Analysis of the gut contents of the needlefish, *Hyporhamphus knysnaensis* (Smith), from Rondevlei, southern Cape

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The gut contents of 313 specimens of *Hyporhamphus knysnaensis* from Rondevlei were analysed. The total lengths of the collected fish varied between 5,1 and 21,8 cm. It was found that the annual cycle in the occurrence of submerged macrophytes in Rondevlei appears to directly influence the feeding of *H. knysnaensis* of 9 to 17 cm long. This length-group fed mainly on animal material (mostly amphipods and isopods) in winter and the first half of spring while submerged macrophytes were scarce. After the submerged macrophytes became more abundant, however, the 9 to 17-cm length-group changed to a predominantly plant diet (consisting of *Ruppia spiralis* and *Potamogeton pectinatus*). *H. knysnaensis* between approximately 5 and 9 cm long appeared in summer and fed mainly on animal material (mostly amphipods and isopods). Of the 47 specimens collected in this length-group between December 1978 and March 1979, all had animal material in their gut contents. It was the dominant food in 94% of the specimens and formed 90% of the gut contents. In general, therefore, *H. knysnaensis* can be considered an omnivore.

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Die derminhoude van 313 eksemplare van *Hyporhamphus knysnaensis* uit Rondevlei is ondersoek. Die totale lengtes van die versamelde vis het tussen 5,1 en 21,8 cm gewissel. Daar is gevind dat die jaarlikse siklus in die voorkoms van onderwater-makrofiete in Rondevlei die voeding van die ongeveer 9 tot 17 cm lange *H. knysnaensis* direk blyk te beïnvloed. Hierdie lengtegroep het hoofsaaklik op dierlike materiaal (meesal Amphipoda en Isopoda) in die winter en eerste helfte van die lente gevoed, terwyl onderwater-makrofiete skaars was. Toe die onderwater-makrofiete egter daarna begin toeneem het, het die 9 tot 17-cm lengtegroep na 'n hoofsaaklik plantaardige dieet (bestaande uit *Ruppia spiralis* en *Potamogeton pectinatus*) oorgeskakel. *H. knysnaensis* tussen ongeveer 5 en 9 cm lank het hul verskyning in die somer gemaak en meesal op dierlike materiaal (hoofsaaklik Amphipoda en Isopoda) gevoed. Die dermkanale van al 47 eksemplare in hierdie lengtegroep wat tussen Desember 1978 en Maart 1979 versamel is, het dierlike materiaal bevat. Dit was die dominante voedsel in 94% van die eksemplare en het 90% van die derminhoude gevorm. In die algemeen kan *H. knysnaensis* dus as 'n omnivoor beskou word.

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Hyporhamphus knysnaensis (Smith) occurs only along the south and east coasts of southern Africa from False Bay to Natal, entering estuaries in this region (Smith 1933, 1965). It is a source of food for various predators in estuaries; e.g. in Lake St Lucia on the Natal coast, South Africa's largest estuarine system, Whitfield & Blaber (1978a) found it to be one of the major prey species of the tenpounder *Elops machnata* and garfish *Tylosurus leiurus*. They also reported *H. knysnaensis* in the stomachs of kob *Argyrosomus hololepidotus*, Caspian Terns *Hydroprogne tschegrava* and pied kingfishers *Ceryle rudis* (Whitfield & Blaber 1978a, 1978b). In the Wilderness Lakes estuarine system on the southern Cape coast where the present study was conducted (Fig. 1), it has so far been found in the stomachs of leervis, *Lichia amia* (D.J. Coetzee, *pers. obs.*). *H. knysnaensis* occurs in all the Wilderness Lakes except Groenvlei, which is the only lake isolated from the sea.

This paper discusses the results of gut content analyses carried out on *H. knysnaensis* collected in Rondevlei from April 1978 to March 1979. This is the first detailed study of the diet of this fish species in South Africa, and is aimed at ascertaining which food sources it utilizes in Rondevlei. The results will contribute towards establishing the role of *H. knysnaensis* in the food web in the Wilderness Lakes.

Material and Methods

Altogether 314 specimens of *Hyporhamphus knysnaensis* were collected at a specific locality in Rondevlei (Fig. 1), using a seine-net with a stretched mesh size of 8 mm. Catches were made each month on one day, more or less in the middle of the month, always between 11h30 and 15h00. The fish were measured (total length), weighed and preserved in formalin. During June and July 1978 *H. knysnaensis* was very scarce at the sampling locality, and only seven specimens were collected in each of these two months despite repeated net hauls.

