

FEEDING STRUCTURES AND ASSOCIATED ORGANS IN THE CICHLID FISH, *OREOCHROMIS ESCULENTUS* (GRAHAM)

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Summary

Teeth anatomy and gut morphology are described in *Oreochromis esculentus* (Graham) and related to the food habits of the species based on existing information and diet and food-utilization. Three rows of oral teeth of different sizes are found on both the upper and lower jaws. They are either bicuspid, on the outer row, or tricuspid, on the inner and middle rows. The dentition does not seem to undergo morphological changes with size of the fish. Teeth are also borne on triangular pharyngeal bones with different lengths and are curved backwards. The toothed surface area of the lower pharyngeal bone reveals a significant positive correlation with fish standard length ($r = 0.65$; $P < 0.05$). The lower pharyngeal teeth are adapted for breaking colonial and filamentous algae while the dorsal ones are used for plankton maceration. The jaw teeth, however, could not be associated with any food type consumed by the species in the lake. The stomach is a distensible sac which is separated from the duodenum by a pyloric sphincter. Only limited digestion takes place there. The intestine is of considerable length, with a ratio of 1.4 - 1:14 to fish standard length and a highly positive correlation between intestine length (IL) and fish standard length (SL) described by the following equation: $\text{Log IL} = 0.50 + 1.23 \text{ SL}$ ($r = 0.88$; $n = 593$).

Introduction

Cichlid fishes, which are the predominant perch-like fishes in Africa, occur naturally also in the eastern Mediterranean region including the Jordan Valley, and in India and Ceylon, and also in South and Central America (Bardach, Ryther & McLarney, 1972; Fryer & Iles, 1972; Philippart & Ruwet, 1982; Trewavas, 1983; Pullin, 1985). They are now found throughout the tropics and some sub-tropical regions where they have been introduced by man and are also cultured in ponds and in other facilities. Due to their wide area of distribution, the cichlids have become adapted to a wide range of food and feeding habits through the evolution of structural and physiological specializations of feeding structures and organs (Fryer & Iles, 1972).

The feeding apparatus and digestive tract of

fishes limit the range of potential food items that can be consumed and digested efficiently (Lagler, Bardach & Miller, 1963; Bowen, 1982). Dentition is often related to the nature of the food and the method employed for its collection. Cichlid tooth structure varies not only at the interspecific level but also through an individual's lifetime. Consequently, dentition of adults can be strikingly different from that of juveniles (Trewavas, 1935; Opiyo, 1991). The positions of the basic teeth types which affect feeding efficiency are also species-specific in cichlids (Fryer & Iles, 1972; Lanzing & Higginbotham, 1976; Trewavas, 1983). The degree of the development of the stomach as well as the length of the intestine in relation to fish length also vary according to the diet (Kapoor, Smith & Verighina, 1975; Wootton, 1990). Similarly, the

relationship between gut length and body length of fish also differs at the interspecific level (Welcomme, 1966, 1967; Caulton, 1976; Pauly, 1976) and, at the intraspecific level, it varies with the sexual state of the fish (Welcomme, 1966).

It was against the above background, coupled with the increasing importance of the oreochromine cichlids as candidates for aquaculture in many parts of the world, that the present research was undertaken to describe the feeding structures and associated organs in *Oreochromis esculentus* as part of an ecological study on the food and feeding habits of the species in Lake Kanyaboli, Kenya.

Experimental

Specimens of gill-netted *O. esculentus* numbering 593 and measuring 30-200 mm SL from Lake Kanyaboli in the western region of Kenya, served as the materials for these investigations which lasted from September 1989 to August 1990. The jaws, upper and lower pharyngeal bones, stomachs and intestines from each fish were dissected. The upper and lower jaws were examined under a dissecting microscope at $\times 24$ to study the rows of teeth and their morphology. The upper and lower pharyngeal bones were also examined in a similar manner to establish their structure. Teeth from both the upper and lower pharyngeal bones were scraped and examined under a binocular microscope to observe their morphology. Measurements were made of the areas occupied by teeth and the entire areas of the lower pharyngeal bones and the results correlated with fish standard length.

