The diet of selected benthic feeding fish in the Mfolozi-Msunduzi system, KwaZulu-Natal

by

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Declaration

I, Jabulile Blessed Busisiwe Nhleko, hereby declare that this whole thesis is my own original work, and to the best of my knowledge, it contains no material previously published or written by person or material submitted in any form for the award of any degree at another university. Where use of the work of others was made it has been duly acknowledged in the text.

Signature**…………………** Date……………………………

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Abstract

The St Lucia estuarine system is considered to be the largest nursery area for estuarine-associated marine fish in southern Africa. The prolonged mouth closure due to regional droughts has resulted in large declines in its fish and prawn communities with deleterious consequences for regional marine populations, especially those that require estuaries for completion of their life cycle. Mouth closure of the St Lucia system contributed to a renewed interest in the St Lucia-Mfolozi System link, particularly the importance of the Mfolozi system in terms of its role as a refuge and alternative nursery area for species which cannot recruit into the closed St Lucia system when the Mfolozi remains open. The Mfolozi-Msunduzi estuarine system is the closest open estuary to St Lucia but there is a paucity of data on the ecological functioning of the system. Studies on the benthos of the Mfolozi-Msunduzi estuarine system have found it to be impoverished but large numbers of benthic feeding fish are present in the system at times. This raised the question: if the zoobenthic community is impoverished and high numbers of benthic feeding fish are nevertheless present in the system, then what are these fish feeding on?

The stomach contents of 961 fish of 15 different species collected between August 2008 and March 2010 using seine and gill nets were examined. Of these 15 species, only six were caught in sufficient numbers for gut analysis. The six species that were used in the analysis were *Leiognathus equula, Acanthopagrus berda, Glossogobius giurus, Ambassis ambassis, Ambassis gymnocephalus and Ambassis natalensis*. Four methods were used for stomach content analysis, namely Frequency of occurrence, Numerical occurrence, Points (Proportional Volumetric) analysis and Index of Relative Importance (IRI).

It was found that the diet of *L. equula* was dominated by the copepod, *P. stuhlmanni,* with the macrobenthos contributing <0.5% to the overall diet of the species. Similarly, the diet of *A. berda* was dominated by *P. stuhlmanni,* with the benthic fauna contributing <1.5% to the diet. The dominant prey in the diet of *G. giurus* was *Glossogobius sp,* while the only benthic species that was fed on was the crab *P. blephariskios,* which contributed not more than 0.3% to the overall diet of the species. A large proportion of the Ambassids (*A. ambassis*, *A. gymnocephalus* and *A. natalensis*) had empty stomachs, whilst most of those that contained food had stomachs < 30% full, based on the Points determination method. The diet of all three Ambassid species was dominated by *P. stuhlmanni*, with *A. gymnocephalus* feeding only on the copepod. The total contribution of the benthic fauna found in the diet of *A. ambassis* was <30% and <1% in *A. natalensis*.

Copepods dominated the diets of the majority of the species examined, indicating that in the Mfolozi system, zooplankton rather than benthic organisms are being fed on. This tends to tie in with the impoverished state of the benthic fauna. The results of this study indicate that only those species capable of adapting their diets to whatever is available and abundant to feed on will be able to survive in the Mfolozi-Msunduzi system.

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Chapter 1: Introduction

1.1 St Lucia-Mfolozi - Historical situation

The St Lucia system is the largest estuarine system in Africa, with a surface area of 350 km^2 and an average depth of 0.9m (Begg, 1978). The system comprises of three interconnected lakes linked to the Indian Ocean via a 21 km channel referred to as the Narrows (Figure 1). It is regarded as the most important estuarine system on the south-east coast of Southern Africa, since it comprises about 80% of the total estuarine area of the KwaZulu-Natal region (Begg, 1978). Historically the Mfolozi River and the St Lucia Narrows flowed into the St Lucia bay before exiting through a common mouth to the sea (Figure 2) (Cyrus *et al*., 2010a). St Lucia received some 30% of its input from the adjacent Mfolozi River system, which drained through the extensive Mfolozi swamps (Figure 2) towards the sea (Vivier & Cyrus, 2009). The Mfolozi swamps acted as a sediment filter which allowed predominantly sediment-free water to pass through to St Lucia Bay. During periods when there was maximal freshwater input entering St Lucia from its rivers, most of the Mfolozi water would have entered St Lucia Bay and then passed out to sea on the ebb tide (Whitfield & Taylor, 2009). During drought periods, the common mouth shared by the two systems would close and the Mfolozi River would then be naturally diverted into the St Lucia system, replacing much of the water lost through evaporation from Lake St Lucia with its shallowness and large surface area. The probability of extreme hyper salinities of >60 occurring would have been low, especially in the South Lake where the diluting effect of inflowing Mfolozi water would have been most effective (Taylor, 1993). During a drought, there would have been no connection of the St Lucia system to the sea and when the drought ended and the rivers began flowing strongly into the lake, water levels would rise within the whole system and back up in the adjacent swamps. The backed up water would gradually rise until it reached a level that would overtop the beach berm that had formed across the mouth of St Lucia (Whitfield & Taylor, 2009).

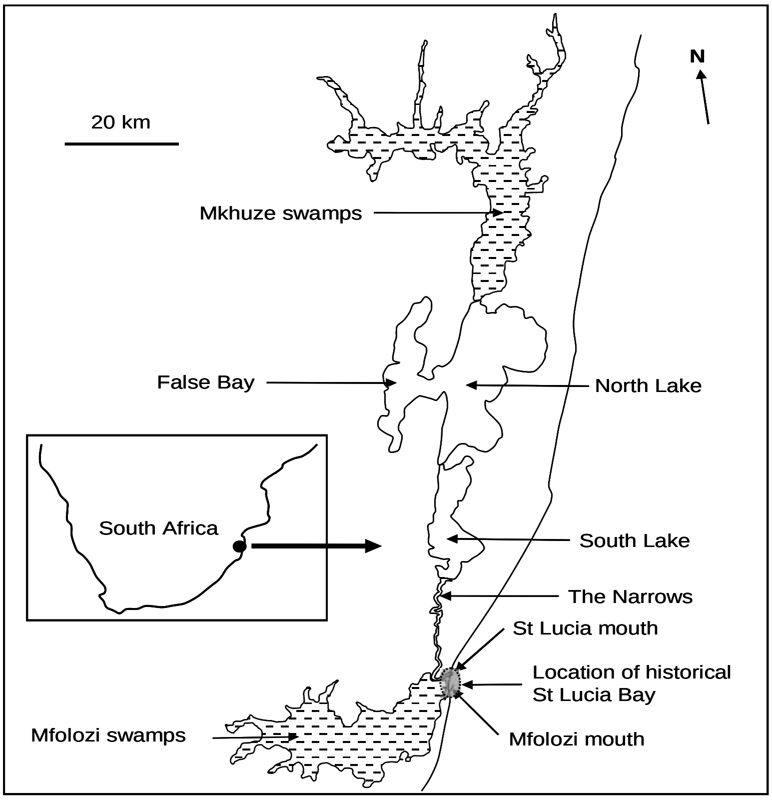

Figure 1: The Lake St Lucia estuarine system. Figure provided by H. L. Jerling, University of Zululand

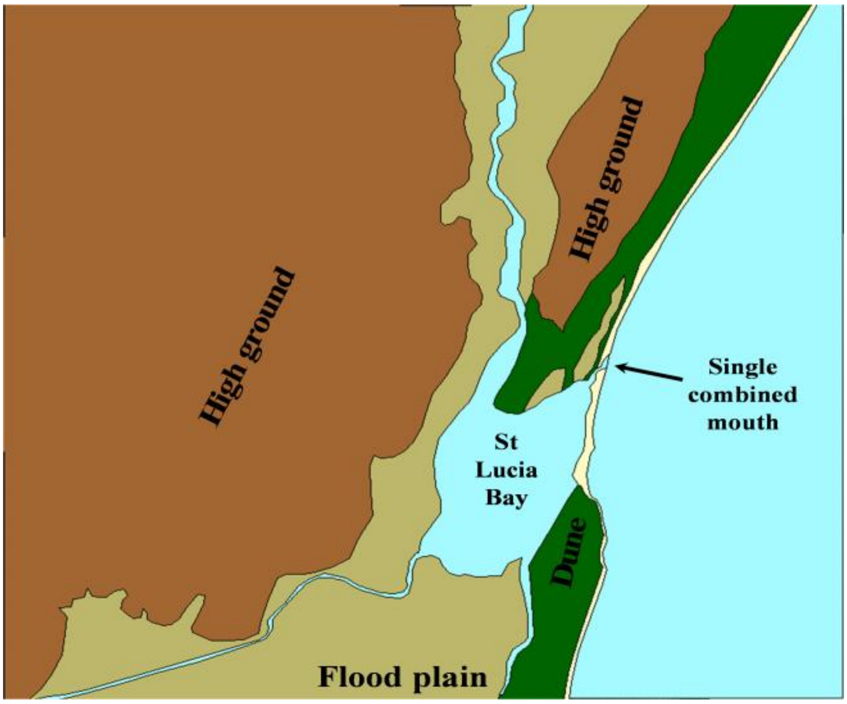

Figure 2: Historical structure of the combined St Lucia- Mfolozi mouth. Figure provided by R.H. Taylor of Ezemvelo KZN Wildlife, Lake St Lucia

1.2 Reasons for the separation of the two systems

Sugarcane farming was commenced in the Mfolozi floodplain and swamp before the 1920s (Whitfield & Taylor, 2009). As a result of the sugarcane farming, swamp areas were drained and to reduce the impacts of the floods in the Mfolozi River, canals were excavated to promote the removal of floodwaters from the floodplain to the sea and reduce inundation of low-lying farms. Excavation of the main canal, Warner’s Drain, in the Mfolozi swamps, resulted in the sedimentation of the St Lucia Bay. Since the canal could not filter and capture the sediments that came down with the water from the Mfolozi River, sedimentation became a permanent feature of the system (Whitfield & Taylor, 2009). During the 1950s drought, the whole mouth area became silted up, cutting off the St Lucia and the Mfolozi systems from the sea. A canal was dredged through to the sea to release the pressure of the backing-up Mfolozi River water and to save the farms from being flooded (Kriel, 1966). This canal, located about 1.5 km south of the existing St Lucia Estuary mouth, became the new Mfolozi Estuary mouth and the Bay was reduced by the dredging that took place in the 1950-1984 period to a mound of spoil (Figure 3) (Taylor, 2006). Since that time, the Mfolozi Estuary has to be artificially breached near Maphelane every few years to keep the two mouths apart since the Mfolozi mouth shows a tendency to link up with the St Lucia Estuary by migrating northwards at an average rate of 60m per month (Whitfield & Taylor, 2009). Without the Mfolozi linkage, St Lucia is now deprived of its single most important source of fresh water during drought periods. In addition to this, the regular flushing of accumulated sediments from the St Lucia Bay area following natural or artificial breaching of the sand berm at the dual mouth also ceased.

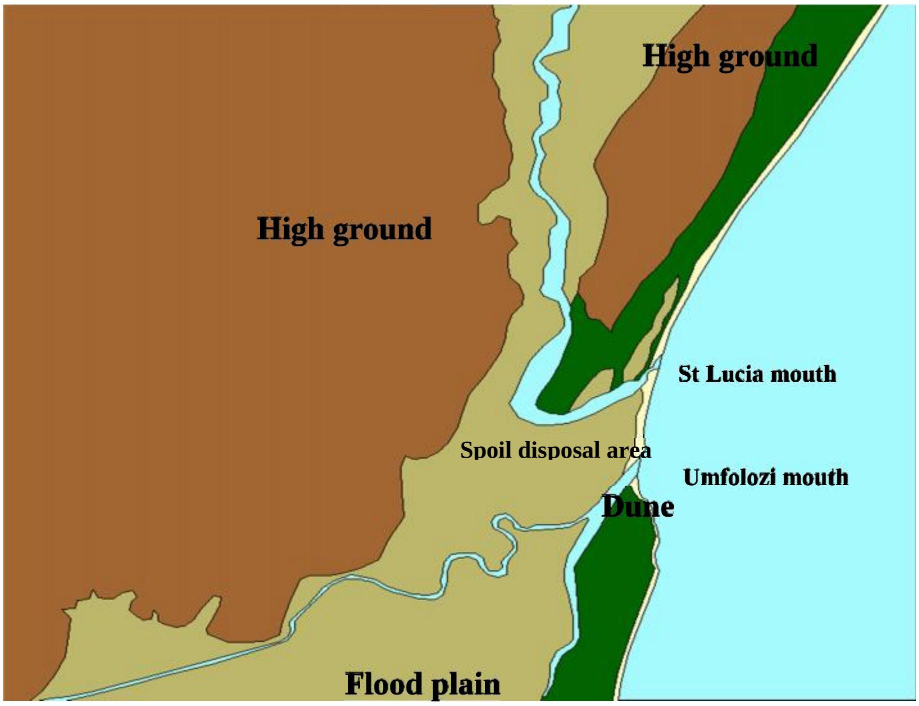

Figure 3: The St Lucia and Mfolozi estuaries after their separation. Figure provided by R.H. Taylor of Ezemvelo KZN Wildlife, Lake St Lucia

1.3 Functioning of the Lake St Lucia system after separation from the Mfolozi-Msunduzi system

After the separation of the two systems, it took five years before St Lucia was once again linked to the sea through a mouth of its own (Taylor, 2006) and an additional eight years of dredging to remove the additional riverine and marine sediments that had accumulated in the estuary and Narrows (Whitfield & Taylor, 2009). During that time it was believed that the St Lucia mouth should be kept open at all times to maintain the link between the estuary and the sea for invertebrates and fish and for this reason a continuous dredging programme was established at the mouth. A further attempt was made to stabilize the St Lucia mouth by building hard structures along both banks of the estuary mouth region but this did not achieve the desired condition of a self-scouring mouth as it still closed at the onset of a drought.

Droughts are a frequent occurrence in northern KwaZulu-Natal and can last for a number of years (Whitfield & Taylor, 2009). After the separation of the Mfolozi River from the St Lucia in 1952, the frequency of the mouth closures increased (Cyrus *et al.*, 2010a). The first drought after the separation of the two systems lasted for four years. It started in September 1955 and ended in February 1961, with the mouth of the St Lucia remaining closed for the entire period. During this period, salinities in the lake remained below 35 thanks to artificial breaching, which took place on three occasions, with the mouth remaining open for a year each time. The drought that occurred from 1967 to 1972 was long and severe; the mouth closed at the start of the drought but was artificially dredged open (Whitfield & Taylor, 2009). The rivers flowing into St Lucia stopped and a large amount of water was lost from the system through evaporation and was replaced by seawater. The seawater entering the system is likely to have carried with it large quantities of marine sediment which were deposited mainly in the lower estuary and in addition to this, some million tonnes of salts were added to the existing salt loading within the lake (Taylor, 2006). The resulting hyper salinity proved to be detrimental for the fauna and flora of the lake. To reduce the hypersalinity in the lake, a canal was excavated in the upper parts of the Mkhuze Swamp (Figure1) in the hope that the limited amount of water that was flowing into the Mkhuze River would bypass the swamps and flow directly into the St Lucia Lake. This attempt did not solve the problem of hyper salinity in the North Lake because far larger amounts of fresh water are needed to dilute the hyper saline water in the lake. On the contrary, it only resulted in adverse ecological consequences for the Mkhuze Swamps, such as the drying up of portions of the swamp and severe erosion (Whitfield & Taylor, 2009). During 1980-1984 another drought occurred during which salinities of 110 were reached in False Bay and 55 in South Lake (Cyrus *et al.*, 2010a). During 1992-1996, the mouth of St Lucia was intermittently closed for short periods of time, during which salinities increased to 55 in both the South and North Lake. Currently the system is experiencing a drought, with low lake levels in evidence since 2002, with no end in sight. Salinities have at times risen to 200 in False Bay and 130 in South Lake (Figure 1) (Cyrus *et al.*, 2010a).

1.4 St Lucia and the current drought

Throughout the current drought, the system has been under stress due to drought-driven hyper salinities that have also resulted in extremely low lake levels that have caused large parts of the lake to dry out (Cyrus *et al*., 2010a).

The low lake levels also meant that, at times, there was insufficient water depth for the fish fauna to survive in the lake. During a flood in the Mfolozi River in January 2004, it overtopped its banks and water flowed into the St Lucia estuary for three days (Whitfield & Taylor, 2009). This temporary linkage enabled juvenile marine fish such as *Pomadasys commmersonnii* to be recruited into the St Lucia Lake via the Narrows and they then migrated into other parts of the Lake (Cyrus & Vivier, 2006a). After just 30 months of mouth closure, June 2002 to December 2004, approximately 40% of the commonly occurring species had disappeared from Lake St Lucia, which showed that this brief link to the marine environment was insufficient to replenish the depleted marine fish stocks in the Lake (Cyrus & Vivier, 2006b). As an experimental intervention, Park managers decided to divert the Mfolozi River winter low-flows into the St Lucia Estuary (Whitfield & Taylor, 2009). When the flow is low, the Mfolozi River carries relatively little sediment. If the Mfolozi mouth is allowed to remain closed, this water backs up into the lower Mfolozi swamp and floodplain and during that stage, whatever sediment there is in the Mfolozi settles as the river water enters this low gradient area and loses energy. This sediment-free water is then allowed to flow through the mangrove-channel that was excavated in the 1960s, into St Lucia, but only the Narrows and a small section of South Lake receives this water (Whitfield & Taylor, 2009). From 31st May 2008 to 5th December 2008, when this connection was operating, some 15 million m^3 of water entered St Lucia, and a further 1.5 million m^3 of water entered during the period 26th December 2008 to 8th January 2009 (Whitfield & Taylor, 2009). The water that entered the Lake was sufficient to reduce salinities in the Narrows to less than 10 and is equivalent to a rainfall of more than 30mm falling over the full St Lucia basin. The practice was again implemented through the winter of 2010.

1.5 Motivation of the study

The St Lucia estuary is considered to be the largest and most important nursery area for estuarine associated marine fish along the east coast of South Africa (Vivier *et al.,* 2010a). The prolonged mouth closure caused by the drought and the low lake levels, have resulted in large declines in fish and prawn communities with deleterious consequences for regional marine populations (Vivier & Cyrus, 2009). Prolonged mouth closure prevents the recruitment of juveniles from the marine environment into the estuary and at the same time, prevents maturing adults that would have grown up in the estuary to recruit into the adult breeding stocks offshore (Cyrus *et al.,* 2010a). Prolonged mouth closure not only affects the closed system but has been shown to have potential impacts on a broader scale in the meta-system. A study was conducted by Mann and Pradervand (2007) on the recruitment of *Rhabdosargus sarba,* a species that breeds in the sea with juveniles showing a strong dependence on estuaries, into the St Lucia Marine Protected Area (MPA) just north of the St Lucia estuary mouth. The study was conducted over the period November 2001-December 2005 and found that there was a gradual but significant decline in the CPUE of the species, which coincided with the first three and a half years of mouth closure at St Lucia.

Declines in the biotic communities of St Lucia have also contributed to a renewed interest in the St Lucia-Mfolozi System link, particularly the importance of the Mfolozi system in terms of its role as a refuge and alternative nursery area for species which cannot recruit into the closed St Lucia system when the Mfolozi remains open. The Mfolozi-Msunduzi system is the closest open estuary along a 70km stretch of coastline when St Lucia is closed and despite its proximity there is a paucity of data on the ecological functioning of the former (Vivier & Cyrus, 2009). A study was conducted in 2007 by the Coastal Research Unit of Zululand (CRUZ) on the fish community of the Mfolozi estuary, during which 48 species of fish were recorded (Vivier & Cyrus, 2009). The system was numerically dominated by *Leiognathus equula*, *Acanthopagrus berda*, *Ambassis spp*. and Mullet. The species that dominated the system were those that usually spawn in the marine environment with the juveniles showing varying degrees of dependence on estuaries. Dietary information on most of the species that occur in high numbers in the system indicates that these species became benthic feeders after their planktonic copepod feeding phase (Whitfield, 1998). Zoobenthic studies in the system found the zoobenthic community to be impoverished (Vivier & Cyrus, 2009, Ngqulana *et al.,* 2010). This raised the question: if the zoobenthic community is impoverished, and benthic feeding fish are present in the system in high numbers, then what are they feeding on?

Although studies have been conducted on benthic feeding fish in a number of South African estuaries, no information was available on the diet of the benthic feeding fish of the Mfolozi-Msunduzi system. Studies on benthic feeders that have been conducted in KwaZulu-Natal estuaries include the Kosi, St Lucia, Richards Bay, Mlalazi, Mhlanga, Durban, Fafa and Mtamvuma estuaries (Blaber, 1984, Blackler *et al.,* 2004, Cyrus & Blaber, 1983a & b, Harman *et al*., 1982, Weerts *et al.,* 1997, Whitfield, 1980a & b, Whitfield, 1985). Other studies conducted in South Africa include the Swartvlei estuary (Coetzee & Pool, 1985, Whitfield, 1988), Swartkop estuary (van der Westhuizen & Marais, 1977), Knysna estuary (Le Quesne, 2000), Kariega and Great Fish estuary (Hecht & van der Lingen, 1992), Gamtoos estuary (Schlacher & Wooldridge, 1996), Palmiet, Kleinmond and Bot River estuaries (Bennett, 1989), Mngazi and Mngazana estuaries (Grant, 2007) and the Igoda estuary (Vumazonke *et al*., 2008). As a result of the lack of data on the benthic feeding fish that recruit into the Mfolozi estuary from the marine environment it was decided to undertake this study. It is aimed at determining what the fish are feeding on and whether the available food source allows these fish to survive and grow up in the system before returning to the marine environment at first maturity. Such a study would contribute to the survival of the offshore breeding stocks and result in recruitment into St Lucia by future generations when that system is once again open to the marine environment.

Leiognathus equula, as the dominant species in the Mfolozi-Msunduzi system Vivier & Cyrus, 2009), is the focus of this study, but other benthic feeding fish samples were also collected and analyzed. *Leiognathus equula* is an estuarine-dependent species that is classified as Category IIb species according to Whitfield’s classification (Whitfield, 1998). Category IIb are species that spawn in the marine environment with the juveniles being more abundant in estuaries than in sea (Whitfield, 1998). These are common in permanently open estuaries on the northern KwaZulu coast but also occur in temporarily closed systems within the subtropical region. They spawn in the marine environment and the juveniles of this species enter estuaries at a total length of <20mm, with size classes between 30mm and 80mm total length. They make extensive use of the KwaZulu-Natal systems as nursery areas during late summer (Whitfield, 1998). Research has been undertaken on *L. equula*, but there is little quantitative information available in South Africa on the species (Day *et al*., 1981, Whitfield, 1980a & b, Whitfield, 1998), Thailand (Hajisamae, 2009, Hajisamae *et al*., 2003, Hajisamae *et al*., 2006, Ikejima *et al.,* 2003) and Australia (Wilson, 1999, Wilson and Sheaves, 2001). This study contributes to knowledge of the feeding habits of *L. equula* and other species in the system.

1.6 Aims of the study

The aims of this study were:

- To determine the diet composition of benthic fish from the Mfolozi-Msunduzi Estuary by:
    - Spatial analysis
    - Temporal (seasonal) analysis
- To determine the relationships between the benthic feeders' diet and the benthos that has been recorded in the estuary.
- To determine the diet composition of benthic fish from the St Lucia Estuary.
- To determine management practices for maintaining benthic feeding fish populations.

Chapter 2: Materials and Methods

2.1 Study Area

The Mfolozi estuary is located on South Africa's subtropical, predominately microtidal KwaZulu-Natal coast, south of the St Lucia lake system on the east coast of Southern Africa (Figure 4) (Vivier & Cyrus, 2009). It is situated 80 km northeast from Richards Bay (Begg, 1978). The Mfolozi estuary shares a common mouth with the Msunduzi estuary and is classified as a river mouth. River mouths are systems where the river usually dominates physical processes within the estuary, with salinities tending towards oligohaline in the middle reaches and these systems often have small tidal prisms with seawater seldom penetrating any significant distance upstream during moderate or high river flow periods (Whitfield, 1992). The Mfolozi estuary has a catchment area that is somewhere between 10 645km^2 and 11068km^2, which is the second largest in KwaZulu-Natal after the Thukela River. The estuary size of the system is 1.8km^2, with a river length of 395km (Begg, 1978). The estuary is situated in a predominately summer rainfall region, with a mean annual runoff estimated at between 887 x 10^6 and 920 x 10^{6}m^3 (Orme, 1974, Whitfield & Taylor, 2009). The Mfolozi estuary is relatively inaccessible being surrounded by swamps and approachable only by means of a road that runs along the foot of high coastal dunes to the Ezemvelo KwaZulu-Natal camp site at Maphelana (Begg, 1978). Further reference to the Mfolozi system hereafter refers to the entire system including the Msunduzi, unless specifically stated.

2.2 Field Sampling

Mfolozi-Msunduzi system

Fish were collected quarterly over a 15-month period, seasonally, from selected sites in the Mfolozi estuary. A total of eight sites were selected for this study (Figure 4). The samples were collected in autumn (March), winter (June), spring (August), summer (November) 2009 and autumn (March) 2010. Additional samples that were collected in August 2008 were also included in the study.

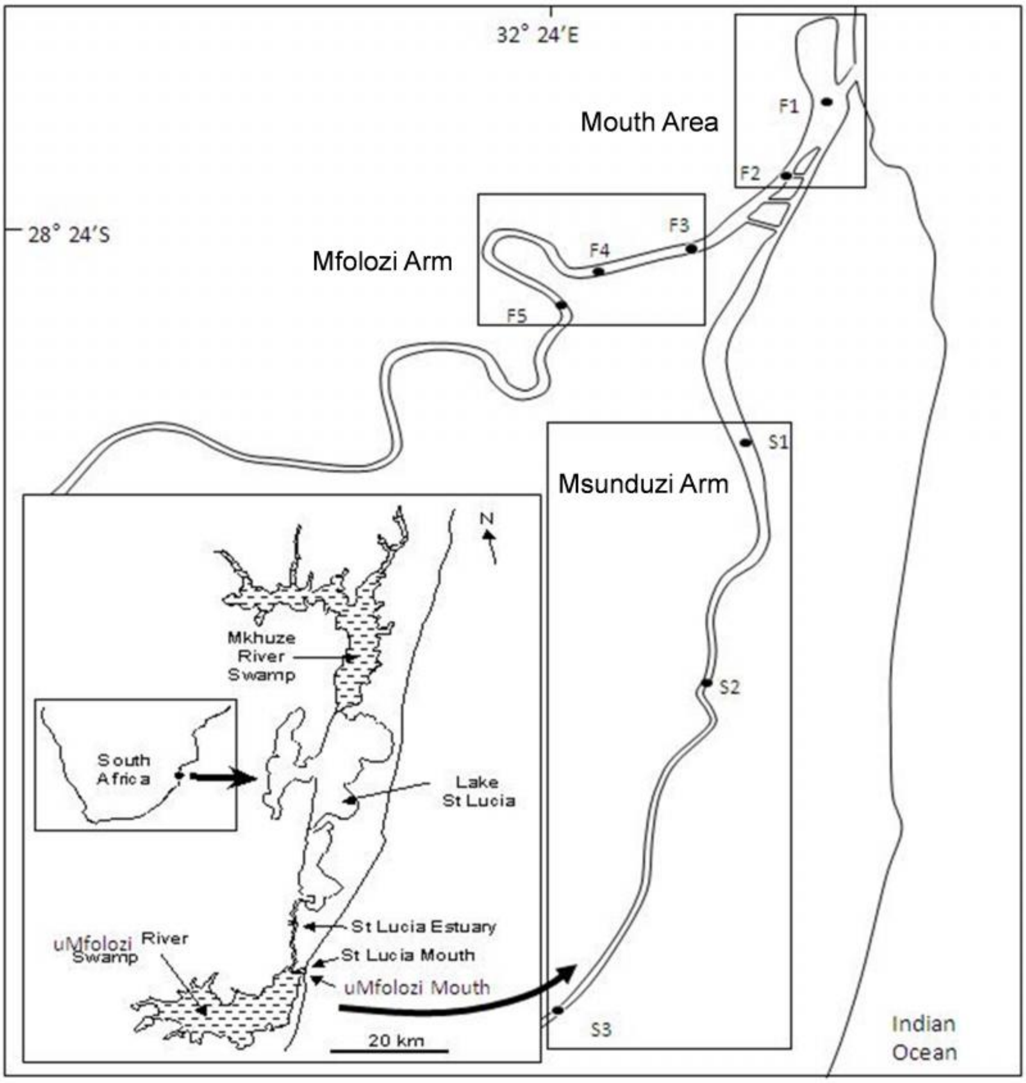

Figure 4: Sampling sites in the Mfolozi (F1-F5) and Msunduzi Estuary (S1 to S3) and the fish sampling zones, the Mouth Area, Mfolozi Arm and Msunduzi Arm.

The fish were collected using four methods: -

Gill Netting:

A set of gill nets with stretched mesh sizes of 50, 75, 100, 125 and 150mm (2"-6") were deployed in the estuary channel.

Large Seine Netting

This was carried out along the shoreline at the different sites using a 70m X 1.5m X 12mm bar stretch mesh seine net.

Small Seine Netting

A small seine measuring 10m X 1.5m X 4mm bar stretch mesh was used to sample the small fish present along the shoreline at each of the different sites.

Beam Trawl

A beam trawl with dimensions, 1.5 X 0.5m and a bag with a bar mesh of 6mm was used to collect bottom fish from within the estuary channel.

Sample preparation

Collected fish were sorted and a sample of the benthic feeding fish kept; the remaining fish were returned to the water. Once the fish were dead, an incision was made from the anus of the fish to open up the body cavity and hasten the absorption of formalin into the gut to prevent further digestion of the food present in the stomach. The fish were then preserved in 10% formalin and taken back to the laboratory for examination. The stomachs of the larger specimens were removed immediately once the fish were dead and preserved.

Physical parameters of the water were measured at each site using a YSI 6920 Sonde (YSI incorporated). These parameters included salinity, temperature, pH, dissolved oxygen, oxygen percentage and depth. Sediment samples were also collected at each site for determination of particle size distribution and organic content.

2.3 General procedures for sample analysis in the lab

Once back at the laboratory fish were soaked overnight in freshwater and then measured to standard length. They were then dissected from the cloaca to near the operculum using a scissors to reveal the body cavity. The percentage fullness was estimated in terms of how much space the stomach occupied in the cavity. Only the stomach region was removed and placed in a petri dish with a little bit of water under a dissecting microscope and dissected using a scissors and tweezers. The contents of the stomach was sorted, identified to the lowest taxonomic level and counted. The stomach contents were then preserved in ethanol and kept for future references.

2.4 Methods of stomach content analysis

The study of diet based upon analysis of stomach contents is now standard practice in fish ecology with a range of methods being used for the studies (Hyslop, 1980). No one method of stomach analysis gives a complete picture of dietary importance and therefore more than one method should be employed for dietary analysis (Hyslop, 1980). None of the investigations reviewed used one method of stomach contents analysis; they all used between four and six methods. Therefore the following four methods were selected for the stomach content analysis in this study:

i. The ‘points’ method of Ricker (1968): the percentage fullness of a stomach was assessed, food items were sorted into species groups, and points were allocated to each group according to the proportion they represented in relation to other groups present and the fullness of the stomach. The maximum total points that can be allocated are 100 for a full stomach. This method gives an approximate volumetric analysis of diet.

ii. Frequency of occurrence: the number of stomachs in which each prey item occurred was recorded and expressed as a percentage of the total number of stomachs examined.

iii. Numerical occurrence: the number of individuals of each food type in all stomachs was expressed as a percentage of the total number recorded.

iv. Index of Relative Importance (IRI) (Pinkas *et al.,* 1971; Hacunda, 1981): This is calculated by summing the numerical and volumetric percentages and multiplying them by the frequency of occurrence percentage value.

These methods were chosen because they are easy to perform and the first three methods were required to calculate the fourth method, Index of Relative Importance.

Canonical correspondence analysis, using CANOCO (ter Braak and Šmilauer, 1998), was used to investigate the influence of environmental factors on the fish community. The benthic data that was used in this study was obtained from a concurrent study of the spatial and temporal distribution of the benthos in the Mfolozi-Msunduzi system (Ngqulana, 2011).

2.5 St Lucia System

Samples of *L. equula* and other benthic feeding fish were also collected from the St Lucia estuary for diet comparison to be made. The fish were collected from three sites, Catalina Bay, Mpate and Honeymoon bend (Figure 5). The fish were collected in two seasons, winter (June) and summer (November), using the same methods as in the Mfolozi-Msunduzi system. The same methods as used in the Mfolozi-Msunduzi system were used for analyzing the St Lucia samples.

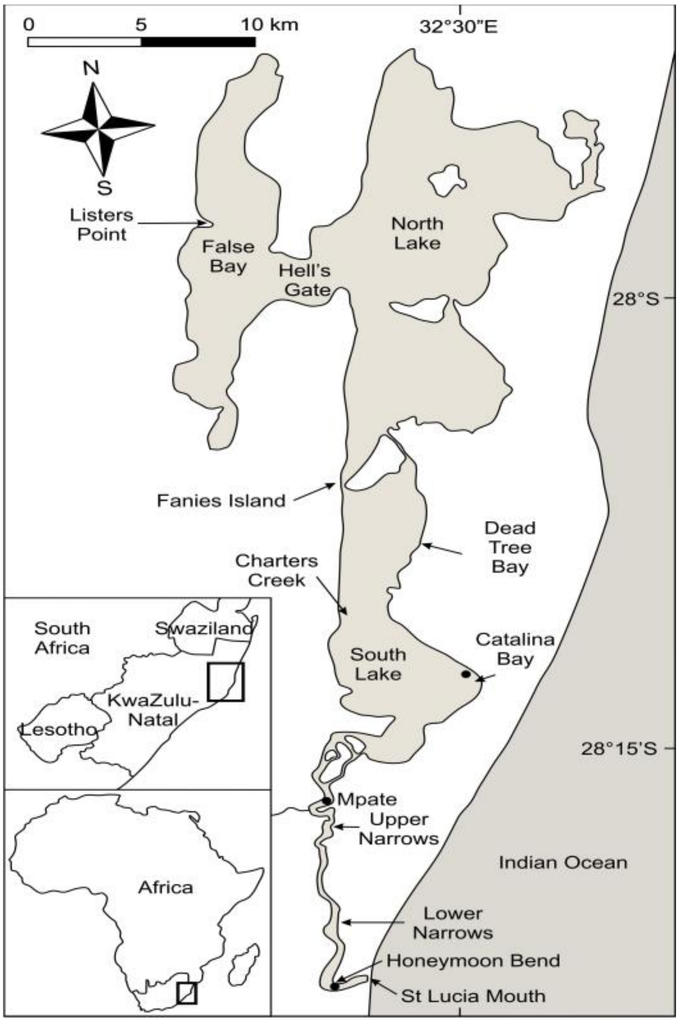

Figure 5: Sampling sites in the St Lucia System (Figure provided by Dr. L. Vivier).

