Food composition and zooplanktonic prey selectivity of *Lates niloticus* (Linne, 1762) juveniles in fishponds (Ivory Coast; West Africa)


Received August 10, 2009 / Reçu le 10 août 2009
Revised November 19, 2009 / Révisé le 19 novembre 2009
Accepted November 23, 2009 / Accepté le 23 novembre 2009

**ABSTRACT**

Prey selectivity of juveniles of *Lates niloticus* was studied by looking at stomach contents of 570 fishes collected from a pond. Zooplankton was also sampled. The results were analysed using the Self-Organising Map and the graphical method of Costello (1990) [J. Fish Biol., 36, 261–263] modified by Amundsen et al. (1996) [J. Fish Biol., 48, 607–614]. Preys, comprising 38 taxa, were predominantly zooplankton (rotifers and copepods). The abundance of prey did not regulate food selectivity and prey size represented a limiting factor for the use of food resources. *Lates niloticus* juveniles were clearly specialised in copepods but occasionally included small proportions of other prey types (rotifers, ostracods, insects and fishes) in their diet. They foraged at this stage according to the Optimal Foraging Theory. Food preference is affected by the accessibility, motility and energy content of food items.

**Résumé**


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INTRODUCTION

In the Ivory Coast, the enormous volume of water resources (500 km of marine coast, numerous rivers, artificial lakes and dams) plays a great role in the modern economic development. Nevertheless, this significant hydrological potential does not cover the population’s nutritional needs as regards aquatic animal proteins. The deficit was estimated at about 180 000 tons per year (FAO, 1999), and hence aquaculture was adopted as a tool in rural food security and economic development.

The development of scientific research programmes and the introduction of fish farms are alternatives to reduce the country’s food demands. *Oreochromis niloticus* was firstly identified to be more adapted to rearing. Later on, other species such as *Chrysichthys nigrodigitatus*, *Heterobranchus longifilis* and *Sarotherodon melanotheron* were popularised. Several studies were conducted in order to diversify the rearing species. To achieve that goal, species that show the best aquacultural characteristics such as a high growth rate, resistance to management and diseases, a good food conversion rate, single nutritional requirements, and omnivorous feeding habits need to be selected (Martinez-Cordova, 1999).

The main species investigated was *Lates niloticus*, the only freshwater species of the Centropomidae family present in West Africa (Lévêque et al., 1992). This species is very appreciated by the African population because of its high gastronomic value and its flesh’s high quality. It was well documented after its introduction into Lake Victoria (Fryer, 1960; Barel et al., 1985; Ogutu-Ohwayo, 1990, 1993, 2004; Mumbo and Ligtvoet, 1992; Schofield and Chapman, 1999). Moreover, this species has a high growth rate. A research programme conducted in the Station de Recherche en Pisciculture of the Centre National de Recherche Agronomique (CNRA, Côte d’Ivoire) led to the control of its reproduction in fishponds. Also, other studies were developed concerning this fish’s diet and feeding habits. The limiting factor in the spread of *L. niloticus* farming is the seed availability. Now our attention is focused on the massive production of juveniles and development of technology for rearing of seedlings. Previous works of Hopson (1972) and Katunzi et al. (2006) have shown that the food items preferred by larvae of *L. niloticus* were zooplankton. According to Hopson (1972), juveniles between 20 and 300 mm feed mainly on planktonic crustaceans and aquatic insects. Katunzi et al. (2006) showed that the diet of Nile perch shifted from zooplankton and midge larvae, to macro-invertebrates (shrimps and dragonfly nymphs) and fish in Lake Victoria. At a size of 3–4 cm Nile perch shifted from size-selective predation on the largest cyclopoids to predation on the largest, less abundant calanoids.

The aim of this study is to discover if all prey items (zooplankton and aquatic insects) at different sizes have the same trophic importance in the diet of juveniles in ponds by evaluating food composition and prey selectivity.

MATERIAL AND METHODS

> BIOLOGICAL MATERIAL SURVEY

A total of 812 juvenile fishes aged 30 to 79 days were obtained by natural reproduction of 12 adults (8 males and 4 females) in four 400-m² fishponds (depth range: 1 to 1.5 m) and stored in a 175-m² fertilised pond.

