Changes in feeding biology of Nile tilapia, *Oreochromis niloticus* (L.), after invasion of water hyacinth, *Eichhornia crassipes* (Mart.) Solms, in Lake Victoria, Kenya

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Abstract: *Oreochromis niloticus* (L.) was introduced to Lake Victoria in the 1950s. It remained relatively uncommon in catches until 1965, when the numbers began to increase dramatically. It is now the third most important commercial fish species after the Nile perch, *Lates niloticus* (L.) and *Rastrineobola argentea* (Pellegrin). *Oreochromis niloticus* is considered a herbivore, feeding mostly on algae and plant material. The diet now appears to be more diversified, with insects, fish, algae and plant materials all being important food items. Fish >5 cm TL have a diverse diet but there is a decline in the importance of zooplankton, the preferred food item of small fish, as fish get larger. The shift in diet could be due to changes which have occurred in the lake. Water hyacinth, *Eichhornia crassipes* (Mart.) Solms, which harbours numerous insects in its root balls, now has extensively coverage over the lake. The native fish species which preyed on these insects (e.g. haplochromines) have largely been eliminated and *O. niloticus* could be filling niches previously occupied by these cichlids and non cichlid fishes. The change in diet could also be related to food availability and abundance where the fish is feeding on the most readily available food items.

Introduction

Oreochromis niloticus (L.), a tilapiine cichlid, is widely distributed in Africa and many parts of the world (Trewavas 1983). It was introduced into Lake Victoria in the 1950s together with other tilapiines like *Oreochromis leucostictus* (Trewavas), *Tilapia zillii* (Gervais) and *Tilapia rendalli* Boulenger (Welcomme 1967; Trewavas 1983). *Oreochromis niloticus* appeared in commercial catches in 1960, constituting less than 1% of landings (Welcomme, 1967). By 1965 it featured prominently in the commercial catch and currently it is the most important tilapiine, whereas the native species *O. variabilis* (Boulenger) and *O. esculentus* (Graham) have largely disappeared (Witte & Densen 1995). Nile tilapia now constitutes the third most commercially important fishery in Lake Victoria after Nile perch, *Lates niloticus* (L.), and *Rastrineobola argentea* (Pellegrin). The dominance of *O. niloticus* over other tilapiines in the lake is attributed to several factors including ability to utilise a wide range of food material and fast growth rates (Welcomme 1967).

Observations made in natural habitats showed that *O. niloticus* prefers algae and plant material in its diet, but it ingests a great variety of foods (Lowe (McConnell) 1958; Moriarty & Moriarty 1973; Ross 1982; Ochumba & Manyala 1992; Getabu 1994). The species tends to feed on bottom deposits derived from the planktonic rain and other sources, and gains nutritive value from organic particles and other organisms which cover their surface (Fryer & Iles 1972; Moriarty & Moriarty 1973). In the Nyanza Gulf of Lake Victoria, *O. niloticus* was found to feed primarily on blue green algae (Cyanophyceae) and diatoms (Bacillariophyceae), desmids (Desmidaceae) and green algae (Chlorophyceae) (Getabu 1992).

In recent years, the fish community structure and ecosystem dynamics of the lake have changed, but no studies have been carried out to assess whether the fishes have altered their diets or feeding behaviour. The aim of this study was to determine whether *O. niloticus* has changed its feeding habits with the encroachment of water hyacinth, *Eichhornia crassipes* (Mart.) Solms. This is particularly important because the arrival of water hyacinth has caused many recent changes to the water quality and fish community structure of the lake where it is found in abundance (Kenyanya 1999; Othina 1999).

Materials and methods

Samples of *O. niloticus* were obtained by bottom trawling and beach seining in Kenyan waters of Lake Victoria (Fig. 1) between November 1998 and July 1999. Immediately after capture total length (TL) of fish was measured (cm) and the gut contents were removed for analysed using a modified point method of Hyslop (1980). Each stomach was awarded an index of fullness from 0 to 20; empty stomach scored 0; quarter full 5; half full 10; three-quarter full 15 and full 20. The stomach contents were then emptied into a petri dish and food items were sorted into categories. Each category was assigned a number of points proportional to the estimated contribution to stomach volume. In addition, the weight of each food category was measured separately in big stomachs, whereas the total weight of the contents was taken for smaller stomachs.

The importance of each food category was expressed as a percentage by dividing the total points awarded to the food type in question by the total number of points awarded to all the stomachs. Gut contents for each 5-cm length class were assessed separately.

