The diet of juvenile *Sillago sihama* (Forsskal, 1775) from three estuarine systems in KwaZulu-Natal

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Abstract

The diet of *Sillago sihama*, a species whose juveniles occur regularly in KwaZulu-Natal estuaries, was investigated in Richards Bay, Durban Bay and Mlalazi Estuary. The species was carnivorous in all three systems, with a distinct size-related change in diet being noted. Small individuals (<60 mm SL) consumed primarily planktonic prey (mainly larvaceans and copepods) whilst larger specimens fed on benthic crustaceans, polychaetes and bivalve siphon tips. Although the prey consumed by *S. sihama* from different systems was similar, the trends of increasing reliance on benthic food sources with size differed. Fish from Mlalazi began feeding on benthos at a smaller size than those from Richards Bay and Durban Bay. This is ascribed to potentially higher plankton densities in the harbours due to animals from the marine environment being swept in through the deep entrance channels.

Introduction

No research has been conducted on the diet of *Sillago sihama* in South African waters. Although not a dominant species, it is fairly common in a number of KwaZulu-Natal estuaries, extending as far south as Knysna, Western Cape (Smith and Heemstra, 1991). The species distribution in KwaZulu-Natal estuaries appears to be inversely related to turbidity, with most frequent occurrence and highest densities being recorded in clear water systems (personal observation) and as a result of the lack of information on the species diet from estuarine localities on the East Coast of Africa, it was considered important to initiate this study.

Studies from elsewhere in the Indo-Pacific have described contrasting diets for *S. sihama* from different regions. Chako (1949) and Radhakrishnan (1957) have reported that adult fish from Mannar Gulf and Palk Bay, India, are omnivorous. Gunn and Milward (1985), however, found no evidence of an omnivorous diet but rather a carnivorous one in juvenile and adult *S. sihama* sampled from beaches and estuaries in the Townsville region of Australia. Given these contrasting results it is unlikely that the role of this species in the food webs of KwaZulu-Natal estuaries can be inferred confidently from studies conducted in other regions. This provided a further reason for this study.

Materials and methods

Sampling

A summary of the location and description of study sites, dates of sampling, sample size and range of fish size classes caught is given in Table 1. Both Richards Bay and Durban Bay are large, shallow estuarine systems which have been modified to form deep-water harbours (Hay et al., 1993a and b). As such they now have wide, deep, permanently open mouths. Mlalazi Estuary is a much smaller system with a narrow shallow mouth that is usually open. Sampling was undertaken as part of a general survey of the fish fauna of the three systems, during daylight hours over high tides. Fish were captured using a seine net (70 m x 2 m x 12 mm bar mesh) deployed from a motor boat and hauled ashore manually. *Sillago sihama* were separated from the rest of the catch and preserved immediately in 10% formalin.

Laboratory

Standard length (SL) of each fish was measured to within 10 mm classes and the alimentary tracts removed. The percentage fullness of each stomach was estimated and the contents examined using a binocular microscope. Food items were identified to the lowest possible taxon and counted. The amount of each food type in individual stomachs was measured using a modification of the method of Hellawell and Abel (1971), in which the volume flattened between two microscope slides one millimetre apart was estimated. To facilitate the estimation of the volume of food, a 1 mm x 1 mm graph-paper grid was attached to the under-side of the bottom slide. Unit depth allowed volume to be extrapolated directly by counting the number of 1 mm^2 squares that were obscured by each particular food type.

Hyslop (1980) has emphasised the need to employ more than one method of dietary analysis. Accordingly stomach contents of *S. sihama* were analysed using three such methods:

- Frequency of occurrence: the number of stomachs in which each food item occurred was counted and expressed as a percentage of the total number of stomachs containing food.
- Numerical occurrence: the number of individual prey items in each food category was expressed as a percentage of the total number of individuals in all food categories.
- The points method of Ricker (1968): points were allocated to each food category according to the volume it represented in relation to that of all food groups in each stomach and the estimated percentage fullness of the stomach:

  Points = (Vol.1/Vol.2) x % fullness

  where Vol.1 = volume of food category in stomach, and
  Vol.2 = volume of total stomach contents.