The contents of the whole digestive tract were removed and inspected under a stereoscopic microscope. Food items were identified as far as possible. Amphipods and isopods were usually broken up and difficult to separate, and consequently grouped together in the results.

A volumetric method was used to analyse the individual gut contents, *i.e.* the percentage that each food item formed of the total gut content of each specimen was estimated. Afterwards the results of the individual

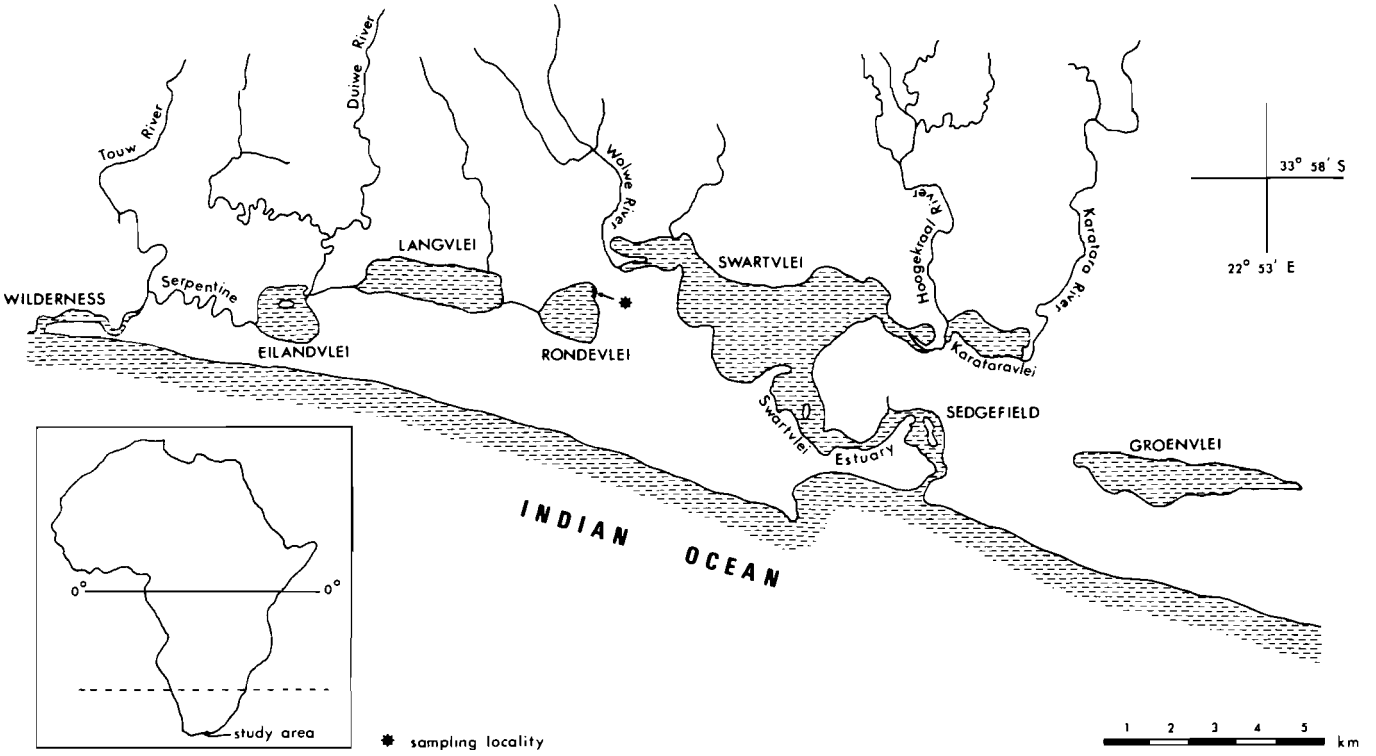

Fig. 1 The study area with the sampling locality indicated.

gut content analyses were combined to obtain overall estimates. The results were further evaluated by means of the occurrence and dominance methods (Hynes 1950). In the former method the number of guts containing a specific food item is expressed as a percentage of the total number of guts analysed, whereas in the latter the number of guts in which a specific food item is dominant is expressed as a percentage of the total number of guts analysed.

Monthly visual observations were made of changes in the occurrence of submerged aquatic macrophytes (consisting of *Ruppia spiralis* and *Potamogeton pectinatus*) at the sampling locality to ascertain whether there was any relationship between the occurrence of macrophytes and the food ingested by *H. knysnaensis*.

