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Food habits of brackish water tilapia *Sarotherodon melanotheron* in riverine and lacustrine environments of a West African coastal basin

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Abstract

The diet of the brackish water tilapia *Sarotherodon melanotheron* is studied in various riverine and lacustrine systems of the Bia River basin (Côte d'Ivoire). Comparison of the diet between sampling sites (upper course, lower course and man-made Lake Ayame) shows significant differences. In the man-made lake, prey described as preferential include *Asterionella* (Bacillariophyceae) and *Bosmina* (Cladocera). In the lower course, the preferential preys are represented by *Lyngbya* (Cyanophyceae) while in the upper course *Lyngbya* and chironomid larvae are preferential. These differences are related to the altered environmental conditions generated by the construction of the dam on the Bia river main stream. In the man-made lake, there is no shift in diet either with the seasons (dry and rainy seasons) or with size.

Introduction

The Bia River is a small coastal basin situated in the south east of Côte d'Ivoire and with its source in Ghana (Fig. 1). On its main stream, a hydroelectric power dam was built in 1959, which led to the creation of man-made Lake Ayame (surface area = 197 km^2; maximum depth 20 m), in between a short riverine lower course and a longer upper course.

The mouth-brooding brackish water tilapia *Sarotherodon melanotheron* Rüppell, 1852 occurs naturally in lagoons, estuaries and lower parts of rivers from Senegal to Angola (Teugels & Thys van den Audenaerde, 1992; Falk et al., 2000). It was listed in the various ecosystems of the Bia basin by Gourène et al. (1999). A population of this species was isolated in the man-made lake when the dam was constructed on the Bia River; since, it became extremely abundant in this artificial environment, representing more than 50% of the commercial catches. It is, to a lesser extent, also present in the upper course of the Bia (Gourène et al., 1999). Based on its geographical distribution (Trewavas & Teugels, 1991), it is suggested that the biology of this species might in part be related to brackish water. The successful presence of *S. melanotheron* in Lake Ayame raises the question of how it is able to adapt itself to these freshwater conditions? It is well known that the adaptive value of fishes to an ecosystem, implies the most effective exploitation of available food resources which enables them to adapt as well as possible to environmental conditions (Paugy, 1994). The interest of the present study is not only related to the fact that it is the first to examine the feeding habits of *S. melanotheron* in freshwater, but it also allows us to underline some of the adaptive capacities of this species through the comparison of its diet from one environment to another.

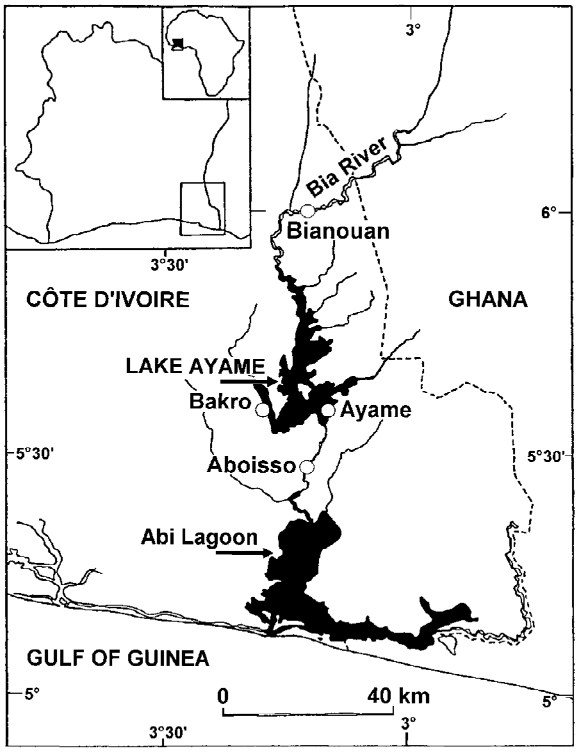

Figure 1. Geographical localisation of sampling sites (○) on the Bia River basin.

Materials and methods

Sampling sites retained were Aboisso on the lower course of the Bia River, Ayame and Bakro on man-made Lake Ayame and Bianouan on the upper course (Fig. 1).