  This method gives an approximate volumetric analysis of diet.

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TABLE 1
SAMPLE SITES, DATES OF SAMPLING, NUMBER OF *SILLAGO SIHAMA* AND RANGE OF SIZE CLASSES (20mm STANDARD LENGTH GROUPINGS) NETTED

Name	Location	Description	Month	No	Size range
Durban Bay	29°53'S 31°01'E	Embayment	6/1 10/91	52 33	21-160 mm
Richards Bay	28°49'S 32°05'E	Embayment	5/91 11/91	64 12	41-160 mm
Mlalazi Estuary	28°58'S 31°48'E	Open estuary	2/92 4/92	7 13	21-140 mm

TABLE 2
SUMMARY OF THE STOMACH CONTENTS OF *SILLAGO SIHAMA* FROM THREE LOCALITIES IN NATAL EXPRESSED BY FREQUENCY OF OCCURRENCE (FRE%), NUMERICAL OCCURRENCE (NUM%) AND PERCENTAGE CONTRIBUTION TO VOLUMETRIC POINT SCORES (VOL%). THE THREE MOST DOMINANT FOOD ITEMS IN EACH ANALYSIS IN BOLD AND UNDERLINED.

Food item	fre%	num%	vol%
Larvacea	**<u>19.05</u>**	**<u>53.81</u>**	**<u>14.61</u>**
Copepoda	**<u>51.70</u>**	**<u>34.79</u>**	**<u>22.23</u>**
Mysidacea	3.40	0.20	1.04
Amphipoda	3.40	0.13	0.14
Natantia	5.44	0.28	3.75
Callianassa kraussi	3.40	0.15	4.70
Brachyura	5.44	0.20	7.19
Decapod larvae	11.56	**<u>6.21</u>**	2.07
Unidentified decapoda	10.20	0.48	5.24
Nemertea	14.29	0.55	7.44
Polychaeta	**<u>35.37</u>**	2.57	**<u>26.68</u>**
Bivalvia (siphons)	9.52	0.60	4.37
Teleostei	0.68	0.03	0.56
Contribution of three most dominant items	76.19	94.81	63.52
No. fish examined = 181 No. feeding fish = 147 (81.2%)			

Results

Diet of *S. sihama*

In all, 34 (18.8%) of the 181 fish sampled had empty stomachs. The frequency of occurrence of different prey items and their proportional contribution to the diet by numerical occurrence and volumetric points analyses are summarised in Table 2. With few exceptions, food items were similar in all three systems studied. Copepods were found in more than half the fish with food in their stomachs. Polychaetes were the next most frequently occurring prey. Of all fish with food in the stomachs, 76.2% had preyed either on copepods, polychaetes or larvaceans, or on some combination of these food items. Only one *S. sihama*, sampled in Durban Bay, had fed on a teleost (an unidentified species of goby), although fish scales did occur in the gut of a single specimen from Mlalazi.

Numerically, larvaceans and copepods accounted for 88.6% of all food items. Copepod prey was dominated completely by marine calanoids, mainly of the genera *Eucalanus, Calanoides* and *Paracalanus*. Decapod larvae, at various stages of development, were also eaten in large numbers and, with larvaceans and copepods, accounted for 94.8% of the total number of prey items in all *S. sihama*.

All these small-bodied planktonic organisms contributed significantly to the numbers of prey items found in *S. sihama*. In terms of volumetric points, however, they accounted for a much reduced proportion of the prey taken. Larger-bodied benthic organisms contributed little numerically but accounted for high proportions of the diet when expressed by the points method. For instance, polychaetes made up only 2.6% of the total number of prey taken but contributed the highest volumetric point score of any single food category (26.7%), with copepods second (22.2%). Indeed, larvaceans, polychaetes and copepods together constituted 63.5% by the volumetric points method (Table 2). Identification of polychaetes was hampered by maceration and digestion, but it appeared that errant species such as *Glycera* and *Dendronereis* spp., as well as *Phyllodoce castanea*, dominated this food group.