For scanning electron microscopy of oral and pharyngeal teeth, the upper and lower jaws and upper and lower pharyngeal bones were carefully dissected and the attached flesh removed. Jaws and pharyngeal bones were kept in a dry plastic container and allowed to dry. They were then cleaned in 90 per cent alcohol, coated with gold in a sputter chamber, examined at different magnifications un-

der a scanning electron microscope JEOL Model JSM-T100 and photographed.

The structure of the stomach was noted. The intestine was uncoiled and measured to the nearest mm, and the ratio of the intestine length to fish standard length established, using the allometric equation:

$$IL = a SL^b$$

where

IL = Intestine length (mm)

SL = Fish standard length (mm)

a = Constant

b = Exponent

Results

Dentition

Oral teeth are located on both the upper and lower jaws in *O. esculentus*. Each jaw carries three rows of teeth, the outermost of which was the longest and the middle row teeth longer compared to the innermost row (Fig. 1). The outer row of teeth are



Fig. 1a. A Scanning electron micrograph of the lower jaw of *O. esculentus*. An inner view of five teeth on the outermost row, two teeth on the middle row and seven teeth on the innermost row.



Fig. 1b. Scanning electron micrograph of the lower jaw of *O. esculentus*. A row of bicuspid teeth. (outer view).

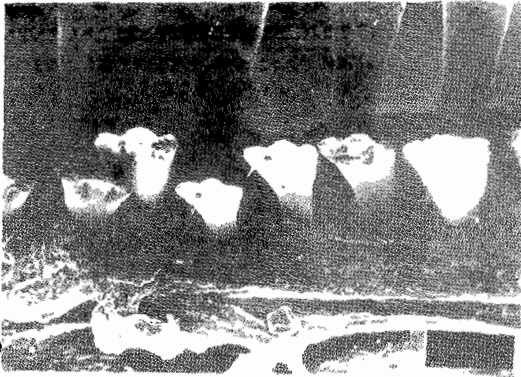


Fig. 1c. Scanning electron micrograph of the lower jaw of *O. esculentus*. A row of tricuspid teeth.

bicuspid with one of the cusps longer than the other (Fig. 1b). The cusps are flattened distally to

form blades, and the distal ends are brownish in colour. The distal regions of the inner and middle rows of the oral teeth, on the other hand, are tricuspid (Fig. 1c). No morphological changes in dentition were observed with size of fish.

Pharyngeal bones

The ventral pharyngeal bone, made up of two fused bones, is triangular in outline and has a central pad with a dense concentration of teeth whose fine distal ends are curved backwards. There is comparatively greater teeth density in the caudal region of the ventral pharyngeal bone (Fig. 2a) than in the rostral region (Fig. 2b). Also, the teeth in the caudal region are longer than those in the rostral region. At lower magnification, each tooth has a match-stick appearance (Fig. 2a). Higher magnification, however, reveals that the distal region of each tooth is slender and hooked posteriorly (Fig.

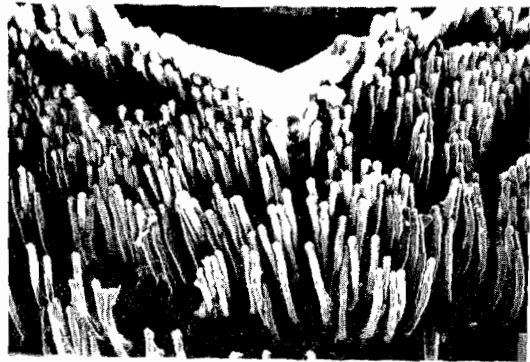


Fig. 2a Scanning electron micrographs of the lower pharyngeal bone of *O. esculentus*. (a) Teeth bone on the caudal region. ($\times 35$)



Fig.2b. Scanning electron micrograph of the lower pharyngeal bone of *O. esculentus*. Teeth borne on the rostral region ($\times 35$).