Samples of minimum 30 specimens were collected weekly at random with a net for seven weeks. Each specimen was measured (standard length) to the nearest 1 mm. They were carefully dissected and stomachs were removed and preserved in 4% formalin until analysis. The study of stomach contents was completed by an analysis of food availability. Thus, zooplankton was collected with an Apstein plankton net (mesh size 40 µm) by doing horizontal tows over 14 m, except in the first week. Zooplankton samples were preserved with 4% formalin solution.
In the laboratory, we used a total of 570 non-empty stomachs of juveniles of *Lates niloticus* (mean length 27.3 ± 0.6 mm) to assess diet. Stomachs and intestinal contents were investigated. The gut contents were diluted in 10 mL water, and gut contents were observed under an inverted microscope using a gridded Petri dish. Because the different prey taxa occurred in pieces of different sizes, biomass could not be quantified. Therefore, gut content was presented as proportions of counted food items, which were classified into several groups. Identification of zooplankton was based on the mandible, furca, post-abdominal claw and exoskeleton structure. They were identified to the lowest taxon possible, genus or species level, following Dussart (1966), Ruttner (1974) and Rey (1986).

**FOOD AVAILABILITY**

The study of stomach contents was followed by an analysis of food availability by sampling zooplankton, which is the main food item in *L. niloticus* juveniles’ diet. Zooplankton abundance in the pond was determined by counting 1-mL sub-samples under a microscope. Species were classified into groups according to the same prey categories in guts. However, the zooplankton composition in the lake was not determined in the seventh week.

**DATA ANALYSES**

> **NON-PARAMETRIC ANALYSIS**

To compare zooplankton densities in the pond, the Kolmogorov-Smirnov test was first applied to check normality in the distribution of data. And accordingly, the Kruskal-Wallis ANOVA and the Mann-Whitney U-test were performed using the STATISTICA 7.1 computer package to test for significant differences between main groups and temporal distribution (over all weeks) of zooplankton densities among each group.

> **STOMACH CONTENT ASSEMBLAGES USING A SELF-ORGANISING MAP (SOM)**

The distribution pattern of fishes was displayed using the Self-Organising Map (SOM) by means of the toolbox developed by Alhoniemi et al. (2003) for Matlab®. First, a prey’s occurrence data set was arranged as a matrix of 89 rows (i.e., the non-empty stomachs) and 29 columns (i.e., the prey’s species). Each of the 89 samples of the data set can be considered as a vector of 29 dimensions. Then, the species occurrence data set was patterned by training the SOM. The architecture of the SOM consisted of two layers of neurons (or nodes): (i) the input layer was composed of 89 neurons connected to each vector of the data set, and (ii) the two-dimensional output layer was composed of 49 neurons (i.e. a rectangular grid with 7 by 7 neurons laid out on a hexagonal lattice). We chose a 49-neuron grid because this configuration presented minimum values of both quantisation and topographic errors, which are used to assess classification quality (e.g. Kiviluoto, 1996; Kohonen, 2001; Park et al., 2003). The SOM algorithm calculates the connection intensities (i.e. vector weights) between input and output layers using an unsupervised competitive learning procedure (Kohonen, 2001), which iteratively classifies samples in each node according to their similarity in species composition. Thus, the SOM preserves the neighbourhood so that samples with close species occurrences are grouped together on the map, whereas samples with very different species occurrences are far from each other.

We checked whether relevant groups of samples characterised distinct prey assemblages by performing a hierarchical cluster analysis (Ward’s linkage and Euclidean distance). To do so, we used a new matrix (49 × 29, output neurons × species) of the connection intensity values estimated by the SOM.
Between-cluster differences in species occurrences were evaluated using the Kruskal-Wallis test, a non-parametric analysis of variance, followed by the Mann-Whitney test to identify specific differences.

The relationships between fish samples associated with each cluster and the factors of the regrouping (fish age and class size), which were not used in the SOM learning process, were assessed. To do so, we calculated for each cluster the relative contribution of each modality (e.g., fish age) of a certain factor (e.g., class size) to the total number of modalities of the factor. Then, we tested for the H₀ that no significant differences were present among these relative values using a test for proportions (G-test) based on the likelihood ratio \( \chi^2 \) statistics (Sokal and Rohlf, 1995; Sachs, 1997). Statistical calculations were performed using R (Ihaka and Gentleman, 1996).

> FEEDING STRATEGY

The Costello method modified by Amundsen et al. (1996) was used to discuss the variation in feeding strategy. Costello’s (1990) analysis is based on a two-dimensional representation, where each point represents the frequency of occurrence and the abundance of a prey taxon. Costello suggested that the two diagonals of the plot represent prey importance (dominant-rare) and predator feeding strategy (specialisation-generalised). In an attempt to overcome the problems inherent in the Costello method, Amundsen et al. (1996) suggested that a new parameter, the prey-specific abundance \( P_i \), is incorporated into the graphical representation of dietary composition. Prey-specific abundance is defined as the percentage comprised by a prey taxon in all those predators which the actual prey occurs, or in mathematical terms:

\[
P_i = \left( \frac{\sum S_i}{\sum S_{ti}} \right) \times 100
\]

where \( P_i \) is the prey-specific abundance of prey \( i \), \( S_i \) the stomach content (volume, weight or number) comprised of prey \( i \), and \( S_{ti} \) the total stomach content in only those predators with prey \( i \) in their stomach.