Fishes were collected monthly from January 1995 to August 1997 using a cast net and two batteries of gill nets of 10, 12, 15, 20, 25, 30, 35, 40 and 50 mm mesh sizes. Specimens caught were measured to the nearest mm, weighed to the nearest 0.1 g and dissected. Fishes were divided into two classes based on the maturity size found by Kone & Teugels (1999). A total of 107 specimens with sizes ranging from 46 to 190 mm standard length (SL) were examined. Fourty nine of them, ranging from 46 to 85 mm SL, were classified as juveniles. The other specimens (n = 58) with standard length over 130 mm were considered as adults.

The stomachs were removed and preserved in a 5% formalin solution. In the laboratory, contents of each stomach was mixed with 100 ml water per gram of stomach contents and filtered through 500 and 100 μ

Table 1. Food items, occurrence percentage (% Oc) and relative importance index (% IRI) of juveniles and adults *Sarotherodon melanotheron* in man-made Lake Ayame (Côte d'Ivoire) from August 1995 to July 1997 (for taxa with occurrence percentage higher than 25%)

Items	Juveniles		Adults	
	% Oc	% IRI	% Oc	% IRI
Phytoplankton				
Cyanophyceae				
Merismopedia	16.33	0.12	41.38	0.14
Gomphosphaeria	44.90	0.79	58.62	1.36
Microcystis	100.00	6.23	100.00	4.60
Anabaena	28.57	1.16	39.66	0.66
Lyngbya	79.59	3.02	89.66	3.43
Euglenophyceae				
Trachelomonas	61.22	1.23	75.86	0.96
Phacus	28.57	0.09	60.34	0.10
Chlorophyceae				
Tetraedron	38.78	0.14	74.14	0.33
Closteriopsis	61.22	1.03	84.48	2.43
Monoraphidium	57.14	0.62	89.66	1.35
Ankistrodesmus	63.27	4.99	84.48	3.42
Coelastrum	55.10	0.67	81.03	0.91
Scenedesmus	44.90	0.41	81.03	0.86
Tetrastrum	22.45	0.08	43.10	0.14
Crucigenia	12.24	0.02	37.93	0.13
Crucigeniella	22.45	0.24	43.10	0.34
Pediastrum	16.33	0.06	68.97	0.21
Conjugatophyceae				
Closterium	63.27	0.65	82.76	0.68
Staurastrum	79.59	1.62	96.55	1.65
Staurodesmus	44.90	0.12	70.69	0.24
Xanthophyceae				
Centritractus	10.20	0.01	43.10	0.04
Bacillariophyceae				
Aulacoseira	95.92	14.03	96.55	16.55
Asterionella	95.92	28.24	94.83	30.34
Frustulia	53.06	0.40	43.10	0.05
Pinnularia	30.61	0.07	46.55	0.06
Navicula	26.53	0.07	39.66	0.05
Dinophyceae				
Peridinium	34.69	0.25	39.66	0.13
Zooplankton				
Rotifers				
Brachionus	10.20	0.00	32.76	0.01
Trichocerca	6.12	0.00	43.10	0.00
Filinia	8.16	0.00	31.03	0.00
Cladocera				
Diaphanosoma	16.33	1.37	58.62	9.39
Moina	26.53	5.66	50.00	14.12
Bosmina	53.06	25.64	65.52	21.12
Copepods				
Thermocyclops	12.24	0.10	46.55	0.77
Copepodite	6.12	0.00	31.03	0.12

mesh size. The particles retained by these meshes were identified and counted under a binocular. For phytoplankton, three microscopic preparations per filtrate were observed under a microscope so as to identify and to count the different prey taxa (Compère, 1974; Iltis, 1980; Dussart 1980, 1989). Food items were identified to the lowest possible taxon and the genus level is considered for comparisons and procession of ordination by principal component analysis.

The diet of the brackish water tilapia *Sarotherodon melanotheron* in the Bia River basin was assessed using numerical percentage (N%) (N% = ni × 100/Nt, where ni is the total number of a type of prey i and Nt total number of all prey) (Hureau, 1970), occurrence percentage (Oc%) (Oc% = Nei × 100 / Net, where Nei is the number of stomachs containing a type of prey i and Net the total number of full stomachs examined) (Hyslop, 1980) and volumetric percentage (V%) (V% = Vli × 100/Vltp, where Vli is the total volume of a type of prey and Vltp the total volume of all prey) (Hyslop, l.c.). Relative importance index (IRI) was computed for each prey item according to Hyslop (l.c.):

$$\%\ IRI = (\%\ N + \%\ V) \times \%\ Oc.$$

Classification of prey items follows Simenstad (1979), discussed by Rosecchi & Nouaze (1987). For that purpose, preys are arranged in descending order according to their relative importance index (%IRI). The cumulative value of these items with a relative importance index of at least 50% are considered preferential. Those with a cumulative value reaching 75% are the secondary preys and the others are accessory preys.

