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Food and feeding habits of juvenile *Oreochromis leucostictus* Trewavas (Teleostei=Cichlidae) in Lakes Naivasha and Oloidien, Kenya

Benson M. Mwangi
Department of Zoology, Kenyatta University, P.O. Box 43844, Nairobi, Kenya.

An eight month-study (July, 1990 to February, 1991) was conducted at five different littoral habitat types of Lakes Naivasha and Oloidien, Kenya, to examine variations in dietary composition of juvenile *Oreochromis leucostictus* Trewavas by habitat and size. Examination of 583 stomachs containing food, revealed that the fish is mainly a detritivore, although phytoplankton and zooplankton were occasionally taken in large amounts at some habitat types. In densely vegetated, fully or partially-enclosed lagoon habitat types, detritus constituted between 58 and 67% of the diet. However, in the more open, densely vegetated habitat types with soft substrata and slightly higher alkalinity, the importance of detritus to the diet decreased to about 32% while that of phytoplankton increased to an almost equal proportion. More food of animal origin, particularly insects and crustaceans, were also taken at such habitat types, constituting over 30% the diet. The blue-green alga, *Microsystis aeruginosa* Kutzing constituted the primary food item for juvenile *O. leucostictus* at Lake Oloidien, due to the high alkaline water conditions which prohibited the development of diverse faunal and floral composition. Food habits of the fish shifted from a diet consisting of large amounts of food of animal origin to one composed mainly of detritus and algae at a very small size of less than 2.5 cm SL, suggesting a very early change in physiological and gut morphological adaptations.

Key words: diet, habitats, *Oreochromis leucostictus,* Lake Naivasha, Lake Oloidien.

INTRODUCTION

Oreochromis leucostictus Trewavas (Teleostei: Cichlidae) currently forms the mainstay of the Lake Naivasha fishery. It was introduced in 1956 (Siddiqui, 1977), when it was carried unintentionally in *Tilapia zillii* Gerväis tanks, as the latter was being introduced to feed on the abundant aquatic macrophytes in the lake (Fryer & Iles, 1972). Soon after introduction the fish established itself unexpectedly well, constituting the largest proportion of the fish catch immediately after (Litterick *et al*., 1979).

Fryer and Iles (1972) reviewed the biology and ecology of tilapias from the great lakes of Africa. Further reviews on tilapia physiology, biology, ecology and aquaculture was done by Pullin and Lowe-McConnell (1982) and Trewavas (1982). Bowen (1982) reviewed their feeding ecology and observed that most species have the ability to take a wide variety of food items including detritus, algae, macrophytes, crustaceans and insects. It may be noted, however, that much of the information so far available on the diet of tilapias is based on adults. In Lake Naivasha, for example, extensive studies on the feeding ecology of adult tilapias have been carried out by Siddiqui (1977, 1979) and Muchiri (1990). However, there is a paucity of information on the feeding ecology of juveniles. Robotham (1990) carried out a three week study to investigate the diet of juvenile *O. leucostictus* collected from Mennel's lagoon on the Northern shores of Lake Naivasha and found that the species feed primarily on zooplankton, chironomid larvae, adult insects and higher aquatic macrophytes. The present study was designed to further investigate the feeding ecology of juvenile *O. leucostictus* in Lakes Naivasha and Oloidien, in relation to habitat variations and size.

MATERIALS AND METHODS

Juvenile *O. leucostictus* of less than 8.0 cm standard length (SL) were caught bi-weekly from July, 1990 to February, 1991, by beach seining from five different littoral (<1.0 m depth) habitat types located all round the shores of Lakes Naivasha and Oloidien (Fig. 1), using a mosquito mesh-sized seine net 25 m long. Habitat types differed in vegetation cover, bottom characteristics and water quality (Table 1). On landing, the fish were immediately placed in a bucket of water, mixed by stirring and a small sample, of about 30 fish, immediately scooped using a small planktonic hand net. The sample was then immediately placed in 10% formalin and the rest of the catch returned to the lake, after estimation of total catch. The sample was transported to the laboratory where, within 2–3 hours after capture, the fish were sorted into species and measured for standard lengths (SL) (to the nearest 0.1 cm) and weights (to the nearest 0.1 g). Individuals of juvenile *O. leucostictus* were then dissected, their stomachs removed and preserved individually in specimen bottles containing formalin–acetic acid–alcohol (FAA) preservative (Lind, 1974).