Effects of size on diet of *S. sihama*

The diet of *S. sihama* changed markedly with growth. Food items taken by different size classes (20 mm SL groups) are shown for all methods of analyses in Table 3. Larvaceans were numerically and volumetrically dominant in the diet of small fish. They became progressively less important in larger size classes, especially in terms of the volumetric points method. Copepods occurred more frequently than any other prey in fish size classes of 21 to 100 mm. They were numerically dominant in the diets of fish in the three size classes from 81 mm to 140 mm but contributed the highest proportion of volumetric points only in the 81 to 100 mm size class.

Polychaetes were most frequently encountered, and dominated the point scores, of prey taken by the size classes 61 to 80 mm and 101 to 140 mm. Only large crustaceans (unidentified decapods, *Callianassa kraussi* and brachyurans) were found in the stomachs of the largest *S. sihama* (141 to 160 mm). Brachyurans prevailed in this size class in terms of all analyses employed.

TABLE 3
DIET OF DIFFERENT SIZE CLASSES OF FISH FROM ALL SYSTEMS BY FREQUENCY OF OCCURRENCE (FRE%), NUMERICAL OCCURRENCE (NUM%) AND PERCENTAGE CONTRIBUTION TO POINT SCORES (VOL%); (-=ZERO NEG = NEGLIGIBLE PROPORTION (<0.01%))

	Size class																				
	21-40 mm			41-60 mm			61-80 mm			81-100 mm			101-120mm			121-140 mm			141-160 mm		
Food item	fre%	num%	vol%	fre%	num%	vol%	fre%	num%	vol%	fre%	num%	vol%	fre%	num%	vol%	fre%	num%	vol%	fre%	num%	vol%
Larvacea	75.00	83.40	54.92	54.55	82.66	41.51	11.76	51.05	8.93	6.90	12.19	0.72	5.00	5.70	0.09	-	-	-	-	-	-
Copepoda	83.33	16.35	26.46	77.27	16.79	30.10	35.29	36.82	15.30	65.52	63.53	44.85	55.00	60.62	16.08	33.33	53.21	3.69	-	-	-
Mysidacea	-	-	-	-	-	-	5.88	0.84	3.57	10.34	0.37	1.58	-	-	-	-	-	-	-	-	-
Amphipoda	-	-	-	-	-	-	5.88	0.42	0.36	10.34	0.28	0.34	-	-	-	-	-	-	-	-	-
Natantia	-	-	-	-	-	-	17.65	1.46	16.13	6.90	0.37	2.68	-	-	-	-	-	-	-	-	-
Callianassa kraussi	-	-	-	-	-	-	2.94	0.21	0.89	3.45	0.19	8.08	-	-	-	4.76	0.92	8.52	25.00	20.00	25.37
Brachyura	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14.29	2.75	20.70	62.50	50.00	67.16
Decapod larvae	-	-	-	-	-	-	5.88	2.93	4.05	34.48	20.19	4.82	20.00	7.77	2.16	4.76	0.92	neg	-	-	-
Decapoda	8.33	0.08	6.33	4.55	0.11	1.46	8.82	0.63	5.27	3.45	0.09	0.25	20.00	2.07	7.49	19.05	5.50	11.35	12.50	30.00	7.46
Nemertea	16.67	0.17	12.29	9.09	0.22	9.83	8.82	0.63	5.63	3.45	0.19	3.99	20.00	2.07	8.92	42.86	8.26	9.92	-	-	-
Polychaeta	-	-	-	9.09	0.22	17.10	35.29	4.60	32.76	41.38	1.95	27.21	65.00	17.62	58.21	61.90	21.10	35.89	-	-	-
Bivalvia (siphons)	-	-	-	-	-	-	5.88	0.42	7.11	13.79	0.65	5.47	15.00	4.15	7.05	23.81	6.42	6.33	-	-	-
Teleostei	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.76	0.92	3.59	-	-	-