Results

The contents of 1441 *O. niloticus* guts were examined. Insects, particularly *Povilla adusta*, fish (*R. argentea*), algae and plant material were the most important food types. with fish of all sizes (Figs 2, 3 & 4 Table 1). Other species of insects encountered included trichopteran nymphs, chironomid larvae and Odonata. Apart from *R. argentea*, other fish species eaten included juvenile haplochromines, *L. niloticus* and *O. niloticus*. Bivalves, zooplankton and *Caridina nilotica* (Roux) occurred frequently. Hirudinea, Oligochaeta and Mollusca were also included in the diet.

Changes in the diet with increasing size were apparent, with all size classes consuming the important food items listed above (Fig. 2). Zooplankton (cladocerans and copepods) were the major food item of small *O. niloticus* under 5 cm TL, but were of little importance to fish larger than 15 cm. Insects were also of little importance to the diet of small Nile tilapia (<5 cm), but were major food items of larger fish. Algae, fish and plant material were consistently important to all size groups. Fish <10 cm did not consume bivalves, *C. nilotica* and oligochaetes. The monthly variation in the feeding pattern of *O. niloticus* showed no obvious trends (Fig. 3). The importance of most food items showed fluctuations between months, probably in response to changes in availability of food items in the environment.

Discussion

The diet of *O. niloticus* in this study was different from that found previously (Trewavas 1983; Getabu 1994) (Figs 4, 5 & 6). In the past, the most important food was algae, but *O. niloticus* has now diversified its diet to include high proportions of insects, fish and algae. These results concur with those of Balirwa (1998) who found that *O. niloticus* in the Ugandan waters of L. Victoria fed on a variety of food items, with plant material and insects dominating.

The increase in insects in the diet of *O. niloticus* is mainly attributed to infestation of the lake by water hyacinth, which harbours a high density of insects in its root ball. The change in diet observed may also be related to food availability, relative abundance and convenient size of food items in the lake. Ogari and Dadzie (1989) noted a similar pattern in *L. niloticus*, an introduced species in L. Victoria which switched from haplochromine cichlids to the more abundant crustacean (*C. nilotica*) when the former declined.

Coulter (1976) reported that in many fishes selection of prey is governed by availability rather than preference for a particular species, which could be the case for *O. niloticus* in L. Victoria. Food selection of *O. niloticus* seemed to depend on availability of different food items in the area and this varied monthly. The change in *O. niloticus* feeding behaviour could also be attributed to its niche breadth. The species is filling niches previously occupied by various cichlids and non cichlids which no longer exist in the lake (Balirwa 1998).

The dominance of zooplankton in *O. niloticus* less than 5 cm TL is in agreement with Moriarty and Moriarty (1973). Adult tilapia take less zooplankton as they change the mode of feeding to gulping water, and zooplankton detect the feeding current and swim away. Small fish did not ingest insects, *C. nilotica*, bivalves or oligochaetes, probably because of their smaller mouth gape. Getabu (1994) made similar observations, whereby the percentage occurrence of invertebrates in *O. niloticus* diet increased with increase in fish size.

These finding hold considerable ecological significance. *Oreochromis niloticus* is a highly adaptable species able to exploit new opportunities and expand its realised niche to successfully colonise new habitats (Cowx 1998). In Lake Victoria the species has widened its traditional niche exploiting algal food resources towards an insectivorous feeding mode. These niches were probably vacated by the disappearance of the haplochromines, and suggests that *O. niloticus* may continue to expand until the lake ecosystem stabilises. This has fundamental implications for the exploitation of *O. niloticus* which may have found a refuge in the water hyacinth, although overfishing of both Nile perch and Nile tilapia may lead to further instability in the lake ecology with unknown consequences.

Acknowledgements

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Table 1. Food of 1441 *Oreochromis niloticus* caught from Kenyan waters of Lake Victoria between November 1998 and July 1999.

