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Diet of the largemouth bass, *Micropterus salmoides* (Lacepède), in Lake Naivasha, Kenya

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Abstract The major food items of adult largemouth bass, *Micropterus salmoides* (Lacepède), in Lake Naivasha, Kenya are not markedly different from those in its native range. Although insects and their larvae are major components of the diet for both temperate and equatorial populations of juvenile bass, the equatorial population also eats *Procambarus clarkii* (Girard), juvenile fish and aquatic weeds. In temperate populations they also eat crustaceans, rotifers and oligochaetes. The frequency of occurrence of the major prey organisms in the stomachs of *M. salmoides* varies seasonally with population peaks in these organisms. Similar to North American populations, the Naivasha population feeds during the day between dawn and dusk. In contrast to temperate populations, the population of *M. salmoides* in this equatorial lake feeds throughout the year, with feeding intensity correlated with water temperature.

KEYWORDS: Diet, Lake Naivasha, largemouth bass, *Micropterus*.

Introduction

Largemouth bass, *Micropterus salmoides* (Lacepède), were introduced into Lake Naivasha, Kenya in 1929, primarily for sport fishing (Aloo 1988). To ensure survival in its new equatorial environment, *Oreochromis spilurus* (Günther), *Oreochromis spilurus niger* (Gunther) and *Tilapia zillii* (Gervais) were introduced as prey species. Despite these attempts to ensure the survival of largemouth bass in its new environment, no studies were carried out on the bass populations for some 40 years when limited observations were made on food, habitat preference and size at maturity (Malvestuto pers. comm.; Siddiqui 1977). Recently, Hickley, North, Muchiri & Harper (1994) have provided information on food requirements. Meanwhile, the species has gained commercial importance in the lake (Aloo 1988).

The present research was carried out between October 1986 and September 1987 as part of an ecosystem study of Lake Naivasha. The objectives of the study were to describe the food habits of *M. salmoides* in this equatorial lake and compare the results with data from its native temperate range.

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Materials and methods

Study area

Lake Naivasha, lying at 0°45′S and 36°20′E at an altitude of 1890 m above sea level, is a shallow equatorial lake in the eastern arm of the Rift Valley in Kenya. The lake is made up of three water bodies: (i) the main lake, (ii) Crescent Lake, lying to the east and separated from the main lake during dry spells by the exposed arm of Crescent Island, and (iii) Oloidien Bay, separated by papyrus and connected to the main lake by a small canal but isolated during low water. Samples were not taken from Oloidien Bay. The lake is a roughly circular, closed basin with a surface area of about 158 km^2 and a depth of 4–6 m. Water conductivity is 300 $\mu S\,cm^{-1}$ at 25°C and Secchi disc readings range from 50 to 164 cm.

The Lake Naivasha basin area is semi-arid; the area receives 620 mm of rainfall, while evaporation is 1735 mm annually. Evaporation exceeds precipitation throughout most of the year except at peak rainfall. The highest rainfall is in April–May with a minor peak in November (Melack 1976). Air temperatures are moderate with annual means of 15.9°–18.5°C, while water temperatures range from 10.5° to 21.5°C at 4–6 m increasing to an average of 25.5°C at the surface (Aloo 1988).

The basin has rich and diverse plant and animal life. Emergent macrophytes are dominated by sedges, primarily *Cyperus papyrus* (L.). Papyrus forms a fringing zone around the lake, separating it from the sorrounding farmland. In the open lake, the floating macrophyte community is dominated by *Salvinia molesta* (Mitch.). *Ceratophyllum demersum* (L.) dominates the submerged macrophyte community and forms extensive beds in the shallow parts of the lake and lagoons (Muthuri 1983).

There are five species of fish in the lake: *Oreochromis leucostictus* (Trewavas), *Tilapia zillii* (Gervais), *Micropterus salmoides* (Lacepède), *Barbus amphigrama* (Boulenger) and *Poecilia reticulata* (Peters).

Fish sampling

Initial trial fishing, coupled with information from the local fishermen confirmed that in Lake Naivasha largemouth bass are primarily littoral predators. Five sampling stations were therefore established around the littoral zones of the lake. Each station was fished weekly using a gang of gill nets of stretched mesh sizes 11, 27, 50, 63, 76, 88, 110 and 114 mm. To support the analysis of diet, some fish were caught by hook and line. The total length (TL) of each fish was measured to the nearest cm and its stomach contents removed and preserved in 5% formalin for subsequent examination in the laboratory, using a low-power microscope. Successive beach seining was carried out at 2-h intervals throughout a 24-h period once a month to determine diurnal feeding activity.