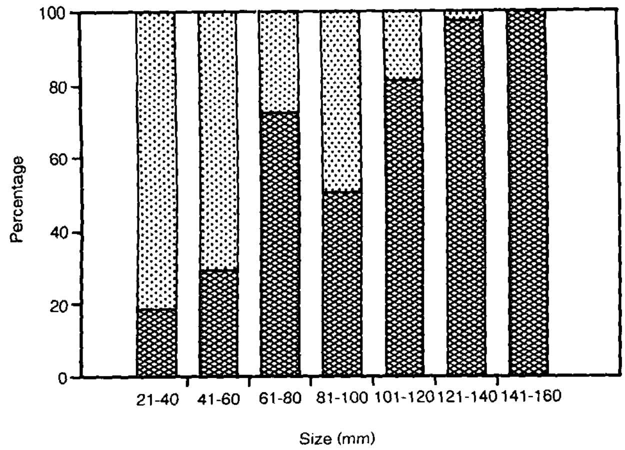

Figure 1
Size-related changes in the volumetric proportions of planktonic and benthic prey taken by S. sihama *(Cross-hatching = benthic, stipple = planktonic)*

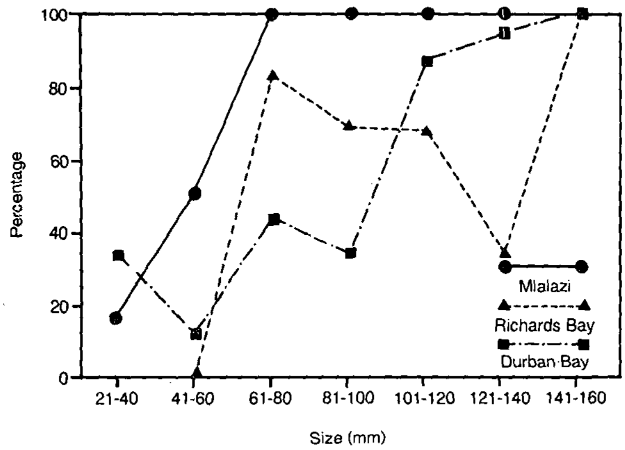

Figure 2
Size-related changes in the frequency of occurrence of benthic prey in the the diet of S. sihama *from three different systems in KwaZulu-Natal*

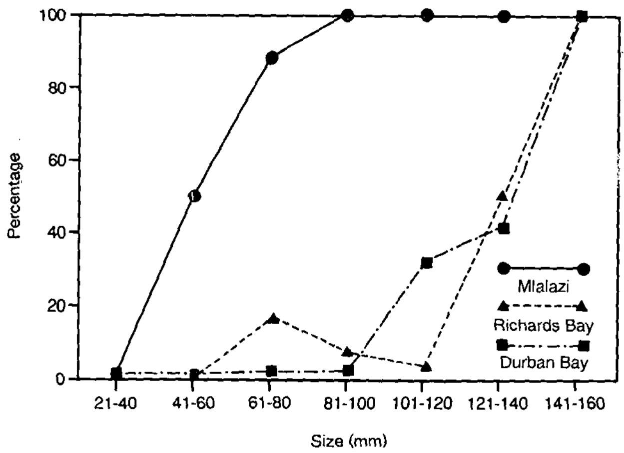

Figure 3
Size-related changes in the numeric proportion of benthic prey taken by S. sihama *from three different systems in KwaZulu-Natal*

