volumetric contributions of different categories (Figure 4.17). Foraminiferans dominated numerically followed by ostracods and sponge spicules, while sand grains and benthic floc dominated the stomach contents volumetrically (Figure 4.17). Table 4.24 shows the frequency of occurrence of different components of the stomach contents of fish from the two size classes.

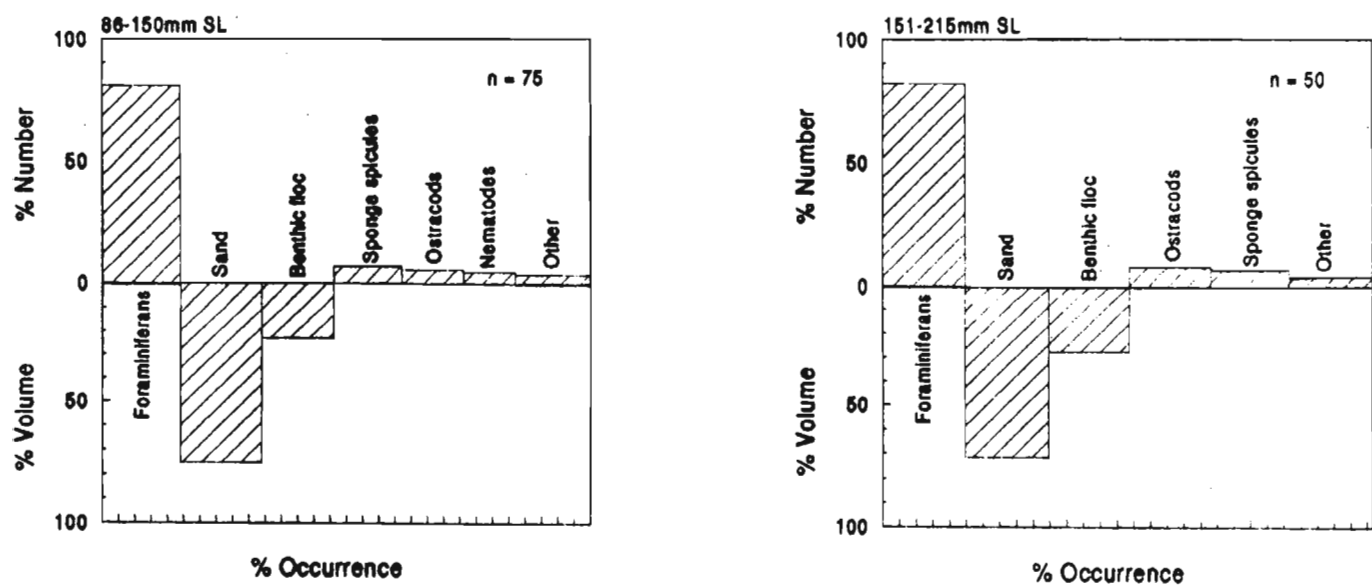


Figure 4.17: Principal components of the stomach contents of *L. dumerilii* from different size classes (x axis tick marks at 20% intervals)

Table 4.24: Percentage frequency of occurrence (%F) of stomach contents of *L. dumerilii* from different size classes

Stomach Contents	86-150 mm SL (n=75)	151-215 mm SL (n=50)
Foraminiferans	96.0	98.0
Sponge spicules	84.0	94.0
Nematodes	62.7	58.0
Bivalves		
<i>Dosinia hepatica</i>	32.0	50.0
<i>Eumarcia paupercula</i>	6.7	6.0
<i>Brachidontes variabilis</i>	2.7	8.0
Bivalve remains	9.3	6.0
Gastropods		
<i>Assiminea ovata</i>	18.7	32.0
<i>Arys cylindrica</i>	0	2.0
<i>Finella natalensis</i>	0	2.0
Gastropod remains	8.0	10.0
Gastropod eggs	2.7	18.0
Polychaete remains	2.7	4.0
Copepods		
Harpacticoids	38.7	50.0
Cyclopoids	0	2.0
Cumaceans	0	2.0
Ostracods	76.0	98.0
Crustacean remains	2.7	4.0
Insect remains	6.7	6.0
Fish eggs	70.7	88.0
Fish scales	18.7	18.0
Plant material	56.0	78.0
Diatoms	31.0	56.0
Filamentous algae	48.0	58.0
Benthic floc	89.0	96.0
<b>Sand grains</b>	<b>100.0</b>	<b>100.0</b>

In terms of frequency of occurrence, the diets of the fish from the two size classes were very similar (89,39%). Sand grains were ingested by all fish in both size classes together with food items (Table 4.24). There was very little difference in the size of the sand particles taken by the fish from the two classes. The median phi values for the *L. dumerilii* stomach sediment in the smaller size class ranged from 2.18 to 2.36 and in larger size class from 2.14 to 2.27 on both banks throughout the study period (Table 4.23).

Specimens were not divided into size classes for the seasonal diet analysis.

### Seasonal changes in diet:

The stomachs of 26 *L. dumerilii* specimens were analysed in autumn (May), 30 in winter (August), 36 in spring (November) and 33 in summer (February). In all four seasons foraminiferans dominated the stomach contents of *L. dumerilii* by number, and sand grains and benthic floc by volume (Figure 4.18).