Chapter 3: Results

The sites that were selected for this study are shown in Figure 4 and due to the small numbers of fish that were recorded at some of the sites, it was decided to pool the sites into three zones. Sites F1 and F2 were pooled to form one zone referred to as the Mouth Area, while F3 – F5 were combined as the Mfolozi Arm, and S2 – S4 to form the Msunduzi Arm (Figure 6).

3.1 Physico-chemical Parameters

The physico-chemical results for the entire study period are shown in Appendix 1. The field data sheet with the data from the Mfolozi side in August 2008 was lost, so only the Msunduzi data for that sampling trip was available. As the sites were joined, it was decided to present the data for MFE 1 to represent the Mouth Area (MA), MFE 4 to represent the Mfolozi Arm (MFA) and MSE 3 to represent the Msunduzi Arm (MSA). These were choosen because they give the best representation of the different parts of the system.

3.1.1 Temperature

The water temperature throughout the sampling period was below 30°C, ranging from 18-28.52°C (Figure 6(a)). Temperatures during autumn ranged between 26.12 and 28.52°C, in winter between 19.02 and 22.87°C, in spring between 19.18 and 20.03°C and in summer between 24.88 and 26.61°C. The lowest temperatures throughout the sampling period were recorded in the Msunduzi Arm, except in summer, where the lowest temperatures were recorded in the Mouth Area.

3.1.2 Salinity

The mouth of the system was open throughout the sampling period, except in spring 2008 and 2009, when it was closed. The salinities were relatively higher at the mouth during the entire sampling period, except during summer when the salinity at the mouth was lower than that of the Msunduzi arm. The system was predominantly fresh in summer with salinities <1, indicating a river-driven system (Figure 6(b)).

3.1.3 pH

There was little spatial and temporal variation in the water pH in the Mfolozi-Msunduzi system (Figure 6(c)). Throughout the study period, from spring 2008 to autumn 2010, the pH in the entire system ranged between 7.8 and 8.9, which is expected because of the influx of marine water which is slightly alkaline in nature.

3.1.4 Dissolved Oxygen (mg/l)

The system remained well oxygenated throughout the study period, spring 2008 to autumn 2010 (5.37- 10.78 mg/l) (Figure 6(d)). There were higher levels of dissolved oxygen in winter and summer than in spring and autumn.

3.1.5 Dissolved Oxygen (%)

The system remained well saturated throughout the entire study period, spring 2008 to autumn 2010 (Figure 7(a)). The dissolved O_2 concentration remained above 100% except during August 2008 and 2009 and March 2010 when it was <100% throughout the system.

3.1.6 Turbidity

Turbidities in the Mfolozi-Msunduzi estuary ranged from 0.39 - 1 291NTU during the study period (Figure 7(b)). Higher turbidities were recorded in the Msunduzi Arm compared to the Mouth Area and Mfolozi Arm, in autumn and winter 2009, as opposed to other sampling periods when the turdidities in these two areas were higher. The system was more turbid in summer than in any other season with turbidities reaching up to 1 290.1NTU as a result of increased river runoff during this period.

3.1.7 Depth

The system was relatively shallow throughout the sampling period with the maximum depth of 2.0m being recorded (Figure 7(c)). The depth ranged from 0.417 - 2.0m, with the mouth area being the shallowest during the entire sampling period (0.417 - 0.80m). The system was deepest during closed mouth conditions.

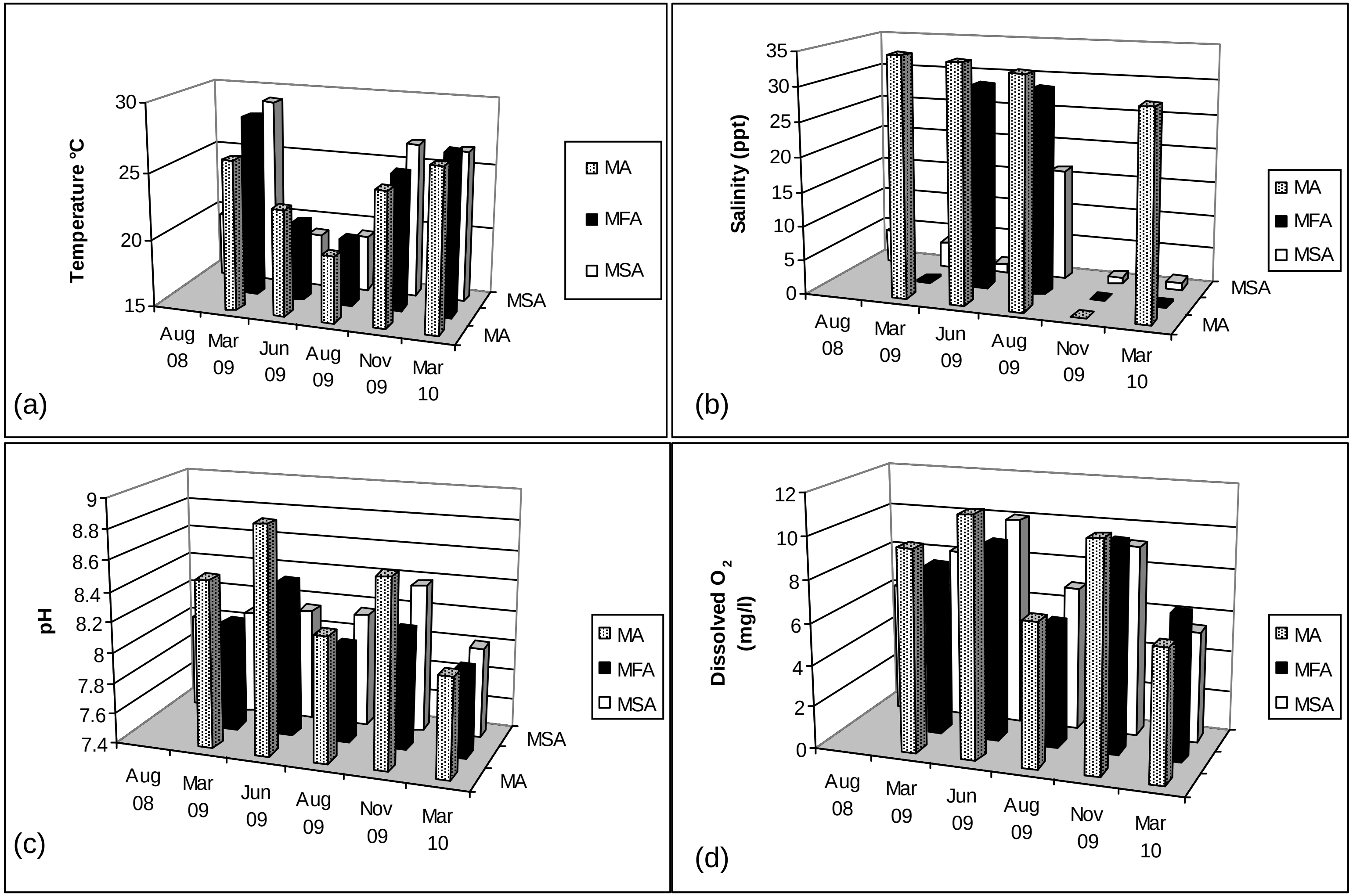

Figure 6: Physico-chemical parameters in the Mfolozi-Msunduzi system from August 2008 to March 2010. (a) Temperature; (b) Salinity; (c) pH and (d) Dissolved O_2 (mg/l) (MA= Mouth Area, MFA= Mfolozi Arm, MSA= Msunduzi Arm).

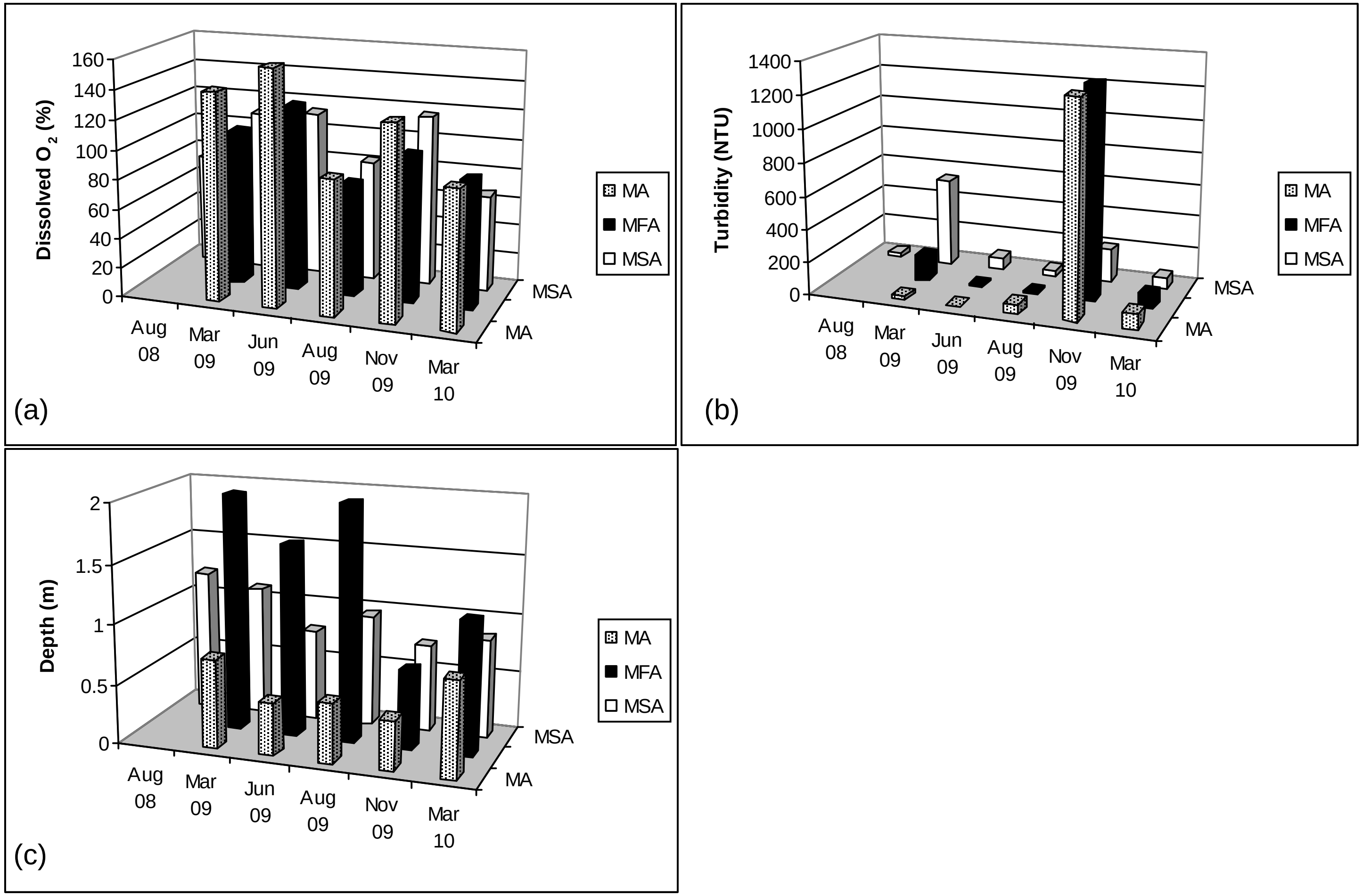

Figure 7: Physico-chemical parameters in the Mfolozi-Msunduzi system from August 2008 to March 2010. (a) Dissolved 0_2 (%); (b) Turbidity and (c) Depth (MA= Mouth Area, MFA= Mfolozi Arm, MSA= Msunduzi Arm).

3.2 Fish community

A total of 960 fish from 15 different species were collected from the Mfolozi-Msunduzi system for analysis during the study. Of these, only six species were caught in sufficient numbers for the stomach content analyses to be undertaken. These were *Glossogobius giurus, Ambassis gymnocephalus, Ambassis natalensis, Ambassis ambassis, A. berda* and *L. equula* (Table 1). The data from the remaining species is summarized in Table 2. Data from the six dominant species in terms of Points method, Frequency of Occurrence and Percentage Occurrence were used to determine the Index of Relative Importance and the results were presented.

Food items in the stomachs of the fish which had been too digested to identify were classified as unidentified material. The dominant prey items in the species diet are bolded in the Tables.

Table 1: The six species caught in the Mfolozi-Msunduzi system over the period August 2008 to March 2010 that were used in the stomach content analysis.

Species	Total caught	No.with prey	No. that were empty
Leiognathus equula (Le)	595	527	68
Acanthopagrus berda (Ab)	104	59	45
Glossogobius giurus (Gg)	43	16	27
Ambassis ambassis (Aa)	75	16	59
Ambassis gymnocephalus (Ag)	22	8	14
Ambassis natalensis (An)	55	19	36

Table 2: Summary of the other species caught in the Mfolozi-Msunduzi system during the study period and their prey items.

Species	**Total caught**	**No. with prey**	**No. that were empty**	**Identifiable prey items**
Gerres acinaces (Ga)	5	5	0	*Dendronereis arborifera, Pseudodiaptomus stuhlmanni*
Gerres filamentosus (Gf)	8	8	0	*Chironomidae, Pseudodiaptomus stuhlmanni, Dendronereides zululandica*
Rhabdosargus sarba (Rs)	4	3	1	*Pseudodiaptomus stuhlmanni*
Solea bleekeri (Sb)	19	0	19	Empty
Pomadasys commersonni (Pc)	13	5	8	*Fenneropenaeus indicus, Pseudodiaptomus stuhlmanni*
Pomadasys kaakan (Pk)	2	1	1	*Dendronereis arborifera*
Glossogobius callidus (Gc)	2	0	2	Empty
Glossogobius tenuiformis (Gt)	10	6	4	*Pseudodiaptomus stuhlmanni*
Oligolepis keiensis (Ok)	3	2	1	*Pseudodiaptomus stuhlmanni*

3.3 Influence of environmental factors on fish community

Canonical correspondence analysis (CCA) was used to determine the influence of environmental parameters on the fish community of the Mfolozi-Msunduzi system (Figure 8). Since the physico-chemical record from 2008 was unavailable, the fish data from 2008 also had to be excluded and that resulted in the omission of two species, *Gerres acinaces* and *Oligolepis keiensis*. The environmental variables most responsible for structuring the benthic feeding fish community included salinity, temperature and depth, with turbidity, pH and dissolved oxygen levels being of lesser importance. Salinity was negatively correlated to turbidity which is understandable because, the samples most characteristic of high turbidities were summer samples which had lower salinities caused by the influx of freshwater. There was no correlation between temperature and salinity or temperature and turbidity. The benthic feeding fish community was greatly influenced by natural seasonal differences, which can be seen from the separation of the warmer seasons (summer and autumn) from the colder ones (winter and spring). *Acanthopagrus berda*, *G. acinaces* and *A. gymnocephalus* were positively correlated to turbidity. The ambassids, *A. natalensis* and *A. ambassis* was more abundant in warmer seasons. *Pomadasys commersonni*, *G. guirus* and *G. callidus* were positively correlated with depth and salinity. There was a negative correlation between temperature and the presence of *L. equula*, *S. bleekeri*, *P. kaakan*, *G. filamentosus* and *R. sarba*, with these species being more abundant in the colder seasons.

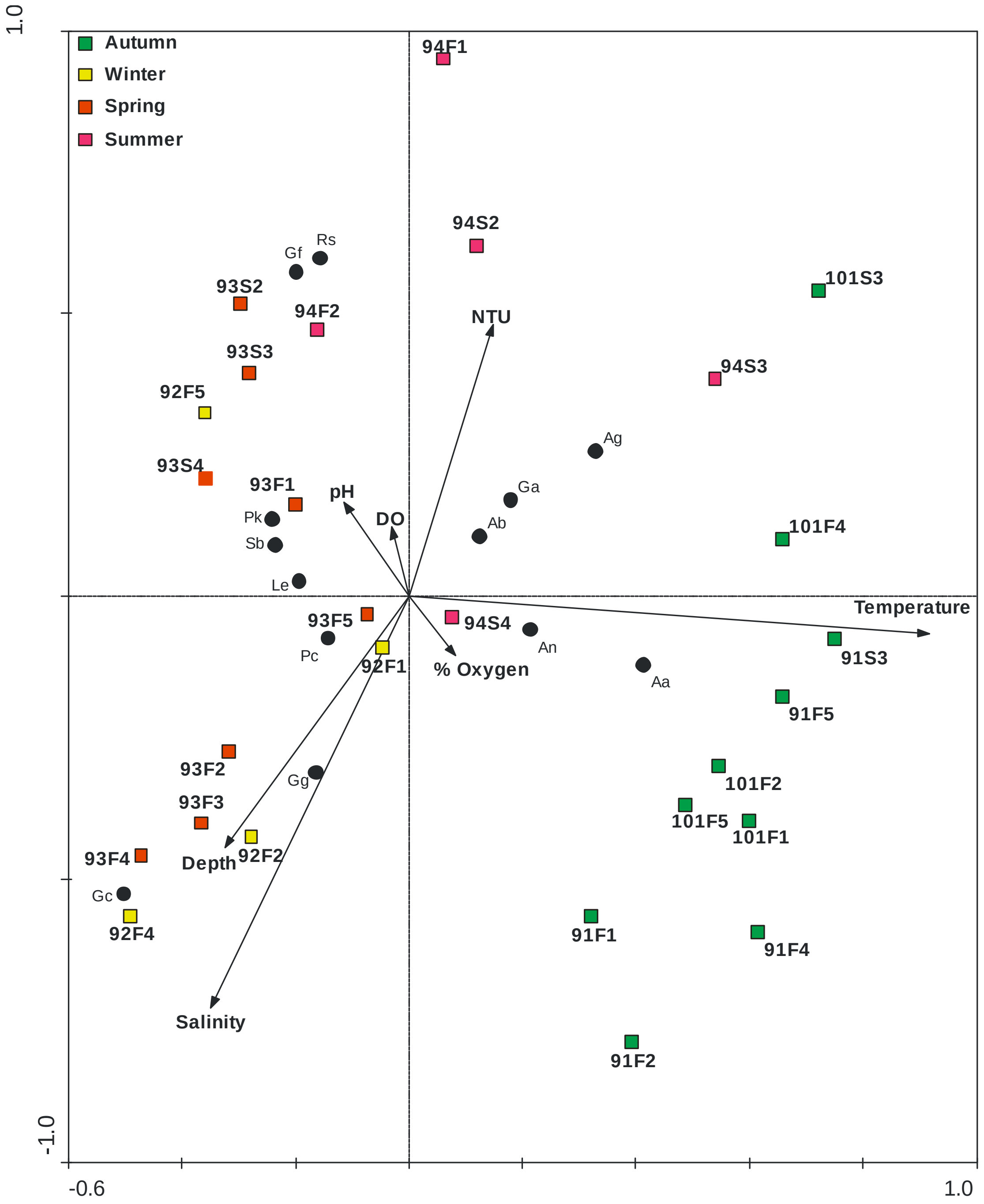

Figure 8: Canonical correspondence analysis triplot of the influence of environmental factors on the benthic feeding fish community of the Mfolozi-Msunduzi system from March 2009 to March 2010. [Letters represent species names (see Table 1 & 2) and codes with numbers (1st number represents the year, i.e. 9- 2009 & 10- 2010; 2nd number represents the seasons, 1- autumn, 2- winter, 3- spring; F1-F5 represents the Mfolozi sites & S2-S4 represents the Msunduzi sites)].

3.4 Overall diet of benthic feeding fish in the Mfolozi-Msunduzi system

Table 3 shows the diet data of six species in terms of Frequency of occurrence, Numerical occurrence, Points, and Index of Relative Importance methods.

3.4.1 *Leiognathus equula*

In terms of the Frequency of occurrence method, the diet of *L. equula* was dominated by the copepod, *Pseudodiaptomus stuhlmanni* (83.53%), followed by unidentified material (70.41%). Results of Numerical occurrence method indicated that *P. stuhlmanni* was dominant in the diet of *L. equula* (98.78%), with the other prey items contributing less than 2% to the overall diet of the species. According to the Points method, *P. stuhlmanni* (84.56%) was dominant in the diet of the species, followed by unidentified material (10.05%). The diet of *L. equula,* in terms of the Index of Relative Importance (IRI), was dominated by *P. stuhlmanni* (95%), while other food items (5%) did not play a significant role in the species' diet (Figure 9a). For other food items, refer to Table 3.

3.4.2 *Acanthopagrus berda*

The diet of *Acanthopagrus berda* according to the Frequency of occurrence method was dominated by unidentified material (43.26%) followed by *P. stuhlmanni* (18.27%). In terms of Numerical occurrence, the diet of *A. berda* was dominated by *P. stuhlmanni* (87.57%). According to the Points method, the diet of *A. berda* was dominated by unidentified material (34.92%) followed by *P. stuhlmanni* (27.64%) and *Macrobrachium sp.* (12.13%). The overall diet of *A. berda,* in terms of IRI method, was dominated by *P. stuhlmanni* (56%), followed by unidentified material (41%), but it also fed on scales (1%) and other prey items (2%) (Figure 9b). For other prey items, refer to Table 3.

3.4.3 *Glossogobius giurus*

The diet of *G. giurus* according to the Frequency of occurrence method, was dominated by *Glossogobius sp.* (20.93%) followed by *Ambassis sp.* (6.98%) and *P. stuhlmanni* (4.65%). In terms of the Numerical occurrence method, *P. stuhlmanni* (73.08%) dominated, followed by *Glossogobius sp.* (17.31%) and *Ambassis sp.* (5.77%). According to the Points method, *Glossogobius sp.* (53.50%) dominated, followed by *Ambassis sp.* (35.02%) and *P. stuhlmanni* (6.42%). The results of IRI method indicated that the dominant prey item found in the diet of *G. giurus* was *Glossogobius sp.* (69%) followed by *P. stuhlmanni* (17%), and *Ambassis sp.* (13%) (Figure 9c). Refer to Table 3 for other prey items.

3.4.4 *Ambassis ambassis*

The diet of *A. ambassis* according to the Frequency of occurrence method, was dominated by unidentified material (13.33%), followed by *P. stuhlmanni* (6.67%) and *Orchestia ancheidos* (6.67%). In terms of Numerical occurrence, the diet of *A. ambassis* was dominated by *P. stuhlmanni* (69.66%) and *O. ancheidos* (20.56%). Results of the Points method showed that unidentified material (31.75%) dominated the diet of *A. ambassis* followed by *O. ancheidos* (30.66%) and *Glossogobius sp.* (14.60%). According to the IRI method, the diet of *A. ambassis* was dominated by *P. stuhlmanni* (38%) but *Orchestia ancheidos* (26%) also formed a major component of the species' diet (Figure 9d). Refer to Table 3 for other prey items.

3.4.5 *Ambassis gymnocephalus*

Ambassis gymnocephalus fed on *P. stuhlmanni* and material that was too digested to be identified. According to Frequency of occurrence, both *P. stuhlmanni* and unidentified material contributed 50% each to the overall diet. Numerical occurrence results indicated that the diet of the species was dominated by *P. stuhlmanni* (100%). Results of the Points method showed that the diet of *A. ambassis* dominated by *P. stuhlmanni* (64%). In terms of the IRI method, the diet of *A. gymnocephalus* was dominated by the *P. stuhlmanni* (82%) (Figure 9e).

3.4.6 *Ambassis natalensis*

In terms of Frequency of occurrence, *P. stuhlmanni* (12.73%) and unidentified material (12.73%) were dominant. Results of the Numerical occurrence method indicated that the dominant prey item in the species' diet was *P. stuhlmanni* (97.17%). The Points method results showed that the species' diet was dominated by *P. stuhlmanni* (41%) followed unidentified material (36.67%). According to the IRI method, the diet of *A. natalensis* was dominated by *P. stuhlmanni* (77%) with plant material forming a very small component of the species' diet (1%)(Figure 9f). For other prey items, refer to Table 3.

Table 3: Diet of the six selected species in the Mfolozi-Msunduzi system as indicated by the four methods used to analyze stomach content (F= Frequency of occurrence, N= Numerical occurrence, P= Points method & IRI= Index of Relative Importance, n= number of non-empty stomachs).

	***Leiognathus equula* (n = 527)**				***Acanthopagrus berda* (n = 59)**				***Glossogobius giurus* (n =16)**				***Ambassis Ambassis* (n = 16)**				***Ambassis gymnocephalus* (n = 8)**				***Ambassis natalensis* (n =19)**			
Food item	**F**	**N**	**P**	**IRI**	**F**	**N**	**P**	**IRI**	**F**	**N**	**P**	**IRI**	**F**	**N**	**P**	**IRI**	**F**	**N**	**P**	**IRI**	**F**	**N**	**P**	**IRI**
Ambassis sp					0.96	0.09	3.29	0.09	6.98	5.77	**35.02**	**13.20**	1.33	0.2	4.38	0.46								
Apseudes digitalis	0.17	0.001	0.01	<0.01																				
Baetidae	2.35	0.07	0.69	0.01	1.92	2.43	6.81	0.47					1.33	0.6	0.36	0.10					1.82	0.12	0.33	0.04
Boltisia minuta																								
Chironomidae	5.38	1.06	2.85	0.13	2.88	2.43	3.35	0.44					1.33	0.2	0.36	0.06								
Cladocera	0.34	0.02	0.19	<0.01																	3.64	2.09	1.44	0.56
Crustacean sp					1.92	0.18	2.64	0.14																
Crustacean eggs																					1.82		1.11	0.09
Dendronereides zululandica													1.33	2	3.65	0.57								
Dendronereis arborifera	2.52	0.03	1.36	0.02	0.96	0.09	0.77	0.02													3.64	0.25	5.56	0.92
Fenneropenaeus indicus	0.17	0.001	0.01	<0.01																				
Formicidae																					1.82	0.25	2.22	0.19
Gastropod sp					0.96	2.78	0.99	0.10																
Glossogobuis sp									20.93	**17.31**	**53.5**	**68.70**	1.33	0.2	14.6	1.48					1.82	0.12	5.56	0.45
Grandidierella bonnieroides	0.34	0.003	0.03	<0.01	3.85	1.22	0.49	0.17																
Grandidierella lignorum													1.33	0.2	0.73	0.09								
Halaelurus sp					0.96	0.09	0.49	0.01																
Macrobrachium sp					3.85	0.43	12.13	1.28	2.33	1.92	3.89	0.63												
Marine amphipod sp	0.85	0.006	0.07	<0.01																				
Mesopodopsis africana													1.33	6.39	7.3	1.37								
Oligochaete	0.17	0.001	0.01	<0.01																				
Orchestia ancheidos													6.67	**20.56**	**30.66**	**25.77**								
Paratylodiplax blephariskios					3.85	0.61	2.74	0.34	2.33	1.92	0.78	0.29												
Plant material					4.8		2.85	0.36													5.45		6.11	1.44
Polychaete sp	0.85	0.014	0.15	<0.01	0.96	0.17	0.22	0.01																
Pseudodiaptomus stuhlmanni	83.53	**98.78**	**84.56**	**95.42**	18.27	**87.57**	**27.64**	**55.88**	4.65	**73.08**	6.42	17.14	6.67	**69.66**	6.2	**38.17**	50	**100**	**63.89**	**81.95**	12.73	**97.17**	**41.00**	**76.12**
Scales	0.17	0.001	0.01	<0.01	2.88	1.57	0.66	0.17																
Unidentified material	70.41	0.003	**10.05**	4.41	43.26	0.35	**34.92**	**40.50**	2.33		0.39	0.04	13.33		31.75	**31.93**	50		36.11	18.06	12.73		**36.67**	**20.20**

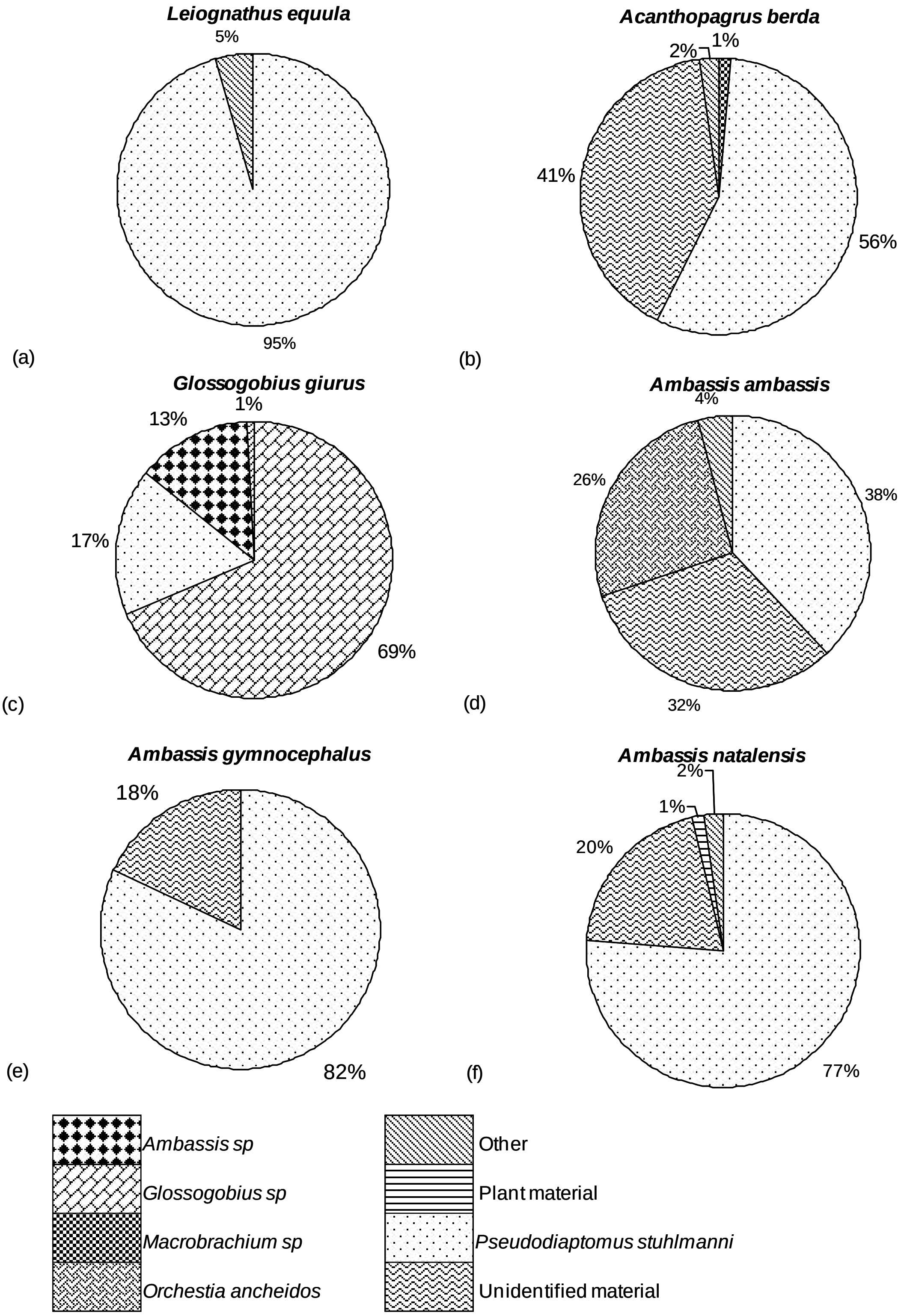

Figure 9: Stomach content analysis of the six dominant species in the Mfolozi-Msunduzi system (August 2008 – March 2010) based on the Index of Relative Importance (Pinkas *et al*., 1970). (a) *Leiognathus equula*; (b) *Acanthopagrus berda*; (c) *Glossogobius giurus*; (d) *Ambassis ambassis*; (e) *Ambassis gymnocephalus* and (f) *Ambassis natalensis*

3.5 Diet of the selected species at different size classes

The diet of the selected species at different size classes was determined in order to establish if there were any changes with increasing age. Graphs were only constructed for *L. equula* and *A. berda* because there appeared to be no differences in the diet of the other species with age.

3.5.1 *Ambassis ambassis*

According to the stomach content of *Ambassis ambassis* at 25-114mm Standard Length (SL), in the overall analysis all fed on the same prey items. The species' diet comprised of *Ambassis sp.*, Baetidae, Chironomidae, *Dendronereides zululandica*, Gastropod *sp.*, *Grandidlerella lignorum*, *Mesopodopsis africana*, *Orchestia ancheidos*, *Pseudodiaptomus stuhlmanni* and unidentified material (Table 3).

3.5.2 *Ambassis gymnocephalus*

The stomach contents of the *Ambassis gymnocephalus* specimens that were examined ranged from 25 to 64mm SL and they all fed on *P. stuhlmanni*.

3.5.3 *Ambassis natalensis*

There was no difference between the stomach contents of *Ambassis natalensis* in the collected size range (25-74mm SL). The species generally fed on Baetidae, Cladocera, crustacean eggs, *D. arborifera*, Formicidae, *Glossogobius sp.*, *P. stuhlmanni* and plant material (Table 3).

3.5.4 *Glossogobius giurus*

The *Glossogobius giurus* stomachs that were examined ranged between 25-274 SL; only two specimens at between 35 and 44mm were examined and they fed on *P. stuhlmanni.* Only one specimen of 30mm SL was examined and it was empty. There were no specimens collected at between 45 and 64mm SL. From 65-274mm SL, the species generally fed on *Ambassis sp.*, *Glossogobius sp.*, *Macrobrachium sp.* and *Paratylodiplax blephariskios* (Table 3).

3.5.5 The diet of different size classes of *Leiognathus equula*

The *L. equula* analysed ranged from 15 to 164mm SL. For the analysis, the size classes were divided into five groups, as shown in Table 4.

15-44mm SL

According to the Frequency of occurrence method, *P. stuhlmanni* (92.05%) dominated in the species' diet at this size class, followed by unidentified material (63.18%). Results of the Numerical occurrence method indicated that *P. stuhlmanni* (99.38%) was dominant in the diet of *L. equula* with the other prey items contributing less than 1% (Table 4). In terms of the Points method, *P. stuhlmanni* (88.8%) dominated followed by unidentified material (6.7%). The diet of *L. equula,* in terms of the IRI method, was dominated by *Pseudodiaptomus stuhlmanni* (97%) but they also fed on other prey items (3%) (Figure 10a). For other prey items, refer to Table 4.

45-74mm SL

According to the Frequency of occurrence method, *P. stuhlmanni* (95.24%) dominated followed by unidentified material (82.25%) at this size class. The diet of *L. equula*, in terms of the Numerical occurrence method, was dominated by *P. stuhlmanni* (98.36%) with the rest of the prey items contributing less than 2% to the total diet. In terms of the Points method, *P. stuhlmanni* (83.64%) dominated, followed by unidentified material (10.60%). Results of the IRI method indicated that the species' diet was dominated by *P. stuhlmanni* (95%), with other prey items making up 5% (Figure 10b). Refer to Table 4 for other prey items.