In the new graphical presentation, the prey-specific abundance is plotted against the frequency of occurrence on a two-dimensional graph. This resembles the Costello plot, but prey-specific abundance is used instead of percentage abundance. The product of prey-specific abundance and frequency of occurrence (expressed as a fraction rather than in percent) equals the prey abundance, provided that the average amount of stomach contents is independent of the prey categories consumed, or that the amount of food in each stomach is standardised to equality (i.e. to 100%) before abundance estimates are made. Therefore, for each point on the graph, the prey abundance is represented by the area enclosed by all the co-ordinates of the two axes. The sum of the areas for all prey types will equal the total area of the diagram (= 100% abundance). Furthermore, any combination of prey-specific abundance and frequency of occurrence equals a certain prey abundance, and different values of prey abundance can be represented by isopleths on the graph.

RESULTS

> FOOD AVAILABILITY

The zooplankton community in the pond, comprising 38 taxa, was represented by Rotifers (24 species), Cladorerans (9 species) and copepods (5 species). We also identified Ostracods and aquatic insects in the samples. The total density of zooplankton showed a drastic reduction over the sampling period (1800 ind·L\(^{-1}\) at the beginning to 126.1 ind·L\(^{-1}\) at the end) (Figure 1A). Rotifers formed the principal part of the community during the first (95%), second (57.8%) and fifth (65%) weeks, whereas copepods appeared mainly in the pond in the third (64.3%), fourth (61.6%) and sixth (61%) weeks (Figure 1B). Cladocerans, Ostracods and aquatic insects represented less than 1% of total density (Figure 1B).
Stomach contents of 570 juveniles collected over seven weeks were examined. The results (SOM map) showed five clusters (A; B1 and B2; C; D; E) of samples at different levels of the Euclidean distance (Figure 2). The sample distribution pattern classification was related to the fish’s size and temporal factors. The G-test showed that clusters B, D and E were grouping according to the sampling date criterion. Thus, clusters B and D were, respectively, composed solely of samples of the sixth and second weeks. Cluster E was mainly composed of the fifth week’s samples. On the other hand, clusters were grouped according to fish size. Clusters A and B were almost entirely made up of fishes over 30 mm, while clusters C, D and E were mainly characterised by fishes of less than 30 mm (Figure 3).

Table I shows the contribution of each prey item in the composition of the diet of fishes (samples) on the SOM map. The next step is to compare the relationship among clusters of samples and the distribution of prey items. Thus, cluster A is related to a cladoceran (Alona monacantha); insect adults and fish. Cluster B was characterised by Chydorus sphericus and Moina micrura (cladocerans), and copepodites. Cluster C was made up of copepods (Thermocyclops consimilis), Simocephalus serrulatus (cladoceran), and Ostracods. Cluster D was represented by cladocerans (Ceriodaphnia affinis and C. cornuta); a copepod (Thermodiaptomus yabensis), a rotifer (Lecane sp.), copepodites and insect larvae. Cluster E was
Figure 2
The map obtained by SOM for patterning fishes with stomach contents reported from the pond. The letters (A, B, C, D and E) represent different clusters. The acronyms in the hexagonal units represent different samples (sampling date in Latin numbers and arabic numbers for fish size).

related to copepods (Thermocyclops decipiens; Mesocyclops, Diaphanosoma excisum and Macrothrix triserialis (cladocerans).

>FEEDING STRATEGY

Figure 4 shows the evolution of the feeding strategy of L. niloticus juveniles according to the Costello method. The population of seedlings is clearly specialised in copepods (located at the upper right of the diagram) during our study period, except at the end of the experiment. Thus, in the sixth week, cladocerans were the main item in their diet, and in the seventh they became generalist. Moreover, small proportions of other prey types (rotifers, ostracods and fishes) were occasionally included in the diet of some individuals, and insects had been eaten occasionally by most individuals.
DISCUSSION

Our results show that preys were more abundant in the 175-m² pond during the first week, and their density decreased heavily in numbers after the introduction of the juveniles. The high abundance of zooplankton at the beginning of the experiment is explained by high availability and diversity of food linked to the fertilisation. Indeed, zooplankton feed upon phytoplankton, which is well developed after the use of dried organic fertilisers (Lanoiselee, 1984). Also, the principal cause of the decline in density was the predation by juvenile fishes, which strongly influence composition and abundance of zooplankton populations.