Total volume of each type of prey is calculated from the volume estimates of each of the species counted in the sample. The commonest way of doing this is to adjust the preys to geometrical figures (Getachew & Fernando, 1989). For each type of prey, the mean value is obtained by measuring a large number of individuals (>30).

Principal component analysis (PCA) was computed from the matrix "absolute abundance of prey taxa × number of stomachs examined" to find out similarities or differences between fishes from the different sampling sites. Analysis of variance was performed to compare absolute abundance of prey taxa that explain the variability in the diet of *Sarotherodon melanotheron.* A critical value of 0.05 was set as the limit of significance.

Results

Diet in man-made Lake Ayame

Change in diet with size

Food items (with an occurrence percentage higher than 25%) of juveniles and adults are listed in Table 1. Main food items of juveniles and adults are similar in diversity with only a few exceptions but differ substantially in the occurrence percentage values. Food items encountered in the stomachs of adults but not in the stomachs of juveniles included 8 genera (Chlorophyceae: *Dictyosphaerium*, *Kirchneriella*, *Micractinium*; Bacillariophyceae: *Cocconeis*, *Cyclotella*, *Gyrosigma, Surirella* and *Terpsinoe*) while 18 prey taxa found in stomachs of juveniles were not encountered in the stomachs of adult specimens (Cyanophyceae: *Anabaenopsis, Oscillatoria*; Chlorophyceae: *Pandorina*, *Schroderia*; Ulotrichaceae: *Bulbochaete, Oedogonium*; Conjugatophyceae: *Mougeotia, Micrasterias*; Bacillariophyceae: *Coscinodiscus*, *Rhopalodia, Nitzschia*; Rhodophyceae: *Audouinella;* Rotifera: *Asplanchna*, *Platyas*, *Lepadella*; and Cladocera *Camptocercus*, *Chidorus*, Macrothricidae).

In juveniles, Bacillariophyceae *Asterionella* (28.24% IRI) and zooplankton *Bosmina* (25.64% IRI) represent the preferential preys, *Aulacoseira* (Bacillariophyceae), *Microcystis* (Cyanophyceae), *Ankistrodesmus* (Chlorophyceae) and *Moina* (Cladocera) being the secondary preys. The others constitute the additional preys.

In adults, Bacillariophyceae *Asterionella* (30.34% IRI) and Cladocera *Bosmina* (21.12% IRI) constitute the preferential prey, Bacillariophyceae *Aulacoseira* (16.55% IRI) and zooplankton *Moina* (14.12% IRI) represent the secondary prey taxa and the others are the additional preys.

Ordination of juvenile and adult specimens by means of principal component analysis based on absolute abundance of prey taxa, did not show any clear difference between the diet of both groups (Fig. 2).

Comparison (ANOVA) of taxa which explain the largest part of the variability in variability in the PCA (*Scenedesmus*, *Monoraphidium*, *Staurastrum*, *Microcystis*, *Pediastrum*, *Tetraedron*, *Asterionella* and *Closterium*) between adults and juveniles revealed no significant difference (df = 7; $F = 1.81$; $P > 0.05$).