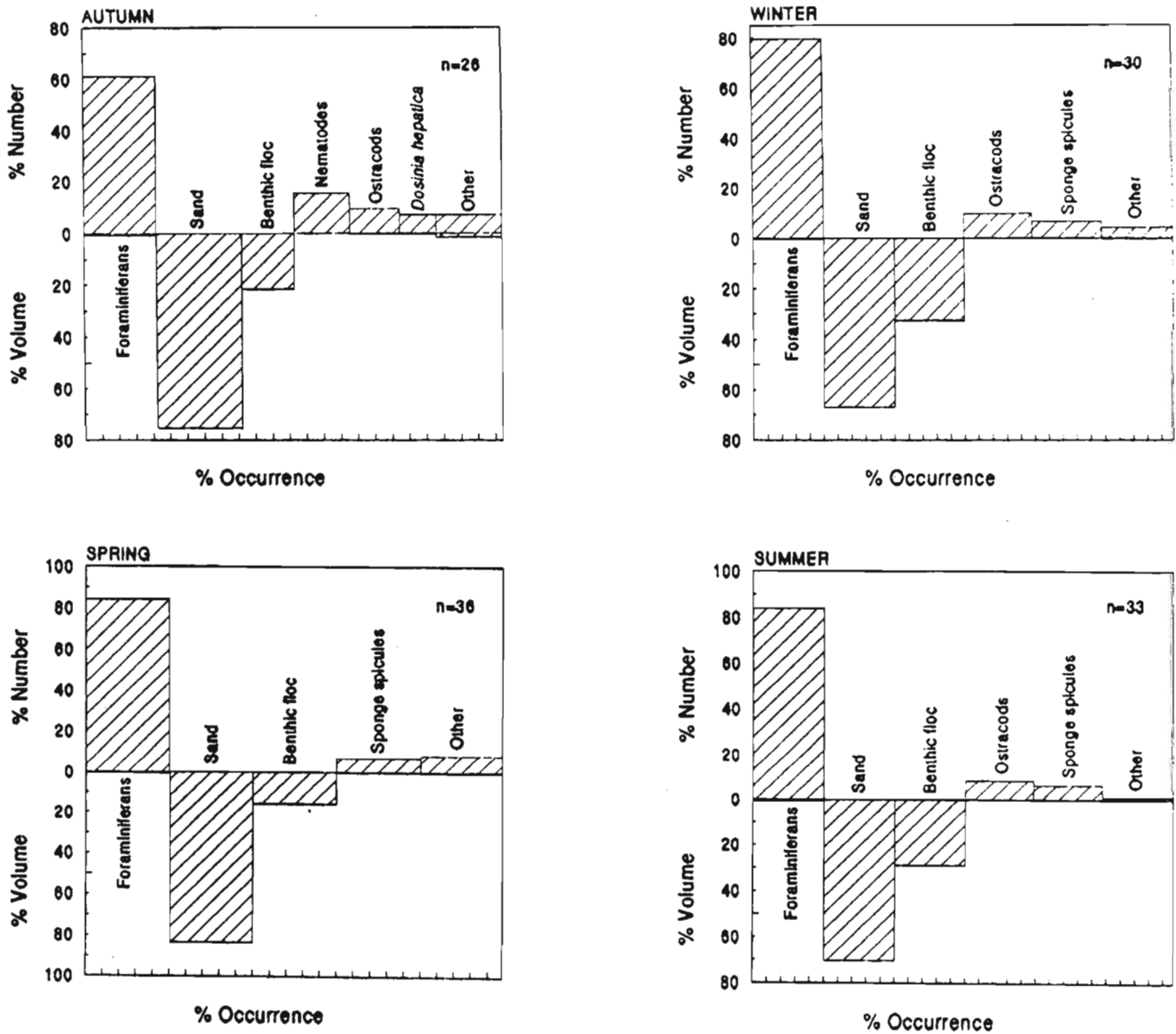


Figure 4.18: Principal components of the stomach contents of *L. dumerilii* caught in different seasons  
(x axis tick marks at 20% intervals)

The diet of *L. dumerilii* changed very little over the four sampling trips (Tables 4.25 and 4.26), with the major food items being consistently consumed throughout the year and sand grains being present in the stomachs of all specimens.

Table 4.25: Percentage frequency of occurrence (%F) of stomach contents of *L. dumerilii* caught in different seasons

Stomach Contents	AUTUMN (n=26)	WINTER (n=30)	SPRING (n=36)	SUMMER (n=33)
Foraminiferans	84.6	100.0	100.0	100.0
Sponge spicules	46.2	100.0	100.0	97.0
Nematodes	65.4	50.0	80.6	45.5
Bivalves				
<i>Dosinia hepatica</i>	42.3	46.7	58.3	9.1
<i>Eumarcia paupercula</i>	7.7	6.7	5.6	12.1
<i>Brachidontes variabilis</i>	3.8	3.3	11.1	0
Bivalve remains	0	16.7	2.8	12.1
Gastropods				
<i>Assiminea ovata</i>	23.1	33.3	30.6	9.1
<i>Arys cylindrica</i>	0	3.3	0	0
<i>Finella natalensis</i>	0	3.3	0	0
Gastropod remains	0	3.3	27.8	0
Gastropod eggs	0	26.7	0	9.1
Polychaete remains	7.7	6.7	0	0
Copepods				
Harpacticoids	26.9	53.3	50.0	42.4
Cyclopoids	0	3.3	0	0
Cumaceans	0	3.3	0	0
Ostracods	57.7	96.7	83.3	97.0
Crustacean remains	7.7	3.3	0	3.0
Insect remains	15.4	0	8.3	3.0
Fish eggs	19.2	100.0	83.3	97.0
Fish scales	34.6	23.3	16.7	3.0
Plant material	61.5	96.7	58.3	45.5
Diatoms	50.0	63.3	19.4	60.6
Filamentous algae	46.2	60.0	69.4	30.3
Benthic floc	61.5	100.0	100.0	100.0
Sand grains	100.0	100.0	100.0	100.0

Table 4.26: Bray-Curtis percentage similarity of the diets of *L. dumerilii* caught in different seasons (in terms of %F)

	AUTUMN	WINTER	SPRING
WINTER	76.26		
SPRING	77.39	86.62	
SUMMER	73.40	87.63	82.85

There was very little variation in the size of the sediment particles ingested by the specimens caught in the different seasons (Table 4.23).