75-104mm SL

The diet of the species' at this size class, according to the Frequency of occurrence method, was dominated by unidentified material (74.69%) followed by *P. stuhlmanni* (56.63%). In terms of Numerical occurrence, the diet of the species' was dominated by *P. stuhlmanni* (98.56%). According to the Points method, *P. stuhlmanni* (66.73%) dominated the species' diet followed by unidentified material (23.15%). Results of the IRI method showed that *P. stuhlmanni* (83%) dominated the species' diet but also fed on other prey items (Figure 10c). Refer to Table 4 for other prey items.

105-134mm SL

The diet of the species' at this size class, in terms of the Frequency of occurrence method indicated that unidentified material (41.38%) dominated followed by *P. stuhlmanni* (24.14%). According to the Numerical occurrence method, the diet of the species was dominated by *P. stuhlmanni* (91.31%). In terms of Points method, *P. stuhlmanni* (47.14%) dominated followed by unidentified material (44.92%). Results of the IRI method showed that the diet of species' was dominated by *P. stuhlmanni* (65%) with *D. arborifera* contributing 1% to the total diet (Figure 10d). At this size classes, unidentified material included prawns.

135-164mm SL

According to the Frequency of occurrence, the diet of the species at this size class, was dominated by unidentified material (76.60%) followed by *P. stuhlmanni* (30.77%). In terms of Numerical occurrence, the diet of the species was dominated by *P. stuhlmanni* (98.60%). Points method results indicated that unidentified material (72.60%) dominated the diet of the species. The diet of the species, according to the IRI method, was dominated by unidentifiable material (61%) but this size class also fed on *P. stuhlmanni* (38%) and other prey items (1%) (Figure 10e). For other prey items, refer to Table 4.

Table 4: Diet of *Leiognathus equula* at different size classes as indicated by the four methods used to analyze stomach contents in the Mfolozi-Msunduzi system (F= Frequency of occurrence, N= Numerical occurrence, P= Points method & IRI= Index of Relative Importance).

	15-44mm (n = 220)				**45-74mm (n = 220)**				**75-104mm (n = 60)**				**105-134mm (n = 11)**				**135-164mm (n = 10)**			
Food item	**F**	**N**	**P**	**IRI**	**F**	**N**	**P**	**IRI**	**F**	**N**	**P**	**IRI**	**F**	**N**	**P**	**IRI**	**F**	**N**	**P**	**IRI**
Apseudes digitalis	0.42	0.01	0.03	<0.01																
Baetidae	2.93	0.10	0.87	0.02	2.60	0.07	0.61	0.01	1.20	0.02	0.11	0.01								
Chironomidae	5.86	0.45	2.38	0.09	7.36	1.52	3.94	0.22	1.20	1.03	0.77	0.02								
Cladocera	0.42	0.05	0.27	<0.01	0.43	0.01	0.14	<0.01	0.01	0.01	0.00	0.00								
Dendronereis arborifera	0.84	0.01	0.29	<0.01	3.03	0.02	0.89	0.02	7.23	0.20	6.50	0.43	6.90	0.60	7.94	1.08	7.69	0.47	9.37	0.82
Fenneropenaeus indicus	0.42	0.01	0.57	<0.01					1.20	0.01	0.11	0.01								
Grandidierella bonnieroides									2.41	0.03	0.40	0.01								
Marine amphipod sp.	0.42	0.01	0.02	<0.01	1.30	0.01	0.12	<0.01												
Oligochaeta																	7.69	0.47	1.17	0.14
Polychaete sp.					0.43	0.01	0.07	<0.01	4.82	0.12	1.43	0.07								
Pseudodiaptomus stuhlmanni	92.05	**99.38**	**88.84**	**97.49**	95.24	**98.36**	**83.64**	**94.98**	56.63	**98.56**	**67.32**	**83.88**	24.14	**99.32**	**47.14**	**64.79**	30.77	**98.60**	**15.69**	**38.22**
Scales																	7.69	0.47	1.17	0.14
Unidentified material	63.18	0.01	6.74	2.39	82.25	0.01	**10.60**	4.78	74.70	0.02	**23.35**	**15.59**	41.38	0.09	**44.92**	**34.13**	76.92	0.00	**72.60**	**60.69**

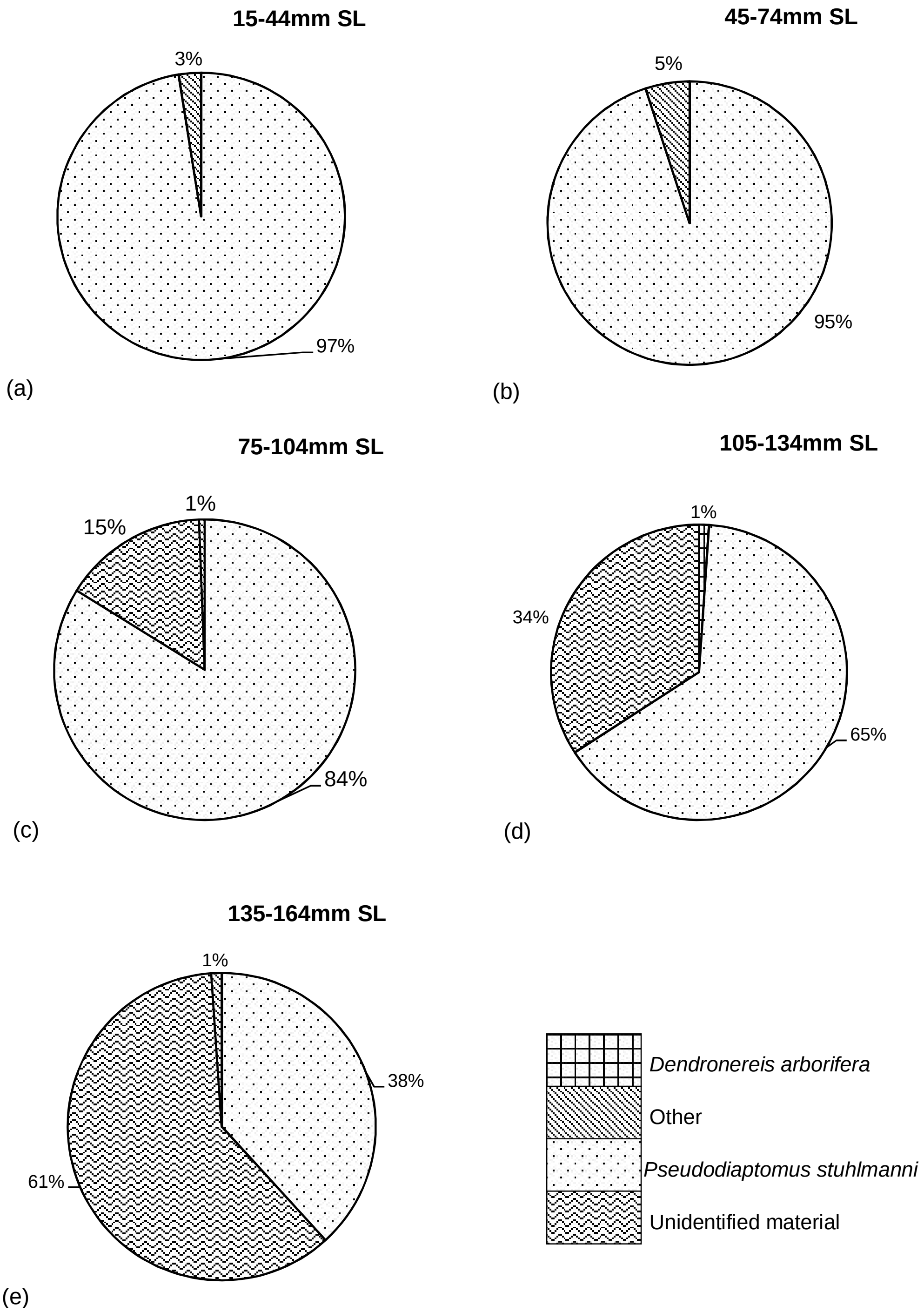

Figure 10: The diet of different size classes of *Leiognathus equula* in the Mfolozi-Msunduzi system based on the Index of Relative Importance.

3.5.6 The diet of different size classes of *Acanthopagrus berda*

The *A. berda* specimens that were analysed ranged from 15 to 334mm SL. Only a few specimens larger than 164mm SL were caught and their diet is summarized in Table 5. For the analysis, the size classes were divided into five groups and only specimens whose length was between 15 and 164mm were considered since they were caught in suffient numbers (Table 6).

Table 5: Summary of the diet of the other sizes classes of *Acanthopagrus berda* in the Mfolozi-Msunduzi system.

Size	**No. of specimens**	**Diet**
170	1	Unidentified material
180	2	Empty
200	3	Empty
210	2	Plant material
220	1	Empty
240	3	Unidentified material, *Paratylodiplax blephariskios*
250	1	*Paratylodiplax blephariskios*
290	2	Empty
330	1	*Halaelurus sp, Macrobrachium sp*

Table 6 shows the diet data of different size classes of *Acanthopagrus berda* in terms of Frequency of occurrence, Numerical occurrence, Points and Index of Relative Importance methods.

15-44mm SL

The diet of *A. berda* at this size class, according to the Frequency of occurrence method, was dominated by *P. stuhlmanni* (69.23%) followed by unidentified material (61.54%). According to Numerical occurrence, *P. stuhlmanni* (93.57%) dominated the diet of *A. berda*. In terms of the Points method, *P. stuhlmanni* (63.17%) dominated, followed by Baetidae (17.56%). Results of the IRI method indicated that *A. berda* fed on *P. stuhlmanni* (90%), Baetidae (3%) and Chironomidae (1%) (Figure 11a).

45-74mm SL

The Frequency of occurrence method indicated that unidentified material (39.29%) dominated the diet of the species, followed by *P. stuhlmanni* (25%) at this size class. In terms of Numerical occurrence, the dominant prey item in the diet of the species was *P. stuhlmanni* (99.55%). According to the Points method, *Macrobrachium sp.* (52.08%) dominated the diet of the species. The IRI method showed that the diet of the species was dominated by *P. stuhlmanni* (64%), followed by *Macrobrachium sp.* (9%) and other prey items (1%) (Figure 11b).

75-104mm SL

According to the Frequency of occurrence method, the diet of the species was dominated by unidentified material (58.33%) at this size class. The Numerical occurrence method indicated that the diet of the species was dominated by *P. stuhlmanni* (94.24%). In terms of the Points method, the diet of *A. berda* was dominated by unidentified material (65.06%) followed by plant material (30.25%). The IRI method indicated that the species’ diet was dominated by unidentified material (67%) while they also fed on plant material (4%), *P. stuhlmanni* (28%) and other prey items (1%) (Figure 11c).

Unidentified material included prawns at this size class. Refer to Table 6 for other prey items.

105-134mm SL

According to the Frequency of occurrence method, unidentified material (57.14%) dominated the diet of *A. berda* at this size class. In terms of Numerical occurrence, the diet of *A. berda* was dominated by Gastropod *sp.* (49.23%), followed by scales (23%). In terms of the Points method, the species' diet was dominated by unidentified material (69.94%). According to the IRI method, the diet of the species comprised of unidentifiable material (83%), Gastropod *sp.* (5%), *Grandidlerella bonnieroides* (4%), scales (5%) and other prey items (3%) (Figure 11d). At this size class, unidentified material included fish. For other prey items, refer to Table 6.

135-164mm SL

In terms of the Frequency of occurrence, the diet of *A. berda* was dominated by unidentified material followed by *P. blephariskios* (14.29%) at this size class. Results of the Numerical occurrence method indicated that *P. blephariskios* (40%) dominated the diet of *A. berda* at this size class*.* According the Points method, unidentified material (42.13%) dominated, followed by *Ambassis sp.* (27.78%). The IRI method showed that the diet of the species was dominated by unidentifiable material (69%) while it also fed on *Paratylodiplax blephariskios* (17%), *Ambassis sp.* (8%) and other prey items (1%) (Figure 11e). Unidentified material included fish at this size class. For other prey items, please refer to Table 6.

Table 6: Diet of *Acanthopagrus berda* at different size classes as indicated by the four methods used to analyze stomach content in the Mfolozi-Msunduzi system (F= Frequency of occurrence, N= Numerical occurrence, P= Points method & IRI= Index of Relative Importance).

	15-44mm (n = 9)				**45-74mm (n = 11)**				**75-104mm (n = 5)**				**105-134mm (n = 11)**				**135-164mm (n = 6)**			
Food item	**F**	**N**	**P**	**IRI**	**F**	**N**	**P**	**IRI**	**F**	**N**	**P**	**IRI**	**F**	**N**	**P**	**IRI**	**F**	**N**	**P**	**IRI**
Ambassis sp																	7.14	20.00	**27.78**	7.62
Baetidae	15.38	3.27	17.56	2.67																
Chironomidae	15.38	3.16	8.50	1.49									4.76	1.54	0.31	0.18				
Crustacean sp													4.76	1.54	8.59	0.98	7.14	20.00	13.89	5.41
Dendronereis arborifera					3.57	0.15	3.65	0.31												
Gastropod sp													4.76	**49.23**	5.52	5.32				
Grandidierella bonnieroides									16.67	2.16	1.23	0.97	9.52	**16.92**	2.15	3.71				
Macrobrachium sp					7.14	0.30	**52.08**	8.64					4.76	1.54	6.13	0.75				
Paratylodiplax blephariskios																	14.29	**40.00**	13.89	**17.20**
Plant material					3.57		2.60	0.21	16.67	0.00	**30.25**	4.32					7.14	0.00	2.31	0.37
Polychaete sp													4.76	3.08	1.23	0.42				
Pseudodiaptomus stuhlmanni	69.23	**93.57**	**63.17**	**90.32**	25.00	**99.55**	13.54	**65.31**	16.67	**94.24**	2.84	**27.76**	4.76	1.54	0.31	0.18				
Scales									8.33	2.16	0.62	0.40	9.52	**23.08**	3.37	5.14				
Unidentified material	61.54		10.76	5.51	39.29		**28.13**	25.52	58.33	1.44	**65.06**	**66.55**	57.14	1.54	**69.94**	**83.33**	50.00	20.00	**42.13**	**69.40**

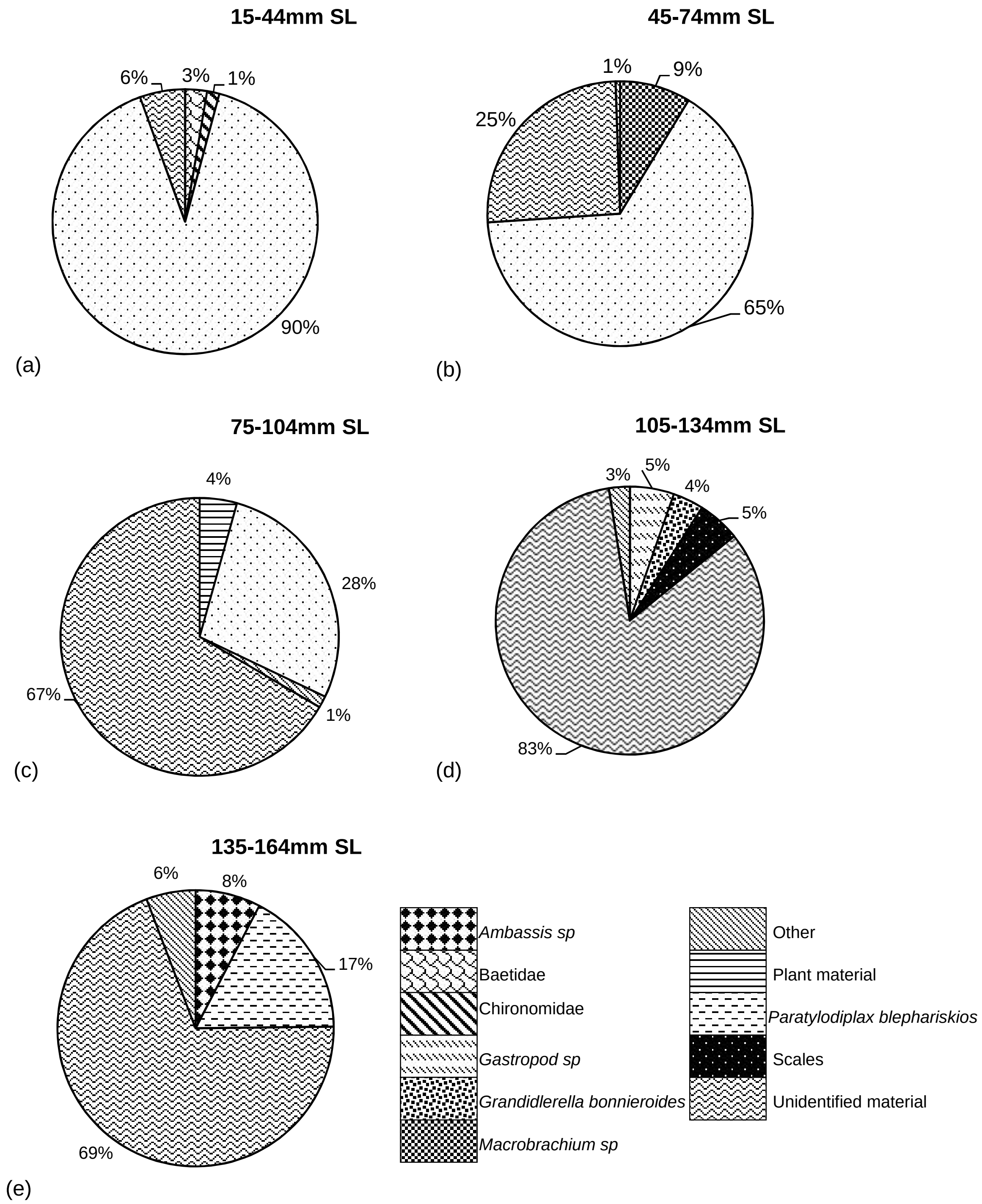

Figure 11: The diet of different size classes of *Acanthopagrus berda* in the Mfolozi-Msunduzi system.

3.6 Overall diet of the species in the different zones

3.6.1 *Leiognathus equula*

Table 7 shows the diet data of *L. equula* in terms of the Frequency of occurrence, Numerical occurrence, Points and Index of Relative Importance methods in the different zones.

According to the Frequency of occurrence method, unidentified material (60.46%) dominated the species' diet followed by *P. stuhlmanni* (50.39%) in the Mouth Area. In the Mfolozi and Msunduzi Arms, *P. stuhlmanni* (>70%) dominated the diet of *L. equula*. Results of the Numerical occurrence method indicated that the species' diet in all the zones was dominated by *P. stuhlmanni* (>98%). In terms of the Points method, the diet species diet' was dominated by *P. stuhlmanni* (>74%) in all three zones. In terms of IRI, the diet of *L. equula* in all the zones was dominated by *P. stuhlmanni* (>85%), with other items being of minor importance (Table 7) (Figure 12).

Table 7: Diet of *Leiognathus equula* as indicated by the four methods used to analyze stomach content in the selected sites of the Mfolozi-Msunduzi system (MA= Mouth Area, MFA= Mfolozi Arm, MSA= Msunduzi Arm, F= Frequency of occurrence, N= Numerical occurrence, P= Points method & IRI= Index of Relative Importance).

	Le MA (n = 82)				**Le MFA (n = 373)**				**Le MSA (n = 72)**			
Food item	**F**	**N**	**P**	**IRI**	**F**	**N**	**P**	**IRI**	**F**	**N**	**P**	**IRI**
Apseudos digitalis									1.43	0.02	0.09	<0.01
Baetidae	0.78	0.02	0.09	<0.01	3.42	0.09	0.90	0.02				
Chironomidae					8.42	1.35	3.76	0.24				
Cladocera					0.53	0.03	0.25	<0.01				
Dendronereis arborifera	3.88	0.03	3.73	0.15	2.63	0.03	1.29	0.02				
Fenneropenaeus indicus					0.26	0.001	0.01	<0.01				
Grandidierella bonnieroides	1.55	0.03	0.34	0.01								
Marine amphipod sp	3.89	0.05	0.71	0.03								
Oligochaete	0.78	0.01	0.09	<0.01								
Polychaete sp	3.88	0.10	1.50	0.06								
Pseudodiaptomus stuhlmanni	50.39	**99.74**	**74.27**	**88.04**	95.53	**98.50**	**83.73**	**95.23**	75.00	**99.98**	**94.05**	**98.51**
Scale					0.26	0.001	0.01	<0.01				
Unidentified material	60.46	0.02	**19.27**	**11.71**	81.84	0.00	**10.04**	4.49	37.50		5.86	1.49

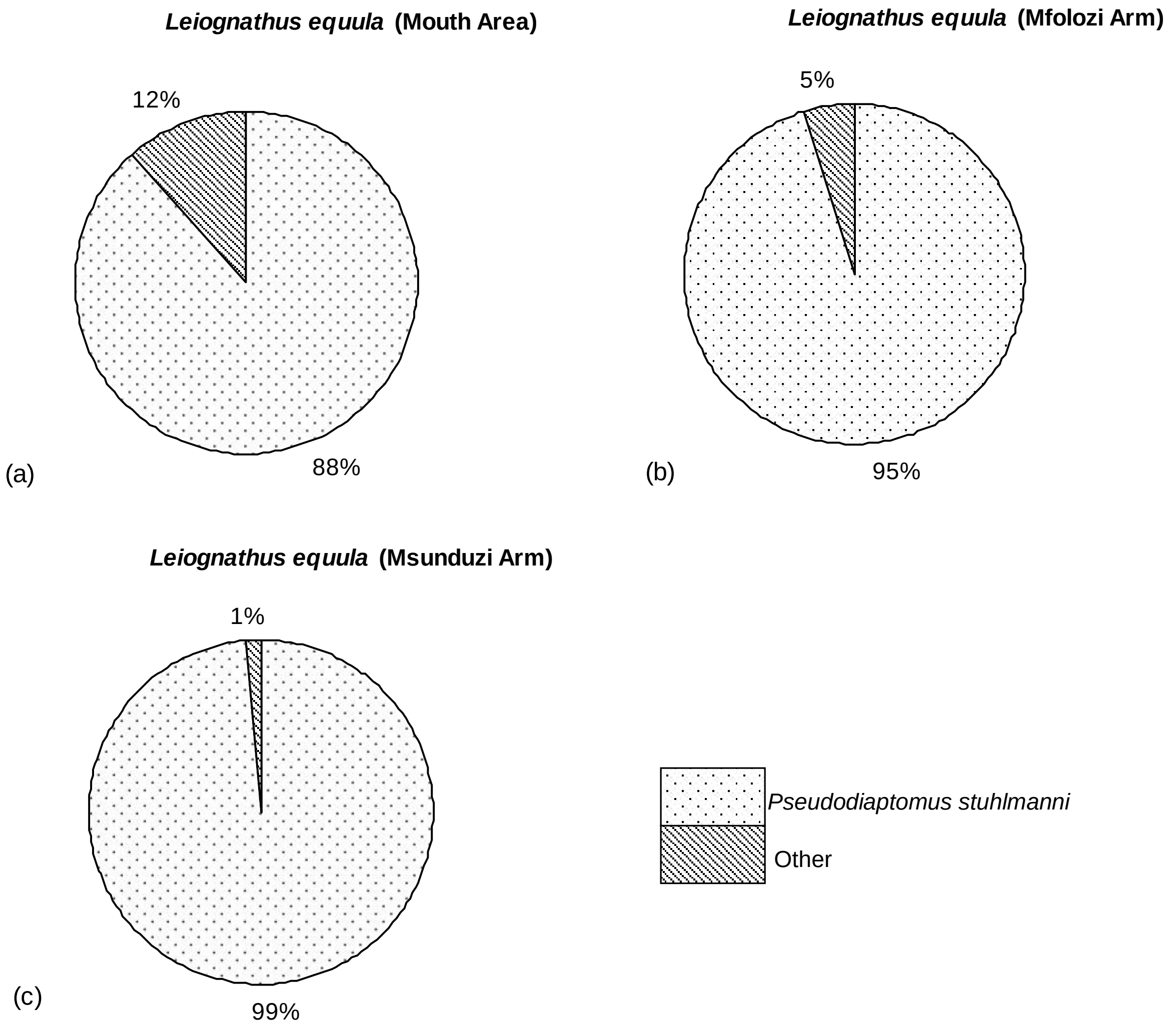

Figure 12: The diet of *Leiognathus equula* from the three zones in the Mfolozi-Msunduzi system.

3.6.2 *Acanthopagrus berda*

Table 8 shows the diet data of *A. berda* in terms of Frequency of occurrence, Numerical occurrence, Points and Index of Relative Importance methods.

In terms of the Frequency of occurrence method, unidentified material (>23%) dominated the species diet' in the Mouth Area, Mfolozi Arm and Msunduzi Arm. Results of the Numerical occurrence method indicated that *P. stuhlmanni* (>45%) dominated the diet of *A. berda* in all three zones. The Points method indicated that the species' diet was dominated by unidentified material (50.37%) followed by *Macrobrachium sp.* (25.06%) in the Mouth Area. In the Mfolozi Arm, the diet of the species was dominated by Baetidae (36.05%) followed by unidentified material (19.19%). In the Msunduzi Arm, the species' diet was dominated by *P. stuhlmanni* (62.62%). In term of the IRI, the diet of *A. berda* was dominated by unidentified material (51%) followed by *P. stuhlmanni* (44%) in the Mouth area (Figure 13a). *Macrobrachium sp.* (3%) and other prey items were also part of the species' diet (2%) (Table 8). The diet of the species in the Mfolozi Arm was dominated by material which was identifiable (29%); *P. stuhlmanni* (28%), Baetidae (22%) and Chironomidae (14%) were also important components in the species' diet. Other prey items were also included in the species' diet (Refer to Figure 13b & Table 8). In the Msunduzi Arm, the diet of *A. berda* was dominated by *P. stuhlmanni* (78%) but they also fed on other prey items (Figure 13c & Table 8).

Table 8: Diet of *Acanthopagrus berda* as indicated by the four methods used to analyze stomach content in the selected sites of the Mfolozi-Msunduzi system (MA= Mouth Area, MFA= Mfolozi Arm, MSA= Msunduzi Arm, F= Frequency of occurrence, N= Numerical occurrence, P= Points method & IRI= Index of Relative Importance).

	Ab MA (n = 25)				**Ab MFA (n = 18)**				**Ab MSA (n = 16)**			
Food item	**F**	**N**	**P**	**IRI**	**F**	**N**	**P**	**IRI**	**F**	**N**	**P**	**IRI**
Ambassis sp									2.38	0.14	9.83	0.96
Baetidae					12.50	14.51	**36.05**	**21.74**				
Chironomidae					12.50	14.51	17.73	13.86				
Crustacean sp	3.58	0.24	5.47	0.41								
Dendronereis arborifera	1.79	0.12	1.59	0.06								
Gastropod sp					6.25	16.58	5.23	4.69				
Grandidierella bonnieroides	7.14	1.65	1.03	0.39								
Halaelurus sp									2.38	0.14	1.48	0.16
Macrobranchium sp	5.36	0.35	**25.06**	2.74					2.38	0.29	0.16	0.04
Paratylodiplax blephariskios	3.57	0.24	3.42	0.26					4.76	0.72	3.28	0.77
Plant material	5.35		5.01	0.54	6.25		2.32	0.50	2.38		1.64	0.16
Polychaete sp					6.25	1.04	1.16	0.47				
Pseudodiaptomus stuhlmann	21.43	**95.77**	7.02	**44.35**	12.50	**49.74**	17.44	**28.89**	11.90	**98.70**	**62.62**	**77.69**
Scale	3.57	1.29	1.03	0.17	6.25	3.63	0.87	0.97				
Unidentified material	50.01	0.36	**50.37**	**51.08**	43.75		**19.19**	**28.88**	23.81		**20.98**	**20.22**

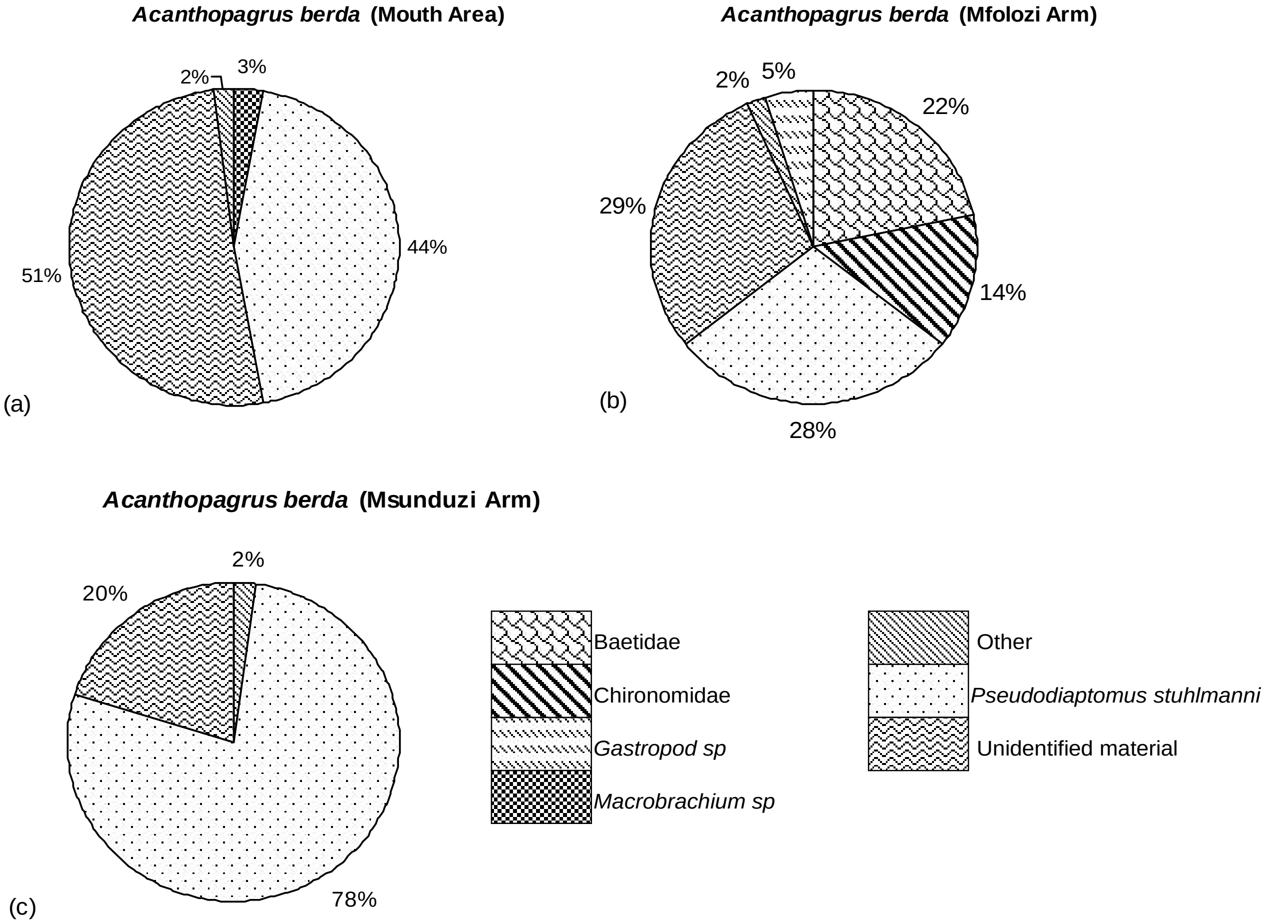

Figure 13: The diet of *Acanthopagrus berda* from the three zones in the Mfolozi-Msunduzi system.

3.6.3 *Glossogobius giurus*

Table 9 shows the diet data of *G. giurus* in terms of the Frequency of occurrence, Numerical occurrence, Points and Index of Relative Importance methods. Only one specimen was caught from the Msunduzi Arm and as its stomach was empty, it could not be used in the analysis.

In terms of the Frequency of occurrence method, *Ambassis sp.*, *Glossogobius sp.* and *Macrobrachium sp.* contributed evenly to the diet of the species in the Mouth Area (20%). In the Mfolozi Arm, the diet of the species was dominated by *Glossogobius sp. (*21.88%). The species' diet, in terms of the Numerical occurrence method, *Ambassis sp.*, *Glossogobius sp.* and *Macrobrachium sp.* contributed equally, scoring the same percentage (33.33%) to the total diet of *G. giurus* in the Mouth Area. In the Mfolozi Arm, the diet of the species was dominated by *P. stuhlmanni* (77.55%). According to the Points method, *Glossogobius sp.* (78.26%), dominated the diet of the species in the Mouth Area. In the Mfolozi Arm, the diet of the species was dominated by *Glossogobius sp.* (46.37%) followed by *Ambassis sp.* (43.86%). Results of the IRI method indicated that the diet of *G. giurus* caught in the Mouth area was dominated by *Glossogobius sp.* (56%), while *Macrobrachium sp.* (25%) and *Ambassis sp.* (19%) were also important components in the species' diet (Figure 14a). In the Mfolozi Arm, the species' diet was dominated by *Glossogobuis sp.* (62%) but it also fed on *P. stuhlmanni* (24%) and other prey items (14%) (Figure 14b). Refer to Table 9, for other prey items.

Table 9: Diet of *Glossogobius giurus* as indicated by the four methods used to analyze stomach content in the selected sites of the Mfolozi-Msunduzi system (MA= Mouth Area, MFA= Mfolozi Arm, F= Frequency of occurrence, N= Numerical occurrence, P= Points method & IRI= Index of Relative Importance).

	Gg MA (n = 3)				**Gg MFA (n = 13)**			
Food item	**F**	**N**	**P**	**IRI**	**F**	**N**	**P**	**IRI**
Ambassis sp	20.00	33.33	4.35	18.84	6.25	4.08	**43.86**	13.50
Glossogobuis sp	20.00	33.33	**78.26**	**55.80**	21.88	**16.33**	**46.37**	**61.83**
Macrobranchium sp	20.00	33.33	17.39	**25.36**				
Paratylodiplax blephariskios					3.13	2.04	1.00	0.43
Pseudodiaptomus stuhlmanni					6.25	**77.55**	8.27	**24.17**
Unidentified material					3.13		0.50	0.07

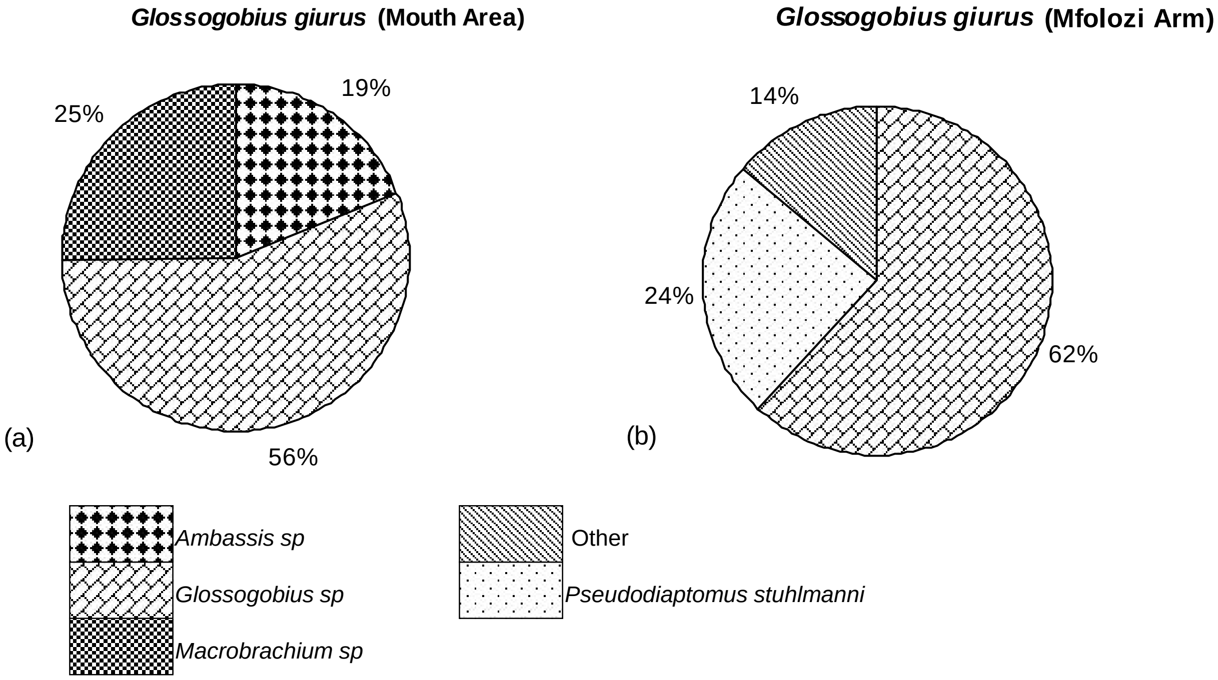

Figure 14: The diet of *Glossogobius giurus* from the two zones in the Mfolozi-Msunduzi system.