Stomach contents analysis

The stomach contents of 420 adult and 69 juvenile *M. salmoides*, ranging from 50 to

500 cm TL, were identified to genus, and wherever possible, to species. In each stomach, the number of individuals in each prey taxon was recorded. The number of stomachs in which each food item occurred was expressed as a percentage of the total number of stomachs examined (the frequency of occurrence method, Hynes 1950). Stomach fullness of the fish caught at each sampling interval was estimated according to the subjective scale of Lebedev (1946) but based on a scale of fullness ranging from 0 (empty) to 4 (stomach fully distended with food). The index of stomach fullness (Blegvad 1917), modified slightly by Okach & Dadzie (1988) was: (wet weight (g) of stomach contents/weight of fish (g)) × 100.

Results

Micropterus salmoides in Lake Naivasha feed on a variety of prey items (Fig. 1). The items range in size from insect larvae (e.g. *Chironomus* spp.) to vertebrates (fishes and amphibians).

The frequency of prey items in the stomach of *M. salmoides* varied seasonally (Fig. 2). During the dry and sunny months of September to October and the short rains in November to December, the percentage frequency of occurrence of *Procambarus clarkii* in the diet was very high (mean 46.1%). In January, part of the dry season which is neither wet nor cold, a high consumption of juvenile fish (28.5%) and

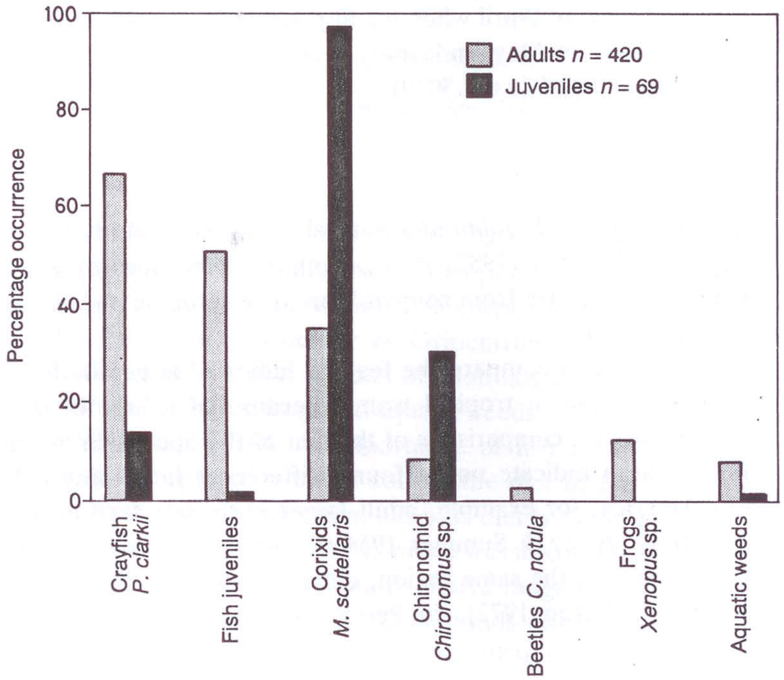

Figure 1. Food habits of adult and juvenile largemouth bass.