#### 4.4 DISCUSSION

Due to its importance as an angling and table fish (Smith and Heemstra, 1986), much research has previously been undertaken in South Africa on the feeding habits of *P. commersonnii*. Frequency of occurrence, numerical and volumetric methods of stomach content analysis, as well as the index of relative importance and the determination of percentage energy contribution of different food items, have all been used to investigate the diet of *P. commersonnii*, and differences in diet have been found at different localities (Whitfield, 1980b; Hay, 1982; Hecht and van der Lingen, 1992).

The diet of *P. commersonnii* in this study consisted primarily of bivalve siphon tips, crustaceans, fish scales, molluscs and polychaetes. Volumetrically, crustaceans were dominant throughout the year and in the larger size class, but numerical analysis and the index of relative importance showed that bivalve siphons, particularly those of *D. hepatica* and *S. cylindraceus*, were important throughout the period of the study. Unpublished research done by Hay (1982) in Durban Bay showed that *P. commersonnii* of approximately the same size range (40-200 mm SL) fed predominantly on the same food items, with benthic or burrowing crustaceans (mainly amphipods, harpacticoid copepods and the mudprawn, *Upogebia africana*) being volumetrically dominant (Hay, 1982).

In St Lucia South Lake and the Kosi system, KwaZulu Natal, crustaceans and bivalves were also dominant dietary components, by volume and frequency of occurrence, while in the latter system chironomid larvae and plant material were also important (Hay, 1982). In St Lucia, the crustaceans consumed were mainly the tanaid, *Apseudes digitalis*, and the amphipod, *Grandidirella lignorum*, and in the Kosi system the sandprawn, *Callinassa*

*kraussi*, was the dominant crustacean taken by *P. commersonnii*. Work done on this species from the Mdloti estuary, KwaZulu Natal, also showed that benthic crustaceans, particularly copepods, tanaids and amphipods, were dominant in the diet in terms of percentage occurrence, but that polychaetes and unidentified remains were also significant (Blaber, Hay, Cyrus and Martin, 1984). In the Mhlanga estuary, KwaZulu Natal, crustaceans, particularly anomurans, made the highest percentage energy contribution to the diet of *P. commersonnii* (33-169 mm SL) (Whitfield, 1980b).

In the Swartkops estuary, eastern Cape, benthic or burrowing crustaceans appeared in 94% of *P. commersonnii* stomachs examined. These were mainly *U. africana*, *C. kraussi* and Brachyura. Gastropod and bivalve molluscs were found in 28% and polychaetes in 14% of the stomachs. Aquatic plants were present in 25% of the stomachs (van der Westhuizen and Marais, 1977). Crustaceans, particularly *U. africana* and the crab, *Paratylodioplax algoense*, formed 93.5% of the diet of *P. commersonnii* (380-670 mm fork length) caught in the Breede river estuary, southern Cape (Coetzee and Pool, 1991). In both the Kariega and Great Fish estuaries, eastern Cape, *U. africana* and other crustaceans formed the major dietary component of *P. commersonnii* (127-600 mm SL) in terms of the index of relative importance (Hecht and van der Lingen, 1992).

Although crustaceans were dominant in the diet of *P. commersonnii* in KwaZulu Natal and eastern and southern Cape estuaries, the particular species eaten varied with locality. The same applied to the molluscs and polychaetes, and it has been suggested that the composition of the diet of *P. commersonnii* reflects the availability of the different macrobenthic species in a particular system (Blaber, 1983).

In most of the previous studies the mudprawn, *Upogebia africana*, and/or sandprawn, *Callinassa kraussi*, featured prominently in the diet. These species were, however, not consumed by *P. commersonnii* in this study, but the upper size limit of fish in the previous studies was much higher. It is possible that juveniles are unable to extract these organisms from the substratum (Blaber, 1983).

The diet of fish from the two size classes in this study was similar, but the relative importance of bivalve siphons decreased with fish size while the relative importance of molluscs, polychaetes and fish scales increased. The same trend was observed in this species at St Lucia, where the siphons of the bivalve, *S. cylindraceus*, were dominant in the stomachs of smaller individuals, but larger fish tended to take whole animals rather than siphons (Hay, 1982). Small prey, viz. harpacticoid copepods and nematodes were only consumed by the smaller fish. No differences were found in the diets of different sizes of *P. commersonnii* in the Swartkops estuary (van der Westhuizen and Marais, 1977), but no comparison could be made with results from this study as size classes were not given.