Stomachs were later opened and the contents emptied into a small petri dish. 1–2 ml of distilled water was added to the contents, which were then thoroughly mixed and observed for large food items, such as chironomid larvae and adult insects, under a low power binocular microscope. A small sample of the content was then placed on a slide and observed under a compound microscope for microscopic food items such as detritus, algae and zooplankton. Food items were identified to the lowest possible taxonomic category and their quantitative contribution to the fish diets assessed by the points method (Hynes, 1950), as modified by Muchiri (1990), as follows: food items were visually allotted points ranging from 1–10 depending on the volumetric contribution to the diet, due regard being given to the size and abundance of the food item; one large organism scored as many points as many small food items; a food item that was eaten singly scored 10 points, while a mixture of food items eaten together shared the ten points among themselves.

RESULTS

An analysis of 583 stomachs containing food of juvenile *O. leucostictus* from Lakes Naivasha and Oloidien, revealed that the fish is mainly a detritivore (Fig. 2). Detritus was eaten in largest amounts, followed by phytoplankton at most of the habitat types (Table 2). Other food items, including fry of their own kind, were taken only occasionally in small amounts.

Fish collected from partially or fully-enclosed lagoon habitat types 1, 2 and 3, fed largely on detritus mixed with small amounts of grit, constituting 66.4%, 58.2% and 65.7% of the diet, respectively (Table 2). Phytoplankton was second in importance, constituting between 16.5 and 20.2% of the diet. The taxonomic composition of phytoplankton, however, differed among the habitat types, with the green alga *Chlorella* dominating at habitat types 1 and 3 while benthic diatoms dominated at habitat type 2. Zooplankton and macrobenthos also formed important food items for the species constituting about 7.4 and 7.6% of the diet, respectively. At habitat type 2, food of animal origin constituted 20.2% as compared to 13.3% and 13.2% at habitat types 1 and 3, respectively.

In the more open, densely vegetated, alkaline habitat type 4, with slightly higher conductivity (Table 1), the importance of detritus to the diet of juvenile *O. leucostictus* declined but that of phytoplankton increased (Table 2). Detritus, for example, constituted about 31.9% of the diet, while phytoplankton constituted an almost equal proportion of about 32.1% of the diet. In this habitat type, zooplankton, particularly *Daphnia* sp., *Simocephalus*. sp. and *Diaphanosoma* sp., were taken in large amounts, constituting 25.7% of the diet. Here, more food of animal origin was taken than at any other habitat type in Lakes Naivasha and Oloidien, constituting a total of about 35.5% of the diet.

At the highly alkaline habitat type 5 (Lake Oloidien), the blue-green alga, *M. aeruginosa,* constituted the primary food item for juvenile

O. leucostictus, constituting 48.8% of the diet. Detritus was eaten in relatively small amounts, constituting 37.3% of the diet. Other food items were taken only in small amounts. Occasionally, the fish also included in their diet fry of their own kind.

Food habits of juvenile *O. leucostictus* shifted from a diet consisting of large amounts of food of animal origin at size-class of 2.1–2.5 cm SL to one composed mainly of detritus and algae in fish of larger size classes (Table 3a; b). The importance of food of animal origin declined with size, being taken only occasionally by fish larger than 4.6 cm SL. Zooplankton and insects, particularly the corrixid, *M. scuttelaris*, formed the most important components of food of animal origin in the diet of fish less than 2.5 cm SL. Detritus constituted a small proportion of less than 50% of the diet of that size-class. Fish larger than2.5 cm SL, fed on increasingly higher amounts of detritus, often constituting over 50% of the diet. By the time the fish reached 3.6 cm SL, detritus constituted over 70% of the diet, while food of animal origin declined to less than 5%.