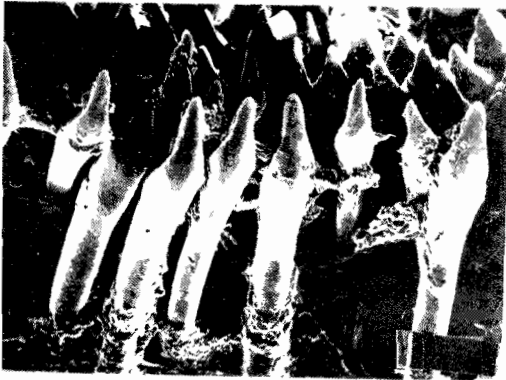


Fig.2c. Scanning electron micrograph of the lower pharyngeal bone of *O. esculentus*. Teeth borne on the rostral region (rear view) ($\times 75$).

2c).

A significant, positive correlation was found between fish standard length and the area of the toothed surface of the lower pharyngeal bone ($r = 0.65$; $P < 0.05$).

The dorsal pharyngeal bone is made up of three

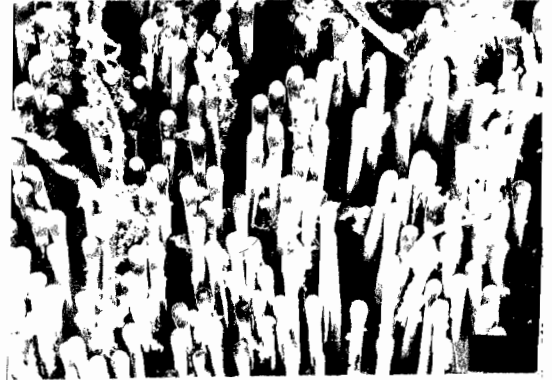


Fig.3a. Scanning electron micrographs of the upper pharyngeal bone of *O. esculentus*. Pharyngeal bone teeth. ($\times 75$).



Fig.3b. Scanning electron micrographs of the upper pharyngeal bone of *O. esculentus*. bulged end of pharyngeal bone teeth. ($\times 1000$).

bones which are not fused but covered by a large number of teeth projecting distally into the pharyngeal cavity (Fig. 3a). The distal region of each tooth ends in a bulge (Fig. 3b).

Stomach

The stomach of *O. esculentus* is morphologically a distensible sac which is separated from the duodenum by a pyloric sphincter. Most of the stomach contents were found intact most of the time, regardless of the time of capture. There was, however, some macerated zooplankton in the stomach.

Intestine

The intestine of *O. esculentus* is a delicate structure of considerable length. The first portion (about one-third of the total) is thin-walled and transparent. The ratio of fish standard length to intestine

$$\text{Log IL} = 0.50 + 1.23 \text{ SL} \quad (n = 593; r = 0.88)$$

Discussion

Few studies have addressed the bucco-pharyngeal anatomy of *O. esculentus*. The limited studies based only on gross anatomy indicate that jaw teeth are bicuspid and tricuspid; that the lower pharyngeal teeth are fine and hooked at the distal end and that the upper pharyngeal teeth are cusped at the distal end (Fryer & Iles, 1972; Trewavas, 1983). The lower pharyngeal bone in adult is longer than wide (Trewavas, 1983). Fine scanning electron microscopy technique used in the present study produced corroborative evidence to support existing information and detailed morphological structure of the feeding apparatus provided for the first time. The morphology of the stomach and intestine was also investigated in the light of the food and feeding habits of the species.