The diet of this species in Durban Bay was similar in autumn and winter, the only seasons when specimens were obtained. Bivalve siphon tips were the most important food item in both seasons, although the dominant species changed from *S. cylindraceus* to *D. hepatica*. This switch in species may be explained by the decline in the density of *S. cylindraceus* in winter (Appendix 1). Dominant species of juvenile estuarine fish tend to exhibit generalised patterns in food habits and the ability of juveniles to switch from one prey item to another provides a selective advantage over species which have restricted diets

(Miller and Dunn, 1980). Most natural environments vary both spatially and temporally and flexibility in foraging behaviour of fish is thus an important adaptive feature which has been shown to occur (Dill, 1983). No previous work has been done to enable a comparison of seasonal differences in the diet of this species.

*P. commersonnii*, irrespective of size or season, positively selected crustaceans, took bivalve siphons in proportion to their availability, and tended to avoid polychaetes. The positive selection for crustaceans may, however, have been overemphasised, although positive selection by this species for crustaceans has been previously documented (Blaber, 1983). What is deemed available prey by the researcher may not be available to the predator due to behaviour of the predator or the prey, the area sampled or the sampling method employed (Tipton and Bell, 1988). In this study, certain small benthic organisms may have passed through the mesh of the net used to sieve benthic samples and, thereby, affected some of the selectivity results.

Throughout the study, very little variation occurred in the selectivity of *P. commersonnii* for different prey species, although the electivity indices calculated for *D. hepatica* changed seasonally and differed in the two size classes. *S. cylindraceus* siphons as well as amphipods were always positively selected.

The diet of *G. filamentosus* (>40 mm SL) in two estuarine systems in KwaZulu Natal, was investigated by Cyrus and Blaber (1983a, 1984b), but the diet of this species in Durban Bay has not been previously investigated. Five sites in the Kosi system were sampled. At three of the sites, numerical, volumetric and percentage energy contribution

analyses all showed that bivalve siphon tips were the most important prey item in the diet, but bivalves were not the most abundant prey in the benthos. At the other two sites, polychaetes and chironomid larvae, respectively, were dominant in terms of all three methods (Cyrus and Blaber, 1984b). In the Mlalazi estuary, only percentage energy contribution to the diet was determined, and this method showed that bivalve siphon tips were again dominant (Cyrus and Blaber, 1983a).

The dominant dietary items of *G. filamentosus* in both size classes and throughout the four seasons in Durban Bay, in terms of number, volume, frequency of occurrence and, hence, index of relative importance, were bivalve siphon tips. Crustaceans, polychaetes and whole bivalves were also taken by *G. filamentosus* in this study.

Analysis of stomach contents of *G. filamentosus* (10-172 mm TL) from the Pulicat Lake, India, showed that crustaceans, primarily amphipods, were volumetrically dominant, followed by polychaetes, bivalves and detritus (Prabhakara Rao, 1968). On the Madras coast, India, polychaetes made up 57% of the diet of *G. filamentosus* by volume, and crustaceans 40% (Job, 1940 in Prabhakara Rao, 1968). Research on the diet of *G. filamentosus* in the Trinity Inlet, eastern Australia, showed that, in terms of frequency of occurrence, polychaetes were the most important food items, followed by crustaceans (penaeids and tanaids) and then bivalves (Blaber, 1980).

Thus, in India and Australia, *G. filamentosus* feeds predominantly on polychaetes, crustaceans and whole bivalves, but in KwaZulu Natal, bivalve siphon tips, which have not been recorded elsewhere as a food item, are a major dietary component.

A size-related change in the diet of *G. filamentosus* in the Kosi system from a planktonic to a benthic mode of feeding was recorded, where fry (<20 mm SL) fed primarily on marine calanoid copepods. With an increase in size, the number of food items taken and the importance of polychaetes to the diet increased, with a corresponding decrease in the importance of copepods (Cyrus and Blaber, 1983b). A difference in the diet of different size classes of *G. filamentosus* from the Pulicat Lake was also found, with small prey such as copepods and mysids being dominant in the smallest specimens, followed by a gradual increase in the occurrence of polychaetes in the fish in the largest size class (Prabhakara Rao, 1968).

In this study little variation was found in the diets of fish from the two size classes, but this may be expected as they did not cover a very wide range of sizes. Bivalve siphon tips were relatively more important than the other major food categories in the larger fish, but the siphons of the same species, viz. *D. hepatica*, were dominant in both size classes. Small differences were found in the polychaete and crustacean species consumed. Because of the narrow size range of *G. filamentosus* caught in this study, the size classes were not comparable with size classes used by other authors to investigate changes in the diet of *G. filamentosus* with age.

Little seasonal variation was found in the diet of *G. filamentosus* from other KwaZulu Natal estuaries studied (Cyrus and Blaber, 1984b) or from India (Prabhakara Rao, 1968). In this study, the overall diet did not change over the year, but the relative contributions of different food categories to the diet varied seasonally. In winter and spring crustaceans were relatively more important and in summer bivalve siphon tips dominated almost

exclusively. This was not, however, coupled with an increase in bivalve densities in summer (Appendix 1). *D. hepatica* siphons were volumetrically dominant in the diet throughout the year, but the numerically dominant species varied.

Selectivity of *G. filamentosus* for major prey categories did not vary much in fish from the two size classes or those caught in different seasons, except in summer. Generally, bivalve siphons and crustaceans were positively selected, while negative electivity values were recorded for polychaetes. The selectivity for crustaceans may, however, have been overemphasised. In other KwaZulu Natal estuaries it has been found that *G. filamentosus* is highly selective and that if bivalves occur in the substrates on which this species is feeding, siphon tips are selected for and form a major part of the diet (Cyrus and Blaber, 1983a). Although a certain degree of selectivity was evident in this study, *G. filamentosus* was not particularly selective in Durban Bay.