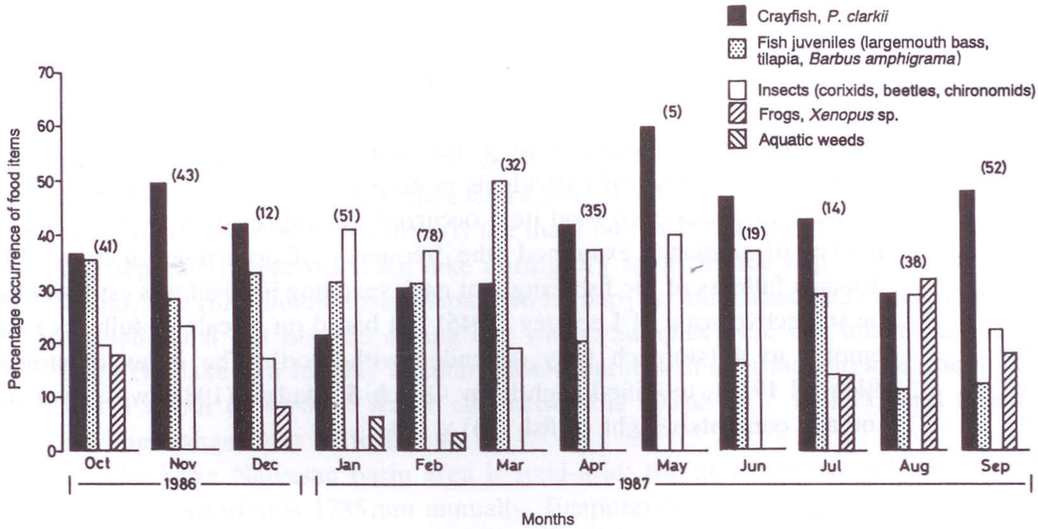

Figure 2. Monthly variations in the diet composition of adult *M. salmoides*. Figures in parentheses indicate sample size.

P. clarkii (22.5%) was observed. There was a very high percentage occurrence of insects during the long wet months from February (47%) to June (46%), and into August (35%).

Most fish exhibited diel variations in stomach fullness (Fig. 3) with full stomachs in the morning and evening and empty stomachs at night. It appears that *M. salmoides* in Lake Naivasha feed actively throughout the day, but especially at dawn and dusk.

Maximum stomach fullness occurred from September to February, and declined rapidly in March to April when feeding activity reduced markedly (Fig. 4). The fullness index increased in May, indicating a resurgence in feeding. The changes seem to be temperature-related ($r = 0.5079$).

Discussion

In general, adult *M. salmoides* eat fish, crayfish and insects; however, according to Hodgson & Kitchell (1987) it is an opportunistic forager and its diet includes prey ranging greatly in size from zooplankton to vertebrates (fishes, amphibians, reptiles and small mammals).

It is difficult to compare the feeding habits of largemouth bass in North American waters with those in tropical waters because of a lack of data from other tropical waters. However, comparisons of the diet of this species in its native range with that in Lake Naivasha indicate no profound differences in feeding habits. In Lake Mead in North America, for example, adult largemouth bass feed on fish, insects, crustaceans and detritus (Jonez & Summer 1954; Espinosa & Deacon 1973; Morgensen 1982). In Lake Mohave, in the same region, crayfish, fish, aquatic weeds and salamanders were important (Johnson 1972). In Peter and Paul Lakes (Michigan) the following prey

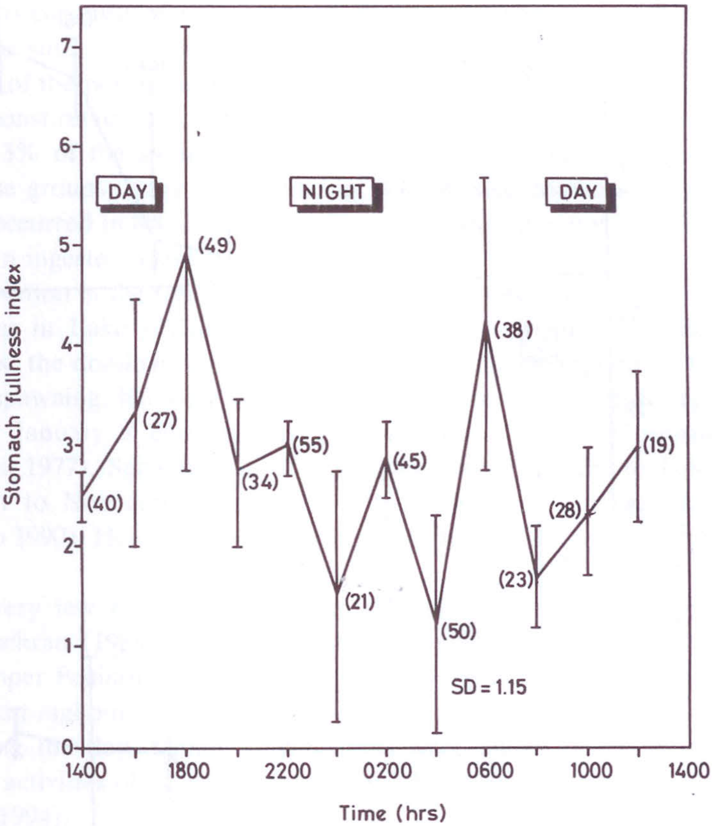

Figure 3. Diurnal changes in feeding habits of *M. salmoides*. Vertical bars indicate standard deviations. Figures in parentheses indicate sample size.