3.6.4 *Ambassis ambassis*

Table 10 shows the diet data of *A. ambassis* in terms of Frequency of occurrence, Numerical occurrence, Points and Index of Relative Importance methods in the different zones.

In terms of the Frequency of occurrence, the diet of the species in the Mouth Area was dominated by unidentified material (12.7%) followed by *O. ancheidos* (7.94%). In the Mfolozi Arm, *P. stuhlmanni* and unidentified material contributed evenly to the total the diet of the species (50%). In the Msunduzi Arm, the diet of the species was dominated by *Ambassis sp* (3.45%), *Glossogobius sp* (3.45%) and *M. africana* (3.45%). The Numerical occurrence method indicated that the diet of *A. ambassis* was dominated by *P. stuhlmanni* (46.9%) followed *O. ancheidos* (45.58%) in the Mouth Area. In the Mfolozi Arm, *P. stuhlmanni* (100%) dominated the diet of the species. The diet of the species in the Msunduzi Arm was dominated by *M. africana* (94.12%). According to the Points method, the diet of the species in the Mouth Area was dominated by *O. ancheidos* (35.90%), followed by unidentified material (32.91%) and *Glossogobius sp.* (17.09%). In the Mfolozi Arm, *P. stuhlmanni* and unidentified material contributed evenly to the total diet of the species (50%). In the Msunduzi Arm, the diet of the *A. ambassis* was dominated by *Glossogobius sp.* (48.78%) followed by *M. africana* (24.39%). In terms of the IRI method, the diet of the species caught at the Mouth Area was dominated by *O. ancheidos* (48%), *P. stuhlmanni* (17%) and other prey items (4%) were included in the species' diet (Figure 15a). In the Mfolozi Arm, the diet *A. ambassis* was dominated by *P. stuhlmanni* (75%) (Figure 15b). The diet of the species was dominated by *Mesopodopsis africana* (60%) in the Msunduzi Arm, *Glossogobius sp.* (25%) also being included in the diet (Figure 15c). For other prey items, please refer to Table 10.

Table 10: Diet of *Ambassis ambassis* as indicated by the four methods used to analyze stomach content in the selected sites of the Mfolozi-Msunduzi system (MA= Mouth Area, MFA= Mfolozi Arm, MSA= Msunduzi Arm, F= Frequency of occurrence, N= Numerical occurrence, P= Points method & IRI= Index of Relative Importance).

	Aa MA (n = 10)				**Aa MFA (n = 2)**				**Aa MSA (n = 4)**			
Food item	**F**	**N**	**P**	**IRI**	**F**	**N**	**P**	**IRI**	**F**	**N**	**P**	**IRI**
Ambassis sp	1.59	0.44	5.13	0.65					3.45	2.94	14.63	8.80
Baetidae	1.59	1.33	0.43	0.21								
Chironomidae	1.59	0.44	0.43	0.10								
Dendronereides zululandica	1.59	4.42	4.27	1.02								
Glossogobuis sp	1.59	0.44	**17.09**	2.05					3.45	2.94	**48.78**	**25.91**
Grandidierella lignorum	1.59	0.44	0.85	0.15								
Mesopodopsis africana									3.45	**94.12**	**24.39**	**59.36**
Orchestia ancheidos	7.94	**45.58**	**35.90**	**47.60**								
Pseudodiaptomus stuhlmanni	4.76	**46.90**	2.99	**17.47**	50.00	**100.00**	**50.00**	75.00				
Unidentified material	12.70		**32.91**	**30.75**	50.00		**50.00**	25.00	3.35		12.20	5.93

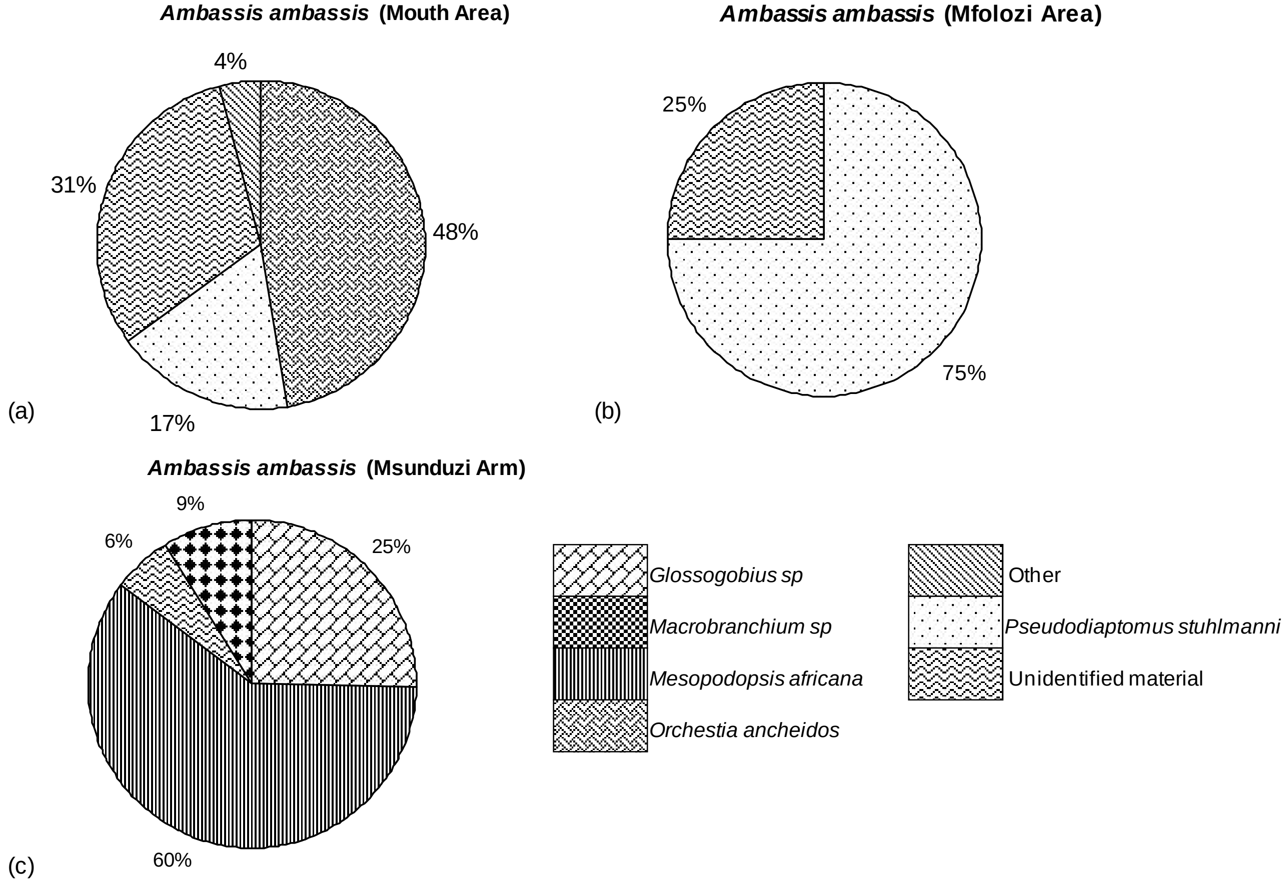

Figure 15: The diet of *Ambassis ambassis* from the three zones in the Mfolozi-Msunduzi system.

3.6.5 *Ambassis gymnocephalus*

Table 11 shows the diet data of *A. gymnocephalus* in terms of Frequency of occurrence, Numerical occurrence, Points and Index of Relative Importance methods in the different zones. No specimens of *A. gymnocephalus* were collected from the Mouth Area during the study period.

The diet of *A. gymnocephalus* comprised only of *P. stuhlmanni* and unidentified material. According to the Frequency of occurrence, *P. stuhlmanni* and unidentified material contributed evenly to the diet of *A. berda* (55.55%) in the Mfolozi Arm. In the Msunduzi Arm, *P. stuhlmanni* and unidentified material also contributed evenly to the diet of the species (40%). The Numerical occurrence method indicated that *P. stuhlmanni* (100%) dominated the species' diet in both the Mfolozi and Msunduzi Arms. In terms of the Points method, the dominant prey item in the diet of *A. gymnocephalus* was *P. stuhlmanni* (67.05%) in the Mfolozi Arm. In the Msunduzi Arm, unidentified material (56.52%) dominated the diet of the species. Results of IRI method showed that *P. stuhlmanni* (>70%) was dominant in the diet of the species in both the Msunduzi and Mfolozi Arms (Figure 16).

Table 11: Diet of *Ambassis gymnocephalus* as indicated by the four methods used to analyze stomach content in the selected sites of the Mfolozi-Msunduzi system (MFA= Mfolozi Arm, MSA= Msunduzi Arm, F= Frequency of occurrence, N= Numerical occurrence, P= Points method & IRI= Index of Relative Importance).

	Ag MFA (n = 9)				**Ag MSA (n = 5)**			
Food item	**F**	**N**	**P**	**IRI**	**F**	**N**	**P**	**IRI**
Pseudodiaptomus stuhlmanni	55.55	**100.00**	**67.05**	**83.53**	40.00	**100.00**	43.47	**71.74**
Unidentified material	55.55		32.95	16.48	40.00		**56.52**	28.26

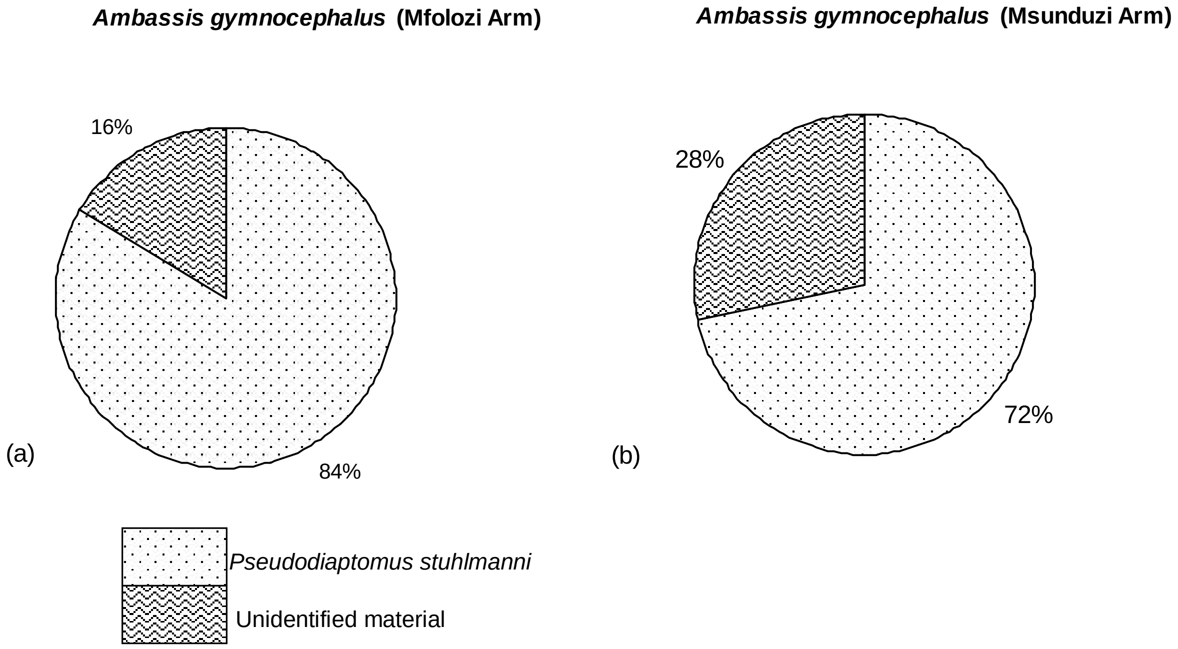

Figure 16: The diet of *Ambassis gymnocephalus* from the two zones in the Mfolozi-Msunduzi system.

3.6.6 *Ambassis natalensis*

Table 12 shows the diet data of *A. natalensis* in terms of Frequency of occurrence, Numerical occurrence, Points, and Index of Relative Importance methods in the different zones. Specimens of the species were caught in the Mouth Area and their stomachs were all empty.

In terms of Frequency of occurrence method, *P. stuhlmanni* dominated the species diet (>23.08%) in both arms. The species' diet, in terms of Numerical occurrence method was dominated by *P. stuhlmanni* (>95%) in both the Mfolozi and Msunduzi arms. According to the Points method, the diet of the species was dominated by *P. stuhlmanni* (>38%) in both the Mfolozi and Msunduzi arms. Results of the IRI method indicated that the species' diet was dominated by *P. stuhlmanni* (79%); crustacean eggs (1%), Formicidae (2%) and plant material (6%) were also included in the species' diet (Figure 17a) in the Mfolozi arm. In the Msunduzi arm, the diet of the species was dominated by *P. stuhlmanni* (79%); *Dendronereis arborifera* (1%) and other prey items

(2%) were also included in the species' diet (Figure 17b). For other prey items, refer to Table 12.

Table 12: Diet of *Ambassis natalensis* as indicated by the four methods used to analyze stomach content in the selected sites of the Mfolozi-Msunduzi system (MFA= Mfolozi Arm, MSA= Msunduzi Arm, F= Frequency of occurrence, N= Numerical occurrence, P= Points method & IRI= Index of Relative Importance).

	An MFA (n = 5)				**An MSA (n = 12)**			
Food item	**F**	**N**	**P**	**IRI**	**F**	**N**	**P**	**IRI**
Baetidae					4.17	0.14	0.44	0.05
Cladocera					8.33	2.44	1.91	0.73
Crustacean eggs	7.69		4.55	0.87				0.00
Dendronereis arborifera					8.33	0.29	7.35	1.27
Formicidae	7.69	1.71	9.09	2.07				
Glossogobuis sp					4.17	0.14	7.35	0.63
Plant material	15.38		15.91	6.10	4.17		2.94	0.25
Pseudodiaptomus stuhlmanni	23.08	**98.29**	**38.64**	**78.76**	29.17	**96.99**	**41.97**	**81.14**
Unidentified material	15.38		**31.82**	**12.20**	20.83		**38.24**	**15.94**

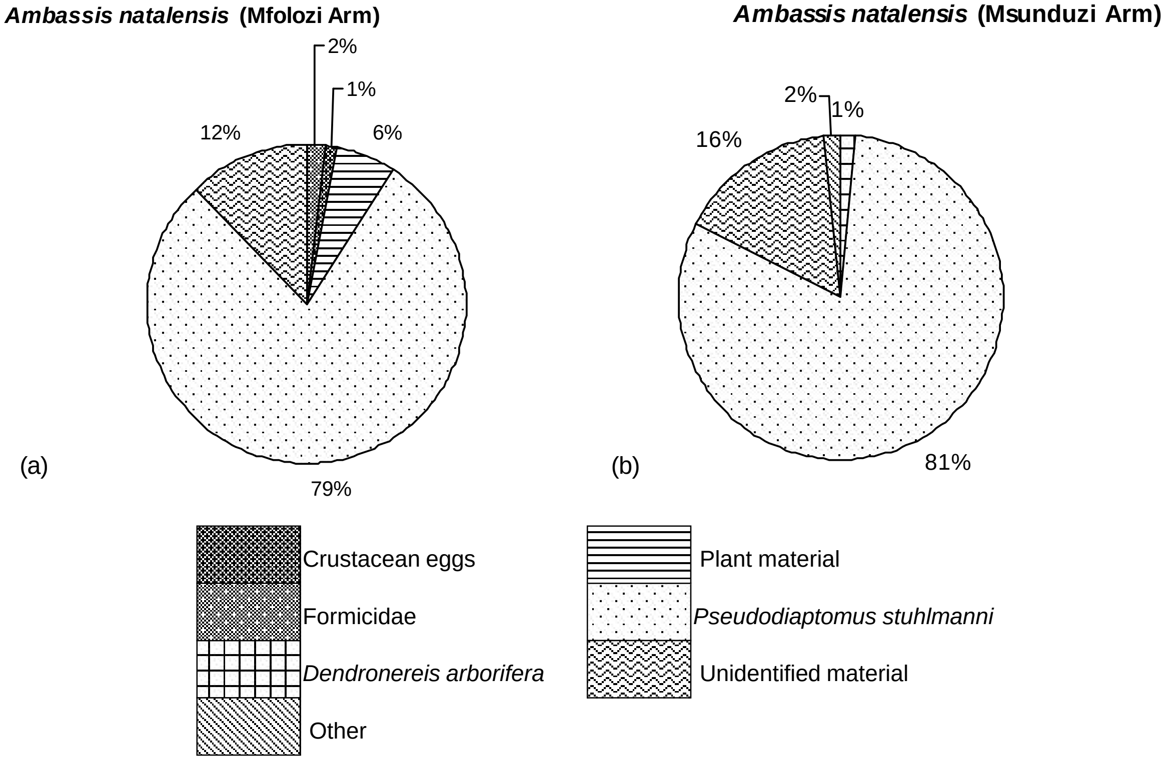

Figure 17: The diet of *Ambassis natalensis* from the two zones in the Mfolozi-Msunduzi system.

3.7 Seasonal diet of the species

3.7.1 *Leiognathus equula*

Table 13 shows the diet data of *L. equula* in terms of Frequency of occurrence, Numerical occurrence, Points, and Index of Relative Importance methods seasonally.

According to Frequency of occurrence, the species' diet in autumn and spring was dominated by *P. stuhlmanni* (>76%). In terms of Numerical occurrence, the diet of *L. equula* was dominated by *P. stuhlmanni* (>95%) during four all seasons. Points method results indicated that *P. stuhlmanni* (>56%) dominated in all four seasons. In winter and summer, the species' diet was dominated by unidentified material (>73%) followed by *P. stuhlmanni* (>64%). The diet of *L*. *equula,* in terms of IRI method, was dominated by *P. stuhlmanni* (>76%) during all four sampling seasons (Figure 18).

Table 13: Diet of *Leiognathus equula* as indicated by four methods used to analyze stomach contents in the different seasons of the Mfolozi-Msunduzi system (F= Frequency of occurrence, N= Numerical occurrence, P= Points method, IRI= Index of Relative Importance, S1= autumn, S2= winter, S3= spring & S4= summer).

	Leiognathus equula **S1 (n = 9)**				***Leiognathus equula*** **S2 (n = 109)**				***Leiognathus equula*** **S3 (n = 399)**				**Leiognathus equula S4 (n = 10)**			
Food item	**F**	**N**	**P**	**IRI**	**F**	**N**	**P**	**IRI**	**F**	**N**	**P**	**IRI**	**F**	**N**	**P**	**IRI**
Apseudes digitalis									0.23	0.002	0.02	<0.01				
Baetidae									3.29	0.09	0.88	0.02				
Chironomidae									7.51	1.28	3.65	0.25				
Cladocera									0.47	0.03	0.24	<0.01				
Dendronereides zululandica																
Dendronereis arborifera	11.11	0.07	7.39	0.43	3.47	0.10	3.00	0.08	2.11	0.01	0.71	0.01				
Fenneropenaeus indicus					0.69	0.05	0.05	<0.01								
Grandidierella bonnieroides									0.47	0.005	0.04	<0.01				
Marine amphipod sp									1.16	0.01	0.09	<0.01				
Oligochaete									0.23	0.002	0.01	<0.01				
Polychaete sp									1.17	0.02	0.20	<0.01				
Pseudodiaptomus stuhlmanni	100.00	**99.93**	**89.66**	**99.20**	64.58	**99.85**	**78.83**	**89.57**	76.52	**98.55**	**85.58**	**95.65**	90.00	**100.00**	**56.36**	**76.33**
Scale					0.69	0.01	0.05	<0.01								
Unidentified material	23.40		2.96	0.36	73.61	0.03	**18.07**	**10.34**	69.72		8.58	4.06	100.00		43.64	**23.67**

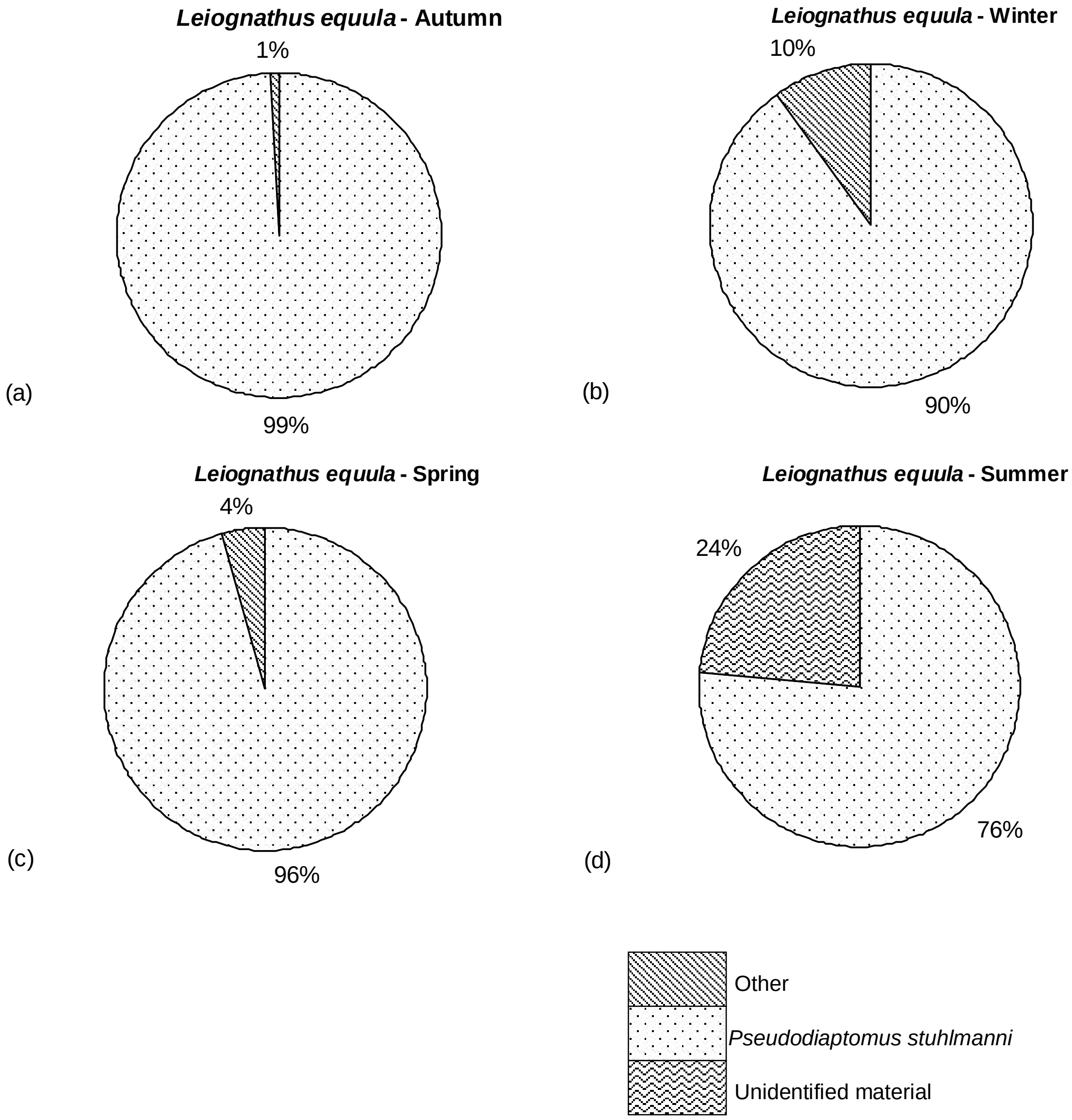

Figure 18: The diet of *Leiognathus equula* in the Mfolozi-Msunduzi system over four seasons.

3.7.2 *Acanthopagrus berda*

Table 14 shows the diet data of *A. berda* in terms of Frequency of occurrence, Numerical occurrence, Points, and Index of Relative Importance methods, seasonally.

In terms of Frequency of occurrence method, the species' diet was dominated by unidentified material (>13%) in autumn. In winter the species' diet was dominated by plant material while in spring and summer, the species diet was dominated by unidentified material. The diet of *A. berda,* according to the Numerical occurrence method was dominated by *P. stuhlmanni* in autumn and spring (>91%). *Acanthopagrus berda* only fed on plant material in winter. In summer, the species' diet was dominated by *P. blephariskios* (35.71%) followed by *Macrobrachium sp.* and *P. stuhlmanni* (21.43%). The Points method results indicated that the species' diet was dominated by unidentified material (>40%) in autumn and summer. In winter, the species' diet was dominated by plant material while in spring it was dominated *P. stuhlmanni* (45.56%). According the IRI method, in autumn, the diet of *A. berda* was dominated by material which could not be identified (64%), *Pseudodiaptomus stuhlmanni* (30%), *Macrobrachium* sp. (4%) and other prey items (2%), which also formed an important component of their diet (Figure 19a). In winter, the species fed entirely on plant material (100%) (Figure 19b). The diet of *A. berda* was dominated by *P. stuhlmanni* (75%) but it also fed on Baetidae (1%) and other prey items (2%) in spring (Figure 19c). Unidentified material (47%) was the dominant food item in the specimens collected in summer, but they also fed on *Ambassis sp.* (8%), *Macrobrachium sp.* (15%), *Paratylodiplax blephariskios* (21%) and other prey items (9%) (Figure 19d). Refer to Table 14 for the other prey items.

Table 14: Diet of *Acanthopagrus berda* as indicated by four methods used to analyze stomach contents in the different seasons of the Mfolozi-Msunduzi system (F= Frequency of occurrence, N= Numerical occurrence, P= Points method, IRI= Index of Relative Importance, S1= autumn, S2= winter, S3= spring & S4= summer).

	***Acanthopagrus berda* S1 (n = 22)**				***Acanthopagrus berda* S2 (n = 2)**				***Acanthopagrus berda* S3 (n = 27)**				***Acanthopagrus berda* S4 (n = 8)**			
Food item	**F**	**N**	**P**	**IRI**	**F**	**N**	**P**	**IRI**	**F**	**N**	**P**	**IRI**	**F**	**N**	**P**	**IRI**
Ambassis sp													4.35	7.14	28.57	8.40
Baetidae									5.00	2.09	12.13	1.19				
Chironomidae									5.00	2.09	5.97	0.68				
Crustacean sp	4.66	0.52	7.82	1.00												
Dendronereis arborifera	2.33	0.26	2.28	0.15												
Gastropod sp									2.50	2.39	1.76	0.17				
Grandidierella bonnieroides									10.00	1.05	0.88	0.32				
Halaelurus sp													4.35	7.14	4.29	2.69
Macrobrachium sp	4.65	0.52	**32.58**	3.94									8.70	**21.43**	10.00	**14.79**
Paratylodiplax blephariskios	2.33	0.26	3.26	0.21					2.50	0.07	0.98	0.04	8.70	**35.71**	9.52	**21.28**
Plant material	2.33		0.81	0.05	50.00		**100.00**	**100.00**	7.50		5.97	0.75	4.35		4.76	1.12
Polychaete									2.50	0.15	0.39	0.02				
Pseudodiaptomus stuhlmanni	11.62	**95.08**	6.03	**30.11**					32.50	**91.55**	**45.56**	**74.83**	4.35	**21.43**	0.48	5.15
Scale	4.65	2.85	1.47	0.51					2.50	0.52	0.29	0.03				
Unidentified material	53.86	0.52	**45.87**	**64.03**					50.00	0.07	**26.07**	**21.95**	17.39	7.14	**42.38**	**46.57**

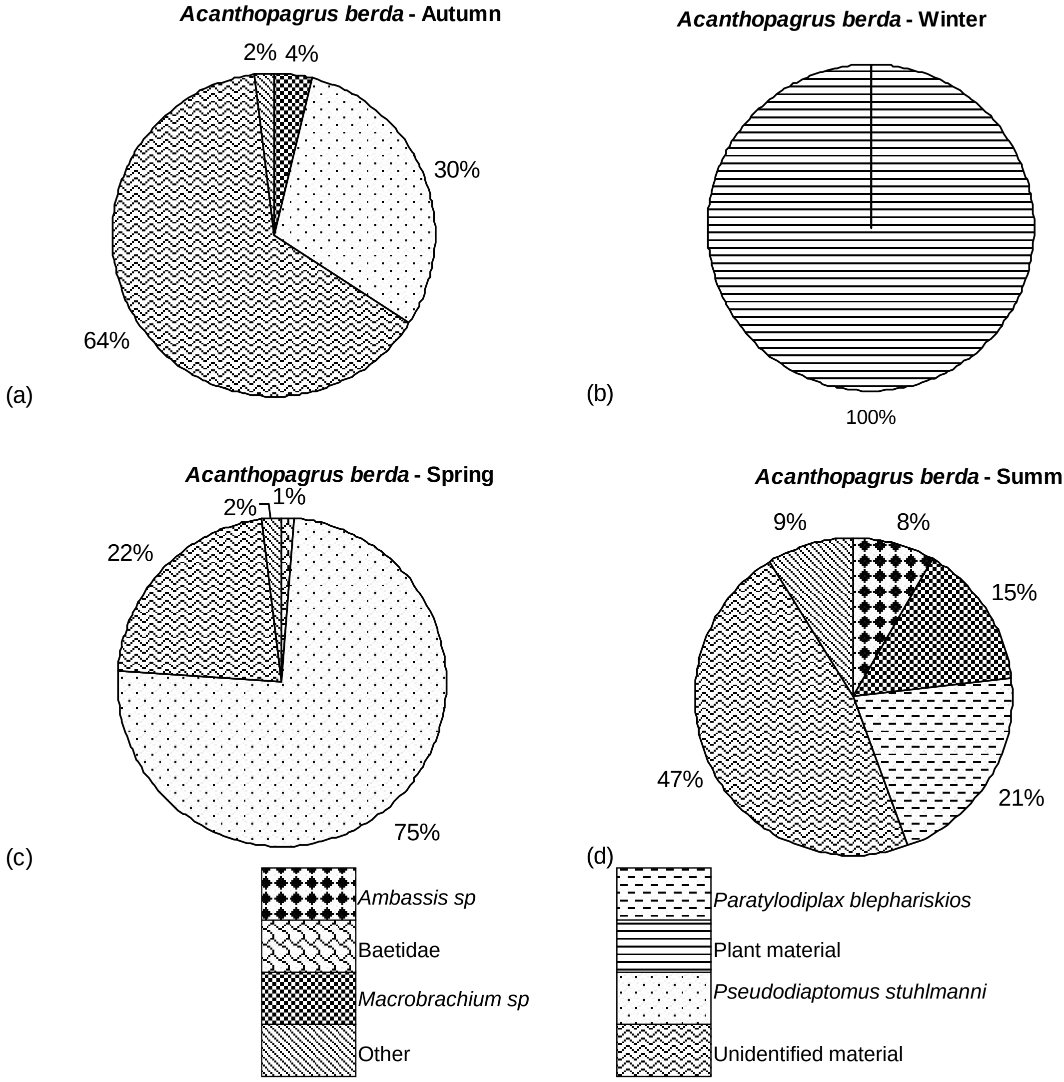

Figure 19: The diet of *Acanthopagrus berda* in the Mfolozi-Msunduzi system over four seasons.

3.7.3 *Glossogobius giurus*

Table 15 shows the diet data of *G. giurus* in terms of Frequency of occurrence, Numerical occurrence, Points, and Index of Relative Importance methods seasonally. No specimens of the species were caught in summer.

The species' diet comprised only of *Glossogobius sp.* (100%) in winter. According to the Frequency of occurrence, the species' diet fed on three items of equal dominance, *Ambassis sp.*, *Glossogobius sp.* and *Macrobrachium sp.* (20%) in autumn. The diet of the species in spring was dominated by *Glossogobius sp. (*25.93%). In terms of Numerical occurrence, *G. giurus* fed on three items of equal dominance, *Ambassis sp.*, *Glossogobius sp.* and *Macrobrachium sp.* (33.33%) in autumn. In spring, the species' diet was dominated by *P. stuhlmanni* (79.17%). The Points method results showed that the species' diet was dominated by *Glossogobius sp.* (78.26%) in autumn and *Ambassis s.p* (47.43%) followed by *Glossogobius sp.* in spring. The diet of *G. giurus*, in terms of the IRI method, was dominated by *Glossogobius sp.* (56%); *Ambassis sp*. (19%) and *Macrobrachium sp.* (25%) were also part of the species diet in autumn (Figure 20a). In winter, the diet of *G. giurus* comprised only of *Glossogobius sp*. (Figure 20b). In spring, the species diet comprised of *Glossogobius sp.* (58%), *P. stuhlmanni* (26%) and other prey items (16%), with the dominated prey item being *Glossogobius sp*. (Figure 20c). Refer to Table 15 for other prey items.

Table 15: Diet of *Glossogobius giurus* as indicated by four methods used to analyze stomach contents in the different seasons of the Mfolozi-Msunduzi system (F= Frequency of occurrence, N= Numerical occurrence, P= Points method, IRI= Index of Relative Importance, S1= autumn, S2= winter & S3= spring).