Selectivity for principal prey species was also calculated and it showed that *D. hepatica*, *T. prismatica* and *S. cylindraceus* siphons were positively selected. Although *E. paupercula* siphons were the second most important siphons taken, they were only consumed in proportion to their availability. Regardless of the method of selectivity measurement used, differential availability of prey to the predator and differential digestion of prey may be significant sources of error in the interpretation of data (Strauss, 1979). The availability of prey to predators depends on its population density as well as on its activity, exposure and defence mechanisms (Vinyard, 1980). *E. paupercula* retracts its siphons much more quickly than the other species when disturbed and remains closed for longer (pers. obs.). It is possible that the siphons of *E. paupercula* were thus not as

"available" as the siphons of the other species.

Very little work has been done on the diet of *L. equula* in South Africa, but a study of the trophic relationships within the fish community of the Mhlanga estuary, KwaZulu Natal, showed that *L. equula* (25-58 mm SL) fed on zoobenthos, with cumaceans and copepods being dominant in terms of percentage energy contribution to the diet (Whitfield, 1980b). Studies on frequency of occurrence, numerical or volumetric contributions of different food items to the diet of *L. equula* in South African estuaries have not been previously undertaken, nor have size-related or seasonal changes in diet been investigated.

Leiognathids constitute an important fishery in India (James, 1975) and consequently much work has been done on their feeding habits. In Manila Bay, from April to September, *L. equula* (65-164 mm TL) consumed a wide variety of food organisms, with diatoms, copepods, unidentified animals and fish eggs being dominant (Tiews *et al.*, 1973).

The diet of *L. equula* in this study was not completely dominated by any one food type, but consisted primarily of crustaceans, polychaetes and bivalve siphons. A wide range of crustaceans, similar to those taken by the previous two species, was consumed, but harpacticoid copepods were entirely dominant. These organisms, however, have a very low energy value compared with bivalve siphon tips (Cyrus and Blaber, 1983a). The siphons of *D. hepatica* and *T. prismatica* were the main bivalve siphons taken by this species, and the important polychaetes were *Cossura coasta*, *Cirriformia* sp. and *Prionospio* spp..

Studies of size-related changes in diet of species belonging to the family Leiognathidae have been undertaken in India (Kuthalingham, 1958; Wright, 1989; Jayabalan, 1991), but no work has been done on size-related changes in the diet of *L. equula*. In the present study it was found that crustaceans, particularly harpacticoid copepods, and nematodes decreased in importance with fish size, while the relative importance of polychaetes, bivalve siphons and molluscs increased. Strong positive selection was exhibited by fish in the smallest size class for crustaceans, but as fish became larger, they became less selective. This same size-related trend has been reported in other fish species (Prabhakara Rao, 1968; Alheit and Scheibel, 1982). It is probable that as fish become larger they are able to handle bigger prey and selectivity declines as a wider range of prey types becomes available.

In terms of volume, the diet of *L. equula* caught in the different seasons was very similar in the first three seasons, but differed in summer. This change in the diet was not, however, reflected in the benthos (Appendix 1). Small differences in species consumed throughout the year were evident, but generally the major species were always present in the diet. No other studies have been undertaken on seasonal changes in the diet of this species.

Selectivity results revealed that *T. prismatica* siphons were positively selected throughout the study whereas *D. hepatica* siphons tended to be avoided. *Prionospio* species also had negative electivity indices, but selectivity for the other two major polychaetes fluctuated. However, across the seasons when one was positively selected the other always had a negative electivity. Although these results may have been influenced by the small number

species of bivalve were consumed by all three fish species the two most important bivalve species differed. In addition, *D. hepatica* siphons were taken in proportion to their availability by *P. commersonnii* and were positively selected by *G. filamentosus*, while *L. equula* tended to avoid them. The siphons of the other important species taken by each fish species were positively selected or, in the case of *G. filamentosus*, taken in proportion to their availability.

Harpacticoid copepods were especially dominant in the diet of *L. equula*, while harpacticoid copepods and tanaids were important in the diet of *G. filamentosus*. In terms of volume, brachyurans, which were not consumed by any other species, dominated the diet of *P. commersonnii*, but amphipods and harpacticoid copepods were numerically important.

*P. sexoculata*, being by far the most abundant species of polychaete in the benthos in all four seasons (Appendix 1), was important in the diet of all three fish species and was the only polychaete taken by *P. commersonnii*. The other important species taken by *G. filamentosus* were *Glycera* spp., while *Cossura coasta* and *Cirriformia* sp. were the other important species in the diet of *L. equula*.

The diet of *L. dumerilii* differed from the previous three species in terms of major food categories (using all diet composition analysis methods). Previous studies on the diet of *L. dumerilii* usually only considered frequency of occurrence of different prey items (Payne, 1976; Blaber, 1977), but by doing this the quantity of food item (either numerically or volumetrically) was not considered. Percentage frequency is not valid

may have influenced the counts of diatoms.