items were found in the diet of largemouth bass: zooplankton, Ephemeroptera, *Chaoborus* spp., mites, chironomid pupae, Coleoptera, Odonata, Trichoptera, Notonecta, Mollusca, leeches, benthic macroinvertebrates and terrestrial insects (Hodgson & Cochran 1988; Hodgson, Carpenter & Gripentrog 1989; Hodgson, Hodgson & Brooks 1991). In the present study, the diet of adult largemouth bass in Lake Naivasha consisted of crayfish, fish, insects, frogs and aquatic weeds. Contrary to the observations of Hickley *et al*. (1994) on the lack of importance of fish in the diet of bass in Lake Naivasha, this prey item played a major role in the diet of the species in the present study. The main recent change in largemouth bass diet is the importance of the corixid *Micronecta scutellaris* (Hickley *et al*. 1994), which was also evident in the present study.

The diet of juvenile *M. salmoides* from its native range seems to differ from that in equatorial lakes. In North American hatchery ponds (Rogers 1968), and in lakes in Michigan (Hodgson & Kitchell 1987; Hodgson *et al*. 1989) largemouth bass ate copepods, cladocerans and rotifers. The rotifers were probably eaten by accident because *Daphnia* spp. seems to be the smallest prey consumed (Hodgson & Kitchell, 1987). In contrast, the few (69) Lake Naivasha juvenile (150–200 mm) *M. salmoides* consumed crayfish,