	Glossogobius giurus **S1 (n = 3)**				***Glossogobius giurus*** **S2 (n = 1)**				***Glossogobius giurus S3*** **(n = 12)**			
Food item	**F**	**N**	**P**	**IRI**	**F**	**N**	**P**	**IRI**	**F**	**N**	**P**	**IRI**
Ambassis sp	20.00	33.33	4.35	18.84					7.41	4.16	**47.43**	15.19
Glossogobuis sp	20.00	33.33	**78.26**	**55.80**	20.00	**100.00**	**100.00**	**100.00**	25.93	**14.58**	**42.01**	**58.32**
Macrobrachium sp	20.00	33.33	17.39	**25.36**								
Paratylodiplax blephariskios									3.70	2.08	1.08	0.46
Pseudodiaptomus stuhlmanni									7.41	**79.17**	8.94	**25.95**
Unidentified material									3.70		0.54	0.08

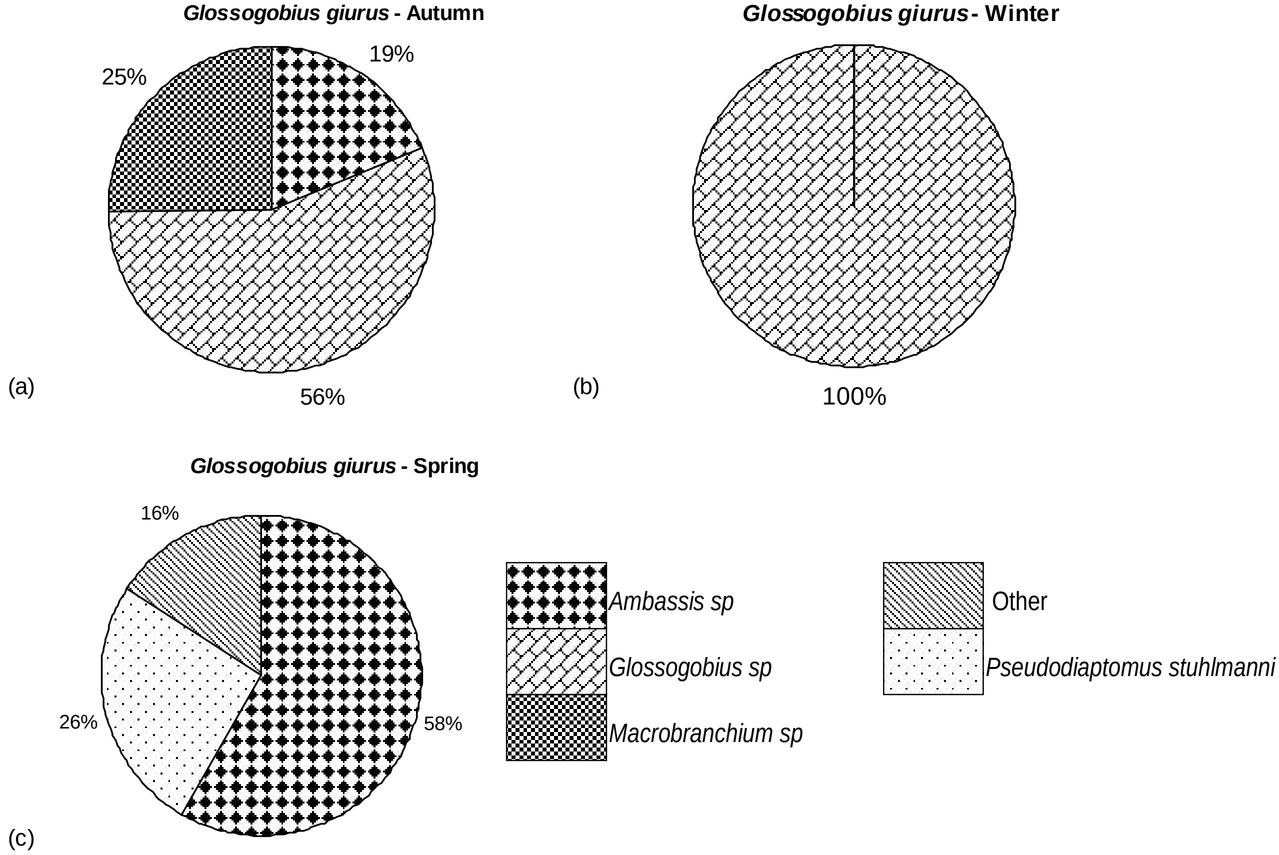

Figure 20: The diet of *Glossogobius giurus* in the Mfolozi-Msunduzi system over three seasons.

3.7.4 *Ambassis ambassis*

Table 16 shows the diet data of *A. ambassis* in terms of Frequency of occurrence, Numerical occurrence, Points, and Index of Relative Importance methods seasonally. No specimens of the species were caught in winter and only one was caught in summer, but its stomach was empty.

In terms of Frequency of occurrence method, the species' diet was dominated by unidentified material (12.7%). In spring, the species' diet was dominated by *P. stuhlmanni* and unidentified material (20%). Results of the Numerical occurrence method indicated that the diet of *A. ambassis* was dominated by *P. stuhlmanni* in autumn and spring (>45%). According to the Points method, *O. ancheidos* (35.9%) dominated the diet of the species in autumn. In spring, the species' diet was dominated by *M. africana* (50%). The diet of *A. ambassis*, in autumn, in terms of IRI method, was dominated by *Orchestia* *ancheidos* (48%) and also comprised of *Glossogobius sp.* (2%), *P. stuhlmanni* (17%) and other prey items (2%) (Figure 21a). In spring, the species' diet was dominated by the *P. stuhlmanni* (67%) but it also fed on *Mesopodopsis africana* (18%) (Figure 21b).

Table 16: Diet of *Ambassis ambassis* as indicated by four methods used to analyze stomach contents in the different seasons of the Mfolozi-Msunduzi system (F= Frequency of occurrence, N= Numerical occurrence, P= Points method & IRI= Index of Relative Importance, S1= autumn & S3= spring).

	Ambassis ambassis S1 (n = 13)				**Ambassis ambassis S3 (n = 3)**			
Food item	**F**	**N**	**P**	**IRI**	**F**	**N**	**P**	**IRI**
Ambassis sp	1.59	0.44	5.13	0.65				0.00
Baetidae	1.59	1.33	0.43	0.21				0.00
Chironomidae	1.59	0.44	0.43	0.10				0.00
Dendronereides zululandica	1.59	4.42	4.27	1.02				0.00
Glossogobuis sp	1.59	0.44	**17.09**	2.05				0.00
Grandidierella lignorum	1.59	0.44	0.85	0.15				0.00
Mesopodopsis africana				0.00	10.00	11.64	**50.00**	18.22
Orchestia ancheidos	7.94	**45.58**	35.90	**47.60**				0.00
Pseudodiaptomus stuhlmanni	4.76	**46.90**	2.99	**17.47**	20.00	**88.36**	25.00	**67.01**
Unidentified material	12.70		**32.91**	**30.75**	20.00		25.00	14.78

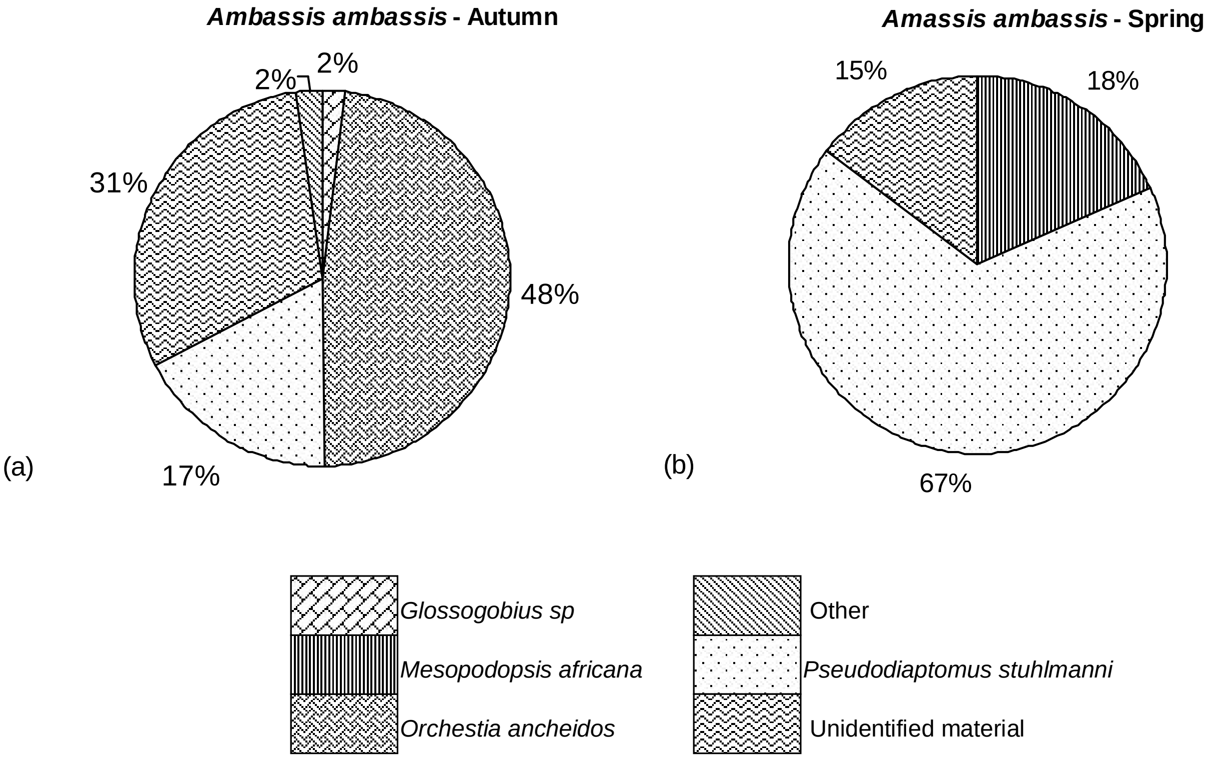

Figure 21: The diet of *Ambassis ambassis* in the Mfolozi-Msunduzi system over two seasons.

3.7.5 *Ambassis gymnocephalus*

Table 17 shows the diet data of *A. gymnocephalus* in terms of Frequency of occurrence, Numerical occurrence, Points, and Index of Relative Importance methods seasonally. No specimens of the species were caught in winter and summer.

In terms of Frequency of occurrence method, *P. stuhlmanni* and unidentified material were equally dominant (16.67%) in the species' diet autumn. In spring, the species' diet was also dominated by *P. stuhlmanni* and unidentified material (55.55%). According to Numerical occurrence, the diet of *A. gymnocephalus* was dominated by *P. stuhlmanni* (100%) both autumn and spring. Results of the Points method showed that *P. stuhlmanni* and unidentified material were equally dominant (50%) in autumn. In spring, the species was dominated by *P. stuhlmanni* (67.05%). The species' diet, in terms of the IRI method, was dominated by *P. stuhlmanni* (>70%), both in autumn and spring (Figure 22).

Table 17: Diet of *Ambassis gymnocephalus* as indicated by four methods used to analyze stomach contents in the different seasons of the Mfolozi-Msunduzi system (F= Frequency of occurrence, N= Numerical occurrence, P= Points method, IRI= Index of Relative Importance, S1-autumn & S3-spring).

	Ambassis gymnocephalus **S1 (n = 2)**				***Ambassis gymnocephalus*** **S3 (n = 12)**			
Food item	**F**	**N**	**P**	**IRI**	**F**	**N**	**P**	**IRI**
Pseudodiaptomus stuhlmanni	16.67	**100.00**	50.00	**75.00**	55.55	**100.00**	**67.05**	**83.53**
Unidentified material	16.67		50.00	25.00	55.55		32.95	16.48

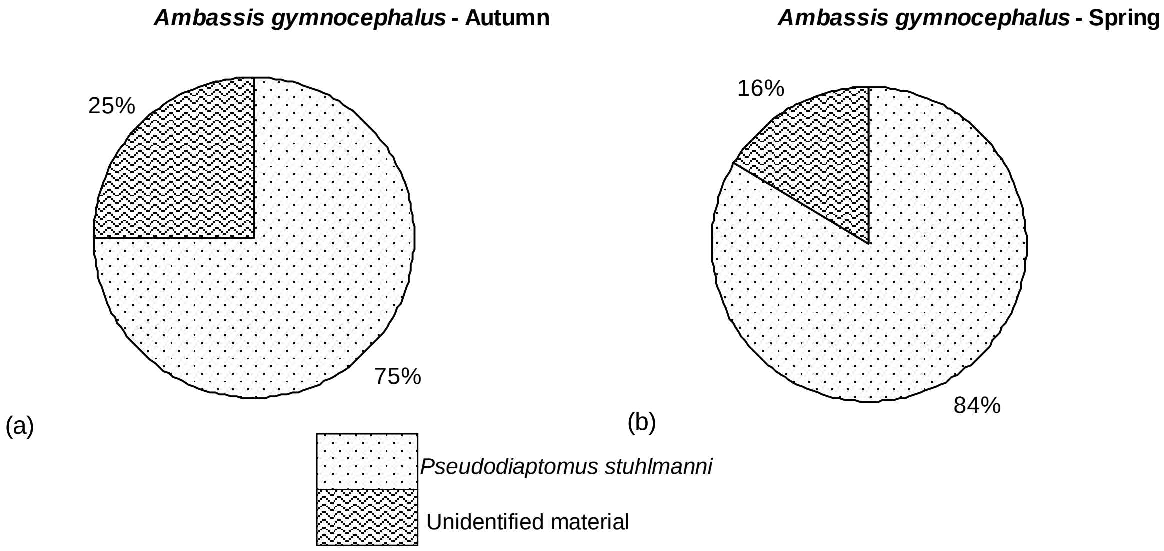

Figure 22: The diet of *Ambassis gymnocephalus* in the Mfolozi-Msunduzi system over two seasons.

3.7.6 *Ambassis natalensis*

Table 18 shows the diet data of *A. natalensis* in terms of Frequency of occurrence, Numerical occurrence, Points, and Index of Relative Importance methods seasonally. Specimens of the species were caught in winter but their stomachs were all empty and no specimens were caught in summer.

According to the Frequency of occurrence method, the species' diet was dominated by *P. stuhlmanni* and unidentified material (10.71%). In spring the species' diet was dominated by *P. stuhlmanni* (33.33%). In terms of Numerical occurrence, the diet of *A. natalensis* was dominated by *P. stuhlmanni* (>95%) in autumn and spring. Results of the Points method showed that the species' diet was dominated by unidentified material (50%) followed by *P. stuhlmanni* in autumn. *Pseudodiaptomus stuhlmanni* (41.97%) dominated the species' diet in spring. The diet of *A. natalensis,* according to the IRI method, was dominated by the *P. stuhlmanni* (71%) but plant material (3%) was also present in the species' diet in autumn (Figure 23a). In spring, the diet was dominated by *P. stuhlmanni* (84%), unidentifiable material (12%)

and other prey items (4%) were present in its diet (Figure 23b). For other prey items, refer to Table 18.

Table 18: Diet of *Ambassis natalensis* as indicated by four methods used to analyze stomach contents in the different seasons of the Mfolozi-Msunduzi system (F= Frequency of occurrence, N= Numerical occurrence, P= Points method, IRI= Index of Relative Importance, S1= autumn & S3= spring).

	***Ambassis natalensis* S1 (n= 7)**				***Ambassis natalensis* S3 (n =12)**			
Food item	**F**	**N**	**P**	**IRI**	**F**	**N**	**P**	**IRI**
Baetidae					4.76	0.14	0.39	0.05
Cladocera					9.52	2.34	1.71	0.70
Crustacean eggs					4.76		1.33	0.12
Dendronereis arborifera					9.52	0.28	6.58	1.19
Formicidae					4.76	0.28	2.63	0.25
Glossogobuis sp					4.76	0.14	6.58	0.58
Plant material	3.57		14.29	2.50	9.52		4.61	0.80
Pseudodiaptomus stuhlmanni	10.71	**100.00**	**35.71**	**71.25**	33.33	**96.82**	**41.97**	**84.41**
Unidentified material	10.71		**50.00**	26.25	19.05		**34.21**	11.89

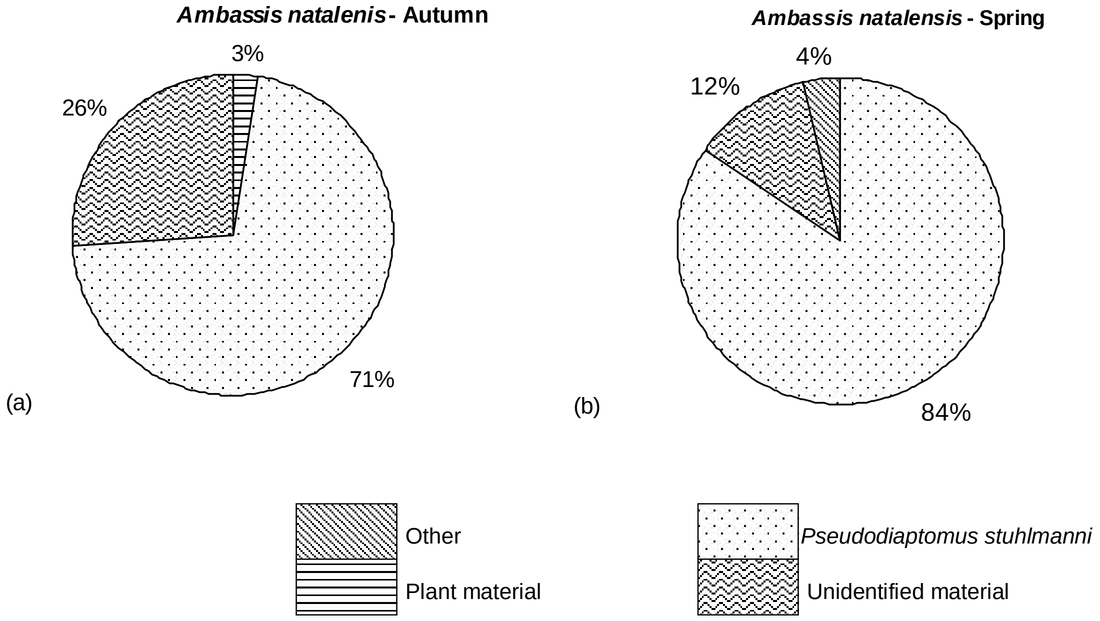

Figure 23: The diet of *Ambassis natalensis* in the Mfolozi-Msunduzi system over two seasons.

3.8 Relationships between the species' diets and the benthos in the Mfolozi-Msunduzi system

3.8.1 Overall

Figure 24a shows the diet of the benthic feeders in the Mfolozi-Msunduzi system. All of the species' diets were dominated by *P. stuhlmanni* except for *G. giurus,* which was dominated by *Glossogobius sp*. *Ambassis gymnocephalus* was the only species in the analysis which did not have any benthos in its diet. The benthic organisms found in the species' diet contributed less than 28% to the total diet of the individual species.

Figure 24b shows the relationship between the overall benthos and the benthic organisms found in the diet of fish species from the Mfolozi-Msunduzi system. The overall benthos of the Mfolozi-Msunduzi system was dominated by *P. blephariskios* and *D. arborifera*. The benthic items that were present in the diet of *L. equula* were Chironomidae, *D. arborifera* and Baetidae. The benthic items that were present in the diet *A. berda* were Baetidae, Chironomidae and *P. blephariskios*. The diet of *G. giurus* only had one benthic item present which was *P. blephariskios*. The benthos present in the diet of *A. ambassis* was dominated by *O. ancheidos* followed by *M. africana* and *A. digitalis*. The diet of *A. natalensis* was dominated by *D. arborifera* and also had Baetidae present in its diet.

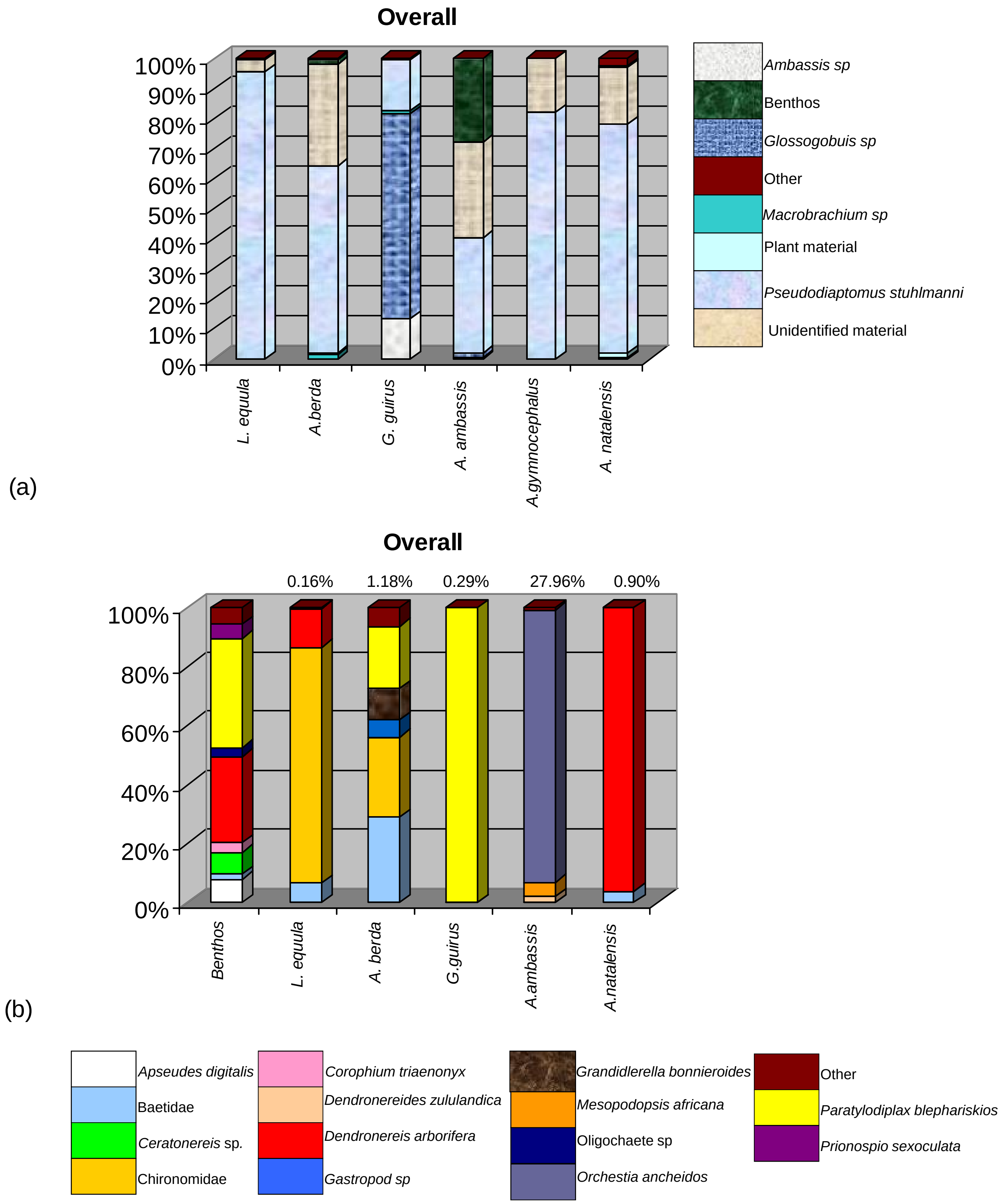

Figure 24: Percentage composition of the diet of six species of fish from the Mfolozi-Msunduzi Estuarine system (a); Percentage composition of benthos of the five species of fish, benthic invertebrates items in relation to the benthic infaunal composition in the system (b) (Ngqulana, 2011).

3.9 Relationships between the species diets and the benthos in the Mfolozi-Msunduzi system according to sites

3.9.1 Mouth Area

Figure 25a shows the diet of the benthic feeders in the Mouth Area. In the specimens caught in the Mouth Area, the dominant prey item in the species diet was *P. stuhlmanni* for *A. berda*, and *L. equula* with *G. giurus* feeding mainly on *Glossogobius sp.* No specimens of *A. gymnocephalus* were caught in the Mouth Area, specimens of *A. natalensis* were caught but their stomachs were empty. Only three of the species, *L. equula*, *A. berda* and *A. ambassis* had benthic organisms present in their diet.

Figure 25b shows the relationship between the overall benthos and the benthic organisms found in the diet of fish species from the Mouth Area. The dominant benthic species in the Mouth Area were *D. arborifera*, *P. blephariskios* and *Ceratonereis sp*. The dominant prey item in the diet of *A. ambassis* was *O. ancheidos;* the benthos in the diet of *A. ambassis* contributed about 50% to the total diet of the species. The dominant benthic items in the diet of *L. equula* were *D. arborifera* and an unidentified polychaete; of the total diet they contributed less than 1%. The benthic items that were dominant in the diet of *A. berda* were *Grandidlerella bonnieroides* and *P. blephariskios,* but they contributed less than 1% of the total diet.

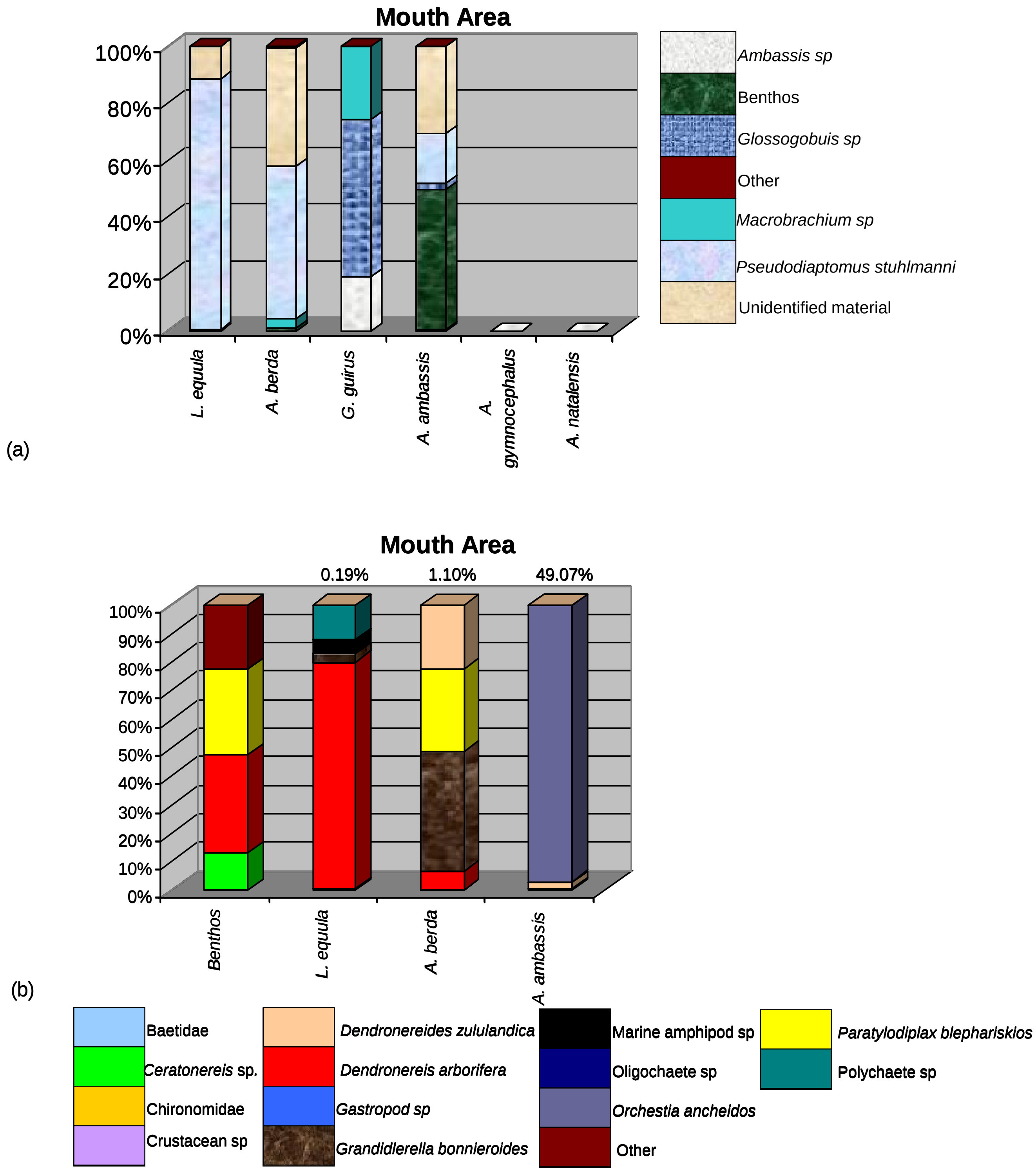

Figure 25: Percentage composition of the diet of six species of fish from the Mouth Area in the Mfolozi-Msunduzi Estuarine system (a); Percentage composition of benthos and of the three species of fish, from the Mouth Area benthic invertebrate items in their diet in relation to the benthic infaunal composition in the system (b) (Ngqulana, 2011)

3.9.2 Mfolozi Arm

Figure 26a shows the diet of the benthic feeders in the Mfolozi Arm. All the species diets were dominated by *P. stuhlmanni* except *G. giurus* whose diet was dominated by *Glossogobius sp*. Only three of the species, *L. equula, A. berda* and *G. giurus* had benthic items in their diet.

Figure 26b shows the relationship between the overall benthos and the benthic diet of fish species in the Mfolozi Arm. The benthos in the Mfolozi Arm was dominated by *D. arborifera* and *Ceratonereis sp*. The benthic items present in the diet of *L. equula* were dominated by Chironomidae, *D. arborifera* and Baetidae were also present. The benthic items present in *L. equula* contributed less than 1% of its total diet. The benthic items present in the diet of *A. berda* included Baetidae, Chironomidae and Gastropod *sp.* and contributed less than 42% to the total diet of the species. The only benthic item present in the diet of *G. giurus* was *P. blephariskios* and it contributed less than 1% to the total diet.

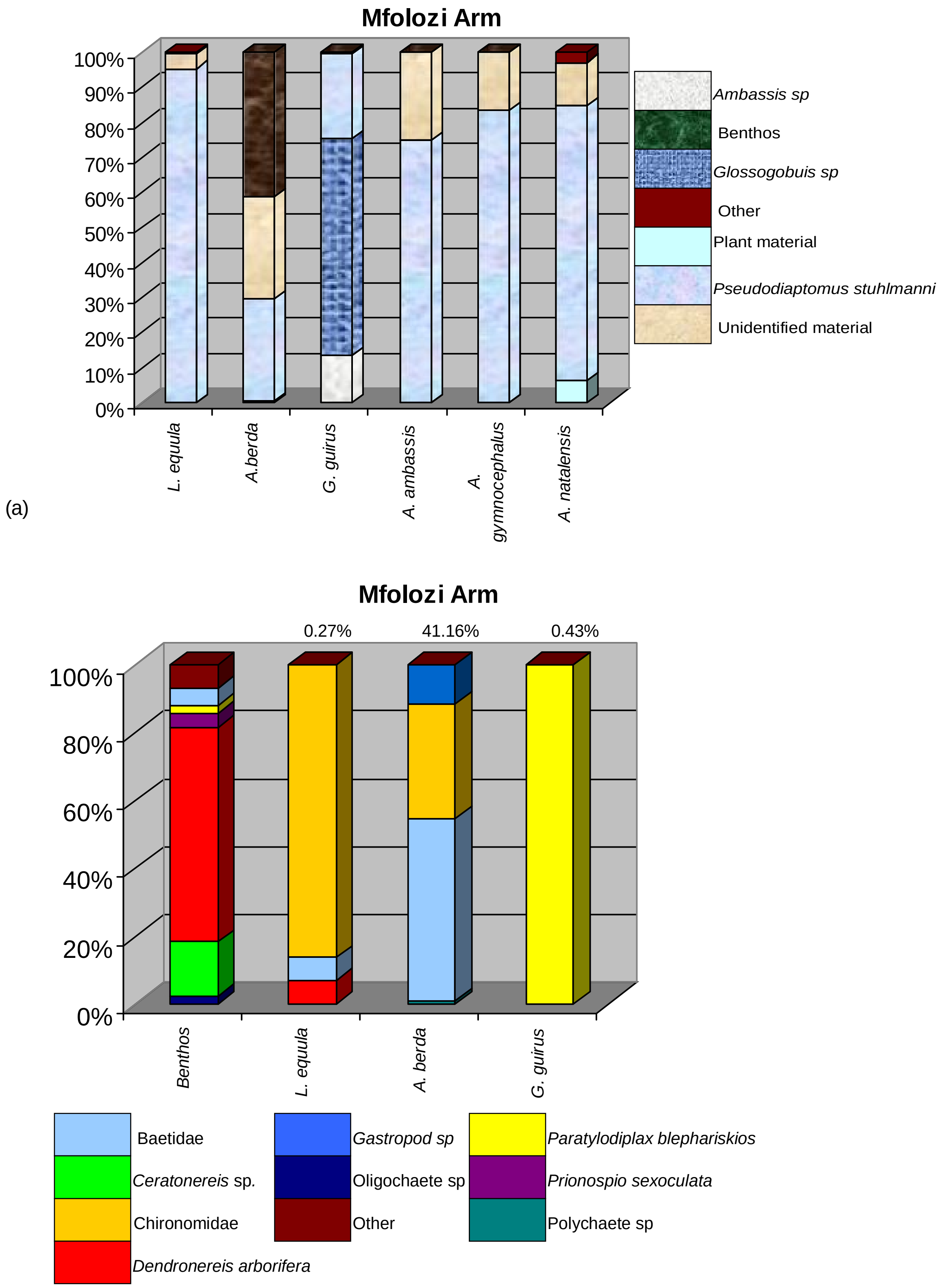

Figure 26: Percentage composition of the diet of six species of fish from the Mouth Area in the Mfolozi-Msunduzi Estuarine system (a); Percentage composition of benthos of the three species of fish, from the Mfolozi Arm benthic invertebrate items in their diet in relation to the benthic infaunal compositon in the system(b) (Ngqulana, 2011).

3.9.3 Msunduzi Arm

Figure 27a shows the diet of the benthic feeders in the Msunduzi Arm. The diet of four of the species that were investigated was dominated by *P. stuhlmanni*. Only one specimen of *G. giurus* was caught in the Msunduzi Arm and its stomach was empty. *Ambassis ambassis* fed predominantly on benthos. Only *L. equula*, *A. ambassis* and *A. natalensis* had benthic species present in their diet.

Figure 27b shows the relationship between the overall benthos and the benthic diet of fish species in the Mfolozi Arm. The benthos of the Msunduzi Arm was dominated by *P. blephariskios* and *A. digitalis*. The only benthic item that was present in the diet of *L. equula* was *A. digitalis* and contributed less than 0.001% of the total diet. The benthos present in the diet of *A. ambassis* consisted only of *Mesopodopsis africana* and contributed about 65.09% to the overall diet. The benthos present in the diet of *A. natalensis* of *D. arborifera* and Baetidae and contributed about 1.33% to the total diet.