Food item	Class size (cm)										
	0-4.9	5-9.9	10-14.9	15-19.9	20-24.9	25-29.9	30-34.9	35-39.9	40-44.9	45-49.9	50-54.9
Insects	0.00	15.90	22.29	30.82	41.00	26.00	28.34	39.10	44.51	36.40	30.00
Algae	14.64	40.42	20.56	21.67	22.00	26.12	20.00	18.50	15.95	21.19	18.20
Fish	16.29	28.20	15.78	21.84	20.30	25.70	29.91	22.02	19.67	17.18	31.60
Plant material	10.77	1.43	20.26	10.62	8.90	11.16	16.90	13.00	13.45	18.92	18.00
Zooplankton	58.30	13.42	6.86	1.54	0.10	0.00	0.11	0.76	0.27	0.03	0.00
Caridina	0.00	0.63	8.77	2.45	2.20	3.12	0.24	0.54	0.02	0.54	0.00
Bivalves	0.00	0.00	3.30	10.15	5.10	7.90	4.50	5.70	5.40	4.23	1.92
Oligochaetes	0.00	0.00	2.18	0.91	0.40	0.00	0.00	0.35	0.73	0.89	0.28

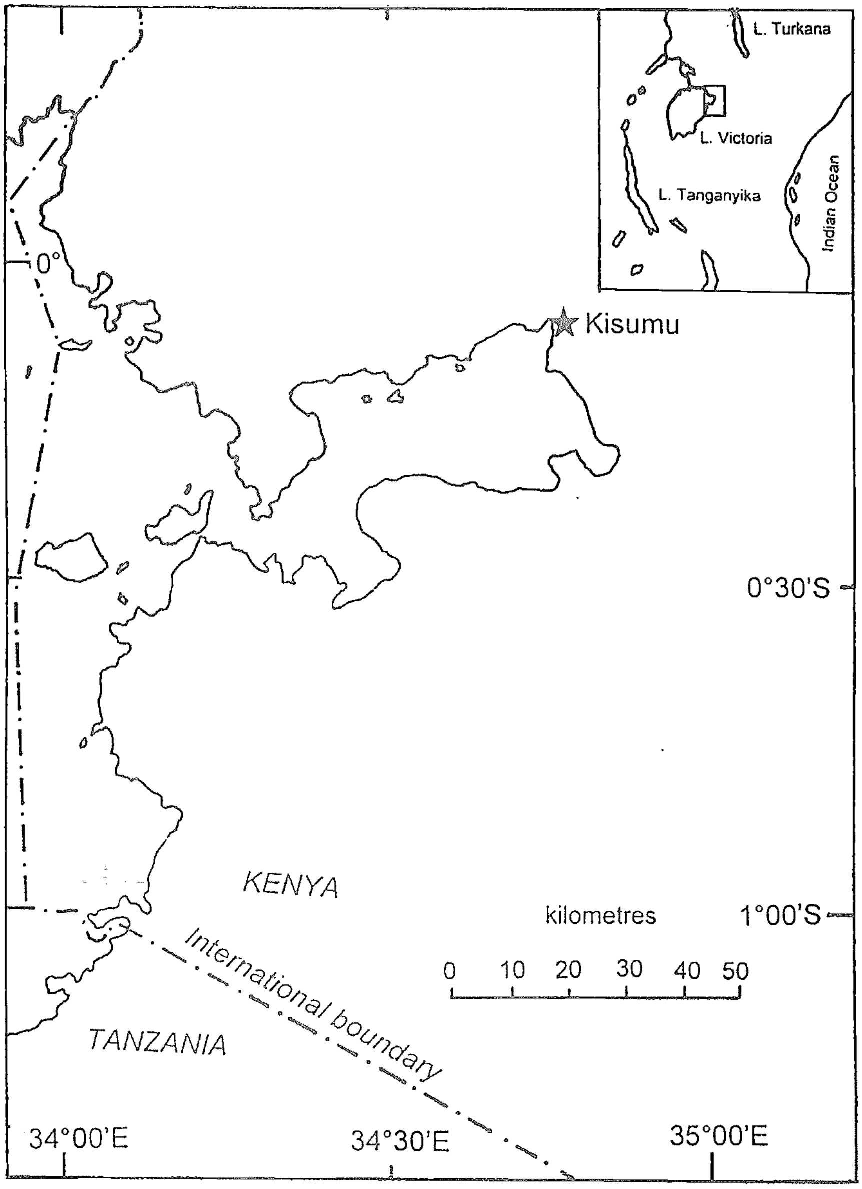

Fig. 1. Map of the sampled Kenyan waters of Lake Victoria.