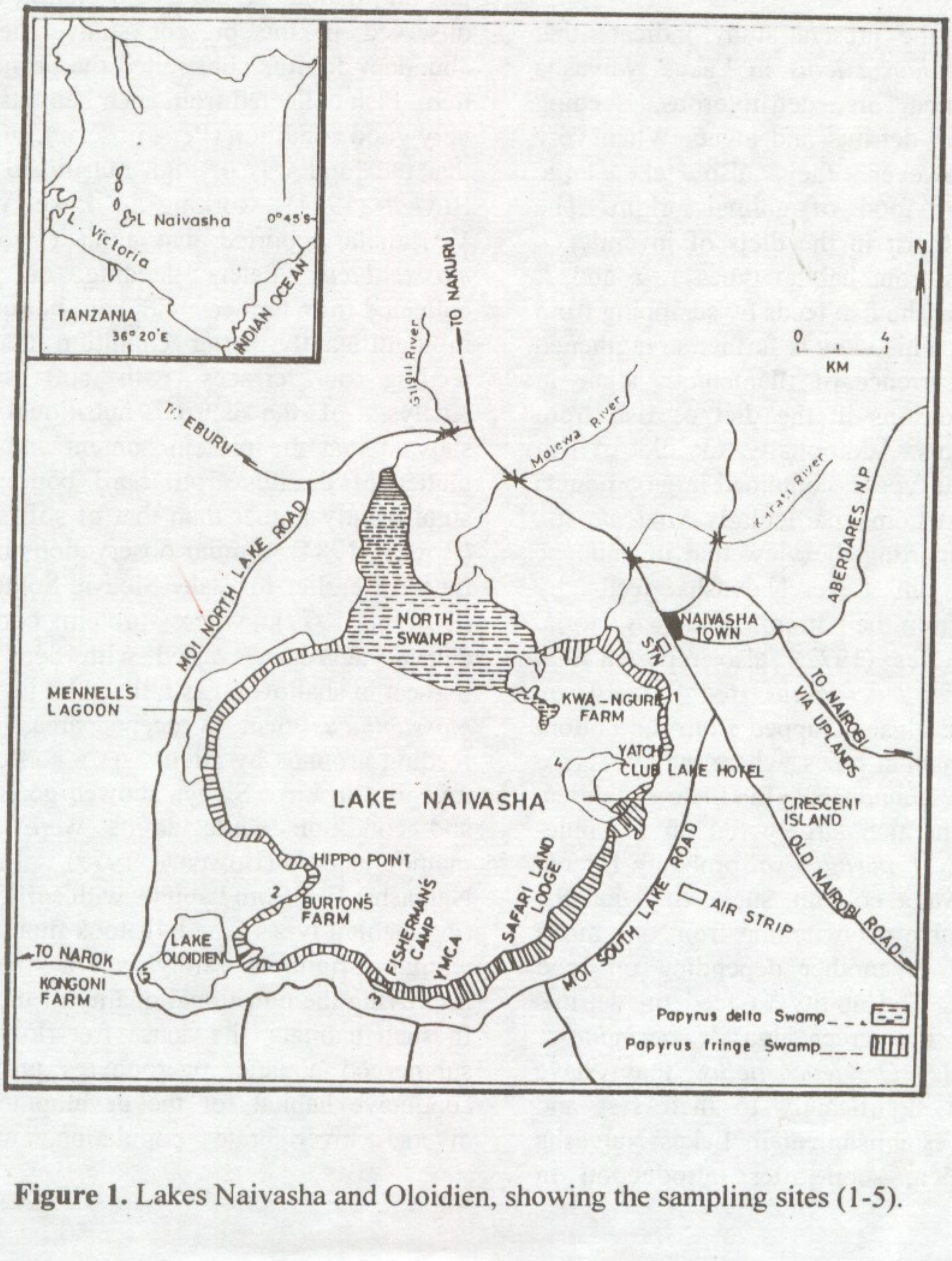

Figure 1. Lakes Naivasha and Oloidien, showing the sampling sites (1-5).