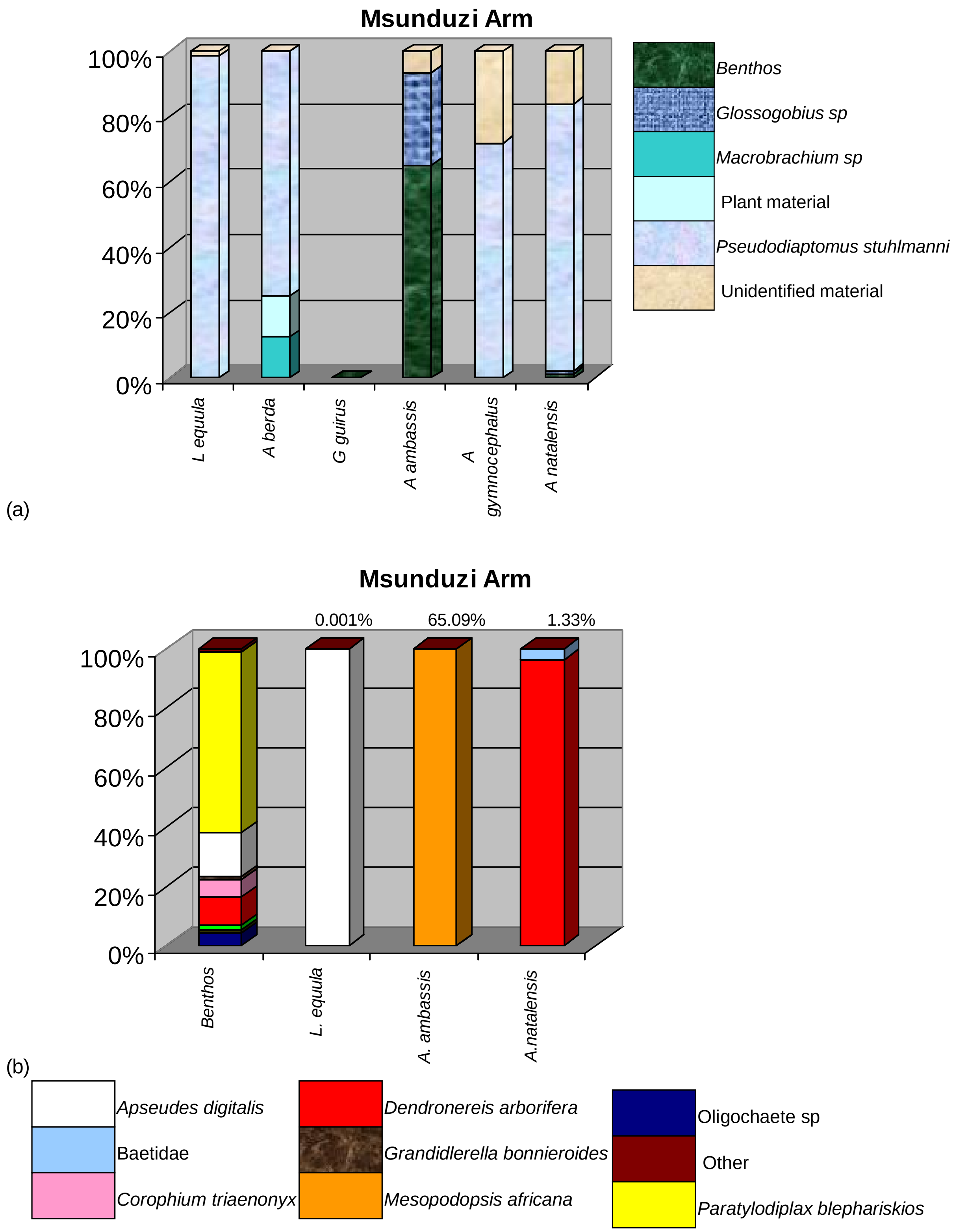

Figure 27: Percentage composition of the diet of six species of fish from the Mfolozi Arm in the Mfolozi-Msunduzi Estuarine system (a); Percentage composition of benthos of the three species of fish from the Msunduzi Arm benthic invertebrate items in their diet in relation to the benthic infaunal compostion in the system (b) (Ngqulana, 2011).

3.10 Relationships between the species diets and the benthos in the Mfolozi-Msunduzi system according to seasons

3.10.1 Autumn

Figure 28a shows the diet of the species of the Mfolozi-Msunduzi system in autumn. Of the six species, only three, *A. ambassis*, *L. equula* and *A. berda*, had benthos present in the diet.

Figure 28b shows the relationship between the benthos and the benthic diet of the fish in autumn. The benthos in the system was dominated by *D. arborifera*, Baetidae and *Ceratonereis sp*. The diet of *A. ambassis* consisted of *O. ancheidos* and *D. zululandica* which contributed about 50% to the total diet. The only benthic item that was present in the diet of *L. equula* in autumn was the polychaete, *D. arborifera* and it contributed less than 1% to the total diet of the species. The benthic diet of *A. berda* included Baetidae and Chironomidae. The benthos presented in *A. berda* contributed less than 2% to the total diet of the species.

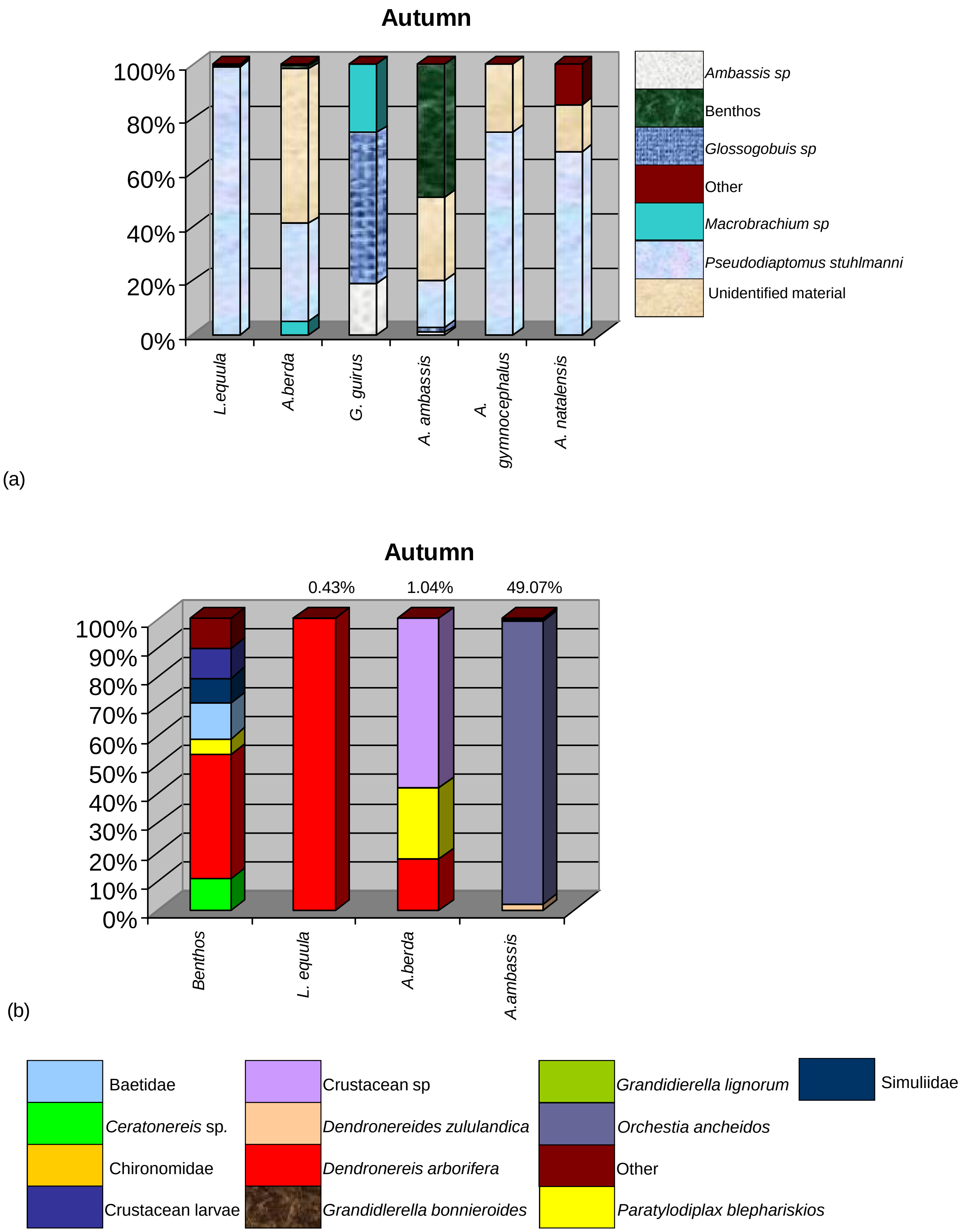

Figure 28: Percentage composition of the diet of six species of fish from the Mfolozi-Msunduzi Estuarine system in autumn (a); Percentage composition of benthos of the three species of fish in autumn benthic invertebrate items in their diet in relation to the benthic infaunal composition in the system (b) (Ngqulana, 2011).

3.10.2 Winter

Figure 29a shows the diet of the benthic feeders in the Mfolozi-Msunduzi system in winter. Only three species, *G. giurus*, *L. equula* and *A. berda*, were used in the analysis since no specimens of *A. ambassis* and *A. gymnocephalus* were caught, the specimens of *A. natalensis* that were caught were all empty. Of the three, only *L. equula* had benthos in its diet.

Figure 29b shows the relationship between the benthos and the diet of the fish in the Mfolozi-Msunduzi system winter. The benthos of the system was dominated by *D. arborifera* and *Ceratonereis sp*. The benthos found in the diet of *L. equula* consisted only of *D. arborifera* and it contributed less than 1% to the total diet of the species.

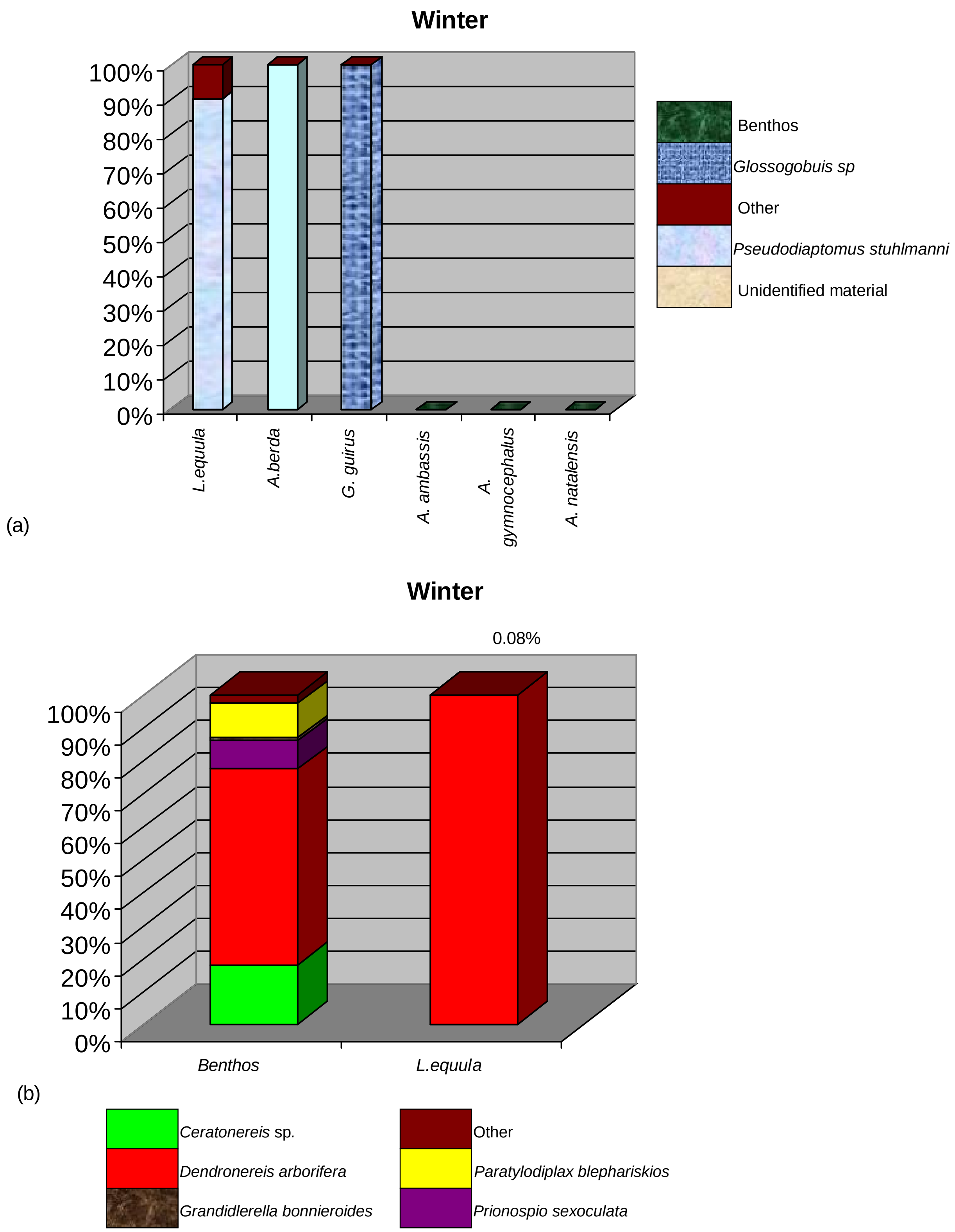

Figure 29: Percentage composition of the diet of six species of fish from the Mfolozi-Msunduzi Estuarine system in winter (a); Percentage composition of benthos in the diet of *Leiognathus equula* in relation to the benthic infaunal composition in the system in winter (b) (Ngqulana, 2011).

3.10.3 Spring

Figure 30a shows the diet of the benthic feeders in the Mfolozi-Msunduzi system in spring. All the species, except *A. gymnocephalus*, had benthos present in their diet.

Figure 30b shows the relationship between the benthos and the diet of the fish in the Mfolozi-Msunduzi system during spring. The benthos of the system was dominated by *P. blephariskios*, *A. digitalis* and *D. arborifera*. The diet of *L. equula* was included Chironomidae, Baetidae and *D. arborifera* and these benthic species contributed less than 0.5% to its total diet. The benthic diet of *A. berda* consisted of Baetidae, Chironomidae and *G. bonnieroides* which contributed about 3% to the total diet. The only benthic item that was present in the diet of *G. giurus* was *P. blephariskios* and contributed less than 1% to the total diet. The only benthic item that was present in the diet of *A*. *ambassis* was *M. africana* and it contributed less than 20% to the total diet. The benthic diet of *A. natalensis* consisted of *D. arborifera* and Baetidae and contributed about 1% to the total diet.

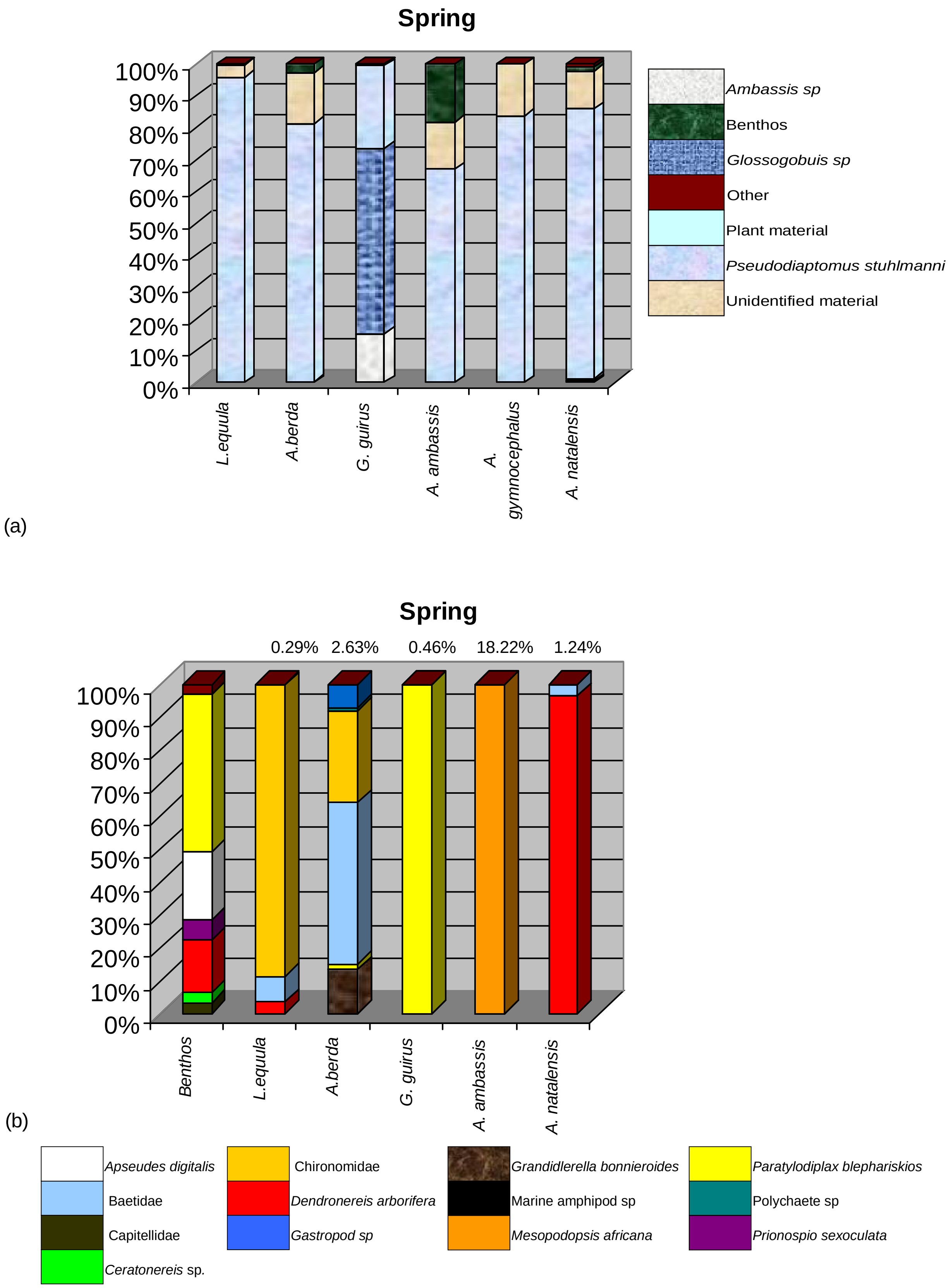

Figure 30: Percentage composition of the diet of six species of fish from the Mfolozi-Msunduzi Estuarine system in spring (a); Percentage composition of benthos of the five species of fish in spring benthic invertebrate items in their diet in relation to the benthic infaunal composition in the system (b) (Ngqulana, 2011).

3.10.4 Summer

Figure 31a shows the diet of the benthic feeders in the Mfolozi-Msunduzi system in summer. Only two species, *L. equula* and *A. berda* had food present in their stomachs. No specimens of *G. giurus*, *A. gymnocephalus* and *A. natalensis* were caught in summer. Stomachs of specimens of *A. ambassis* that were caught were all empty. *Acanthopagrus berda* was the only species that had benthos present in its diet in summer.

Figure 31b shows the relationship between the benthos and the diet of the fish in the Mfolozi-Msunduzi system during summer. The only benthic item that was present in *A. berda* was *P. blephariskios* and it contributed about 25% to the total diet.

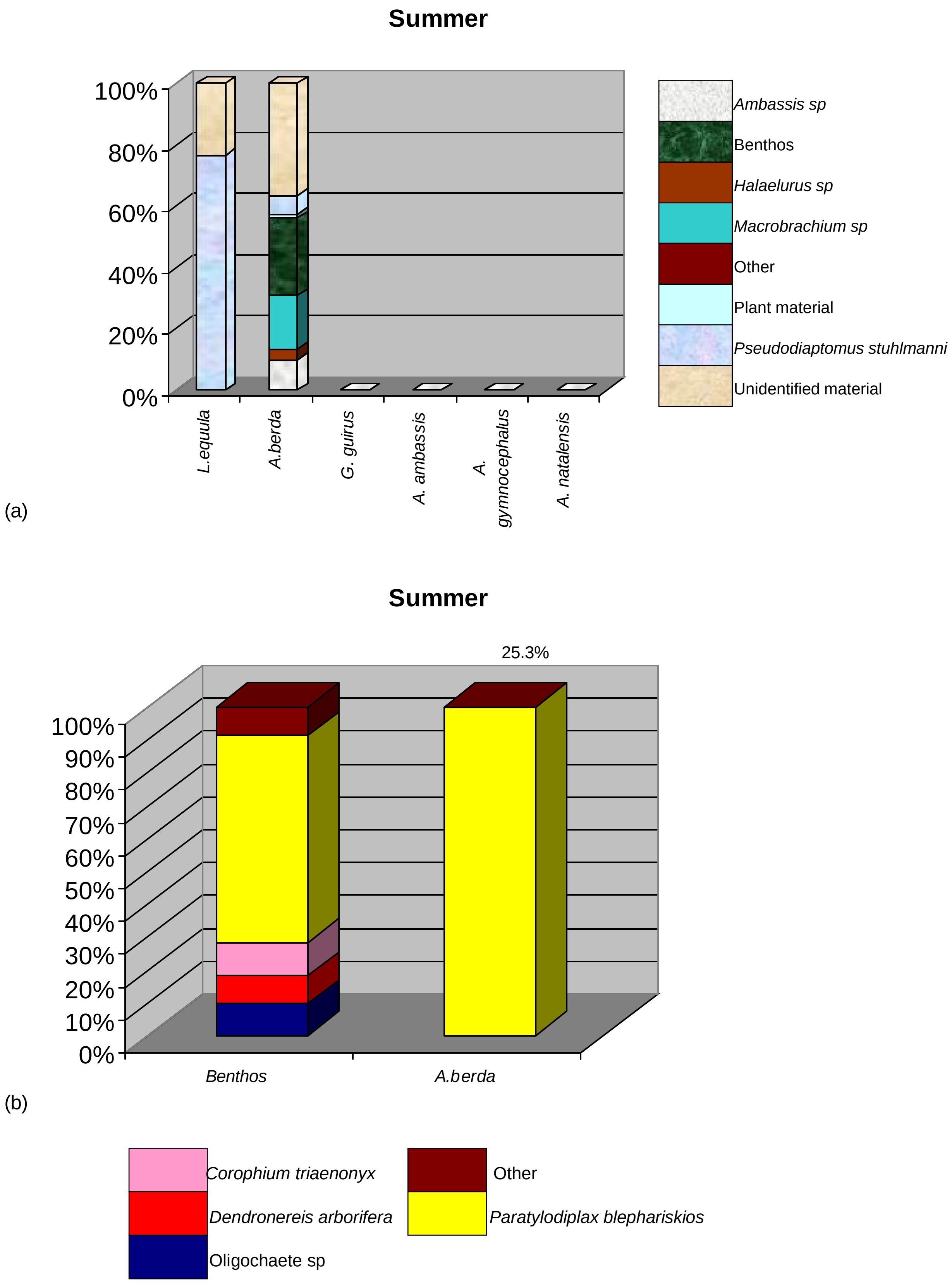

Figure 31: Percentage composition of the diet of six species of fish from the Mfolozi-Msunduzi Estuarine system in summer (a); Percentage composition of benthos in the diet of *Acanthopagrus berda* in relation to the benthic infaunal composition in the system in summer (b) (Ngqulana, 2011)

3.11 St Lucia System

3.11.1 Fish community

A total of 109 fish of 8 different species were collected during the study for stomach content analysis from the St Lucia System. Of the eight species that were caught, only one species was used in the analyses, *L. equula*. The species that were excluded from the analysis were excluded because they were caught in low numbers; details are given in Table 19. Data of *Leiognathus equula* in terms of Points method, Frequency of occurrence and Percentage occurrence were used to determine the Index of Relative Importance and the results are presented.

Food items in the stomachs of the fish which had been too digested to identify were classified as unidentified material.

Table 19: Summary of the other species caught in the St Lucia system and their prey items

Species	**Total caught**	**No. with prey**	**No. that were empty**	**Identifiable prey items**
Acanthopagrus berda	10	3	7	*Apseudes digitalis, Macrobrachium sp,* plant material
Gerres acinaces	1	0	1	Empty
Gerres filamentosus	1	0	1	Empty
Monodactylus argenteus	8	8	0	*Mesopodopsis africana, Pseudodiaptomus stuhlmanni, zoea larva*
Pomadasys commersonni	11	11	0	*Apseudes digitalis, Dendronereis arborifera*
Pomadasys olivaceum	8	8	0	*Apseudes digitalis, Chironomidae, Pseudodiaptomus stuhlmanni, plant material*
Rhabdosargus sarba	7	6	1	*Apseudes digitalis, Boltisia minuta, plant material, zoea larva*

3.11.2 Overall diet of *Leiognathus equula* in the St Lucia System

Table 20 shows the diet data of *L. equula* in terms of Frequency of occurrence, Numerical occurrence and Points Index of Relative Importance methods.

In terms of the Frequency of occurrence method, the species' diet was dominated by *A. digitalis* (57.14%) followed by unidentified material (55.56%). The diet of *L. equula*, in terms of Numerical occurrence, was dominated by *P. stuhlmanni* (85.11%). The Points method results indicated that the species' diet was dominated by *P. stuhlmanni* (56.76%) followed by *Apseudes digitalis* (30.35%). According to the IRI method, the diet of *Leiognathus equula* in system was dominated by *P. stuhlmanni* (70%) (Figure 32). The species diet also comprised of *Apseudes digitalis* (24%) and other prey items (6%). For other prey items, please refer to Table 20.

Table 20: Overall diet of *Leiognathus equula* in the St Lucia System. (F= Frequency of occurrence, N= Numerical occurrence, P= Points method & IRI= Index of Relative Importance).

	***Leiognathus equula* (n = 56)**			
Food item	**F**	**N**	**P**	**IRI**
Apseudes digitalis	57.14	**14.71**	**30.35**	**23.66**
Boltisia minuta	3.17	0.02	0.27	0.01
Corophium trianonyx	3.17	0.02	0.24	0.01
Mesopodopsis africana	3.17	0.05	0.52	0.02
Pseudodiaptomus stuhlmanni	53.97	**85.11**	**56.76**	**70.37**
Unidentified material	55.56		11.60	5.92
Zoea larva	1.59	0.08	0.24	<0.01

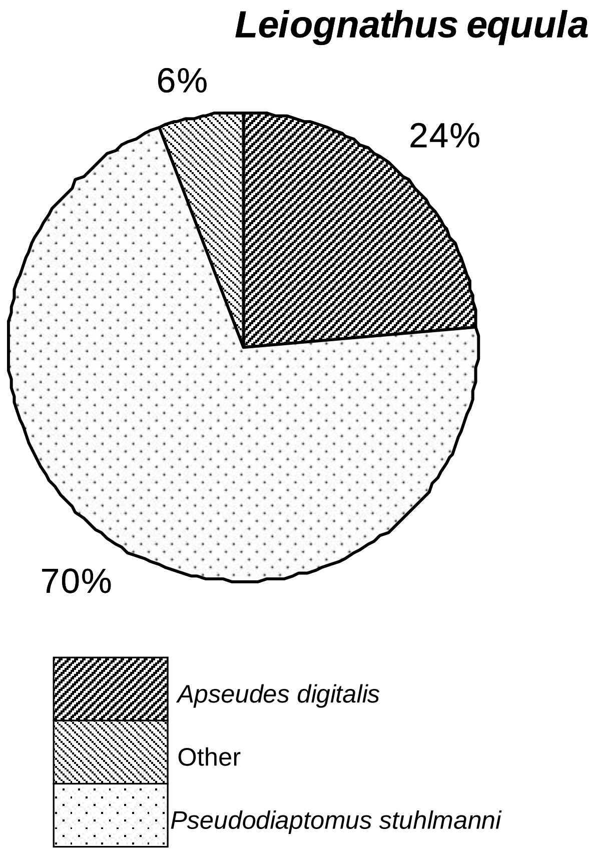

Figure 32: Overall diet of *Leiognathus equula* in the St Lucia Estuary.

3.11.3 The diet of *Leiognathus equula* in different sites

Table 21 shows the diet data of *L. equula* in terms of Frequency of occurrence, Numerical occurrence, Points and Index of Relative Importance methods in the different sites.

Leiognathus equula was collected from two different sites, Mpate and Honeymoon Bend (Figure 5). In terms of the Frequency of occurrence, in Mpate, the species' diet was dominated by unidentified material (58.82%) followed by *A. digitalis* and *P. stuhlmanni* (49.02%). *Apseudes digitalis* (91.67%) dominated the species' diet at Honeymoon bend. The species' diet, according to Numerical occurrence, was dominated by *P. stuhlmanni* (>85%) in both sites. The Points method results indicated that the species diet was dominated by *P. stuhlmanni* (>56%) followed by *A. digitalis* (>30%) in both sites. According to the IRI method, at Honeymoon Bend, the diet of the species was dominated by *P. stuhlmanni* (70%) and also comprised of *A.*

digitalis (27%) and other prey items (3%) (Figure 33a). At Mpate, the diet of the species was dominated by *P. stuhlmanni* (70%) and also comprised of *A. digitalis* (22%) and other prey items (8%) (Figure 33b). For other prey items, please refer to Table 21.

Table 21: Diet of *Leiognathus equula* as indicated by four methods used to analyze stomach contents from the two sites in the St Lucia system (F= Frequency of occurrence, N= Numerical occurrence, P= Points method & IRI= Index of Relative Importance).

	Mpate (n = 45)				**Honeymoon bend (n = 11)**			
Food item	**F**	**N**	**P**	**IRI**	**F**	**N**	**P**	**IRI**
Apseudes digitalis	49.02	**14.94**	**30.39**	**22.46**	91.67	**14.17**	**30.26**	**26.66**
Boltisia minuta	3.92	0.03	0.38	0.02				
Corophium trianonyx					16.67	0.07	0.91	0.11
Mesopodopsis africana					16.67	0.19	1.95	0.23
Pseudodiaptomus stuhlmanni	49.02	**85.03**	**56.14**	**69.93**	75.00	**85.57**	**58.44**	**70.70**
Unidentified material	58.82		12.76	7.58	41.67		8.44	2.30
Zoea larva	1.96	0.12	0.33	0.01				

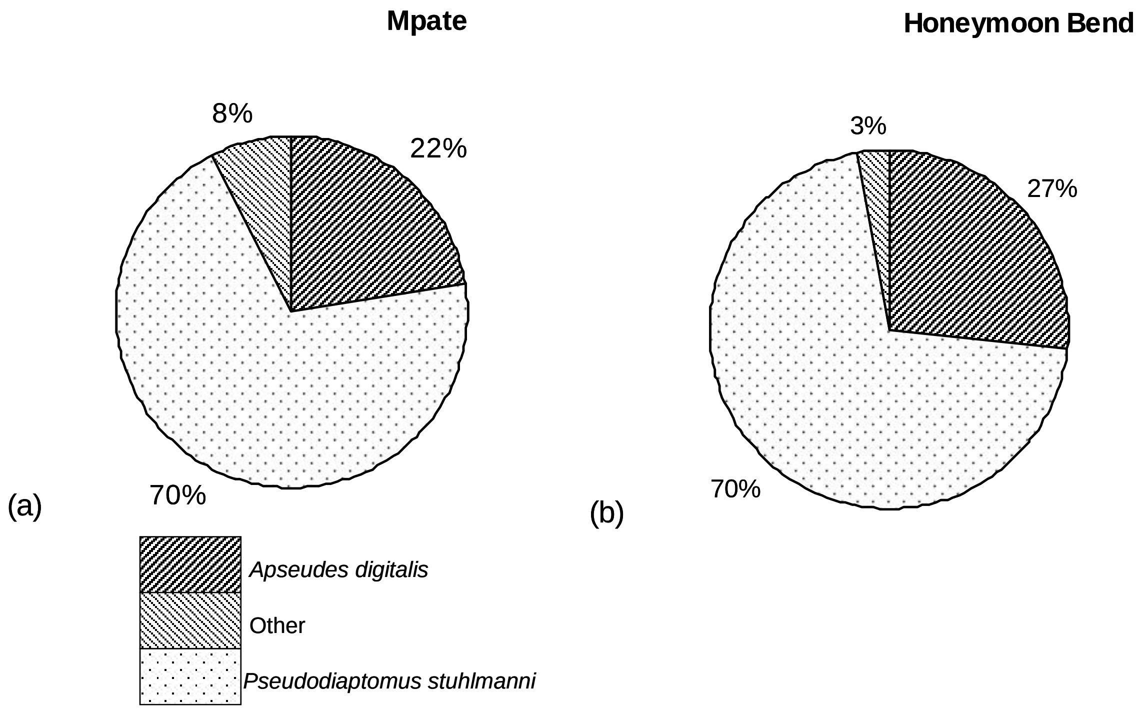

Figure 33: The diet of *L. equula* at the two sites in the St Lucia Estuary

3.11.4 Seasonal diet of *Leiognathus equula* in the St Lucia System

Table 22 shows the diet data of *L. equula* in terms of Frequency of occurrence, Numerical occurrence, Points and Index of Relative Importance methods seasonally. Sampling was only undertaken in winter and summer.

In terms of Frequency of occurrence, the species' diet was dominated by *A. digitalis* (79.31%) and unidentified material (48.28%) in winter, while *P. stuhlmanni* (70.59%) and *A. digitalis* dominated its diet in summer (79.31%). In terms of Numerical occurrence, the species' diet was dominated by *P. stuhlmanni* (>74%) in both seasons. The Points method results indicated that the diet of *L. equula* was dominated by *P. stuhlmanni* (66.73%) followed by *A. digitalis* in winter and *A. digitalis* (44.01%) followed by *P. stuhlmanni* (42.48%) in summer. According to the IRI method, the diet of the species in summer was dominated by *P. stuhlmanni* (85%) in winter and *A. digitalis* (55%) dominated the species diet in summer (Figure 34). In winter, the diet also comprises of *A. digitalis* (9%) and other prey items (6%).