Generally, mullet species ingest large quantities of sediment particles together with food items (Blaber, 1976). It has been suggested that the grinding action of the muscular gizzard and abrasion by these sand grains aid in the digestion of plant material in the gut (Payne, 1978). Particle sizes consumed by each species vary according to locality but within any one system, each mullet species tends to select a particular size range, thereby avoiding interspecific competition (Blaber, 1977). In this study sand grains were ingested by all specimens. The median phi values of *L. dumerilii* stomach sediment calculated in this study revealed that the grain size of the sand particles ingested by *L. dumerilii* was smaller than that taken by this species in other studies. Median phi values recorded throughout the study period corresponded to a grain size of between 125  $\mu\text{m}$  and 250  $\mu\text{m}$  (Gray, 1981). In the Swartkops estuary it was found that *L. dumerilii* ingested sand particles up to 500  $\mu\text{m}$  (Masson and Marais, 1975; Marais, 1980), but in other KwaZulu Natal estuaries, this species ingested particles with mean sizes ranging from 230 to 567  $\mu\text{m}$  (Blaber, 1977). The particle size of the sediment ingested by a particular mullet species does, however, vary according to locality (Blaber, 1977).

The diet and particle size preference of *L. dumerilii* from different size classes and seasons was very similar. This is supported by studies in six KwaZulu Natal estuaries where no change in diet with season or age was recorded for this species ( $> 50$  mm SL) (Blaber, 1976; Blaber, 1977). Particle size preference ( $< 500$   $\mu\text{m}$ ) was also found to be consistent in the two size classes (100-150 mm and  $> 150$  mm) of *L. dumerilii* from the Swartkops estuary (Marais, 1980).

Median phi values calculated for the sediment in the channels in Durban Bay in unpublished surveys in 1991 and 1992 were all greater than 4, which corresponds to very fine sand (Gray, 1981). Sediment in the *L. dumerilii* stomachs had lower median phi values, which matched the sediment of the BS and CW banks as well as that of the other sandbanks in the bay (Tables 2.1 and 2.2). It was thus concluded that *L. dumerilii* of both size classes in all seasons were feeding on the sandbanks in Durban Bay.

All major prey species in the diets of *P. commersonnii*, *G. filamentosus* and *L. equula* were benthic, although benthic harpacticoids can leave the sediment temporarily and have short pelagic phases (Hauspie and Polk, 1973 in Alheit and Scheibel, 1982). Comparison of the benthos at sites on the sandbanks and in the channels sampled in two unpublished surveys in 1991 and 1992 revealed that no bivalves were found at the channel site adjacent to the BS bank in 1991 and very low densities were recorded in 1992 (<sup>5</sup>A.T. Forbes, pers. comm.). High densities of bivalves were recorded on the BS bank in both years (Table 4.27). An analysis of the similarity (Bray-Curtis) of the sandbank and channel sites yielded a dissimilarity of 85.39% (Clarke and Warwick, 1994), which could be attributed primarily to the differences in bivalve densities. Although polychaetes and crustaceans were found in the channels, they were also found at very high densities on the sandbanks (Table 4.27). Polychaetes were, however, not selected by any species. It thus appeared that *P. commersonnii*, *G. filamentosus* and *L. equula* of all size classes and in all seasons were feeding mainly on the BS sandbank. Molluscs, especially the bivalve, *D. hepatica*, were also relatively important dietary components of *L. dumerilii*, suggesting that *L. dumerilii* was also feeding on the sandbanks.

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Table 4.27: Mean densities (no./m<sup>2</sup>) of benthic organisms on the BS sandbank and in the adjacent channel in Durban Bay in 1991 and 1992

Species	BS Bank		Channel	
	1991 (n=5)	1992 (n=5)	1991 (n=5)	1992 (n=5)
Phylum: Cnidaria				
Class: Anthozoa				
Order: Actiniaria	0	424	0	0
Phylum: Nematoda	0	85	0	59
Phylum: Annelida				
Class: Polychaeta				
Errantia				
Family: Pilargidae				
<i>Ancistrosyllis constricta</i>	313	0	35	10
Family: Nereidae				
<i>Dendronereides zululandica</i>	0	51	0	0
<i>Laeonereis ankyloseta</i>	25	0	0	0
<i>Platynereis dumerillii</i>	0	25	0	0
Family: Nephtyidae				
<i>Nephtys dibranchis</i>	0	0	59	0
Family: Glyceridae				
<i>Glycera longipinnis</i>	0	34	0	0
<i>Glycera</i> sp.	68	0	0	0
Family: Eunicidae				
<i>Epidiopatra hupferiana monroi</i>	0	25	0	0
<i>Onuphis</i> sp.	0	8	0	0
Sedentaria				
Family: Spionidae				
<i>Prionospio sexoculata</i>	0	830	0	216
<i>Prionospio</i> sp.	0	0	35	0
Family: Cirratulidae				
<i>Cirriformia tentaculata</i>	0	8	0	0
Family: Trochochaetidae				
<i>Poecilochaetus serpens</i>	0	0	65	0
Family: Cossuridae				
<i>Cossura coasta</i>	0	0	76	0
Family: Capitellidae	0	25	88	10
Phylum: Arthropoda				
Subphylum: Crustacea				
Class: Copepoda	8	42	0	20
Class: Malacostraca				
Order: Cumacea	8	51	0	0
Order: Amphipoda				
Family: Coropiidae				
<i>Aora kergueleni</i>	76	68	0	0
<i>Corophium triaenonyx</i>	0	42	0	0
<i>Corophium</i> sp.	0	76	0	0
Order: Tanaidacea				
<i>Apseudes digitalis</i>	0	8	0	0
Order: Mysidacea				
<i>Gastrosaccus brevifissura</i>	0	8	0	0
Order: Decapoda				
Infraorder: Anomura				
<i>Upogebia africana</i>	0	0	65	0
Infraorder: Brachyura				
<i>Paratylodiplax blephariskios</i>	0	0	23	108
<i>Thaumastoplax spiralis</i>	0	0	0	10
Infraorder: Penaeidea	0	8	0	0