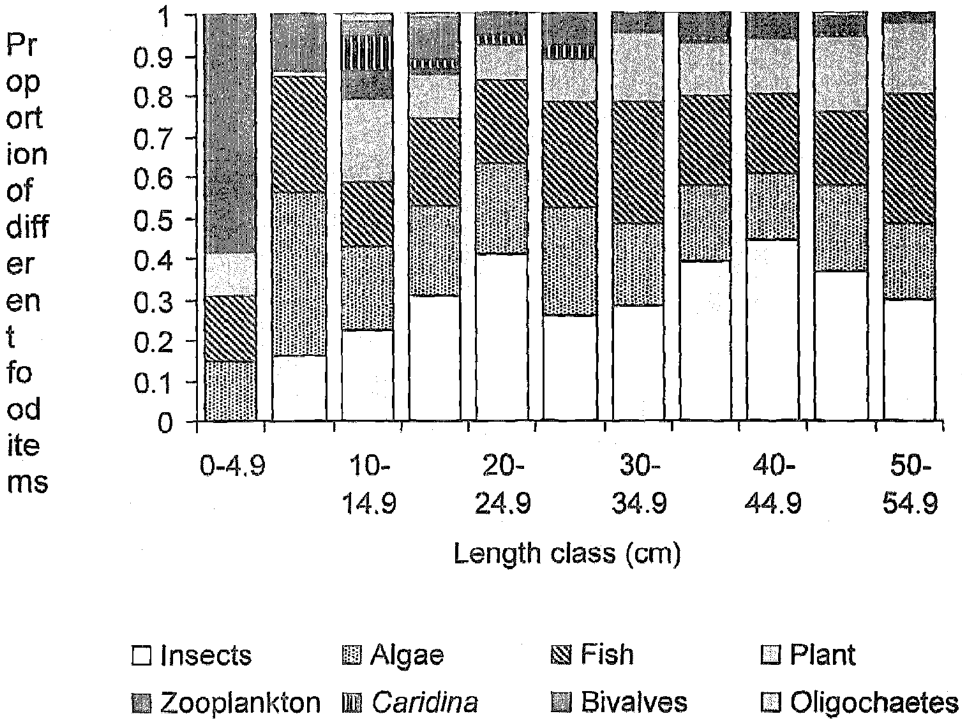

Fig. 2. Food of *Oreochromis niloticus* from Kenyan waters of Lake Victoria between November 1998 and July 1999. The importance of food items is expressed as the proportional contribution to the total points for each size class, (n = 1441).

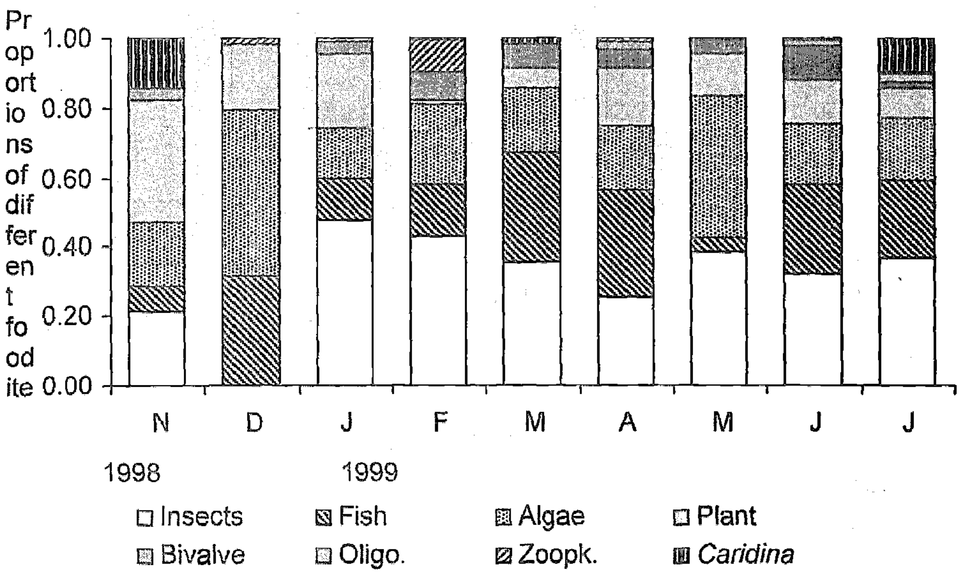

Fig. 3. Monthly contribution of various food items to the diet of *Oreochromis niloticus* Zoopk = Zooplankton.