Similar to the finding of Bonou (1990) in a pond and Ouéda et al. (2008) in Lonmbila lake, rotifers were consistently the most abundant component of zooplankton, and appeared earliest in the pond. This corroborates that *Lates niloticus*, which generally do not feed on ostracods (Hopson, 1972; Loiselle, 1972; Assi, 1989), were found to feed on them when other preferred preys were absent. Juvenile feeding, however, did not strictly reflect zooplankton availability in the pond. In fact, preys such as *Ceriodaphnia cornuta, Ceriodaphnia affinis, Simocephalus serrulatus, Alona monacantha* and *Chydomorus sphericus*, copepods (*Thermodiaptomus yabensis*), and ostracods, relatively less observed in the pond, appeared abundantly in the diet of the juveniles. On the other hand, rotifers, and *Moina micrura* and *Diaphanosoma excisum* were not preyed upon regardless of their high density. This finding is not corroborated by the literature data, which revealed that prey density was important in determining diet composition of juveniles of *Salmo salar* (Tonney and Gibson, 1989) and in the food intake and diet composition of three native fish species of the Macintyre River (Medeiros and Arthington, 2008). Angermeier (1982) noted that fluctuations in the availability of food type may affect all...
Table I
Distribution patterns of prey species in each cluster defined by the hierarchical clustering applied to the self-organising map (SOM) units. Dark represents high probability of occurrence, and light indicates lower probability.

Tableau I
Patron de distribution des espèces proies dans chaque groupe défini par la classification hiérarchique appliquée aux cellules de la carte auto-organisatrice. La couleur sombre représente les fortes probabilités d’occurrence ; la couleur claire représente les faibles probabilités d’occurrence.

<table>
<thead>
<tr>
<th>Clusters</th>
<th>Taxa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cluster A</td>
<td><em>Alona monacantha</em>; adult insect; fish</td>
</tr>
<tr>
<td>Cluster B</td>
<td>Copepodes; <em>Chydorus sphericus</em>; <em>Moina micrura</em></td>
</tr>
<tr>
<td>Cluster C</td>
<td><em>Thermocyclops consimilis</em>, <em>Simocephalus serrulatus</em>; Ostracods</td>
</tr>
<tr>
<td>Cluster D</td>
<td>Copepodes, <em>Ceriodaphnia affinis</em>; <em>C. cornuta</em>, <em>Thermodiaptomus yabensis</em>; <em>Lecane</em> sp.; insect larvae</td>
</tr>
<tr>
<td>Cluster E</td>
<td><em>Thermocyclops decipiens</em>; <em>Mesocyclops</em>; <em>Ceriodaphnia cornuta</em>; <em>Diaphanosoma excisum</em>; <em>Macrothrix triserialis</em></td>
</tr>
</tbody>
</table>
Figure 4

Figure 4
foraging aspects and diet to some extent. The food selection of *L. niloticus* juveniles might be related to the size of copepods; they preferentially fed on large copepods when they were abundant (Rajasilta and Vuorinen, 1983). Female copepods with egg sacs which slow down their swimming speeds are vulnerable to fish predation. Also, the prey selection was found to change with fish size. *Simocephalus serrulatus* (Cladoceran) were the preferred food item of small fishes (less than 20 mm size), whereas large fishes (more than 30 mm size) mainly fed on Copepodites, *Alona monacantha*, adult insects and fish larvae. A similar pattern in dietary composition with fish size has also been reported by Katunzi et al. (2006), who noted that the proportion of the relatively large calanoids increased with fish size, and made up between 35 and 80% of the diet in Nile perch of 30–40 mm in Lake Victoria.

A similar pattern in dietary composition with fish size has also been reported by Diomandé et al. (2001) for *Synodontis bastiani* in the Ayamé man-made lake (Côte d’Ivoire). This shift in diet composition was linked to the size of food items: small fishes were found to eat small items, whereas larger fishes ate large items. It is well known that several factors such as prey size, availability, distribution, motility, vulnerability and its capacity to escape predators influenced the choice of prey items (Moore and Moore, 1976; Lauzanne, 1988; Stergiou and Fourtouni, 1991; Brewer and Warburton, 1992; Barry and Ehret, 1993).

*Lates niloticus* juveniles are specialised in copepods, though they did show minor variations in their diet at the end of the experiment. These observations agree with the findings of Prejs and Prejs (1987), and Pusey and Bradshaw (1996), who reported that changes were caused by changes in the availability of major food resources. The generalist feeding strategy is therefore favoured when food density is low or continuously fluctuating.

**CONCLUSION**

The present study showed that *Lates niloticus* found in the pond depend to a large extent on zooplankton, particularly copepods, as food at the juvenile stage. The rank of abundance of food items in the pond was different from that found in the guts of fishes. Food preference is very complex and affected by many factors such as the accessibility, motility and energy content of food items. Interestingly, fish shifted their diet during the study: consumption of and the contribution of cladocerans and insects increased slightly when consumption of main items decreased.

**ACKNOWLEDGEMENTS**

We are grateful to Ricardo Beldade (University of California) for improving the English in the manuscript.

**REFERENCES**