Species	BS Bank		Channel	
	1991 (n = 5)	1992 (n = 5)	1991 (n = 5)	1992 (n = 5)
Phylum: Mollusca				
Class: Bivalvia				
Subclass: Autobranchia				
Order: Mytiloida				
Family: Mytilidae				
<i>Brachidontes virgilae</i>	0	263	0	0
Subclass: Lamellibranchia				
Order: Veneroida				
Family: Veneridae				
<i>Dosinia hepatica</i>	1797	1051	0	0
<i>Eumarcia paupercula</i>	915	1127	0	0
<i>Tapes sulcarius</i>	8	0	0	0
Family: Tellinidae				
<i>Tellina prismatica</i>	102	85	0	39
Family: Solenidae				
<i>Solen cylindraceus</i>	17	0	0	0
Class: Gastropoda				
Subclass: Prosobranchia				
Order: Mesogastropoda				
Family: Assimineidae				
<i>Assiminea ovata</i>	0	17	0	0
Family: Diastomidae				
<i>Finella natalensis</i>	195	0	0	0
Order: Neogastropoda				
Family: Nassariidae				
<i>Nassarius kraussianus</i>	25	42	0	0
Subclass: Opisthobranchia				
Order: Cephalaspidae				
Family: Tornatinidae				
<i>Acteocina fusiformis</i>	76	0	0	0
Family: Haminoeidae				
<i>Arys cylindrica</i>	0	127	0	0
Gastropod spp.	0	8	0	0

#### 4.5 CONCLUSIONS

In this study it was found that, despite major developments in the Port of Durban, it is still functioning as an important nursery ground for juvenile fish. The juveniles of *P. commersonnii*, *G. filamentosus*, *L. equula* and *L. dumerilii* all appeared to be utilising the BS sandbank and juvenile *L. dumerilii* appeared to be utilising the CW bank in Durban Bay as feeding grounds throughout the size ranges studied and throughout the year. By removing these sandbanks for the construction of Pier 3, important juvenile feeding grounds will be eliminated in Durban Bay.

Although the mangroves and part of the SW sandbank will be excluded from any future development (<sup>6</sup>D.G. Hay, pers. comm.), this is a very small area. It is important to conserve sufficient feeding grounds as well as different habitat types and their associated assemblages of species within the harbour.

Ideally, both the CW and BS banks should be excluded from any future developments as they both appear to be supporting high numbers of juvenile fish. If the construction of the new Pier 3 does proceed, it is suggested that the BS bank, or part thereof, which supports all four species, be left intact. A study should be initiated to assess this possibility. If this is not possible the pier should be constructed with "soft edges" (sloping sandbanks), created using the dredge spoil, on its north side to promote the recolonization of benthic organisms.

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# APPENDIX 1

Mean densities (no./m<sup>2</sup>) of benthic organisms on the BS sandbank in Durban Bay during different seasons

Species	AUTUMN (n=3)	WINTER (n=3)	SPRING (n=3)	SUMMER (n=3)
Phylum: Cnidaria				
Class: Anthozoa				
Order: Actiniaria	42	14	0	28
Phylum: Annelida				
Class: Polychaeta				
Errantia				
Family: Phyllodocidae				
<i>Phyllodoce castanea</i>	0	14	28	14
Family: Pilargidae				
<i>Ancistrosyllis constricta</i>	0	14	14	14
Family: Nereidae				
<i>Dendronereis arborifera</i>	42	0	0	0
<i>Dendronereides zululandica</i>	14	0	0	0
Unidentified nereid	14	0	0	0
Family: Glyceridae				
<i>Glycera natalensis</i>	113	57	141	42
<i>Glycera papillosa</i>	14	0	0	0
Family: Eunicidae				
<i>Epidiopatra hupferiana monroi</i>	14	0	0	0
<i>Marphysa corallina</i>	14	0	0	0
<i>Marphysa</i> sp.	0	0	0	14
Unidentified eunicid	14	0	0	0
Sedentaria				
Family: Spionidae				
<i>Prionospio cirrifera</i>	14	0	0	0
<i>Prionospio sexoculata</i>	1752	2812	3081	1668
<i>Polydora</i> sp.	14	0	141	0
Family: Cirratulidae				
<i>Cirriformia</i> sp.	57	240	0	382
Family: Trochochaetidae				
<i>Poecilochaetus serpens</i>	0	0	14	0
Family: Cossuridae				
<i>Cossura coasta</i>	85	57	0	721
Family: Capitellidae	0	42	0	14
Family: Sabellidae				
<i>Desdemona ornata</i>	0	0	28	198
Family: Serpulidae				
<i>Hydroides norvegica</i>	14	0	0	0
Unidentified polychaetes	14	0	0	141
Phylum: Arthropoda				
Subphylum: Crustacea				
Class: Copepoda				
Order: Harpacticoida	14	0	113	14
Class: Malacostraca				
Order: Cumacea	28	155	226	85
Order: Amphipoda				
Family: Coropiidae				
<i>Corophium triaenonyx</i>	28	85	0	339
Order: Tanaidacea				
<i>Apseudes digitalis</i>	0	0	0	693
Order: Decapoda				
Infraorder: Penaeidea	0	0	0	14