Results

Environmental conditions

No physico-chemical measurements were taken of the aquatic environment at the sampling locality itself, but monthly physico-chemical readings taken at a station in the middle of Rondevlei during 1978 (Coetzee & Palmer 1979), and a follow-up programme by the Institute for Freshwater Studies of Rhodes University using the same station (A.K. Whitfield, *pers. comm.* February 1980), showed that the salinity of Rondevlei remained more or less constant at about 15°/oo over the present survey period. Mean temperatures for the water column in the middle of Rondevlei varied between 12,1 °C in June 1978 and 25,7 °C in February 1979 (Fig. 2).

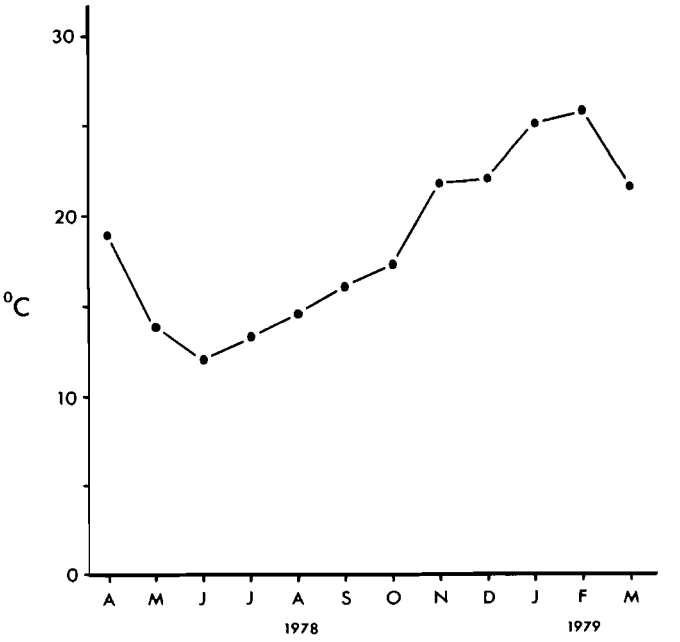

Fig. 2 Mean monthly temperature (°C) of the water column in the middle of Rondevlei over the period April 1978 to March 1979.

Submerged aquatic macrophytes

Few submerged aquatic macrophytes (*Ruppia spiralis* and *Potamogeton pectinatus*) were observed at the sampling locality and its immediate vicinity from April to July 1978, and from August to September 1978 the sandy substrate appeared to be devoid of any submerged macrophytes, apart from dead shoots. In late October and November macrophytes made their appearance again. From December 1978 to February 1979 they were abundant at the sampling locality, and large numbers of the coot *Fulica cristata* fed on them in December. These submerged macrophytes have subsequently decreased considerably and few were seen at the time of sampling in March 1979.

Total lengths of analysed fish

Of the 314 specimens of *H. knysnaensis* which were collected, only one had a practically empty digestive tract and was therefore discarded. The total lengths of the remaining 313 fish varied between 5,1 and 21,8 cm, 55% of the fish being between 12,0 and 15,9 cm in length. *H. knysnaensis* can attain a maximum length of about 25,4 cm (Smith 1965).

Younger fish of between 5 to 9 cm in length were observed in the Rondevlei catches from December 1978 onwards. According to Smith (1933) *H. knysnaensis* appears to be present in estuaries throughout the year, but although the young fish are abundant around the end of the year, they disappear after February. The minimum length of the 65 fish collected in Rondevlei during March 1979 was 7,7 cm, whilst the minimum length of the 135 fish caught between April and November 1978 was 10,2 cm. The younger fish possibly left the littoral zone (where all collecting took place) for deeper water during this period.

Gut contents

The survey period was divided into four quarters consisting of three months each, which roughly coincided with changes in the occurrence of submerged aquatic macrophytes at the sampling locality. The composition of the gut contents of *H. knysnaensis* collected during each quarter is given in Table 1, and their size composition illustrated in Fig. 3.

First quarter (April to June 1978)

During the first quarter macrophytes were present but relatively scarce. *H. knysnaensis* collected during this period were between 11,6 and 16,1 cm in length, and fed mainly on amphipods and isopods (together comprising 44,2% of the diet) and the bivalve *Musculus virgiliae* (28,8% of the diet). Both these food items occurred in 88% of the digestive tracts, the former being dominant in 38% and the latter in 35%. Macrophytes made up 24,5% of the diet and were the dominant food item in 27% of the digestive tracts.