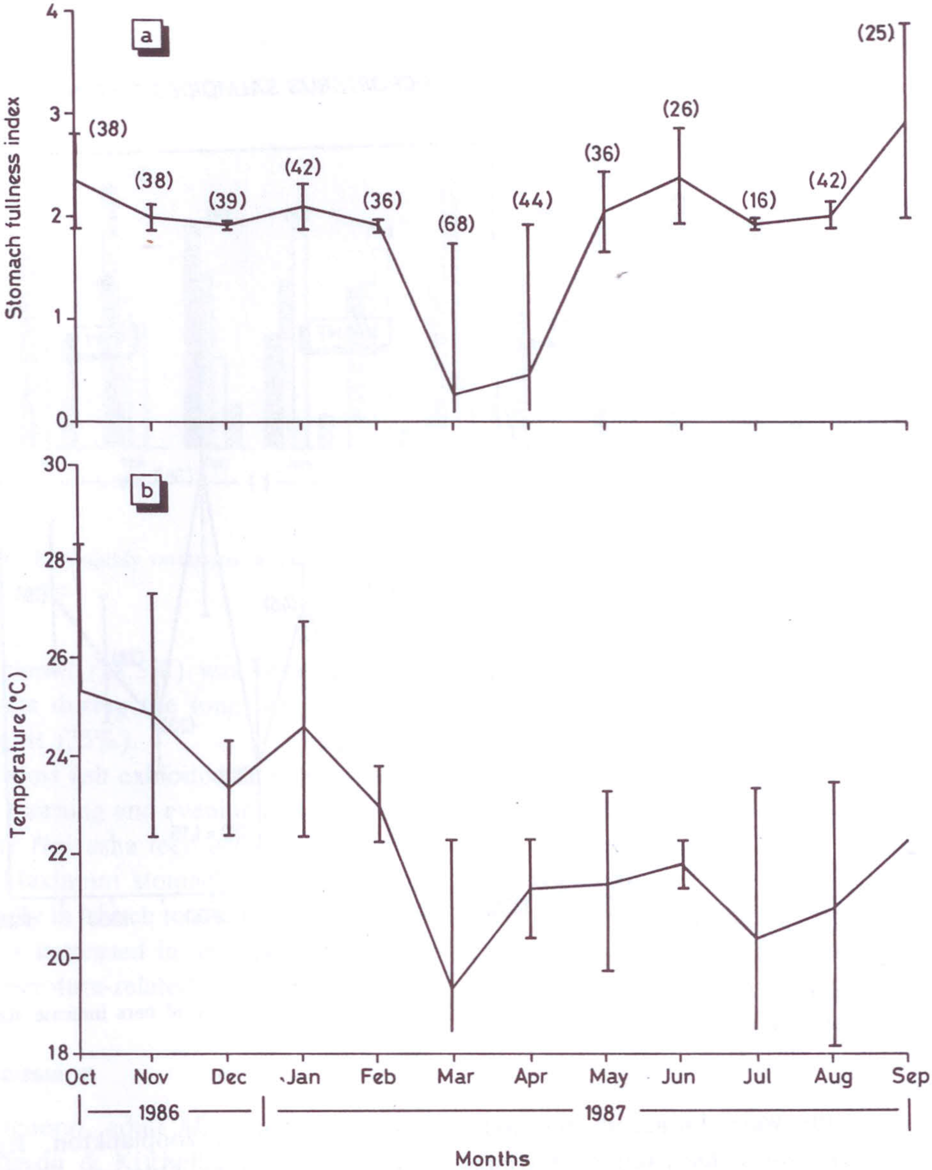

Figure 4. Monthly variations in (a) feeding activity of largemouth bass and (b) water temperature. Figures in parentheses indicate sample size. Vertical bars indicate standard deviations.

juvenile fish and some aquatic weeds and avoided zooplankton, although the latter was consumed by individuals smaller than 80 mm in the same lake in an earlier study (Hickley *et al.* 1994). Adult insects and their larvae were the only prey items found in common in juvenile bass from the two regions. In Lake Naivasha, however, juvenile bass fed predominantly on insect prey, thus confirming the observations of Malvestuto (pers. comm.), Siddiqui (1977) and Hickley *et al.* (1994).

Changes in occurrence of prey items in *M. salmoides* in Lake Naivasha seem to have taken place since the earlier studies of Siddiqui (1977). Siddiqui (1977) reported that about 78% of the percentage occurrence was made up of crayfish while insects and fish juveniles constituted 15% and 7% respectively. In the present study, crayfish occurred in 63.3% of the stomachs, juvenile fish in 51.7% and insects in 47.8%. In addition to these groups, frogs were found in 14% of bass stomachs (adults only) and aquatic weeds occurred in 8% of the stomachs. The latter may not be a food item and might have been ingested accidentally.

Seasonal variation in the frequency of occurrence of prey organisms in the stomachs of *M. salmoides* in Lake Naivasha coincided with population peaks in these prey organisms. Thus, the dominance of *P. clarkii* in the diet from September to December coincides with spawning, hatching and appearance of active crayfish during this period (Oluoch 1983). January is characterized by very high numbers of juvenile tilapiine species (Siddiqui 1977). Spawning of *M. salmoides* lasts from June to January, with a peak in August to November and young-of-the-year (YOY) appearing in January (Dadzie & Aloo 1990). Hence cannibalism on YOY dominates the diet of *M. salmoides* in January.

There are very few reports on the diurnal feeding patterns of largemouth bass. Hodgson & Cochran (1988) noted diel prey availability in Paul, Peter and Tuesday Lakes in the Upper Peninsular of Michigan, while Moyle & Holzhauser (1978) observed that bass fed throughout a 24-h period in Lake California, but most foods were consumed during the day. Similar observations were made in the present study on diurnal feeding activities of *M. salmoides* in Lake Naivasha and confirm the findings of Hickley *et al.* (1994).

From the findings of the present study, it may be suggested that largemouth bass in Lake Naivasha feed throughout the year, unlike populations in North America where feeding analysis revealed seasonal variations (Dubets 1954; Zweiacker & Summerfelt 1974). The continuous feeding behaviour of the species in Lake Naivasha may be due to prolonged favourable environmental conditions, i.e. high water temperatures and high productivity leading to intensive feeding throughout the year. However, variations in feeding activity correlated with water temperature were observed. The reduced feeding activities in March and April coincided with the period just after spawning (Dadzie & Aloo 1990). The feeding pattern followed, generally, those described earlier whereby juvenile largemouth bass, a macropredator, commenced feeding on macro-invertebrates, followed by insect prey, then crayfish, fish and frogs as their size increased (Malvestuto pers. comm.; Siddiqui 1977; Hickley *et al.* 1994). In the present study, however, the switch to crayfish and fish took place at a comparatively smaller length-class while absence of zooplankton from the diet might be due to the small sample size of the juvenile bass.

Acknowledgement

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