At habitat type 5 (Lake Oloidien), juvenile *O. leucostictus* showed a shift in their feeding habits at a much smaller size of less than 2.0 cmSL (Table 3b). Fish of less than 2.0 cmSL fed on a mixed diet of detritus (38.6%), phytoplankton (28.7%) and food of animal origin (36.6%), including zooplankton, macrobenthos and their fry. Above 2.0 cm SL, the fish shifted in their feeding habits to exclusively the blue green alga, *M. aeruginosa* mixed with detritus, and occasionally, small amounts of food of animal origin.

DISCUSSION

Results of the present study indicate that juvenile *O. leucostictus* in Lakes Naivasha and Oloidien are detritivorous, feeding primarily on detritus and algae. When very young, however, they also take large amounts of food of animal origin. The presence of grit in the diets of juvenile *O. leucostictus* from habitat types 1, 2 and 3, suggests that the fish feeds by scrapping from the bottom. This view is further strengthened by the occurrence of filamentous algae in large proportions in the diet of fish from these habitats. Additionally, the diet of fish from habitat type 2, contained large amounts of benthic diatoms, particularly *Navicula* sp., further supporting the view that juvenile *O. leucostictus* in Lake Naivasha feeds by scrapping from the bottom. In Lake Victoria, Fryer and Iles (1972), also reported that juvenile *O. leucostictus* fed largely on detritus and algae scrapped from the bottom of lagoon habitat types, where they occurred in highest abundance. In Lake Oloidien, however, the fish largely fed on the blue-green alga, *M. aeruginosa*, probably filtered from the water column, suggesting that the fish is capable of switching from one mode of feeding to another depending on food availability. The ability to feed on detritus and on the blue-green alga, *M. aeruginosa,* by juvenile *O. leucostictus* may have contributed significantly to their fast and successful establishment in Lakes Naivasha and Oloidien, soon after introduction in 1956, owing to the great abundance of these food items in these lakes. Detritus is highly abundant in Lake Naivasha, being contributed by the dense free floating, submerged and emergent macrophytes after death and decay. Similarly, *M. aeruginosa* is highly abundant in Lake Oloidien due to its low water quality conditions (Njuguna, 1982).

The importance of different food items to the diet of juvenile *O. leucostictus* varied among habitat types, probably as a consequence of variations in food availability and nutritional quality. In densely vegetated lagoon habitat types with hard bottoms, observed in the present study, the highly abundant detritus constituted the primary food item. Fish collected from such habitats were in very good condition (Pers. observ.), suggesting that the food was of high nutritional quality. Bowen (1984), working in Lake Valencia, Venezuela, reported that adult *Oreochromis mossambicus* Peters feeding on detritus collected from terraces with hard bottoms were in significantly better condition than those feeding on terraces with soft substrata. Analysis of the detrital nutritional quality showed that the protein content and organic matter of detritus from hard bottoms were significantly higher than that of soft substrata (Bowen, 1984). Similar observations had been reported earlier for Lake Sibaya, South Africa (Bowen, 1979), where protein content of detrital aggregate varied with depth, being highest in shallow areas utilised by juvenile *O. mossambicus* than in deeper areas used as feeding grounds by adults. As a consequence, juveniles in Lake Sibaya showed good growth and condition while adults were severely malnourished (Bowen, 1979). In Lake Naivasha, fish from habitats with soft substrata (*e.g.* habitat types 2 and 4), took more food of animal origin, possibly as a means of improving the nutritional quality of their diets. In such habitats, the dense free-floating and submerged aquatic macrophytes provided a conducive habitat for the development of a diverse invertebrate population, including

Table 1. General physical-chemical characteristics of sampled habitat types in Lakes Naivasha and Oloidien, Kenya, from July 1990 to February 1991.