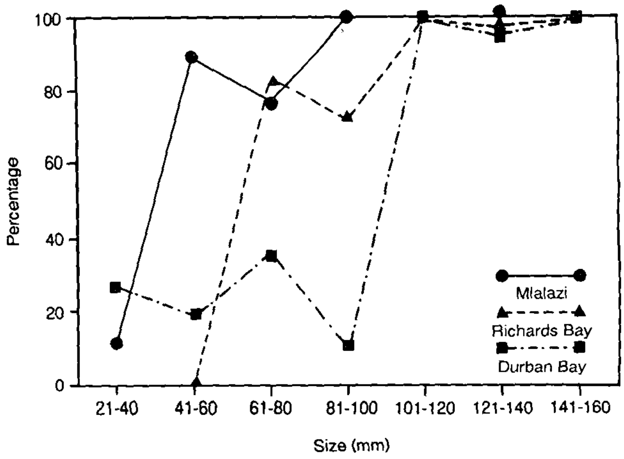

Figure 4
Size-related changes in the volumetric proportion of benthic prey taken by S. sihama *from three different systems in KwaZulu-Natal*

The presence of polychaetes, bivalve siphon tips and whole bivalves (*Solen capensis*) in the intestines of some of the largest fish was noted but not included as only the gut contents were used in the analyses. No planktonic prey were taken by large *S. sihama*.

The change of diet with increase in size is clearly shown in the results of all three methods of analyses (Table 3) and specifically in the volumetric analysis (Fig. 1). For the purpose of this study larvaceans, copepods and decapod larvae were regarded as planktonic and other food groups as benthic or epibenthic. The diet of the size class 81 to 100 mm is inconsistent with the general change from planktonic to benthic diet with increasing size. This was due to the incidence of high numbers of copepods and decapod larvae in the stomachs of *S. sihama* taken from Richards Bay on 25/05/91, and of copepods in fish from Durban Bay on 26/10/91. But for one animal, all the fish sampled from these areas on these dates were of SL >81 mm.

Dietary change in different systems

Despite the fact that the food taken by *S. sihama* was similar in all three systems, the pattern of increasing reliance on benthic food was different for each system. In terms of frequency of occurrence, all fish in Mlalazi were feeding on benthos exclusively by the 61 to 80 mm size class. However, this was only true of fish from Richards Bay and Durban Bay once the 141 to 160 mm class was reached (Fig. 2). The trends of an increase in the numeric contribution of benthic food groups to the diet of fish in Durban Bay and Richards Bay were similar, but the change-over only became clear-cut when the fish were over 100 mm SL (Fig. 3). In terms of volume however, the proportion of benthic food taken increased sharply in the 21 to 40 mm size classes of fish from Mlalazi, 41 to 60 mm in fish from Richards Bay and 81 to 100 mm in fish from Durban Bay (Fig. 4). Although these differences were marked it should be noted that the sample size of fish taken from Mlalazi Estuary was small (20) compared to that from Durban Bay (85) and Richards Bay (76).

Discussion

Diet of *S. sihama*

Studies in India have indicated the 50% level of maturity in *S. sihama* to be at 205 to 225 mm (TL) (Krishnamurthy and Kaliyamurthy, 1978). The largest recorded size for South Africa is 300 mm SL (Smith and Heemstra, 1991). In this study no fish larger than the 141 to 160 mm size class were caught, and all of these were juveniles. The nature of the gut contents indicated that *S. sihama* is carnivorous in KwaZulu-Natal estuaries. Most food groups reported for *S. sihama* from Australia (Gunn and Milward, 1985) and from Pulicat Lake, India (Krishnamurthy, 1969) were also preyed on in the three systems in this study. Larvaceans, which featured prominently in the diet of the smaller size classes in this study were not, however, mentioned as food items in either of the two reports referred to above.

Bivalve siphon tips, found commonly in the specimens from KwaZulu-Natal, have also not been documented as prey items of *S. sihama* in other areas, but they are an important food of sub-adult *Sillago analis* in southern Queensland, Australia (Brewer and Willan, 1985). According to Cyrus and Blaber (1983), *Gerres* spp. in KwaZulu-Natal estuaries crop siphons of *Hiatula lunulata* which provide a renewable food resource with high energy content. Siphon tips of *Solen cylindraceus* are the favoured prey of *Solea bleekeri* in the St Lucia system (Cyrus, 1991). During periods when this food source is absent from the system (e.g. after episodic flushing events) *S. bleekeri* changes diet to feed opportunistically on other available benthic prey items (Cyrus, 1991).