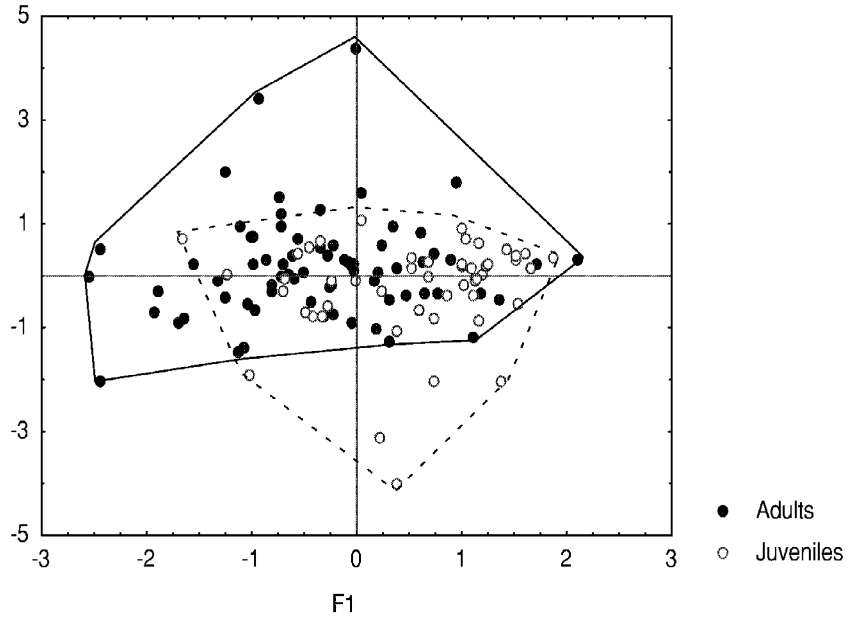

Figure 2. Ordination of *Sarotherodon melanotheron* specimens from lake Ayame based on a PCA of absolute abundance of 83 prey taxa: ○ = juveniles ($n = 49$); • = adults ($n = 58$).

Shift in diet with season

Specimens ($n = 167$) examined were grouped on the basis of their capture date: dry season and rainy season periods.

Compositions of the diet of *S. melanotheron* in both dry and rainy seasons are illustrated in Table 2 for prey taxa with an occurrence percentage higher than 25%.

In the dry season, 78 prey taxa were counted in the stomach contents of fishes against 89 in the rainy season. Certain preys found in the stomachs of fish caught in the rainy season were not found during the dry season: *Oscillatoria* (Cyanophyceae), *Schroderia*, *Micractinium*, *Dictyosphaerium* and *Oedogonium* (Chlorophyceae), *Mougeotia* (Conjugatophyceae), *Terpsinoe*, *Cocconeis*, and *Hantzschia* (Bacillariophyceae), *Asplanchna*, *Polyatra*, *Lepadella* (Rotifera), *Camptocercus*, *Chidorus* and Macrotricidae (Cladocera). Other preys were found only in stomachs of fishes caught in the dry season [*Kirchneriella, Elakatothrix* (Chlorophyceae), *Micrasterias* (Conjugatophyceae), *Rhopalodia* and *Nitzschia* (Bacillariophyceae)]. Among prey taxa found only during one season, *Elakatothrix* has the highest percentage of occurrence (11%), its relative importance index being 0.002%. Except for the genus *Hantzschia* that has an occurrence of about 5% in the rainy season, all the others have lower occurrence percentages. Relative importance index of these preys is also very low (<1%). This shows that differences between diet in dry and rainy seasons that qualitatively can have a certain importance, quantitatively do not constitute a significant part in the feeding of *S. melanotheron*.

In the rainy season, Bacillariophyceae *Asterionella*, (27.08% IRI), *Aulacoseira* (19.46% IRI) and the zooplankter *Bosmina* (18.52% IRI) constitute the preferential preys, Cyanophyceae *Microcystis* (5.89% IRI), zooplankter *Diaphanosoma* (5.52% IRI) and *Moina* (8.40% IRI) represent the secondary preys. The others constitute accessory preys.

In the dry season, Bacillariophyceae *Asterionella* (31.30% IRI) and the zooplankter *Bosmina* (21.15% IRI) represent the preferential preys; Bacillariophyceae *Aulacoseira* (10.32% IRI), zooplankter *Moina* (8.76% IRI), *Diaphanosoma* (3.67% IRI), Cyanophyceae *Microcystis* (3.40% IRI), *Lyngbya* (3.95% IRI) and Chlorophyceae *Ankistrodesmus* (4.69% IRI) represent the secondary preys; the others are accessory preys.