Habitat type	Local name	Cover and vegetation type	Bottom characteristics	Mean conductivity (μScm^{-1}) ± SE.	Mean pH ± SE	Mean TDS (Mg/l) ± SE.	Mean DO (mg/l) ± SE
1 (Fresh)	Kwa-Ngure Farm — located at the North-eastern shoreline of Lake Naivasha	Lagoon enclosed by thick papyrus swamp. Very sparse mats of *Salvinia molesta* present.	Gently sloping bottom with hard substratum covered by a thick layer of detritus rich in organic matter from crayfish remains	328.8 ± 7.48	6.95 ± 0.09	165.8 ± 4.03.	4.60 ± 0.44
2 (Fresh)	Burton's Farm — Western shore	Open with thin discontinuous papyrus swamp; very sparse *Salvinia* mats mixed with *Eichhornia*.	Steep slope; very deep soft muddy substratum, mixed with gravel, sand and pebbles	287.8 ± 12.96	7.51 ± 0.27	140.6 ± 3.68	6.02 ± 0.54
3 (Fresh)	Fisherman's Camp — Southern shoreline	Lagoon enclosed by thick papyrus swamp. Moderately dense cover of *Salvinia* mats and *Eichhornia*.	Gentle slope; Hard sandy bottom with a thin layer of detritus	303.5 ± 9.45	7.27 ± 0.21	155.0 ± 9.75	4.59 ± 0.71
4 (Fresh)	Crescent Island — Eastern shoreline	Open and subject to strong wave action. Papyrus absent but dense cover of *Salvinia* and *Eichhornia*. Wide array of rooted submerged macrophytes.	Very gently sloping bottom; thick soft muddy substratum mixed with thick layer of detritus from decaying vegetation and animal dung	356.2 ± 6.11	7.79 ± 0.29	179.9 ± 7.03	8.20 ± 1.25
5 (Mesosaline)	Kongoni Farm — Lake Oloidien	Open and subject to strong wave action. Emergent and Macrophytes lacking . Bottom covered by sparse rooted sedges.	Gentle slope; hard bottom covered by a thin layer of detritus. Along the shoreline occurred dense fresh grass-like vegetation recently heaped by waves.	1296.6 ± 45.84	8.96 ± 0.06	652.0 ± 23.4	5.22 ± 0.31

other insects, which were readily available to the fish.

In the more alkaline habitat type 5 (Lake Oloidien), the blue-green alga *M. aeruginosa* constituted the primary food item for juvenile *O. leucostictus,* as here the high alkaline water conditions prohibited the development of diverse faunal and floral composition, thus limiting the diversity of food sources available to the fish. Njuguna (1982) reported that for most part of the year, the phytoplankton composition of Lake Oloidien is dominated by *M. aeruginosa.* In lakes where *M. aeruginosa* dominates the phytoplankton biomass, it often constitutes the primary food item for the native fish species. In Lake George, Uganda, for example, it constitutes the most abundant phytoplankton group, as well as the primary food item for adult *O. leucostictus* (Dunn, 1972; Gwahaba, 1975). Similarly, *M. aeruginosa* constituted the primary food item for the native *Tilapia grahami* Boulenger in Lake Magadi, Kenya, where it dominates the primary production biomass (Vareschi, 1979). These observations strengthen the conclusion of Mckaye and Marsh (1983), that although most cichlid species are specialised in their feeding habits, they can, especially at times of abundance, utilise a wide variety of other food items.