Second quarter (July to September 1978)

Submerged aquatic macrophytes were very scarce during this quarter. The collected fish (between 10,2 and 16,4 cm long) had ingested very little plant material (2,6%), and this occurred in only 12% of the digestive tracts. The major food item was the combination of amphipods and isopods (92,5%), which was dominant in 93% of the fish.

Third quarter (October to December 1978)

Macrophytes made their appearance, increased and became abundant in December. Specimens of *H. knys-*

Table 1 Composition of the gut contents of 313 *Hyporhamphus knysnaensis* collected in Rondevlei from April 1978 to March 1979 (c = composition, o = occurrence, d = dominance)

	April – June 1978 (n = 26)			July – September 1978 (n = 74)			October – December 1978 (n = 63)			January – March 1979 (n = 150)		
	% c	% o	% d	% c	% o	% d	% c	% o	% d	% c	% o	% d
Sand particles				< 0,05	14	0	< 0,05	13	0	2,0	79	0
Protozoa												
Foraminifera										0,3	36	0
Filamentous algae										1,5	5	2
Aquatic macrophytes												
Ruppia spiralis + *Potamogeton pectinatus*	24,5	65	27	2,6	12	3	39,3	54	41	50,7	81	54
Polychaeta										< 0,05	2	0
Crustacea												
Ostracoda	1,8	62	0	3,4	34	4	11,4	84	10	16,9	80	17
Copepoda												
Harpacticoida										< 0,05	5	0
Tegastidae										< 0,05	1	0
Amphipoda + Isopoda	44,2	88	38	92,5	97	93	38,0	62	40	13,9	51	15
Insecta												
Chironomidae larvae	0,1	4	0	0,1	1	0				0,1	3	0
Chironomidae pupae							< 0,05	5	0	0,2	3	0
Coleoptera	0,2	4	0	0,2	3	0	0,1	10	0			
Terrestrial insects	0,4	12	0	0,7	20	0	8,9	48	8	0,3	5	0
Arachnida												
Araneida	0,1	4	0				0,9	6	0	< 0,05	1	0
Mollusca												
Lamellibranch veligers										0,4	1	0
Musculus virgiliae	28,8	88	35	0,4	4	0	1,8	19	2	13,4	53	13
Osteichthyes												
Fish eggs							< 0,05	2	0	0,2	1	0
Fish larvae							< 0,05	6	0			
Aves												
Pieces of feather	< 0,05	4	0	< 0,05	1	0	< 0,05	6	0	0,1	2	0