This study revealed no evidence of the omnivorous diet reported by Chako (1949) and Radhakrishnan (1957) for Indian *S. sihama* from Mannar Gulf and Palk Bay. This type of difference in the diet of a species over its distributional range is not restricted to *S. sihama*. For instance, Chako (1949) reported aquatic macrophytes to be the major component of the diet of three species of *Gerres* in India while Cyrus and Blaber (1983) found *Gerres* in the estuaries of Natal to be carnivorous.

Effects of size on diet of *S. sihama*

A distinct, age-related dietary shift was evident from the results of the analyses. Such change in diet with increase in fish size is common in fish (Wootton, 1990) and it has previously been recorded in *S. sihama* from India (Radhakrishnan, 1957; Krishnamurthy, 1969) and Australia (Gunn and Milward, 1985). In all cases the shift involved a change from planktonic prey being taken by small juveniles to benthic organisms being eaten by larger juveniles, sub-adults and adults. According to Whitfield (1985), zooplankton is the major nutritional resource of larval and postlarval fish in most aquatic environments owing to its high energy content relative to other organisms of similar size. With growth, fish have increasing ability to handle larger food items (Bennett, 1989) which are often, in terms of energy, more profitable as prey.

Krishnamurthy (1969) found copepods to be the dominant element of the food of *S. sihama* up to a total length of 40 mm. Polychaetes were present only in fish larger than 61 mm (TL) and this prey group dominated the diet of animals greater than 100 mm (TL). The smallest fish from the current study which had consumed polychaete prey was 51 mm (SL). Gunn and Milward (1985) found that Australian *S. sihama* less than 81 mm (TL) fed mainly on copepods. The importance of copepods then declined rapidly with increasing size in fish from 81 mm to 200 mm (TL). Polychaetes dominated the diet of fish of those sizes, with penaeids and brachyuran crabs becoming increasingly important in specimens >200 mm (TL). These observations were based on analyses of the frequency of occurrence and a weighted points method similar to the points method of Ricker (1968) used in the current study. Despite the marginal differences in the size classes of *S. sihama* studied in India (Krishnamurthy, 1969) and Australia (Gunn and Milward, 1985) relative to those in the present study the trend of dietary change appeared to be similar.

Dietary change in different systems

Differences shown in the trend of increasing reliance on benthic food organisms as the fish grew larger may be attributable to the different nature of the systems sampled (Figs. 2 and 4). The wide and deep mouths of Richards Bay and Durban Bay permit a greater tidal exchange compared with that of Mlalazi. It is therefore plausible that marine plankton swept into the harbours result in increased densities in those systems. *Sillago sihama* in these environments appear to prolong the period of exploitation of plankton as a food source because of its availability. In contrast, the relative paucity of estuarine zooplankton in a system such as the Mlalazi could force small juveniles to exploit alternative food resources in the system.

Gunn and Milward (1985) noted a degree of dietary flexibility in *S. sihama* and reported that the species occasionally abandoned its usual prey in Australian waters to feed on blooms of pelagic sergestids. The high frequency of large numbers of planktonic prey in *S. sihama* larger than 81 mm SL sampled from Richards Bay (25/05/91) and Durban Bay (26/10/91) may have been the result of a similar incident, and suggests that individual fish feed opportunistically on abundant and available resources. The small sample size (Table 1) which resulted from dividing the fish into distinct size categories from each system may have had an influence on perceived trends of dietary change in different systems. It is, however, apparent that there are three trophic stages in the life of *S. sihama* in KwaZulu-Natal estuaries. Young fish feed primarily on planktonic prey (mainly copepods and larvaceans) following which larger benthic prey in the form of crustaceans and polychaetes are increasingly targeted. Larger juveniles and sub-adults feed only on benthic food groups.

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