Food habits of juvenile *O. leucostictus* shifted from a diet consisting of large amounts of food of animal origin to one composed mainly of detritus and algae at a very small size of less than 2.5 cmSL, thus suggesting a very early change in the physiological and gut morphological adaptations of the species in order to cope with the less digestible plant material. De Moor *et al*. (1986), working in Hartbeesport Dam, South Africa, also observed that juvenile *O. mossambicus* shifted in their feeding habits, from a diet primarily composed of food of animal origin, to one of detritus and algae, at a very early age when weighing only 4 g. These observations suggest that detritivorous tilapiine species generally shift to feeding on a diet of plant origin at a very early stage in their life history. Bowen (1982) suggested that small tilapias require high amounts of food of animal origin as this provides the high energy required to support their fast growth. As the fish increase in size, however, the demand for food of high energy content decreases and the fish shifts to feeding on the more readily available food of plant origin. Occasionally, fish feeding on low quality food may take any readily available food of animal origin, such as fry of their own kind (as was observed in Lake Oloidien), possibly as a means of improving the nutritional quality of their diet. Such more readily available food items demand lower search energy expenditure than would be the case with the more scarcely available zooplankton or insects in waters of high alkalinity. Although cannibalism has not been widely reported among tilapias, Fagade (1971) and Khallaf and Alne-na-ei (1987) reported fish eggs and scales in diets of adult *Oreochromis niloticus* L.

Results of this study show that although juvenile *O. leucostictus* is detritivorous, at sizes less than 2.5 cmSL, it prefers food of high nutritional quality. This is in agreement with the conclusion reached by Fryer and Iles (1972) for juvenile *O. leucostictus* in Lake Victoria, where the fish were found to feed primarily on detritus and phytoplankton, picked from the bottom. It is also apparently evident that low alkaline, enclosed habitat types with hard substrata provided high quality detritus which was readily taken by juvenile *O. leucostictus*, supporting good growth and condition. The availability of high quality detritus in the densely vegetated lagoon habitat types of Lakes Naivasha may have been, therefore, a major factor contributing to the fast and successful establishment of *O. leucostictus* in the lake soon after its unintentional introduction in 1956.

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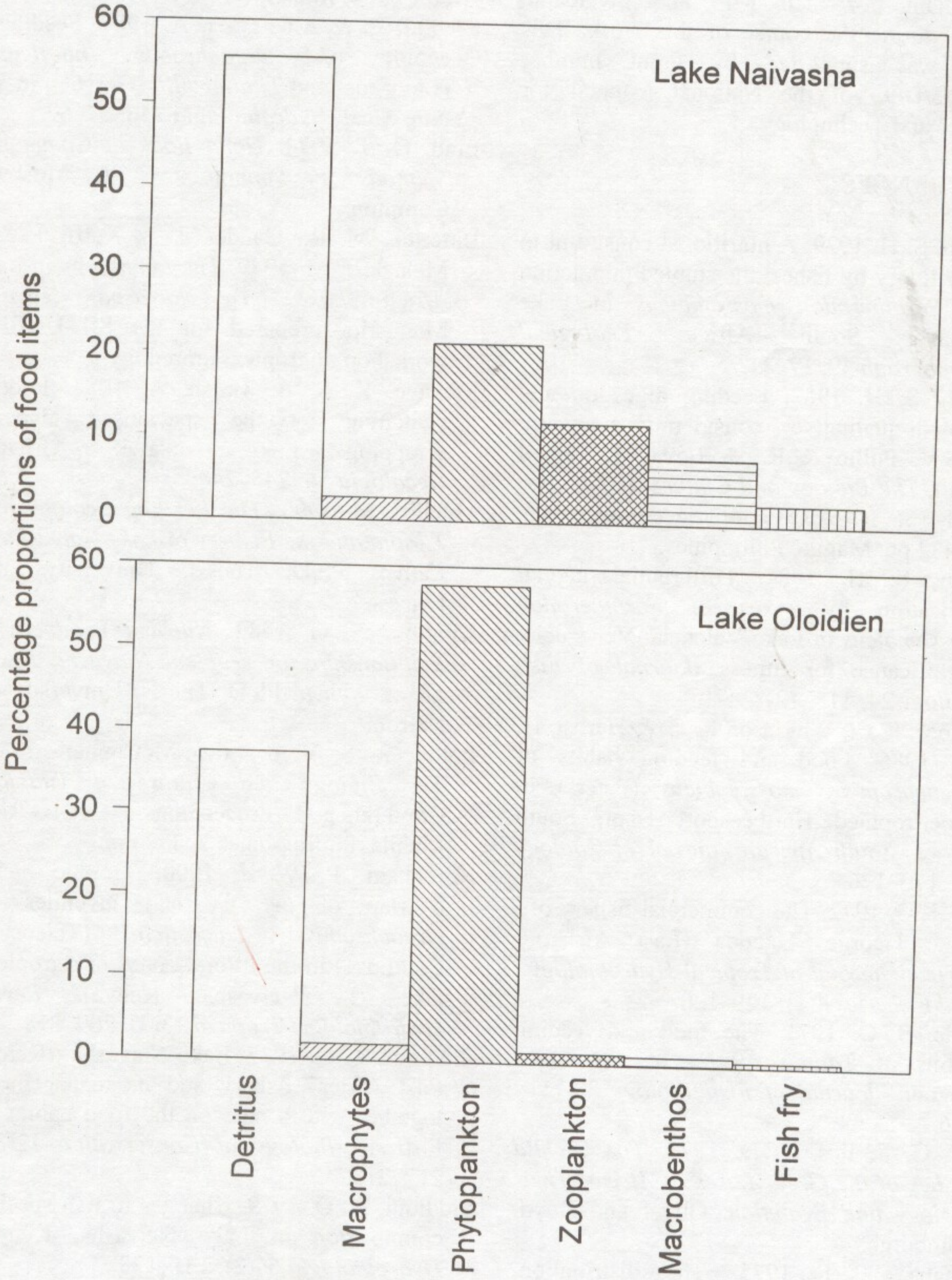