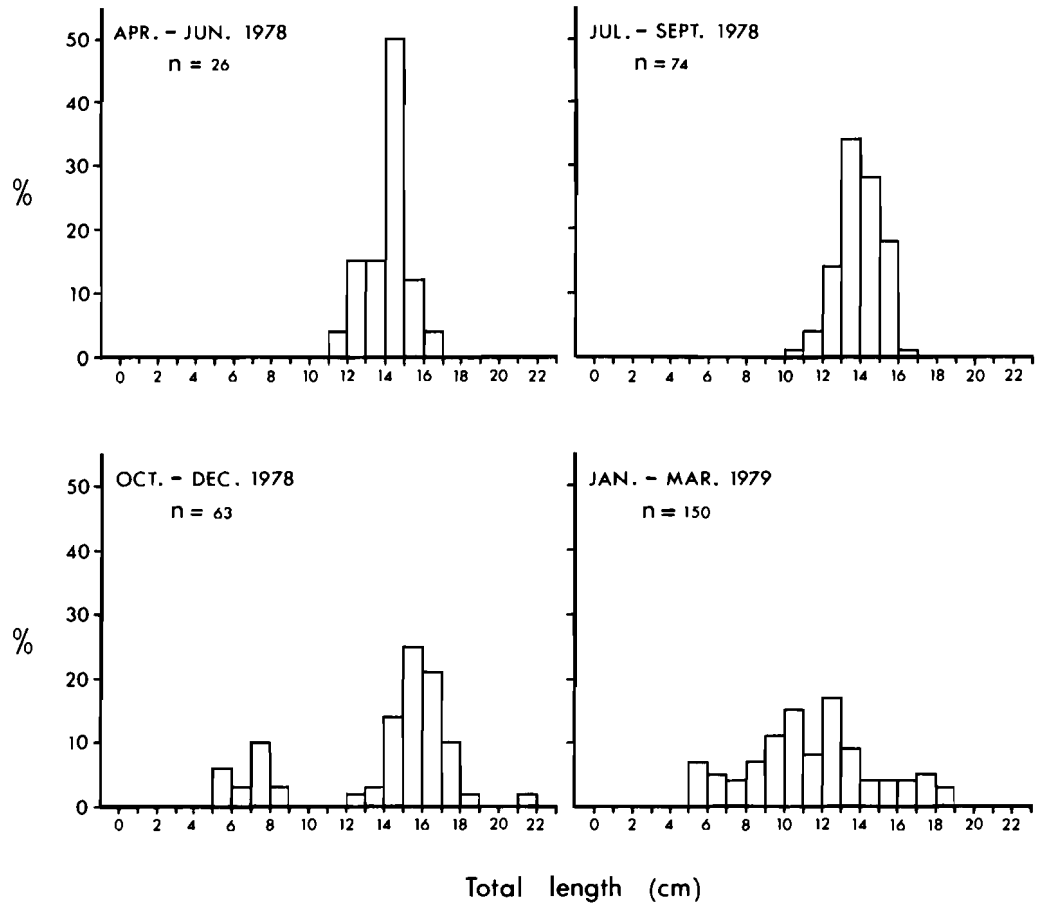

Fig. 3 Quarterly length distribution of 313 specimens of *H. knysnaensis* collected in Rondevlei from April 1978 to March 1979.

naensis varied between 5,2 and 21,8 cm in length and fed mainly on macrophytes (39,3%) and amphipods and isopods (38,0%). Ostracods were not as abundant (11,4%), but occurred in more digestive tracts (84% occurrence) than either macrophytes (54% occurrence) or amphipods and isopods (62% occurrence). Terrestrial insects formed a relatively large proportion of the gut contents during this time of the year (8,9%), and occurred in 48% of the digestive tracts.

Fourth quarter (January to March 1979)

Macrophytes were abundant during the first two months of this quarter, but scarce in March. *H. knysnaensis* specimens of between 5,1 and 18,3 cm long were collected during this period. They fed mostly on macrophytes (50,7%) which represented the dominant food item in 54% of the digestive tracts. Ostracods were the second most abundant food item (16,9%), followed by amphipods and isopods (13,9%) and *Musculus virgiliae* (13,4%).

The results of the last two quarters, however, are complicated by the fact that fish of between 5 and 9 cm long were also obtained for the first time in the catches from December onwards. During the summer months (December 1978 to February 1979), while the submerged aquatic macrophytes were plentiful, these young fish fed mainly on small benthic and epiphytic invertebrates, whereas fish of between approximately 9 to 17 cm long fed mostly on macrophytes (Fig. 4). *H. knysnaensis* above 17 cm mostly ingested the bivalve *Musculus virgiliae*. There was therefore a definite swing from animal food in the second quarter (when plant food was scarce) to plant food in the third and fourth quarters (when plant food became plentiful) by fish of approximately 9 to 17 cm. This is further illustrated in Fig. 5.

Generally speaking *H. knysnaensis* is an omnivore in Rondevlei, feeding mainly on submerged aquatic macrophytes, crustaceans and the bivalve *Musculus virgiliae* (Table 2). From the composition of its gut contents it appears that it is not a bottom-feeder, but that it feeds amongst the submerged aquatic macrophytes. The role of the beak in feeding (if any), however, remains uncertain.

Discussion

Hyporhamphus knysnaensis belongs to the family Hemirhamphidae, a group of fish in which the lower jaw has developed into a long beak. According to Smith (1933) the Hemirhamphidae are exclusively surface-dwellers. This assumption is partially based on the fact that he has never detected sand-particles whilst analysing the stomach contents of numerous members of this family. Their stomachs generally contained surface plants, larval crustacea and fish, and pelagic eggs. However, the results obtained with *H. knysnaensis* in Rondevlei show that their digestive tracts can often contain sand-particles, although this does not necessarily disprove that *H. knysnaensis* is a surface-dweller. The specimens for the present study were collected in shallow water (0,5 to 1 m deep) over a sandy bottom. Small waves caused by wind action, a regular phenomenon at the sampling locality, can keep the finer sand-particles in suspension and result in incidental intake by *H. knysnaensis*.