Table 22: Diet of *Leiognathus equula* as indicated by four methods used to analyze stomach contents from the different seasons of the St Lucia system (F= Frequency of occurrence, N= Numerical occurrence, P= Points method & IRI= Index of Relative Importance

	***Leiognathus equula* - Winter (n = 32)**				***Leiognathus equula* - Summer (n = 24)**			
Food item	**F**	**N**	**P**	**IRI**	**F**	**N**	**P**	**IRI**
Apseudes digitalis	38.24	8.48	**20.82**	8.60	79.31	**25.50**	**44.01**	**54.68**
Boltisia minuta	5.88	0.03	0.47	0.02				
Corophium trianonyx					6.90	0.06	0.59	0.04
Mesopodopsis africana					6.90	0.14	1.27	0.10
Pseudodiatomus stuhlmanni	70.59	**91.49**	**66.73**	**85.70**	34.48	**74.07**	**42.48**	**39.86**
Unidentified material	61.76		11.98	5.68	48.28	0.00	11.05	5.29
Zoea larva					3.45	0.23	0.59	0.03

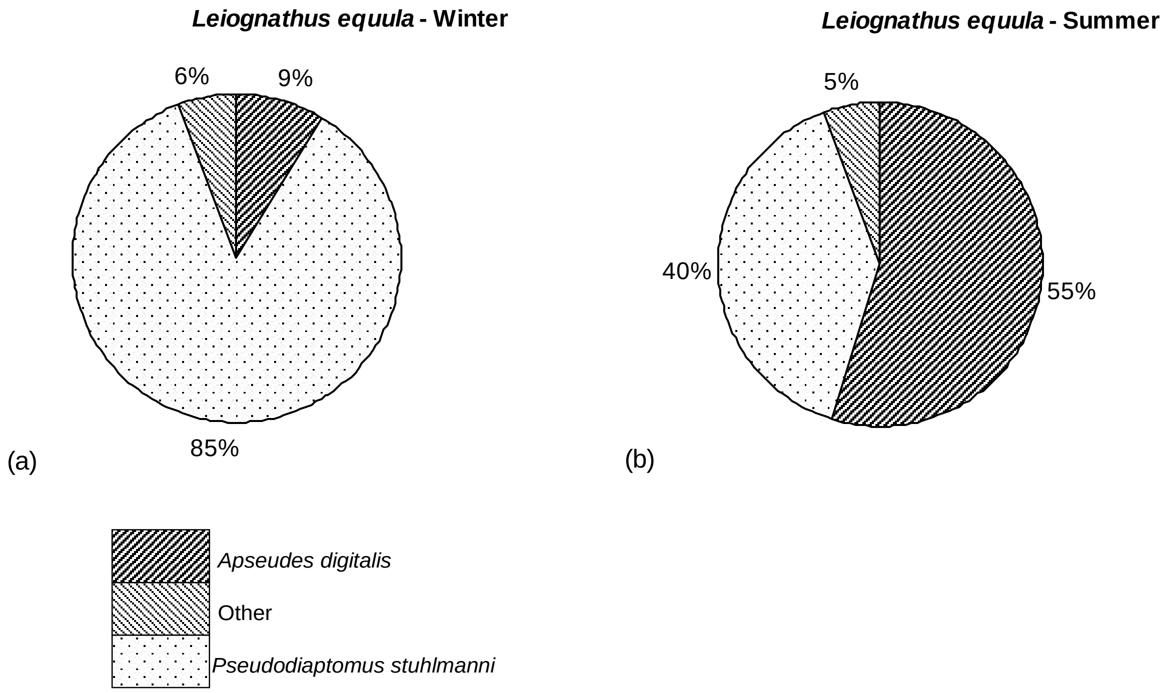

Figure 34: Seasonal diet of *L. equula* in the two sites from the St Lucia Estuary.

Chapter 4: Discussion

4.1 Physico-chemical parameters

Temperatures in the Mfolozi-Msunduzi system during the study period ranged between 18 and 28°C (Figure 6), which are well in the range of the expected temperatures in subtropical estuaries. Other studies in the Mfolozi Estuary, such as sampling conducted biannually in March and August during 2007 and 2008, found the temperatures to range from 18-31°C (Ngqulana *et al*., 2010, Vivier *et al*., 2010b). Harrison (2004) found the temperatures of estuaries in KwaZulu-Natal to generally register above 20°C, which coincides with results from the current study and other studies which also reported temperatures in subtropical estuaries to reach above 20°C (Day *et al*., 1981, Begg, 1984, Whitfield, 1980a, Graham, 1994, Blacker *et al.*, 2004, Vivier *et al.*, 2010a, MacKay *et al.*, 2010).

A gradient was observed in the system with salinities being highest at the Mouth Area. This salinity gradient occurred not only when the mouth of the system was open in autumn, winter and summer, but also in spring, when the mouth was closed (Figure 6). Even when the mouth was closed in spring, salinities were still higher in the Mouth Area than in the Mfolozi and Msunduzi Arms. This could be attributed to the fact that sampling was undertaken in early spring during which the catchment receives low rainfall thus resulting in low freshwater flows into the system. The system was predominantly fresh in summer, with salinities of <1, indicating a river-driven system, which is expected because the Mfolozi-Msunduzi system is classified as a river mouth. The physical process of river mouths are dominated by the river with salinities tending towards oligohaline in the middle reaches (Whitfield, 1992). The catchment experiences peak rainfall in summer and therefore it is expected that the system will be predominately fresh because of the influx of fresh water. The salinities during this study were generally similar to those recorded in the system in 2007 and 2008 (Vivier & Cyrus, 2009, Ngqulana *et al*., 2010, Vivier *et al*., 2010a & b).

The entire system remained well oxygenated throughout the study period with levels being between 5.6 and 10.8 mg/l (Figure 6). Previous studies have also indicated that the system was well oxygenated (Ngqulana *et al.*, 2010, Vivier *et al.*, 2010b). KwaZulu-Natal estuaries have been found in general to be well oxygenated throughout the year because they are generally shallow, as is the case with the Mfolozi-Msunduzi system (Begg, 1984). Harrison (2004) sampled approximately 40 subtropical estuaries and discovered the dissolved oxygen levels to be generally above 5.0 mg/l. Dissolved oxygen levels in the Mfolozi-Msunduzi system were also found to be above 5.0 mg/l.

Turbidity in the Msunduzi Arm was generally higher than that of the Mfolozi Arm and the Mouth Area, which can be attributed to the fact that the substratum of the Msunduzi Arm is very muddy (Figure 7). This corresponds to previous studies on the Mfolozi-Msunduzi system (Ngqulana *et al.*, 2010, Vivier *et al.*, 2010b). Turbidities in the system were highest in summer, which could be attributed to the fact that the catchment receives a predominantly summer rainfall. Harrison (2004) also found that higher turbidities in subtropical estuaries were usually associated with periods of higher rainfall.

4.2 Fish community

Fifteen species of benthic feeding fish were collected from the Mfolozi-Msunduzi system. Of these, only six were caught in sufficient numbers for stomach content analysis to be undertaken.

Of the fish species investigated in this study, *Gerres acinaces*, *G. filamentosus* and *Rhabdosargus sarba* were recorded in the system in low numbers, most probably because they are species that are associated with clear to partially turbid water (Cyrus & Blaber, 1987a & b). The Mfolozi-Msunduzi system is very turbid and therefore it would be expected these species would occur in low numbers or be absent. *Solea bleekeri* was present in very low numbers in the system. Cyrus (1991) found that *S. bleekeri* fed on the siphon tips of *S. cyclindraceus,* but changed its diet to whatever was available if no siphons were present. *Solen cylindraceus* was not recorded in the benthos of the system and therefore was not available for

S. bleekeri to feed on. It is rather surprising that *S. bleekeri* did not change to feeding on other benthic prey since Cyrus (1991) stated that is an opportunistic feeder and therefore can feed on other benthic prey. *Pomadasys commersonni* and *P. kaakan,* which were recorded in low numbers, are regarded as being indifferent to turbidity (Cyrus & Blaber, 1987a & b, van der Elst, 1988, Hecht & van der Lingen, 1992), so their presence in estuaries is not affected by turbidity. A possible reason for them being recorded in low numbers in the estuary is the poor availability of food. Vivier *et al*. (2010b) reported that benthic feeding fish in the system could experience a food shortage due to the impoverished nature of benthos in the system. *Glossogobius callidus, G. tenuiformis* and *O. keiensis* were also recorded in low numbers, which could be related to low food availability or turbidity.

4.3 The influence of environmental factors on the fish community

Estuaries are highly variable and unpredictable habitats, in which the physico-chemical parameters are constantly changing. Parameters such as salinity, temperature, turbidity, pH and dissolved oxygen fluctuate both temporally and spatially (Whitfield, 1990, 1994). These changes place considerable physiological demands on organisms that utilize estuaries and therefore the advantages of living in estuaries are only available to species that are adapted to or can tolerate the biotic and abiotic variability of estuaries (Whitfield, 1999). Juveniles of marine fish are known to utilize estuaries because they have calm and shallow waters, reduced predation pressure, good food availability and have turbid waters that generally offer a form of protection from predators (Blaber & Blaber, 1980).

Vivier *et al.* (2010b) found salinity, temperature, sediment grain size and organic content to be the most important factors in structuring the fish assemblage in the system. In the present study, the results indicate that salinity, turbidity and temperature were most important in determining species distribution (Figure 8). The difference in factors most responsible for structuring the fish community between the two studies could be related to the fact that the present study only looked at benthic feeding fish. Although sediment analysis was undertaken, the results were not included in the study because it did not appear to affect the diet or the distribution of the fish. The system was muddy in the Mouth Area and in the Msunduzi Arm, with the Mfolozi Arm being characterized by medium-fine sand (Ngqulana *et al*., 2010, Ngqulana, 2011). Vivier *et al.* (2010b) stated that it was not clear how sediment particle size and organic content influenced the variation in the fish assemblage, because the entire system was generally muddy. The relative abundance of *L. equula* in the system is believed to be turbidity related, since it is a turbid water species (Cyrus, 1987a & b, 1992a, Vivier & Cyrus, 2009, Vivier *et. al.,* 2010b). According to the current study, this does not appear to be the case because no correlation was found between the species presence and turbidity. The abundance of *L. equula* in the system was either related to food availability, since it fed mainly on *P. stuhlmanni,* which was extremely abundant in the Mfolozi-Msunduzi system, or to the absence of a predator. Day *et al.* (1981) stated that *L. equula* was preyed upon by the eel, *Muraenesox bagio,* which was only recorded in the system in low numbers, and as such, predation by this eel could hardly have affected the *L. equula* population (Vivier & Cyrus, 2009, Vivier *et al.,* 2010b). In addition, none of the specimens of piscivorous species that were examined had *L. equula* in their diet.

Most fish species associated with South African estuaries are tropical in origin and have been found to prefer warm, turbid, brackish water conditions (Harrison & Whitfield, 2006). Most studies in South African estuaries and around the world have focused on one or two factors that influence fish distribution and abundance (Whitfield, 1996). Studies in different parts of the world found salinity and temperature to play an important role in the distribution of fish (Bennett, 1985, Marais, 1988, Cyrus & McLean, 1996, Whitfield, 1996, Blaber, 1997, Marshall & Elliot 1998, Marais, 1999, McLusky & Elliot, 2004, Pombo *et al.* (2004), Harrison & Whitfield, 2006). Due to the variability of salinity in estuaries, species that live in estuaries have to be tolerant of both high and low salinities. In the St Lucia estuary, mass mortalities of fish occurred when salinities dropped below 3 and the temperatures were less than 12°C (Cyrus & MacLean, 1996), indicating that many marine fish are intolerant of a combination of low salinity and temperature.

Turbidity acts as a form of protection for juvenile fish against predators and is also associated with areas of abundant food (Blaber, 1997). The vision of larger fish is reduced in turbid waters and therefore they have difficulty in locating prey. Blaber (1985) found that where turbidities were high, predation decreased. Hecht and van der Lingen (1992) found that the rate of feeding of visual predators was reduced at higher turbidities. Cyrus and Blaber (1987c) and Cyrus (1992a) suggested that turbidity was the single most important factor influencing fish distribution in estuaries. Cyrus and Blaber (1992) indicated that turbidity and salinity were the most important variables that influence fish distribution. Hagan and Able (2003) and Abookire *et al.* (2004) all found that turbidity and temperature were responsible for determining seasonal distribution patterns of fish in estuaries. The current study, in agreement with Pombo *et al.* (2004), showed that seasonal changes, which can be seen by the length of temperature vector (temperature is a factor influenced by season), followed by salinity (Figure 8), was most important in structuring the benthic fish community.

4.4 Diet of the fish species

Food and feeding ecology studies have long been of interest to ecologists around the world (Blaber, 1997). Information on diets, food availability and feeding behaviour of fish are important in understanding their community structure, their distribution patterns and their life history strategies. In order to predict changes that might occur as a result of natural or anthropogenic intervention or to describe how estuarine communities function, detailed knowledge of the often complex diets of fishes, feeding behaviour patterns, and predator-prey relationships is needed (Blaber, 1997).

Estuarine fish feed on a wide variety of food types and to increase the probability of successfully handling and ingesting a particular group of prey, most of them have evolved various adaptations (Day *et al.,* 1989). The design of the mouth of fish has important implications for food acquisition. The mouth location and size determine how the fish feed and what they feed on. In estuaries, fish that feed on small benthic organisms and off leaf surfaces of plants have extremely conspicuous modifications of the jaw structure to allow for the extrusion of the mouth to capture the benthic organisms (Day *et al.,* 1989). Fish with dorsal mouths often suck in floating insects from the water surface. Top predators, which usually pursue other fish species, have long terminal mouths, while demersal fish have ventral mouths. Fish that feed in both the pelagic and benthic pathways have semiventral mouths (Day *et al*., 1989).

4.4.1 *Leiognathus equula*

The diet of *L. equula,* in terms of Frequency of occurrence, Numerical occurrence, Points and IRI methods in the system, was strongly dominated by the copepod, *Pseudodiaptomus stuhlmanni*, both temporally and spatially. Juveniles fed on *P. stuhlmanni,* which also formed an important component of the adults' diet, contributing more than 35% to the total diet. During feeding, this species protrudes its mouth into the substrata and sucks in organisms which are present. It is more likely that *L. equula* feeds during the day as *Pseudodiaptomus stuhlmanni* remains near the substrata during the day to reduce predation and migrates to near surface waters at night to feed (Grindley, 1972, Fancett & Kimmerer, 1985). Densities of *P. stuhlmanni* in system have been shown to be high, reaching peak densities of 79 000 individuals m^{-3} in the water column (Jerling *et al.,* 2010a). The probability of catching *P. stuhlmanni* is therefore great if the predator feeds during the day when the prey species is on or near the bottom substrata.

Although *L. equula* in the current study did feed on benthic prey items, they contributed very little to the overall diet. Graham (1994) and Blackler *et al.* (2004) found the dominant prey item in the diet of *L. equula* changed with body size in Durban Harbour. The small individuals, from 30 to 69mm SL, fed mainly on copepods, while the diet of the specimens from 70 to 115mm SL was mainly dominated by benthic organisms such as Polychaetes and

Tanaids. The specimens that were caught during the current study were between 20-160mm SL (Table 4). The diet of the specimens from 20mm to 130mm SL was dominated by copepods and the dominant prey item did not change with an increase in body size, as was the case in Durban Harbour (Graham, 1994, Blackler *et al*., 2004). This is due to the fact that the benthic fauna of the Mfolozi-Msunduzi is highly impoverished (Ngqulana *et al.*, 2010, Owen *et al*., 2010) and therefore copepods are more available because of their high densities in the system. This indicates that *L. equula* in the system adapted its diet to the low availability of benthic prey by switching to a copepod diet.

Studies on the diet of *L. equula* have been conducted in only a few systems in South Africa (Mhlanga estuary, Durban Harbour, Mngazi and Mngazana) (Whitfield, 1980a & b, Graham, 1994, Blackler *et al*., 2004, Grant, 2007) and internationally (Ross River, Pattani & Narthiwat and Johor Strait) (Wilson, 1999, Wilson & Sheaves 2001, Blaber, 1980, Hajisamae *et al.*, 2003, Hajisamae *et al*., 2006, Hajisamae, 2009). The dominant prey items of *L. equula* in these systems are shown in Table 23.

Table 23: Diet comparisons of *L. equula* in different systems South Africa, Australia, Thailand and Singapore.

Prey item	Mfolozi-Msunduzi system (This study)	St Lucia (Nhleko, 2011)	Mhlanga (Whitfield, 1980a & b)	Durban Harbour (Graham, 1994, Blackler *et al.*, 2004)	Mngazi (Grant, 2007)	Mngazana (Grant, 2007)	Ross River (Australia) (Wilson, 1999, Wilson & Sheaves, 2001)	Johor Strait (Singapore) (Hajisamae et al., 2003)	Pattani, Narathiwat & Songkhla (Thailand) (Hajisamae *et al.*, 2006)	Coastal waters of Pattani & Narathiwat (Thailand) (Hajamsamae, 2009)
Algae							(**)			
Calaniod copepods	**	**	*		*	**			**	
Cumacea			**							
Gammarid amphipods							(**)		*	
Harpacticoid copepods				**			(**)			
Mysidacea						*				
Nematodes								**		
Pleocyemata										*
Polychaete				*		*				**
Tanaidacea		*			**					

** Most dominant prey

* Second most dominant prey

(**) Not indicated in the study which prey item was dominant

Day *et al.* (1981) stated that the main food group of *L. equula* in Southern African estuaries is zooplankton, although the species also feeds on amphipods, polychaetes and bivalves. The diet of *L. equula* was dominated by the copepod, *P. stuhlmanni* followed by Tanaidacea in the neighboring St Lucia system under closed mouth conditions (Table 23). Studies conducted in the Mhlanga estuary, South Africa, found that the diet of *L. equula* was dominated by Cumacea (Table 23), but the species also fed on Copepoda, Bivalves, Oligochaeta and Polychaeta (Whitfield, 1980a & b). Cumacea was the dominant prey item, contributing about 55% to the overall diet. Cumacea were concentrated in the lower reaches of the system, which was the only area were specimens of *L. equula* was caught, indicating that it fed mainly on what was abundant. Graham (1994) and Blackler *et al.* (2004) found that the species diet in Durban Harbour, South Africa, was dominated by Harpacticoid copepods followed by polychaetes (Table 23). Tanaids were also an important dietary component in this system and were consumed by *L. equula* ranging from 60 to 80mm SL (Blackler *et al.*, 2004). The diet of *L. equula* in the Mngazi and Mngazana estuaries in the Eastern Cape was dominated by copepods and tanaids (Table 23) (Grant, 2007).

A study conducted in the Ross River, in North Queensland, Australia, found *L. equula* to feed on harpacticoid copepods, gammarid amphipods and algae, but did not state which prey item dominated (Table 23) (Wilson, 1999, Wilson & Sheaves, 2001). Blaber (1980) found the main food type in the Trinity Inlet System, Northern Queensland, to be plankton and invertebrate benthos, but did not indicate which species were targeted. Hajisamae *et al.* (2003) found that three species, all Leiognathids, including *L. equula*, in the eastern Johor Strait, Singapore, relied on Nematodes as the main food group (Table 23), but also fed on other items such as gammarid amphipods and cypris. Hajisamae *et al.* (2006) found that the diet of *L. equula* in the coastal waters off Pattani, Narathiwat and Songkhla, southern Thailand, was dominated by Calaniod copepods followed by gammarid amphipods (Table 23). In contrast, in the coastal waters of Pattani and Narathiwat, Thailand, in 2009, the diet of the species was dominated by polychaetes followed by shrimp (Table 23), with Calanoid copepods only contributing 2.7% of the total diet (Hajisamae, 2009).

Although *Leiognathus equula* is classified as a benthic feeding fish, the literature clearly seems to indicate that it has a preference for copepods. The current as well as previous studies have all shown that *L. equula* prefers copepods (Calanoid and Harpacticoid) since they have been found to dominate the species' diet in most systems (Table 23). Studies on the diet of other *Leiognathus* species, *L. bindus*, *L. decorus*, *L. splendens*, *L. brevirostris* and *L. stercorarius,* have also shown that their main prey item consists of copepods (Hajisamae, 2009, Hajisamae *et al.*, 2003, Hajisamae *et al.*, 2006, Wilson, 1999). It can thus be concluded that *Leiognathus* species generally feed on copepods, which corresponds with the results from the current study, with *L. equula* in the Mfolozi system feeding mainly on *P. stuhlmanni*.

4.4.2 *Acanthopagrus berda*

The overall diet of *A. berda* during this study was also dominated by the copepod *P. stuhlmanni*, which is highly abundant in the system and therefore the probability of it being preyed upon is great. Day *et al.* (1981) stated that from 20 to 60mm SL, the juvenile stages of *A. berda* in Southern African estuaries feed on zooplankton, amphipods, chironomid larvae, tanaids and small crabs. At between 60 and 120mm SL, the main food is bivalves, gastropods, gobies and weed, but amphipods still form part of the diet. Larger fish and adults feed on crabs, prawns, barnacles and fish. The results of the current study thus correspond to those reported by Day *et al.* (1981), with the diet of specimens ranging from 20 to 60mm SL being dominated by the copepod, *P. stuhlmanni,* but also including Baetidae, Chironomidae and *Macrobrachium sp*. From 70 to 130mm SL, the diet consisted of zooplankton, gastropods, amphipods and scales (Figure 10). The diet of the larger fish, from 140 to 160mm SL, was dominated by material which could not be identified; this unidentified material included unidentifiable fish and prawns (Table 6). The species at this size class also fed on *Ambassis sp.*, *P. blephariskios* and unidentified Crustacea remains (Table 6).

Pseudodiaptomus stuhlmanni formed an important component of *A. berda's* diet, contributing more than 25% in all three zones. This would be expected since it is highly abundant in the system. Baetidae and Chironomidae were also important components in the species' diet in the Mfolozi Arm, contributing 22% and 14%, respectively (Figure 13). *Leiognathus equula, A. ambassis and A. natalensis* also fed on Chironomidae and Baetidae, but these contributed less than 0.1% to the total diet of these fish species. This could mean that *A. berda* fed on Baetidae and Chironomidae either because it preferred these prey items or because there was less competition for these, since they contributed very little to the diet of the other species.

The diet of *A. berda* in summer included *P. blephariskios* (21%), which was dominant in the benthos during this season and therefore it is not surprising that it contributed so much to the total diet. Two specimens were caught in winter, of which one had an empty stomach. The one *A. berda* specimen examined fed on plant material (Figure 19b). In spring, the species' diet was dominated by *P. stuhlmanni* (Figure 19c). Although *P. blephariskios* was also dominant in the benthos in spring, it was not part of the species' diet. Of all the fish species examined, *A. berda* was the species which fed on the highest number of benthic species.

Table 24: Diet comparisons of *A. berda* in different systems in South Africa and Australia

	Mfolozi-Msunduzi system (This study)	**Durban Bay (Day & Morgan, 1956)**	**Mgeni (Harrison, 1991)**	**Three Mile Creek (Beumer, 1978)**	**Embley estuary (Salini et al., *1990*)**
Amphipodae	*	*	*		
Baetidae	*				
Bivalvia		*		*	**
Branchyura					*
Chironomidae	*				
Cirripedia				**	
Copepoda	**	*	*	**	
Crustacea remains	*	*	**		
Cumacea			*		
Dendrobranchiata	*			**	*
Fish	*	*		*	*
Fish scales	*		*	*	
Gastropoda	*		*	*	**
Insecta				*	
Isopoda			*		
Nematoda				*	
Oligochaeta			*		
Ostracods			*		
Plant material	*	*	*	*	*
Pleocyemata				**	
Tanaidacea			*		
Unidentified remains	*		*	*	*

** dominant prey item

Day and Morgan (1956) studied the diet of *A. berda* in the Durban Bay, South Africa. These authors did not state which prey was the most dominant and therefore it was not indicated in Table 24. The specimens that they examined ranged from 39mm to 273mm. The diet of the specimens ranging from 39mm to 50mm consisted of copepods and amphipods. For specimens 50-100mm in length, the diet consisted of amphipods, polychaetes and bivalves. The diet of the larger fish (100mm-200mm) consisted of crabs, gobies, algae and *Zostera*, while adult specimens over 200mm had a varied diet, which consisted of *Zostera*, filamentous algae, amphipods, crabs, *Upogebia*, bivalves and *Balanus amphitrite*. Day *et al.* (1981) reported that in Southern African estuaries, *A. berda* between 20-60mm fed on zooplankton, amphipods, chironomid larvae, tanaids and small crabs, while for specimens between 60-120mm, the diet included amphipods, bivalves, gastropods, gobies and weed. Harrison (1991) found that *A. berda* in the Mgeni estuary, South Africa, fed mainly on crustaceans such as amphipods and tanaids, and fish scales, but also consumed polychaetes, ostracods, gastropods and aquatic plants (Table 24). Van der Elst (1988) stated that the diet of adult *A. berda* in Southern African systems includes polychaetes, bivalves, sand dollars, crabs, prawns, shrimps and small fish. These results from South Africa indicate that the diet of juvenile (20-100mm) *A. berda* consists mainly of copepods, amphipods, polychaetes and bivalves, while that of adults (above 100mm) comprises amphipods, polychaetes, bivalves, gastropods, fish and aquatic plants. This corresponds with results of the current study.

The diet of *A. berda* in Three Mile Creek, North Queensland, Australia, was dominated by Crustaceans, which included Dendrobranchiata, Pleocyemata, Cirripedia and Copepoda (Table 24) (Beumer, 1978). The composition of these groups and their dominancy changed from month to month. Salini *et al.* (1990) found that the diet of *A. berda* in the Embley Estuary, Australia, was dominated by Mollusca, which included Gastropoda and Bivalvia (Table 24). Mollusca dominated the species' diet in terms of Percentage dry weight in this system, while in terms of Frequency of occurrence it was dominated by plant material. The difference between the dominant prey items in the two methods is not surprising because even though plant material might have been present in more specimens than Mollusca, it has a smaller mass than Mollusca.

The diet of *A. berda* in the Mfolozi-Msunduzi system was dominated by Copepoda (Table 24). Copepods were dominant in the diet of *A. berda* in only one other system, Three Mile Creek, although they were also recorded in specimens from Durban Bay and the Umgeni estuary. There was an overlap in the species' diet with differences in terms of the dominant prey item, except at Three Mile Creek, where copepods were also one of the dominant items.

Studies on the diet of other *Acanthopagrus* species (*A. butcheri* and *A. latus*) have found that it consists of Polychaeta, Mollusca, Crustacea, Teleostei, Insecta and plant material (Sarre *et al*., 2000, Platell *et al*., 2007). It therefore can be concluded that the diet of *A. berda*, *A. butcheri* and *A. latus* overlap to a large extent since they all feed on the same taxa.

4.4.3 *Glossogobius giurus*

The overall diet of *G. giurus* was dominated by *Glossogobius sp.* followed by *P. stuhlmanni* and *Macrobrachium sp.* (Table 3). The species also fed on *P. blephariskios* but this contributed very little to its total diet. Only three specimens were caught in the Mouth Area and their stomach content indicates that *G. giurus* in this region fed on *Ambassis sp., Glossogobius sp. and Macrobrachium sp*. In the Mfolozi Arm, the species' diet was dominated by *Glossogobius sp.* Despite the relatively low numbers of specimens analyzed in autumn and winter, the results seem to indicate that the species' diet consisted of *Ambassis sp., Glossogobius sp.* and *Macrobrachium sp.* and that the diet was dominated by *Glossogobius sp.* The results of the current study therefore indicate that in the Mfolozi-Msunduzi system, *G. giurus* is more of a piscivorous feeder than a benthic feeder.

Table 25: Diet comparisons of *Glossogobius giurus* in different systems in South Africa, Australia and India.

	Mfolozi-Msunduzi system (This study)	**Mhlanga (Whitfield, 1980a, 1980b)**	**Lake Kununurra (Morgan *et al.*, 2004)**	**South-west coast of India (Geevarghese, 1983)**
Amphipoda		*		*
Bivalva		*		
Cladocera		*	*	
Copepoda	*	*	*	*
Crustacea	*	*		
Cumacea		*		
Dendrobranchiata	*			*
Fish	**	**		**
Fish scales		*		
Insect larvae		*	**	
Insecta		*	*	*
Isopoda		*		
Oligochaeta		*		
Ostracoda		*	*	
Plant material				*
Pleocyemata		*		
Polychaeta		*		
undentified material	*			

** dominant prey

Table 25 shows the diet of *G. giurus* in different systems in South Africa and elsewhere and also indicates the dominant prey item. In the Mfolozi-Msunduzi system (current study), the Mhlanga estuary (KwaZulu-Natal, South Africa) and the South-west coast of India, the species' diet was dominated by fish (Whitfield 1980a & b, Geevarghese, 1983). In Lake Kununurra (freshwater system), Western Australia, the species' diet was dominated by insect larvae (Morgan *et al.,* 2004). Although Lake Kununurra is a freshwater lake, it was included because *G. giurus* is classified as a freshwater species but is also found in estuaries. Copepods were present in the species diet in all the systems indicating that they are an important component of the diet.

Although other studies have also looked at the diet of *G. giurus*, they were excluded from Table 25 because they either did not indicate were the specimens were collected from or the taxa which it fed on. Skelton (1993) stated that juvenile *G. giurus* in freshwater feed on benthic invertebrates whereas larger individuals prey on fish and tadpoles. According to Day *et al.* (1981) and van der Elst (1988), *G. giurus* feeds on amphipods, tanaids, chironomid larvae and smaller gobies in southern African estuaries. Blaber (1980) found that *G. giurus* feeds on invertebrate benthos in the Trinity Inlet system, North Queensland, Australia. Blaber (1980) only examined specimens at 40mm SL; if he had examined specimens at different size classes, his results would probably have been different. All the prey items that *G. giurus* fed on in the Mfolozi-Msunduzi were also present in the diet of specimens from at least one other system. In conclusion, data from this and other studies indicate that *G. giurus* feeds mainly on fish. The fact that the species fed on fish in the Mfolozi-Msunduzi system was therefore not due to impoverishment with regard to the availability of the benthos, but rather due to what *G. giurus* generally prefers.

4.4.4 *Ambassis ambassis*

The overall diet of *Ambassis ambassis* in the Mfolozi-Msunduzi system was dominated by the copepod, *P. stuhlmanni,* which relates to its high abundance in the system (Table 3). The species' diet in the Mouth Area was dominated by the littoral amphipod, *O. ancheidos,* but *P. stuhlmanni* were also consumed (Table 10)*. Orchestia ancheidos* is a littoral species lurking in submerged vegetation, so the chances of it being collected in the Zabalocki benthic grab is small (Dr Vivier *pers comm*). Although low numbers of *A. ambassis* were examined in two of the three zones, results indicate that the species' diet was dominated by *P. stuhlmanni* in the Mfolozi Arm, while in the Msunduzi Arm it was dominated by *M. africana* (Table 10). Unfortunately, the low number of specimens available for stomach content analysis means that one cannot make generalizations about the species' diet. Martin (1989) suggested that *A. ambassis* can only occur in systems where salinities remain below 10 and temperatures above 15°C, but *A. ambassis* has been recorded in the St Lucia and Mfolozi-Msunduzi systems in salinities and temperatures above those suggested by Martin, which indicates that the species has a wider tolerance range than previously thought. No specimens were caught during the winter sampling, but the reason for this is unclear, because the species has previously been recorded in the Mfolozi-Msunduzi system at salinities above 10 (Dr Vivier *pers comm*). Only three specimens of *A. ambassis* were analyzed in spring and the results indicate that the species fed on *P. stuhlmanni* and *M. africana* (Table 16). In autumn, the diet of *A. ambassis* was dominated by *O. ancheidos*, which was recorded in the system during this particular season, but it was not one of the three dominant benthic species. The low numbers of this amphipod in the benthic samples is therefore not necessarily a true reflection of its abundance in the system.

The diet of *A. ambassis* in the St Lucia, Mlalazi and Mdloti estuaries was dominated by zooplankton (Martin & Blaber, 1983, Martin, 1989). In the upper Kosi system, the diet was dominated by insects (Martin & Blaber, 1983). In the Tongati estuary, the species diet was dominated by fish. It can therefore be concluded that there is a certain degree of overlap in the diet of *A. ambassis* from different systems, because, as in the above systems, the species during the present study also fed on zooplanktonic crustaceans, insects and fish, with differences in the dominant prey items.

4.4.5 *Ambassis gymnocephalus*

Ambassis gymnocephalus during the present study fed only on *P. stuhlmanni* and some material which could not be identified. The species is known to feed exclusively on zooplankton in water columns where salinities remain above 28 and temperatures above 17°C (Martin, 1989). *Pseudodiaptomus stuhlmanni* dominated the species' diet both temporally and spatially. No specimens were caught in the Mouth Area even though the salinity and temperature remained above 28 and 17°C, respectively. Jerling *et al*. (2010a) found that the densities of *P. stuhlmanni* were low when the mouth was open

(<100 ind.m^{-3}) and high when the mouth was closed (>10 000 ind. m^{-3}). During the current study, the mouth remained open for most of time and only closed in August (spring). The lower densities of zooplankton could have resulted in competition amongst different species and with *A. gymnocephalus* being excluded from the Mouth Area. No specimens were caught in summer or winter. The fact that no specimens were caught in summer can be attributed to the fact that the system was predominantly fresh throughout this period and that this species is known to be intolerant of such low salinities (Martin, 1989).

The diet of *A. gymnocephalus* in three KwaZulu-Natal estuaries, namely St Lucia, Mdloti and Durban, was dominated by crustaceans (Martin & Blaber, 1983, Martin, 1989). The diet of the species in the St Lucia estuary was dominated by *P. stuhlmanni,* except in spring when it was dominated by Brachyuran zoeae followed by *P. stuhlmanni*. It can be concluded that *A. gymnocephalus* prefers feeding on *P. stuhlmanni* since, in both the Martin and Blaber (1983) study and the current study, it was found to be the dominant prey item. Martin & Blaber (1983) classified the species as being stenophagic (feeding only on a few different food types). It can be suggested that because of this reason, the preferred food item of *A. gymnocephalus* in the system is *P. stuhlmanni,* not only due to its abundance, but also because this fish has a strong preference for *P. stuhlmanni*.

4.4.6 *Ambassis natalensis*

Specimens of *A. natalensis* were caught in all three sampling zones, but all those that were caught in the Mouth Area had empty stomachs, which could either be attributed to low food availability or to the time of feeding. No specimens were caught in summer, which could be attributed to the fact that the system was predominantly fresh in summer and the fact that the species is intolerant of low salinities (Martin, 1989).

The diet of *A. natalensis* in the Mfolozi-Msunduzi system was dominated by *P. stuhlmanni,* both temporally and spatially, but it also fed on other prey items. Martin & Blaber (1983) classified the species as being euryphagic (feeding on a wide variety of food). *P. stuhlmanni* is extremely abundant in the Mfolozi system, which probably explains why *A. natalensis* so readily utilizes this food source.

In Lake St Lucia, Durban Harbour and the Mlalazi and Mdloti estuaries, the diet of the species was dominated by crustaceans, while in the Kosi system it was dominated by insects (Martin & Blaber, 1983, Martin, 1989). The diet of the species in St Lucia was dominated by *P. stuhlmanni* during all seasons, except in spring, when the Brachyuran zoeae dominated. The species also fed on polychaetes, plant material, Insecta and fish remains in the St Lucia estuary. Day *et al.* (1981) stated that *A. natalensis* feeds on zooplankton, decapod larvae, fish larvae and amphipods. It can therefore be concluded that there was a large overlap in the species' diet between the different systems mentioned and the current study, with the major difference being the dominant prey.

4.5 Relationships between fish species diet and the benthos in Mfolozi-Msunduzi system

4.5.1 Overall

The overall benthos in the system was dominated by *P. blephariskios*, *D. arborifera* and *A. digitalis* (Figure 24b). The dominance of *P. blephariskios* was probably related to its preference of muddy substrata with a median phi of >4 (Owen *et al.*, 2000), such as recorded in the Mouth Area, during closed and low flow conditions (winter and spring), and in the Msunduzi Arm. The dominance of *D. arborifera* and *A. digitalis* is due to the ability of these organisms to colonise and inhabit fluvial sediments characteristic of river-dominated systems (Ngqulana *et al.*, 2010).

Only *L. equula, G. giurus* and *A. natalensis* fed on these dominant benthic species, albeit in small numbers. Although these benthic species were dominant, they were present in far lower densities than those found among *P. stuhlmanni,* in terms of provision of sufficient nutrition for the fish (Ngqulana *et al.,* 2010, Ngqulana *pers comm).* For example, the densities of *P. blephariskios* in the Mfolozi-Msunduzi system ranged between 68-627 ind.m^{-2}, whereas in the St Lucia system, they were recorded in densities of between 1000-1500 ind.m^{-2} (Owen *et al.,* 2010). It could, however, also be that these fish species out-competed the other species for this very limited resource.