Figure 2. Percentage proportions of dietary components eaten by juvenile *Oreochromis leucostictus* in Lakes Naivasha and Oloidien (data for both lakes combined).

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Table 2. Percentage proportions of food items in diets of juvenile *O. leucostictus* at different habitat types in Lakes Naivasha and Oloidien, Kenya.

Food item	Percentage of food items in diets at different habitat types				
	1 (Kwa-Ngure) (183)	2 (Burton's Farm) (58)	3 (Fisherman's Camp) (168)	4 (Crescent Island) (86)	5 (Oloidien Lake) (88)
Detritus	**66.4**	**58.2**	**65.7**	**31.9**	**37.3**
Macrophytes	**3.8**	**5.4**	**1.3**	**0.3**	**2.0**
Phytoplankton	**16.5**	**16.7**	**20.2**	**32.1**	**57.8**
Blue-green algae	2.0	0.6	0.1	0.1	48.8
Diatoms	1.4	10.2	2.9	5.5	8.3
Filamentous algae	3.6	2.6	3.0	2.3	0
Green algae	9.1	3.2	13.8	24.1	0.7
Dinoflagellates	0.4	0.1	0.4	0.1	0
Zooplankton	**7.9**	**7.4**	**6.9**	**25.7**	**1.3**
Copepods	5.1	3.4	2.8	5.0	1.0
Cladocera	2.6	3.6	4.0	18.9	0.3
Rotifers	0.2	0	0	0.1	0
Ostracods	0	0.4	0.1	1.7	0
Macrobenthos	**5.1**	**12.2**	**5.4**	**8.8**	**1.1**
Chironomids	1.4	1.1	1.8	1.6	0
Oligochaetes	0.3	1.4	1.3	3.1	0
Water mites	0	1.6	0.7	0.1	0
Corrixids	1.1	1.3	0.5	0.9	0
Others	2.3	6.8	1.1	3.1	1.1
Fish eggs	**0.2**	**0.1**	**0.1**	**0**	**0**
Fish scales	**0**	**0.5**	**0**	**0**	**0.1**
Fish fry	**0**	**0**	**0.6**	**1.0**	**0.5**

NOTE: Figures in parentheses indicate number of fish.