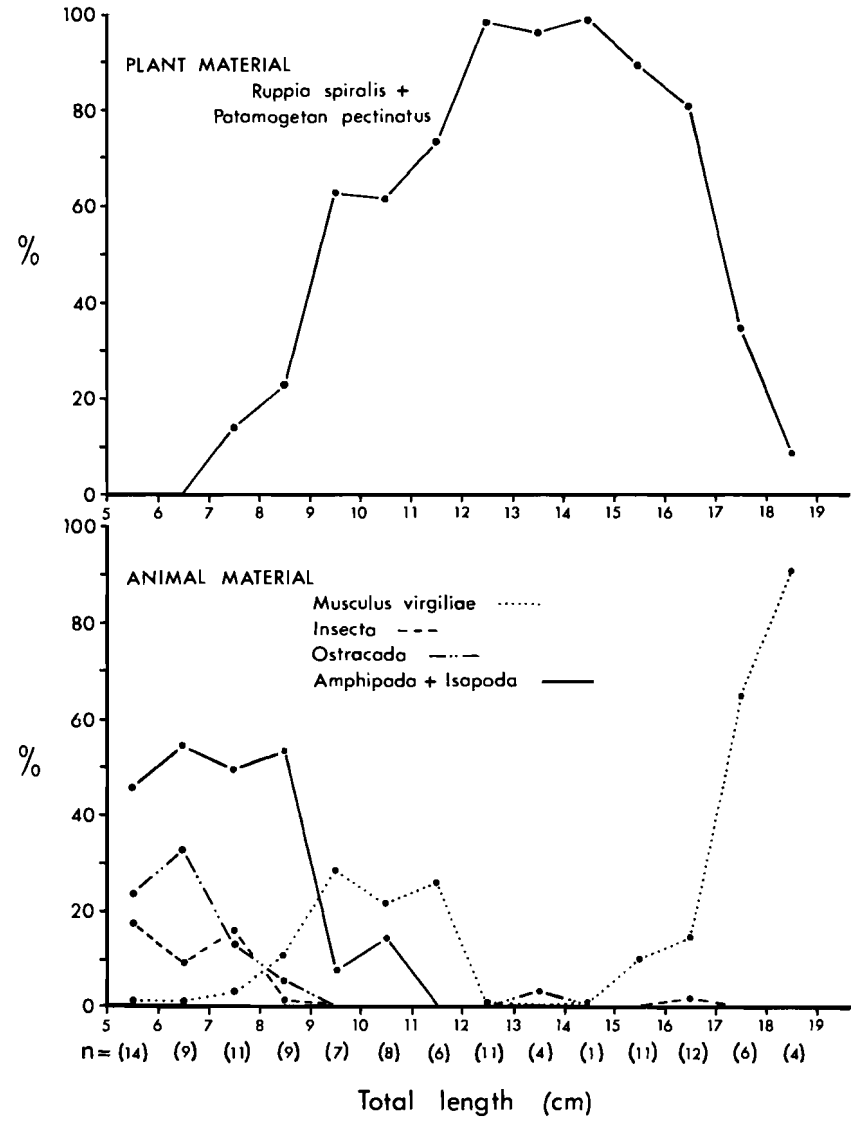

Fig. 4 Mean changes in diet with an increase in size of 113 specimens of *H. knysnaensis* collected in Rondevlei during summer (December 1978 – February 1979). The values in brackets indicate the number of digestive tracts analysed in each length group.