4.5.2 Mouth Area

The benthos of the Mouth Area was dominated by *D. arborifera* and *Ceratonereis sp.* (Figure 25b). The Mouth Area is highly variable in terms of substrata due to frequent flooding which scours the mouth and removes deposited fine sediment. Most opportunistic polychaetes have the ability to recolonise disturbed sediments relatively quickly (Ngqulana *et al*. 2010). Both *A. berda* and *L. equula* fed on these dominant benthic species but it contributed very little to the total diet (<1.5%). *Ambassis ambassis* fed mainly on the amphipod *O. ancheidos*, which contributed >45% to the diet of this fish species. This amphipod species was only recorded in densities of 4 ind.m^{-2} during the benthic study (Ngqulana *et al.*, 2011). This may be attributed to the fact that benthic samples usually exclude floating plant material and *O. ancheidos* is usually found in plant wracks that drift in the water column (Whitfield, 1988).

4.5.3 Mfolozi Arm

In the Mfolozi Arm, the benthos was also dominated by the polychaetes *D. arborifera* and *Ceratonereis sp*. The Mfolozi-Msunduzi system is classified as a river mouth and river-dominated systems are susceptible to frequent flooding (Ngqulana *et al.*, 2010). The diet of *L. equula* consisted of Baetidae, Chironomidae and *D. arborifera,* but these taxa only contributed 0.3% to the total diet (Figure 26b), the remainder being made up by *P. stuhlmanni* and unidentifiable material. In contrast, the diet of *A. berda* was dominated by Chironomidae, Baetidae and Gastropod *sp.,* which comprised 47% of the diet of this species. *Glossogobius giurus* fed on *P. blephariskios,* which contributed less than 0.5% to its diet. No Gastropods were recorded in the benthic study (Ngqulana, 2011) although they were present in the species' diet in the Mouth Area. This could be attributed to fact that fish are mobile, so it is possible that the fish fed on the benthos in places away from the main channel or on marginal vegetation, where sampling was not conducted.

4.5.4 Msunduzi Arm

In the Msunduzi Arm, the benthos was dominated by *P. blephariskios,* followed by *A. digitalis* and *D. arborifera* (Figure 27b). The fish recorded here generally fed on *A. digitalis*, *M. africana*, *D. arborifera* and Baetidae. *Leiognathus equula* was the only species that fed on *A. digitalis,* but this tanaid contributed less than 0.1% to its diet, which means that it was not an important component in the diet. It is surprising that the mysid *M. africana* was not more abundant in the benthic samples, since it contributed 65% to the diet of *A. ambassis*. This could be because mysids are shoaling suprabenthic organisms, which are therefore not effectively sampled with a benthic grab or with a horizontal plankton trawl. Although only four specimens of *A. ambassis* were examined, the results do however strongly suggest that this species targets the suprabenthic mysid *M. africana* and specializes in utilizing a resource not used by other species. Mysids generally form an important component of estuarine crustacean fauna and are regarded as an important prey item for many estuarine fish (Hanamura *et al.*, 2008). The diet of *A. natalensis* was dominated by *D. arborifera*, with this polychaeta contributing less than 1.3% to its total diet. None of the fish species caught in the Msunduzi Arm fed on the most dominant benthic organism, *P. blephariskios,* which could be due to the difficulty of catching them since they burrow deep into the mud (Ngqulana, 2011). The Msunduzi substrate is characterized by deep soft mud and it is expected that the crabs are able to extend their burrows deep into the mud, making it more difficult for predatory fish to reach them. How deep *P. blephariskios* can burrow is unknown.

4.5.6 Seasonal variation

In autumn and winter, the benthic community in the system was dominated by *D. arborifera* and in spring and summer by *P. blephariskios*. River flow is lower in autumn and winter and *D. arborifera* is more abundant under low flow conditions when the substrata is relatively stable (Owen, 2003). *Paratylodiplax blephariskios* is generally more abundant in the Msunduzi Arm as the substratum is more stable due to not being affected by scouring from regular seasonal flooding (Ngqulana *et al.*, 2010, Ngqulana, 2011).

The seasonal diet of *L. equula*, *A. berda*, *G. giurus* and *A. natalensis* indicated that they fed on the dominant benthic organisms throughout the year, although the percentage contribution of benthic prey to the fish's total diet remained very low. This can be attributed to the fact that the benthos in the system remains impoverished throughout the year, with even the dominant taxa occurring in relatively low densities (Ngqulana *et al*., 2010, Owen *et al*., 2010, Vivier *et al.*, 2010a & b).

4.6 St Lucia

Leiognathus equula was the only benthic feeding fish caught in sufficient numbers in the St Lucia estuary to be used for diet analysis in this study, even though the numbers recorded were lower than in the Mfolozi-Msunduzi system. *Leiognathus equula* only contributed 2% of the fish recorded in the St Lucia system (Cyrus & Vivier, 2006a) and 5.6% of the fish recorded between 2006 and 2008 (Vivier *et al.,* 2010b), whereas it was one of the most abundant species in the Mfolozi-Msunduzi system (Vivier & Cyrus, 2009, Vivier *et al.*, 2010a).

The diet of *L. equula* in the St Lucia estuary comprised of six taxa, *A. digitalis*, *Bolttsia minuta*, *C. trianonyx*, *M. africana, P. stuhlmanni* and zoea larvae. The overall and spatial diet of the species was dominated by *P. stuhlmanni*. The diet was dominated by *P. stuhlmanni* (85%) in winter and by *A. digitalis* (55%) in summer, although both of these remained important prey species during all sampling seasons. Both these dominant prey species are highly abundant in the estuary (Jerling *et al*., 2010b, MacKay *et al*., 2010). *Pseudodiaptomus stuhlmanni* can survive in salinities of between 0 and 80 (Grindley, 1981), whereas *A. digitalis* thrives at salinities ranging from about 40 to 60 before its abundance decreases (MacKay *et al.,* 2010). As salinities in the Narrows during both sampling seasons, where most *L. equula* were recorded, were below 14, the difference in the dominancy of the two prey species could not have been related to salinity. *Apseudes digitalis* is regarded as an opportunistic species (Cyrus & Wepener, 1997) which is known to quickly colonise areas where the dominant taxa have been removed due to disturbances (Vivier & Cyrus, 1999). It is therefore possible that there could have been some form of disturbance in the Narrows before the summer sampling trip allowing for the rapid colonization of *A. digitalis* in these areas.

Pseudodiaptomus stuhlmanni and *Acartia natalensis* numerically dominated the mesozooplankton in the St Lucia estuary with high densities of *P. stuhlmanni* being recorded in the estuary when the mouth was closed (Jerling *et al.*, 2010b). *Apseudes digitalis* was present throughout the system and numerically dominated in South Lake and the Narrows (MacKay *et al.*, 2010). *Apseudes digitalis* prefers sandy substrata (Reavell & Cyrus, 1989), which occurs in certain parts of the South Lake and the estuary. The abundance of *P. stuhlmanni* and *A. digitalis* in the system probably accounts for them dominating the diet of *L. equula*, which implies that the species will utilize benthic prey if they are available in sufficient numbers.

A total of 103 taxa of benthic species were recorded in the St Lucia system (MacKay *et al.,* 2010). The most abundant Phylum in the estuary was Annelida (36%), which included oligochaetes, polychaetes and Hirudinea. Although these taxa were abundant, they occurred in far lower densities than *A. digitalis. Apseudes digitalis* contributed no less than 41% to average abundance in all areas sampled during each survey (MacKay *et al.,* 2010). Due to the high densities of *A. digitalis*, the probability of *L. equula* feeding on them was great.

There was an overlap in the diet of *L. equula* from the St Lucia estuary and Mfolozi-Msunduzi system, with overall diet in both systems being dominated by *P. stuhlmanni* (Figure 35). The species also fed on *A. digitalis* in both systems, although in the Mfolozi-Msunduzi system it contributed very little to the species' overall diet. This is attributed to the fact that the benthos of the Mfolozi-Msunduzi system is impoverished and *A. digitalis* was present in very low densities when compared to the St Lucia estuary densities (Ngqulana, 2011). The benthos of St Lucia is much richer, providing predators with a wider choice of organisms to feed on than in the Mfolozi-Msunduzi system. The diet of *L. equula* in both systems was, however, dominated by *P. stuhlmanni, suggesting* that copepods are *L. equula's* preferred food source.

According to Whitfield (2000), Durban harbour is classified as an Estuarine Bay, while the St Lucia system is an Estuarine Lake. The diet of *L. equula* in both systems was similar; Blackler *et al.* (2004) found that the diet of *L. equula* in the Durban harbor, at between 80-100mm SL, was dominated by *A. digitalis*. The specimens that were examined in the St Lucia estuary were between 80 and 120mm SL and *A. digitalis* was the second most dominant prey item in their diet.

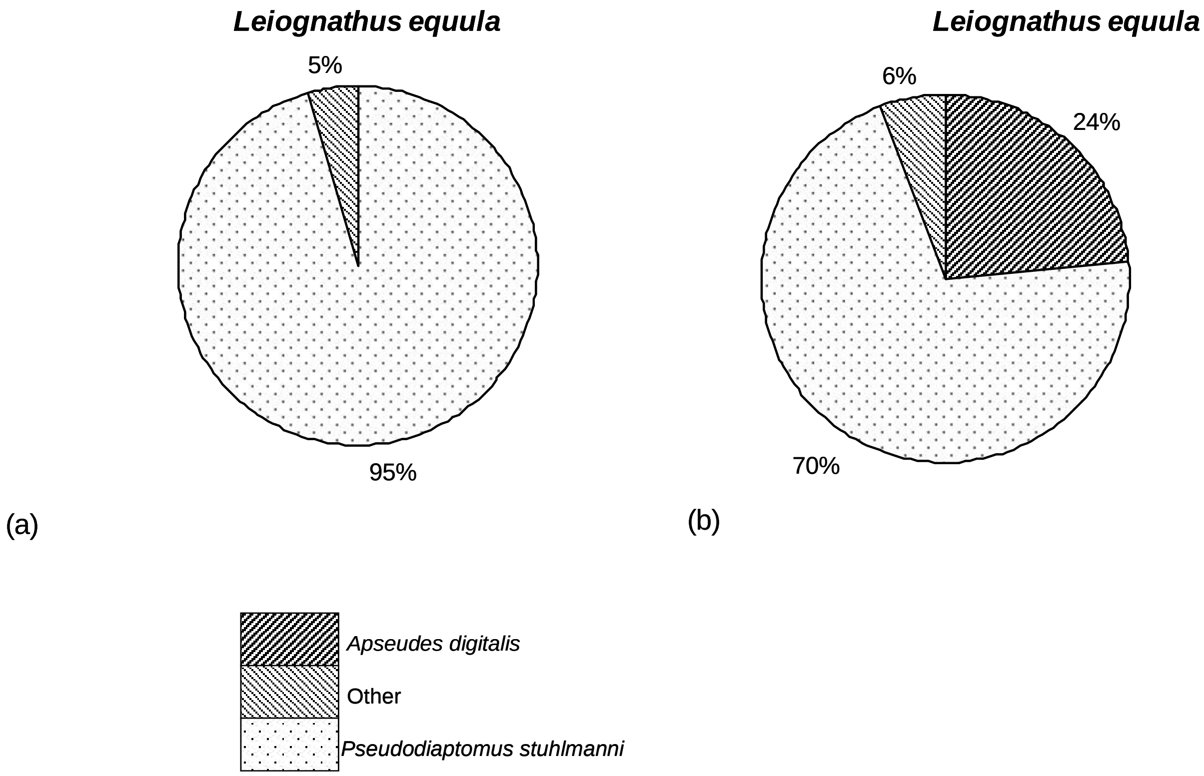

Figure 35: Diet comparisons of *L. equula* in two systems: (a) Mfolozi-Msunduzi system, (b) St Lucia system

During this study, comparisons were made of the diet of *L. equula* in four types of estuaries, namely River mouth (Mfolozi-Msunduzi system), Estuarine Lake (St Lucia system), Estuarine Bay (Durban Harbour) and temporally open/closed system (Mhlanga). In all, except the Mhlanga estuary, copepods dominated the species' diet. Although copepods were not dominant in *L. equula's* diet in the Mhlanga estuary, they were also present. It can therefore be concluded that the diet of *L. equula* was similar, regardless of the estuary type, as in all types they fed on copepods, although in the Mhlanga estuary copepods were not the dominant prey item.

4.7 Summary

The St Lucia system is the largest estuary and therefore the largest estuarine nursery area in KwaZulu-Natal (Cyrus *et al*., 2010a). The mouth of the system has been closed since 2002 due to a drought. Although the country is not currently experiencing a drought, current rainfall in the area and runoff from the catchment floods (2011) have been insufficient to raise water levels to desirable levels or to open the mouth. The ongoing closure of the mouth means that marine spawning fish species that utilize the system as a nursery ground have to seek alternative nursery habitats. The Mfolozi-Msunduzi system is the closest system to the St Lucia and appears to have been acting as an alternative refuge for species which cannot access the St Lucia system (Vivier & Cyrus, 2009). Vivier and Cyrus (2009) found that the species that dominated the Mfolozi-Msunduzi system were those that usually spawn in the marine environment, with juveniles showing varying degrees of dependence on estuaries with many of them having both a planktonic and benthic feeding phase. Unfortunately, the Mfolozi estuarine system consists of only about 0.5% of the surface area of the St Lucia system and therefore it is a relatively inadequate alternative nursery area compared to St Lucia.

The benthic feeding fish that occur in the Mfolozi-Msunduzi system, according to Whitfield’s (1998) categories, are either Category I or Category II species. Category I are estuarine resident species which breed in South African estuaries (Whitfield, 1998). Category II are euryhaline marine species which usually breed at sea and show varying degrees of dependence on South African estuaries. The presence of Category I and II species in the Mfolozi-Msunduzi system indicates the important role it plays as a nursery area. Nhleko (2008) reported that out of the 56 species that were recorded in the system, 25% belonged to Category I and 52% to Category II, showing that the system is an important nursery area, particularly for euryhaline marine species.

Juveniles of marine fish are known to utilize estuaries because these areas have calm and shallow waters, high food availability and their generally turbid waters offer a form of protection against predators (Blaber & Blaber, 1980). The Mfolozi-Msunduzi system is regarded as one of the most turbid and muddy estuaries in South Africa (Lindsay *et al*., 1996). Cyrus and Blaber (1987c) argued that there is higher food availability and a higher benthic biomass associated with turbid estuarine waters. The mean biomass of the benthic invertebrates in the Mfolozi-Msunduzi system was higher (11.20g m^{-2}) than the neighbouring St Lucia (2.63 gm^{-2}) (Blaber *et al.*, 1983). This can be attributed to the fact that the Mfolozi-Msunduzi was dominated by the crab, *P. blephariskios,* which is much larger in body size when compared to other benthic invertebrates (Ngqulana, 2011). Even though the biomass was high, the system was relatively poor in species richness and abundance (Ngqulana *et al.,* 2010, Owen *et al.,* 2010). The low species richness is characteristic of river-dominated systems that are subject to disturbance by periodic flooding (Wooldridge & Deyzel, 2009). Very few fish fed on *P. blephariskios* because of the difficulty of catching them.

Zooplankton played a very important role in the diet of the fish species examined. The diets of all the species, with the exception of *G. giurus*, were dominated by the copepod, *P. stuhlmanni*. The importance of zooplankton to the diet of fish should therefore not be understated, since these fish species are generally regarded as benthic feeders. Most of the fish species that were examined in the current study were in their juvenile or subadult stages and Whitfield (1985) found that zooplankton was an important dietary component of juvenile fish. The reason for this is the fact that zooplankton have a higher energy content than benthic invertebrates due to their ability to store large amounts of lipids (Norrbin & Bamstedt, 1984). In the Mfolozi-Msunduzi system, not only the juveniles but also the adults of the dominant fish species such as *L. equula* fed on zooplankton, although their diet also consisted of a very small portion of the available benthic invertebrates. The findings of this study support the previous reports in the literature, namely that the benthos of the Mfolozi-Msunduzi system was impoverished, and suggests that only those benthic feeding fish species that are able to shift to a plankton diet were able to thrive.

The Mfolozi-Msunduzi system is dominated by marine spawning species (Vivier & Cyrus, 2009), which is a common characteristic of South African estuaries (Whitfield, 1998). During periods when the mouth of the St Lucia system is closed, the relatively high species number and abundance of fish in the Mfolozi-Msunduzi system is indicative of its importance as an alternative nursery area. The system often accommodates high numbers of benthic feeding fish even though the benthos is impoverished (Vivier & Cyrus, 2009, Owen *et al*., 2010, Ngqulana *et al*., 2010). Vivier and Cyrus (2009) found that, other than *L. equula*, many of the benthic species in the system disappear soon after reaching their post larval phase. This was suggested to be related to the fact most benthic feeders start off by feeding on zooplankton as juveniles and then switch over to benthic organisms as they grow older. *Leiognathus equula* appears to be more adaptive and therefore better able to adapt to an alternative food resource, as compared to the other benthic feeding fish recorded in the system, which is why it can survive in the Mfolozi-Msunduzi system. In this regard, the current study corresponds to other studies which have shown that this species prefers copepods even where benthic organisms are abundant. Therefore benthic feeders that can flourish in the Mfolozi-Msunduzi are those that are able to adapt their diet and can feed on anything if their preferred prey item is not available.

4.8 Management of the Mfolozi-Msunduzi and St Lucia systems in terms of benthic feeding fish

The anthropogenic activities associated with the separation of the two systems which took place over 50 years ago (Taylor, 2006), have negatively impacted on both the St Lucia and Mfolozi-Msunduzi systems (Cyrus *et al*., 2010a & b). Cyrus (1992b) stated that all pressures that estuaries face can in one way or the other be considered under the heading Habitat Destruction.

As such, the factors which place the most pressure of the Mfolozi-Msunduzi ecosystem comprise physical changes to the system as well as increased nutrient input.

Chili (2008) suggested that the discharge of chemicals and nutrients in the Mfolozi-Msunduzi system originate mainly from sugar cane farmlands surrounding the system, yet which have little effect on the water quality of the system. Physical activities that have affected the system include the canalization and drainage of the wetland for agricultural purposes and water abstraction for mining purposes by Richards Bay Minerals (RBM) (Lindsay *et al*., 1996). However, it has been found that the excessive sedimentation caused by poor catchment practices combined with the removal of the Mfolozi swamp, has more negative effects than anything else (Chili, 2008).

Such anthropogenic activities place tremendous stress on aquatic ecosystems (Cyrus, 1992b). The Mfolozi-Msunduzi system is prone to flooding, which results in large amounts of sediments being deposited in the system (Lindsay *et al*., 1996). Historically the Mfolozi swamps acted as a filter which allowed only sediment-free water to pass through. This means the sediment load carried by the water was lower than what it currently is and the bottom sediments in the Mfolozi-Msunduzi system were therefore probably more stable than at present. Currently the Mfolozi Msunduzi system is one of the most turbid systems in South Africa (Lindsay *et al*., 1996) and its benthos is impoverished while that of the St Lucia system is diverse. There are no records of the benthos and fish fauna of the Mfolozi-Msunduzi system prior to sugarcane farming and the canalization of the river system, but it is believed that the benthic fauna prior to canalization would have been more diverse. Benthic fauna are closely associated with the substrata and during frequent and severe flooding they are flushed away. Therefore invertebrates that dominate in flood prone systems are those that can quickly recolonize.

Cyrus (1992b) stated that the priority fish species in terms of estuarine conservation are Category I and Category II species since they are directly

dependant on estuaries. All the benthic feeding fish from the Mfolozi-Msunduzi system that were examined during this study belong to these two categories, indicating the importance of the system as a nursery area
The St Lucia Estuary is regarded as the most important estuarine system on the south-east coast of southern Africa as a nursery area, because of its large size (350km^2) (Begg, 1978). With the mouth of the system currently being closed, species that depend on it as a nursery area cannot access it. Vivier and Cyrus (2009) suggested that the Mfolozi-Msunduzi system acts as an alternative nursery area for marine spawning fish. Historically, the Mfolozi-Msunduzi and St Lucia system shared a common mouth and during times of droughts, water from the Mfolozi-Msunduzi would divert up the St Lucia estuary into the lake system and replace water lost through evaporation. Options on how to reconnect St Lucia to the sea is currently a much debated topic among conservation and research agencies. Therefore, any management actions taken in the Mfolozi-Msunduzi system must take into consideration the role that it historically played when it still shared a common mouth with the St Lucia system. Scientists from different fields have come up with different solutions on how to manage the two systems.

Kelbe and Taylor (2011) stated that the entire foodplain should be restored and if that is not a feasible option (and sugarcane farming continues), then other steps should be taken:

1. Maintain the two mouth condition for St Lucia and the Mfolozi and divert the Mfolozi water via the back channel only if the mouth of the Mfolozi is closed and the lake level is low.
2. Maintain the level of the water in the lower floodplain so that it functions as a sediment trap. There also needs to be a controlling structure, such as a natural spillway to control the flood waters entering the back channel. Not only will the spillway act as sediment trap, but it will also prevent St Lucia water from flowing into the Mfolozi whenever the water level is higher in the St Lucia than in the Mfolozi. Therefore the spillway will enable managers to maintain a two-mouth system, where the flood-waters flush directly out to sea and the water can be diverted into St Lucia during low flows.

3. Low lying farms in the Mfolozi floodplain would require protection from back-flooding, which can be accomplished by farmers developing a polder system. The polder system is potentially a good system, but with it there would be a necessity for pumping to remove irrigation and rainwater that accumulates in the fields.

Knox *et al.* (2011) identified insufficient flow as being a major problem in the St Lucia system and proposed a number of solutions to the problem.

1. <u>Transfer water from Pongolapoort Dam</u>

There is already infrastructure in place that will allow the release of water from the Pongolapoort Dam into the Mkuze River catchment, entering the lake system at the head of North Lake. Advantages of such a system is that flow can be diverted almost immediately because the infrastructure is already there.

2. <u>Rehabilitate and complete the Mfolozi-St Lucia link canal</u>

This could be achieved by re-instating and modifying the link canal that was started in the early 1980s and which was damaged by cyclone Demoina. Modification of the canal's intake would be required in order to create better diversion conditions and better silt exclusion, plus the inclusion of a sedimentation bay behind it, allowing only sediment free water to flow from the Mfolozi to the St Lucia estuary during times of medium to low flows. In times of high flow, the canal would have to be isolated to prevent a large intake of sediment and back-flooding from the Mfolozi River, downstream of the intake.

3. <u>Rehabilitation of a small portion of the floodplain</u>

This would involve rehabilitation of the lower portion of the Mfolozi floodplain that becomes inundated during periods of mouth closure. Water will be filtered by the backup of the water in the lower Mfolozi and Msunduzi River floodplains where most of the sediments would be deposited.

4. <u>Construction of a dam on either the Mfolozi or Mkuze Rivers</u>

Constructing a dam on the Mfolozi is probably the most feasible and advantageous of all the options but it would be the most expensive option and take the longest to construct. Water from the dam could be transferred into the Nyalazi River which discharges into False Bay.

The Mkuze catchment is smaller than the Mfolozi, so it will not be able to support as large a dam. A smaller dam implies that the floods and sediment load will be smaller, which potentially makes it a cheaper option.

5. Rehabilitation of catchments

Rehabilitation of catchments is the most logical and least environmentally invasive option, but it would impact on the people that live in the area and depend on the agriculture that takes place there.

Other options that have been brought forward include reconnecting the two systems so that they can have a common mouth (Taylor & Whitfield, 2009, Owen *et al*., 2010, Cyrus *et al*., 2011, Knox *et al*., 2011). Reconnecting the two systems would require the re-establishment of the Mfolozi floodplain as an effective flood control barrier, which would allow only sediment-free water to pass through by trapping the sediments (Owen et al., 2010). Some of the farmlands would have to be rehabilitated and the farmers compensated, which would be expensive, requiring Government backing. Re-establishment of the floodplain can be avoided by allowing the mouths of the two systems to reconnect naturally (Dr Vivier *pers comm*). This would allow water from the Mfolozi-Msunduzi to the St Lucia system during low flow conditions and also allow it to flow out to sea during flooding conditions.

Reclamation and rehabilitation of low-lying swamplands which have been lost to agriculture could alleviate some of the ecological stresses affecting Lake St Lucia (Cyrus *et al.*, 2011), but will have negative effects on the farmers that are dependent on agriculture for their survival.

Reconnecting the two systems will result in the low-lying farms becoming more susceptible to flooding (Whitfield & Taylor, 2009) and more sediment will end up in system. The ideal situation would be to re-establish part or all of the Mfolozi swamps in order to filter the water, as it did in the past, and allow only sediment-free water to pass through. Since there are people that are dependent on the farming that occurs in the Mfolozi swamp, a detailed environmental economic assessment would have to be undertaken to compare the economic values of the wetland in its intact form as opposed to the drained wetland with its productive sugar plantations and associated economic network (Whitfield & Taylor, 2009).

All the options discussed above could potentially work, with the exception of dam construction on the Mfolozi River. Construction of the dam would benefit the communities surrounded by the dam but would have detrimental environmental effects for organisms. Organisms that migrate from the river to the estuary or sea, in order to complete their life cycles, would be prevented from doing so by the dam wall. Building a fishway might work, but it would not be successful for all species. All of the other proposed solutions have some disadvantages and therefore it is important that, before any management actions are taken, all the advantages and disadvantages of the different options should be considered. All the social and economic aspects should also be taken into account and whatever management actions are eventually taken should aim to accommodate all affected stakeholders as much as possible.

The closed mouth condition of the St Lucia system prevents benthic feeding fish that spawn in the marine environment and require the estuarine environment to complete their life cycle, from accessing the system and feeding on the system’s rich benthic fauna. These benthic feeding fish are then forced to enter the Mfolozi-Msunduzi system (which is the closest to the St Lucia system) whose benthic fauna is impoverished. Only those that are able to adapt to the impoverished state of the benthos are able to survive.

The proposed solutions by different authors in managing the two systems will contribute in maintaining the benthic feeding fish species in the following ways:

1. If the two systems are connected and the mouth of the St Lucia system eventually opens, this will give these species access to the system and they will be able to survive there because its benthic fauna is richer than that the Mfolozi-Msunduzi system. Probably the benthic species

from the St Lucia system would also be able to recolonize the Mfolozi-Msunduzi system, increasing the food available for fish.

2. Keeping the mouths separate and restablishing parts or all of the Mfolozi swamps, would result in the substrata of the Mfolozi-Msunduzi being more stable since the sediment load carried by the water during floods would filtered by the swamps. Stable sediments would result in more benthic fauna being able to recolonize the system and therefore more food would be available for fish to feed on. This would also probably increase the species of benthic feeding fish species and their survival.

Chapter 5

5.1 Conclusions

The results of this study have indicated that the Mfolozi Msunduzi system provides an alternative nursery area to the closed St Lucia, since most of the benthic feeding fish were marine spawning species that require estuaries in order to complete their life cycles.

The fish of which the diet was analyzed in the current study are generally regarded as benthic feeding fish, but their diets were dominated by copepods, with the exception of *G. giurus,* which was more of a piscivorous feeder.

Although the species’ diets were not dominated by benthic prey items, they did feed on them, with the exception of *A. gymnocephalus,* which fed entirely on zooplankton. Benthic prey items did not form a significant component in the diet of most of the species, contributing less than 1.2% to the overall diet. These fish species included *L. equula*, *A. berda*, *G. giurus* and *A. natalensis,* with *A. ambassis* being the only species in which benthic prey items contributed almost 30% to the overall diet.

Leiognathus equula, which was the most abundant species in the system during the current study, was able to adapt to the impoverished benthos by switching over their diet to a planktonic diet. The copepod, *P. stuhlmanni*, contributed over 90% to the overall diet of the species.

In both the St Lucia and Mfolozi-Msunduzi systems, the diet of *L. equula* was dominated by *P. stuhlmanni,* even though the St Lucia system is rich in benthos. Most of the studies that looked at the diet of *L. equula* found that the diet of the species was dominated by copepods.

Due to the impoverished benthos, the benthic feeding fish that can thrive in the Mfolozi-Msunduzi system are those that are able to adapt their diet and utilize alternative food resources such as plankton or whatever else is available in the system.

5.2 Recommendations

Management actions should be taken that will result in minimized sediment deposition, through proper catchment management, and reclaiming the lower Mfolozi floodplain, as the majority of the fish in the system are dependent on benthos.

Further research is needed on the survival strategy of benthic feeding fish of the Mfolozi-Msunduzi system. Vivier and Cyrus (2009) found that the benthic feeding fish disappear after their planktonic feeding phase. For this reason, further research needs to be done to determine whether these species migrate back to sea because they are unable to survive in the estuary or die because of the shortage of food.

The benthic feeding fish that occur in the Mfolozi-Msunduzi system are mainly Category II species according to Whitfield’s classification (Whitfield, 1994, 1998). Category II species are species that spawn in the marine environment and show varying degrees of dependence on estuaries. The only benthic feeding fish that was abundant in the Mfolozi-Msunduzi system was *L. equula*; all the other species were recorded in far lower numbers. Further research is needed to find out where exactly these fish species spawn because it is possible that they spawn far from the system. Research also needs to be done to determine the offshore adult population in relation to the post larvae being recruited into the system because a decline in the adult population results in a reduction in the number of juveniles.

Research also needs to be done on other systems that are close to the St Lucia and Mfolozi-Msunduzi systems in order to determine their benthic feeding fish composition because it is possible that these species could be more abundant and thriving in those systems due to higher macrobenthic diversity.

These benthic species are present in the system in such low numbers because of the impoverished state of the benthos. If this is truly the case, the Conservation Managers involved with the Mfolozi-Msunduzi and the St Lucia systems need to find a solution as soon as possible to open the mouth of the St Lucia system. This is necessary, not only because it would provide a far larger nursery area, but its benthos is much richer, thereby providing benthic feeding fish with a wider selection of organisms.

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Chapter 7: Appendix

Appendix 1: Physico-chemical parameters recorded in the Msunduzi-Mfolozi system during the sampling periods.

Site	Temp	Salinity	pH	DO(mg./L)	Oxygen %	Turbidity(NTU)	Depth
83S1	17.90	5.40	8.09	7.90	86.80	36.90	1.40
83S2	18.40	5.40	8.09	7.67	84.60	15.10	1.10
83S3	**19.90**	**4.90**	**8.02**	**6.27**	**74.90**	**28.50**	**1.20**
83S4	18.74	3.00	7.96	6.30	69.20	27.00	1.46
91F1	**26.12**	**34.64**	**8.50**	**9.63**	**140.50**	**16.9**	**0.75**
91F2	26.38	34.67	8.49	9.27	139.80	41.3	1.34
91F3	27.46	30.00	8.46	9.05	136.90	214.0	1.20
91F4	**28.52**	**0.17**	**8.12**	**8.19**	**105.70**	**158.0**	**2.00**
91F5	28.32	0.16	8.02	8.24	106.00	169.0	1.25
91F6	28.30	0.15	7.95	8.13	104.50	216.0	1.40
91S1	26.59	29.50	8.49	9.20	135.30	66.6	1.09
91S2	27.20	25.20	7.84	6.19	100.90	140.0	0.79
91S3	**29.06**	**3.81**	**8.09**	**8.26**	**109.80**	**540.0**	**1.10**
91S4	28.91	2.39	7.93	6.85	87.90	622.0	1.40
92F1	**22.87**	**34.05**	**8.88**	**11.38**	**158.90**	**4.80**	**0.44**
92F2	21.69	33.91	8.71	10.34	143.30	1.00	1.27
92F3	20.44	27.11	8.48	9.84	127.40	16.90	1.59
92F4	**20.92**	**29.62**	**8.42**	**9.43**	**125.70**	**18.00**	**1.62**
92F5	20.36	13.49	8.38	9.39	112.80	15.00	0.70
92F6	19.60	6.10	8.41	9.86	111.60	15.10	1.32
92S1	20.03	22.31	8.39	10.44	133.20	59.00	0.91
92S2	20.24	24.68	8.47	9.35	141.70	0.39	0.39
92S3	**19.02**	**1.31**	**8.14**	**10.03**	**112.90**	**76.00**	**0.77**
92S4	18.68	1.05	7.86	7.34	79.10	75.20	1.50
93F1	**19.90**	**32.98**	**8.22**	**6.86**	**90.90**	**58.70**	**0.50**
93F2	19.48	27.78	7.92	7.35	94.00	34.20	0.96
93F3	20.02	29.05	7.93	7.05	91.60	45.20	1.24
93F4	**20.03**	**29.64**	**8.05**	**5.92**	**76.90**	**11.10**	**1.99**
93F5	20.25	25.32	7.91	3.58	47.80	10.70	1.80
93F6	19.27	8.17	7.82	4.02	48.70	38.60	1.91
93S1	18.72	15.95	8.12	7.88	93.20	17.70	0.97
93S2	18.74	13.87	8.13	7.50	87.30	70.30	0.66
93S3	**19.18**	**16.24**	**8.15**	**6.89**	**81.80**	**31.60**	**0.95**
93S4	19.74	16.41	8.22	6.90	82.90	34.00	1.40
94F1	**24.96**	**0.17**	**8.62**	**10.75**	**130.2**	**1287.80**	**0.417**
94F2	25.01	0.16	8.52	10.54	127.1	1288.00	1.261
94F3	25.37	0.19	8.23	9.47	114.2	1291.00	0.640
94F4	**25.26**	**0.13**	**8.18**	**9.98**	**100.0**	**1290.10**	**0.677**
94F5	25.80	0.12	8.18	9.72	117.8	1287.50	2.370
94F6	24.88	0.12	8.15	9.71	117.5	1289.80	0.850
94S1	25.97	0.38	8.65	10.78	133.1	479.40	0.955
94S2	26.51	1.28	8.61	8.92	105.4	116.90	0.664
94S3	**26.61**	**0.94**	**8.38**	**9.18**	**116.8**	**206.50**	**0.740**
94S4	26.20	0.89	8.27	9.24	111.1	80.80	1.219
101F1	**26.94**	**29.6**	**8.05**	**6.24**	**92.4**	**92.4**	**0.80**
101F2	26.61	27.69	8.06	6.36	92.6	92.6	0.75
101F3	28.17	0.28	7.94	7.28	93.4	93.4	0.85
101F4	**27.08**	**0.24**	**7.97**	**6.93**	**87.2**	**87.2**	**1.13**
101F5	27.27	0.21	7.81	6.96	88.0	88.0	1.75
101F6	26.90	0.20	7.76	6.94	87.1	87.1	1.20
101S1	26.09	21.42	8.04	6.42	89.4	89.4	0.77
101S2	26.62	0.53	8.02	6.96	87.1	65.7	0.50
101S3	**26.37**	**1.10**	**8.00**	**5.37**	**65.7**	**71.8**	**0.84**
101S4	26.66	0.92	7.89	6.11	71.2	76.8	0.65