Table 3. Percentage proportions of food items in diet of juvenile *Oreochromis leucostictus* of different size-classes in Lakes Naivasha and Oloidien, Kenya.

a) Lake Naivasha (data from 4 different habitats combined)

Size classes (cm)	N	Percentage proportion of food items in the diet: Detritus	Macro-phytes	Phytopl-ankton	Zoopl-ankton	Chiro-nomids	Corrixids	other benthos	Total % benthos	Fish fry	Fish scales
<2.0	66	**40.4**	**2.6**	**15.8**	**31.0**	2.5	1.7	5.9	**10.1**	0.1	0
2.1 - 2.5	58	**47.8**	**1.5**	**15.5**	**23.1**	3.4	1.1	7.4	**11.9**	0	0
2.6 - 3.0	48	**52.3**	**2.6**	**24.3**	**15.7**	1.5	0	3.7	**5.2**	0	0
3.1 - 3.5	45	**59.8**	**4.1**	**19.8**	**7.1**	6.4	0	2.3	**8.7**	0	0.3
3.6 - 4.0	40	**72.5**	**5.1**	**7.9**	**10.0**	4.1	0.3	0	**4.4**	0	0
4.1 - 4.5	31	**64.8**	**6.8**	**5.8**	**7.8**	12.5	1.1	1.1	**14.7**	0	0
4.6 - 5.0	41	**77.5**	**2.1**	**15.7**	**4.1**	0	0	0.6	**0.6**	0	0
5.1 - 5.5	28	**84.8**	**2.5**	**7.6**	**1.8**	0	0	0	**3.3**	0	0
5.6 - 6.0	29	**73.1**	**0.6**	**21.5**	**1.1**	3.3	0	2.5	**3.8**	0	0
6.1 - 6.5	20	**73.9**	**1.1**	**21.6**	**0**	1.3	0	3.3	**3.3**	0	0
6.6 - 7.0	28	72.7	0.6	9.4	8.6	0	0	0.2	**0.2**	8.4	0.1
7.1 - 7.5	18	**81.9**	**1.3**	**16.7**	**0.1**	0	0	0	**0**	0	0
7.5 - 8.0	13	**84.1**	**3.9**	**12.0**	**0.1**	0	0	0	**0**	0	0
>8.0	30	**65.8**	**5.6**	**15.7**	**2.4**	4.9	2.7	2.6	**10.2**	0	0.4

b) Lake Oloidien (only 1 site considered)

Size classes (cm)	N	Percentage proportion of food items in the diet: Detritus	Macro-phytes	Phytopl ankton	Zoopl-ankton	Chiro-nomids	Other benthos	Total benthos	Fish fry
<2.0	12	**38.6**	**0.2**	**28.7**	**24.7**	0	3.6	**3.6**	8.3
2.1 - 2.5	12	**50.8**	**0.9**	**41.5**	**1.7**	4.3	0.8	**5.1**	
2.6 - 3.0	22	**48.1**	**8.0**	**39.3**	**1.0**	3.7	0	**3.7**	
3.1 - 3.5	30	**35.0**	**0.7**	**57.6**	**0.3**	6.2	0.2	**6.4**	
3.6 - 4.0	24	**31.1**	**0**	**68.7**	**0**	0.3	0.3	**0.6**	
4.1 - 4.5	20	**38.9**	**0**	**60.6**	**0**	0	0	**0.5**	0.5
4.6 - 5.0	12	**28.9**	**0**	**71.1**	**0**	0	0	**0**	
5.1 - 5.5	8	**29.8**	**0**	**70.3**	**0**	0	0	**0**	
5.6 - 6.0	7	**61.4**	**0**	**38.6**	**0**	0	0	**0**	
6.1 - 6.5	7	**40.4**	5.7	**48.7**	**0**	0	5.40	**5.4**	
6.6 - 7.0	1	**57.5**	**0**	**42.5**	**0**	0	0	**0**	
7.1 - 7.5	6	**31.8**	**0**	**49.9**	**0**	0	18.3	**18.3**	
7.5 - 8.0	3	**29.2**	**0**	**60.2**	**0**	0	10.5	**10.5**	
>8.0	4	**29.4**	**0.8**	**69.9**	**0**	0	0		