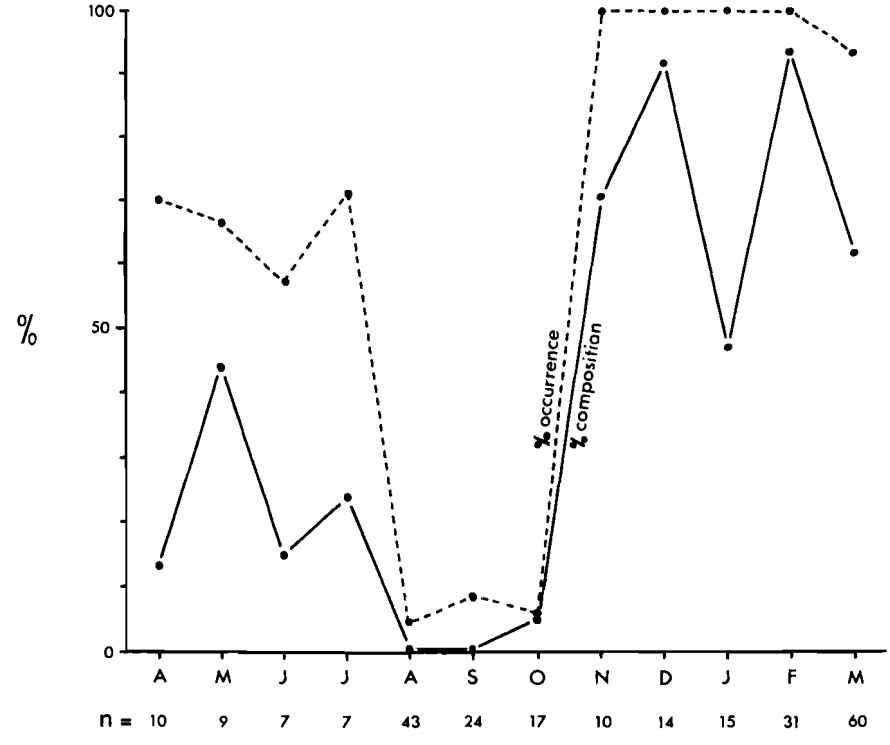

Fig. 5 Monthly percentage occurrence and amount (% of composition) of plant material in the digestive tracts of *H. knysnaensis* between 9 and 17 cm long collected in Rondevlei from April 1978 to March 1979.

Table 2 Average composition of the diet of *Hyporhamphus knysnaensis* in Rondevlei over the period April 1978 to March 1979 (values calculated from monthly mean percentages)

	% composition	% occurrence	% dominance
Sand particles	0,4	23,0	0
Protozoa			
Foraminifera	0,1	7,8	0
Filamentous algae	0,3	0,4	0,4
Aquatic macrophytes			
Ruppia spiralis + *Potamogeton pectinatus*	31,2	58,1	33,8
Polychaeta	< 0,05	0,4	0
Crustacea			
Ostracoda	9,5	69,0	8,9
Copepoda			
Harpacticoida	< 0,05	1,6	0
Tegastidae	< 0,05	0,2	0
Amphipoda + Isopoda	44,4	72,7	45,1
Insecta			
Chironomidae larvae	0,1	2,8	0
Chironomidae pupae	0,1	1,7	0
Coleoptera	0,2	5,4	0
Terrestrial insects	2,4	23,0	1,5
Arachnida			
Araneida	0,2	2,4	0
Mollusca			
Lamellibranch veligers	0,1	0,4	0
Musculus virgiliae	10,9	44,5	10,5
Osteichthyes			
Fish eggs	< 0,05	1,0	0
Fish larvae	< 0,05	1,2	0
Aves			
Pieces of feather	0,1	4,4	0

The isopods ingested by *H. knysnaensis* during the study period were the estuarine species *Exosphaeroma hylecoetes* (predominantly) and *Cirolana fluviatilis*, which occur mostly in the submerged aquatic macrophyte beds of Rondevlei. The amphipods, consisting of *Melita zeylanica* and the tube-dwellers *Grandidierella lignorum* and *Corophium triaenonyx*, are also estuarine species. The latter two can build their tubes on the bottom, on submerged plants and other submerged objects, and are therefore both benthic and epiphytic (Boltt 1969). Not a single tube-dwelling amphipod, however, was found still inside its tube in any of the analysed digestive tracts, neither were they found with sand-particles clinging to their appendages, as has sometimes been the case in the stomach contents of the silverside *Hepsetia breviceps* (*pers. obs.*). During the second quarter of the survey, when 92,5% of the diet of *H. knysnaensis* consisted of amphipods and isopods (mainly *Corophium triaenonyx*), sand-particles were encountered in only 14% of the digestive tracts, forming less than 0,05% of the gut contents. It appears, therefore, that *H. knysnaensis* does not remove these amphipods from the substrate, but feeds only on those moving about outside their tubes. It would probably be difficult for *H. knysnaensis* to remove benthic animals from the bottom because of its long lower jaw, unless it stirs up the substrate with this 'beak', as suggested by Schlesinger (1909), who refers to the Hemirhamphidae as 'typische Grundwühler'. Smith (1933) dismisses the use of the beak as suggested by Schlesinger, because its tip is soft and the rest of it fairly delicate. Furthermore, Smith never found any broken beaks in his examination of hundreds of specimens of the Hemirhamphidae. He concludes that this prolonged lower jaw is probably used during feeding for detecting surface organisms. Uchida (1930 — *vid.* Suyehiro 1942), on the other hand, ascertained that the lower jaw in *Hemirhamphus sajori* is not used during feeding, and decided that it is more of a hindrance than anything else.

Although *H. knysnaensis* between approximately 9 and 17 cm long concentrated on animal food during the colder months due to the scarcity of plant food or because of their specific energy requirements, it is interesting that the change to a predominantly plant food diet should occur towards the end of the year when younger fish, which feed on animals, make their appearance. This could be purely as a result of the abundance of plant material and the specific energy requirements of the older *H. knysnaensis* during the summer, but, on the other hand, has advantages as far as competition for food and consequent survival of the young are concerned (Nikolsky 1963). This feeding pattern means that the fish of approximately 9 to 17 cm long do not compete with the younger fish for food.