The anatomical features of the gut of *O. esculentus* strongly suggest that the species is phytoplanktivore. This suggestion is in support of previous reports indicating phytoplankton as the main food items ingested by the species (Welcomme, 1966; Opiyo & Dadzie, 1994). The overwhelmingly planktonic nature of the food had also been indicated by Fish (1951), Lowe-McConnell (1956), Welcomme (1967) and Bailey *et al.* (1978). The fine, hooked lower pharyngeal teeth are adapted for breaking the large number of colonial and filamentous algae which, according to Opiyo & Dadzie (1994), constitute 94.5 per cent of the gut contents. The association of the concentrations of *O. esculentus* with blooms of the diatom, *Melosira*, established the species as a plankton feeder using the mucus-trap mechanism combined with the combing action of the pharyngeal teeth. The maceration of the zooplankton in the stomach was probably effected using also the pharyngeal teeth, especially the bulged ends of the dorsal ones. Bailey *et al.*

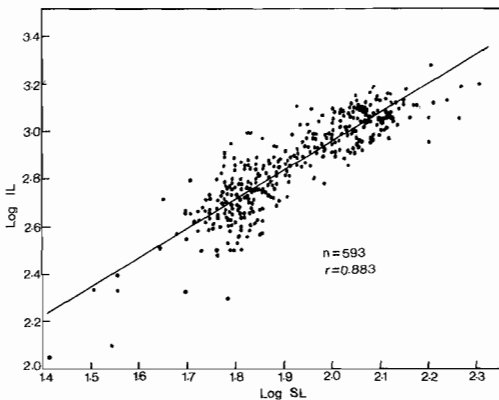


Fig. 4. Relationship between standard length (SL) and intestine length (IL) *O. esculentus*.

length ranged between 1:4 and 1:14. A highly significant, positive correlation ($r = 0.999$; $P < 0.001$) found between fish standard length (SL) and intestine length (IL) (Fig. 4), can be described by the following equation:

(1978) also found zooplankton as an occasional, and very minor, constituent of the stomach contents in an otherwise purely phytoplankton diet in Nyumba ya Mungu reservoir. No relationship was found, however, between the type of food eaten and the cusped, distally-flattened jaw teeth.

Although blue-green and green algae are often not digested by tilapiines, there appear to be exceptions. Moriarty (1973) reported that *T. nilotica* (= *O. niloticus*) can assimilate a maximum of 70-80 per cent of the carbon in the blue-green algae *Microcystis* and *Anabaena*, whereas 50 per cent of the carbon was assimilated from green algae, *Chlorella* sp. Because the fish assimilated more carbon from blue-green algae than from green algae under similar conditions, the authors contended that the cellulose cell wall of green algae was more resistant to lysis.

Opiyo & Dadzie (1994) have confirmed that out of the large quantities of phytoplankton ingested, it is only the diatom which constitutes a meagre 4.4 per cent which is digested, together with 1.9 per cent zooplankton. The bulk of the blue-green algae and green algae pass through and out of the gut undigested. Opiyo (1991) ascribed the undigestibility of the bulk of the phytoplankton in the stomach of *O. esculentus* to the pH of the stomach (4.0 - 8.0) which, according to the author, is not acidic enough to lyse the cell walls of many algae. The few macerated zooplankton, however, were probably digested in the stomach.

The very considerable length of the intestine of *O. esculentus* is typical of herbivores as it increases the efficiency of digestion of plant material (Lagler, Bardach & Miller, 1963; Bowen, 1982). The range of the ratio of fish standard length to intestine length observed (1:4 - 1:14) is close to that reported by Bowen (1982) for most tilapiines (1:7 - 1:11) but Welcomme (1967) obtained values of from 6.7 to 9.1 times SL in the same species measuring 70-170 mm.

The fact that morphological characteristics of the jaw teeth, pharyngeal teeth, stomach and intestine do not change with size suggest that *O. esculentus* of all size-classes feed on similar food types. This conclusion is supported by the results of gut content analysis which revealed no differences in the food of the species of different sizes (Opiyo & Dadzie, 1994).

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