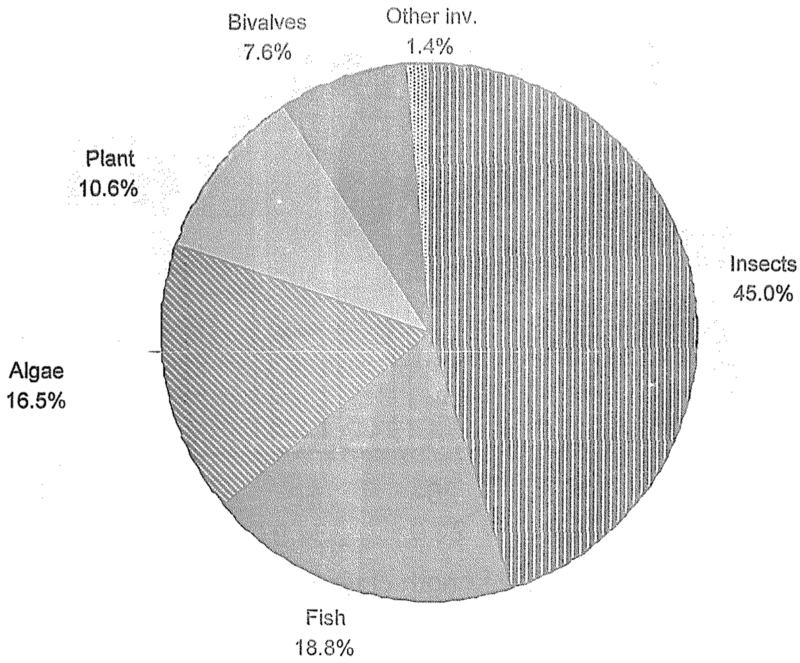

Figure. 4. Percentage contribution of different food items by volume ingested by *Oreochromis niloticus* between November 1998 and July 1999. inv. = invertebrates.

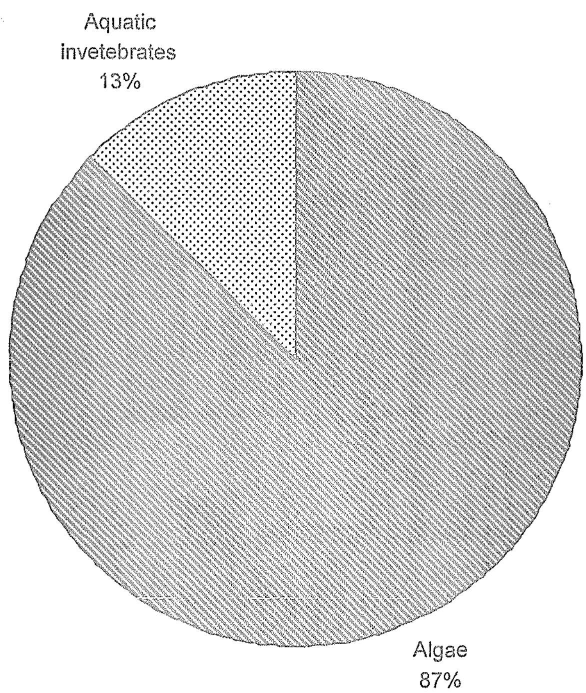

Figure 5. Percentage abundance of different food items ingested by *Orechromis niloticus* in Nyanza Gulf of Lake Victoria (Adapted from Getabu, 1994b).

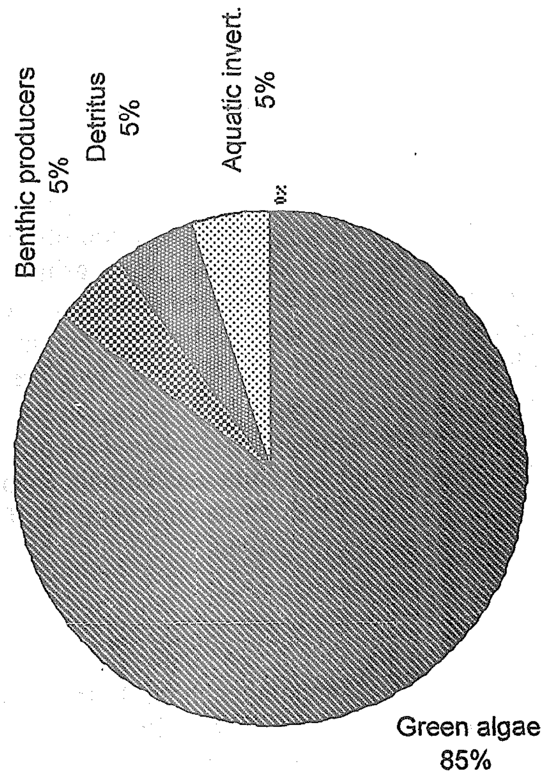

Figure. 6. Percentage abundance of different food items ingested by *Oreochromis niloticus* (Adapted from Trewavas, 1983).