Species	AUTUMN (n = 3)	WINTER (n = 3)	SPRING (n = 3)	SUMMER (n = 3)
Phylum: Mollusca				
Class: Bivalvia				
Subclass: Autobranchia				
Order: Mytiloida				
Family: Mytilidae				
<i>Brachidontes variabilis</i>	3971	339	226	113
Subclass: Lamellibranchia				
Order: Veneroida				
Family: Veneridae				
<i>Dosinia hepatica</i>	4141	1526	1300	2177
<i>Eumarcia paupercula</i>	2007	1625	989	735
<i>Tapes sulcarius</i>	0	28	0	14
Family: Tellinidae				
<i>Tellina prismatica</i>	170	42	85	184
Family: Solenidae				
<i>Solen cylindraceus</i>	127	0	14	99
Class: Gastropoda				
Subclass: Prosobranchia				
Order: Mesogastropoda				
Family: Assimineidae				
<i>Assiminea ovata</i>	0	211	198	113
Family: Diastomidae				
<i>Finella natalensis</i>	141	438	382	325
Order: Neogastropoda				
Family: Nassariidae				
<i>Bullia laevis</i>	0	57	14	57
<i>Nassarius kraussianus</i>	212	99	85	495
<i>Nassarius sp.</i>	0	0	0	42
Subclass: Opisthobranchia				
Order: Cephalaspidae				
Family: Haminoeidae				
<i>Alys cylindrica</i>	0	42	155	113

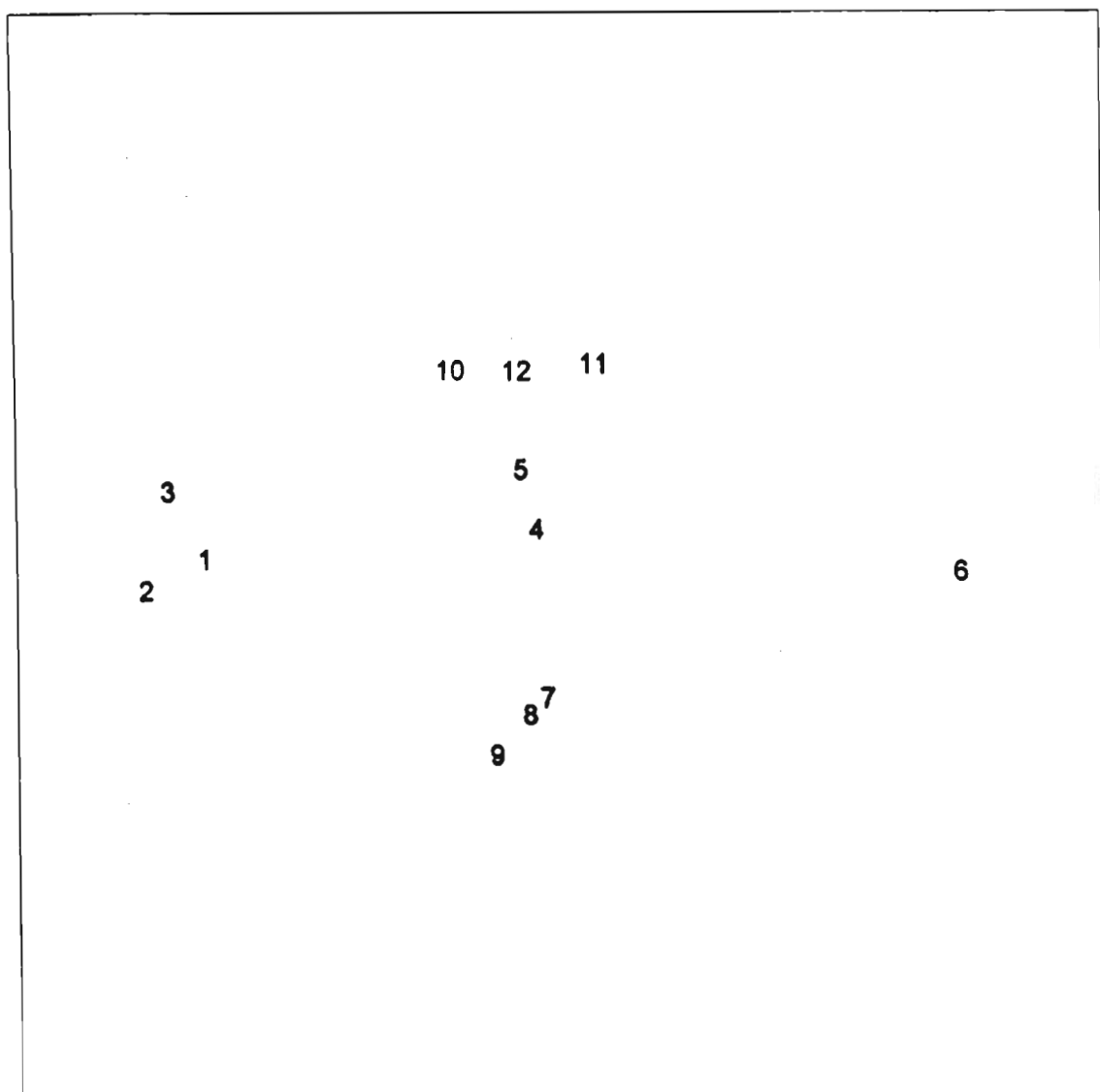


Figure: MDS ordination diagram (stress = 0.06) using % similarities of benthic samples collected on the BS sandbank in Durban Bay

**KEY:**

- 1-3 - May 1993
- 4-6 - Aug 1993
- 7-9 - Nov 1993
- 10-12 - Feb 1994