Eating plants in order to obtain the attached animals does not appear to be the practice of *H. knysnaensis*, although it has a short straight gut usually associated with an animal diet. The animal food items in the digestive tracts of the analysed *H. knysnaensis* were never found to be still attached to bits of plant material, and in some cases the whole digestive tract was filled with nothing but plant material. To what extent this plant material is digested and fills the energy requirements of *H. knysnaensis*, falls outside the scope of this paper. Visually it appears as if little digestion of the plant material takes place. Possibly *H. knysnaensis* digests only the epiphytic diatoms on the macrophytic material, as has been found by Blaber (1974) in the stumpnose, *Rhabdosargus holubi*. Some members of the Hemirhamphidae seem to be purely herbivorous, such as *Hemirhamphus ardelio* which feeds on *Zostera* in Lake Macquarie, Australia, while *Hemirhamphus australis* is omnivorous in the same lake, feeding on algae and crustacea (Thomson 1959).

The extremely sharp decrease in the *Potamogeton pectinatus* population in Swartvlei (approximately 1,7 km east of Rondevlei) during 1978 appeared to be responsible for the simultaneous decline in the population of the bivalve *Musculus virgiliae*, which seems to use *P. pectinatus* primarily as a surface for attachment (Davies 1979). A similar relationship appears to exist between the occurrence of submerged macrophytes and *M. virgiliae* in the digestive tracts of *H. knysnaensis, i.e.* with the decrease and increase in the occurrence of macrophytes in the gut contents during the year, there was a corresponding change in the occurrence of *M. virgiliae* (Table 1).

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References

BLABER, S.J.M. 1974. Field studies of the diet of *Rhabdosargus holubi* (Steindachner) (Teleostei:Sparidae). *J. Zool., Lond.* 173: 407 – 417.

BOLTT, R.E. 1969. The benthos of some southern African lakes. Part II: The epifauna and infauna of the benthos of Lake Sibaya. *Trans. roy. Soc. S. Afr.* 38: 249 – 269.

COETZEE, D.J. & PALMER, N.G. 1979. Algemene fisiese en chemiese toestande in Eilandvlei, Langvlei en Rondevlei gedurende 1978. Unpublished report, Cape Department of Nature and Environmental Conservation.

DAVIES, B.R. 1979. The secondary productivity of *Musculus virgiliae* at Swartvlei. Annual Reports 1978/79, No. 11, Institute for Freshwater Studies, Rhodes University.

HYNES, H.B.N. 1950. The food of fresh-water sticklebacks (*Gasterosteus aculeatus* and *Pygosteus pungitius*), with a review of methods used in studies of the food of fishes. *J. anim. Ecol.* 19: 36 – 58.

NIKOLSKY, G.V. 1963. The ecology of fishes. Academic Press, London and New York.

SCHLESINGER, G. 1909. Zur Phylogenie und Ethologie der Scombresociden. *Verh. zool.-bot. Ges. Wien*: 302 – 339.

SMITH, J.L.B. 1933. The South African species of the genus *Hemirhamphus* Cuv. *Trans. roy. Soc. S. Afr.* 21: 129 – 150.

SMITH, J.L.B. 1965. The sea fishes of southern Africa. Central News Agency, Ltd., South Africa.

SUYEHIRO, Y. 1942. A study on the digestive system and feeding habits of fish. *Jpn. J. Zool.* 10: 1 – 300.

THOMSON, J.M. 1959. Some aspects of the ecology of Lake Macquarie, N.S.W., with regard to an alleged depletion of fish. IX. The fishes and their food. *Aust. J. Mar. Freshwater Res.* 10: 365 – 374.

UCHIDA, K. 1930. Sayori no seikatusi. *Nippon Gakuziutu Kyôkai Hôkoku* 6: 555 – 561, as cited by Suyehiro (1942).

WHITFIELD, A.K. & BLABER, S.J.M. 1978a. Food and feeding ecology of piscivorous fishes at Lake St Lucia, Zululand. *J. Fish Biol.* 13: 675 – 691.

WHITFIELD, A.K. & BLABER, S.J.M. 1978b. Feeding ecology of piscivorous birds at Lake St Lucia, Part 1: Diving birds. *Ostrich* 49: 185 – 198.