Ordination of specimens based on absolute abundance of prey taxa in principal component analysis shows a general similar feeding habit from one season to another (Fig. 3). Comparison (ANOVA) of absolute abundance of taxa which mostly explain the variability in the PCA (*Scenedesmus, Microcystis, Closteriopsis, Staurodesmus, Pediastrum, Monoraph-*

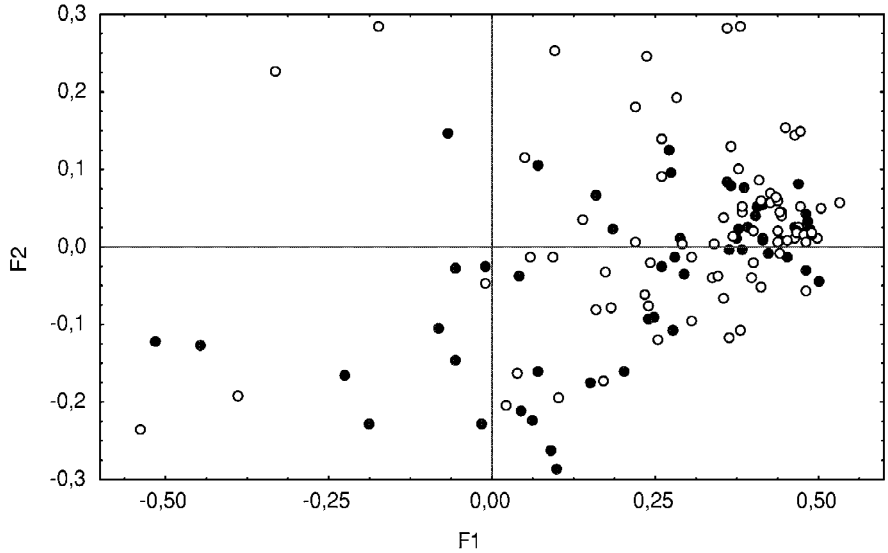

Figure 3. Ordination of *Sarotherodon melanotheron* specimens ($n = 167$) from lake Ayame based on a PCA of absolute abundance of 83 prey taxa: ○ = dry season; • = rainy season.

idium, Ankistrodesmus) does not show a significant difference between seasons (df = 6; $F = 1.053$; $P > 0.05$).

Diet comparison between riverine and lacustrine environments

Food items and their numerical percentage, occurrence percentage, volumetric percentage and relative importance index for the lower Bia (Aboisso), the upper Bia (Bianouan) and in the man-made lake are listed in Tables 3, 4 and 5, respectively.

Total number of taxa found in the stomach of fishes from the upper river is 45 while this number is 58 in the lower stream and 96 in man-made Lake Ayame.

In the lower course (Aboisso), *Lyngbya* (Cyanophyceae) (62.37% IRI) represents the preferential prey, chironomid larvae (11.30% IRI), Bacillariophyceae *Terpsinoe* (6.41% IRI) and *Aulacoseira* (4.49% IRI) constitute the secondary preys and the others represent the additional preys. In this part of the Bia River, the relative importance index of zooplankton is low (0.06% IRI) showing that it is less consumed than in man-made Lake Ayame. The high consumption of *Lyngbya* in the Lower course differs considerably with the situation in the man-made Lake.

In the upper course (Bianouan), Cyanophyceae *Lyngbya* (39.64% IRI) and chironomid larvae (15.95% IRI) constitute the preferential preys, Conjugatophyceae *Mougeotia* (2.74% IRI), Bacillariophyceae *Aulacoseira* (3.84%), *Gomphonema* (4.10% IRI), *Frustulia* (4.63% IRI), *Pinnularia* (8.19% IRI) and *Navicula* (8.12% IRI) represent the secondary preys. The others are additional preys. Results of this prey-classification do neither correspond to those obtained for the specimens in Lake Ayame, nor to those of the lower course (Aboisso).

Ordination of specimens based on absolute abundance of prey items in principal component analysis tend to confirm the difference of food composition between the sampling sites (Fig. 4): the majority of riverine specimens are located on the positive sector of the first factor, while those from the lacustrine environment are on the negative sector. Genera merely defining this division are *Microcystis*, *Asterionella*, *Staurastrum*, *Ankistrodesmus*, *Scenedesmus*, *Gyrosigma*, *Audouinella*, *Monoraphidium* and *Terpsinoe*. Comparison of absolute abundance of these prey taxa (ANOVA) indicates significant differences between the various sampling sites (df = 8; $F = 82.62$; $P < 0.05$).

Discussion

Data presented in this study confirm that *S. melanotheron* is planktivorous (Pauly, 1976; Nwadiaro & Ayodele, 1992; Ugwumba & Adebisi, 1992).

From our monthly observations, we deduced that *S. melanotheron* feeds both in open water and also on the bottom. Most of phytoplankton genera collected in the water column were found in the stomach con-

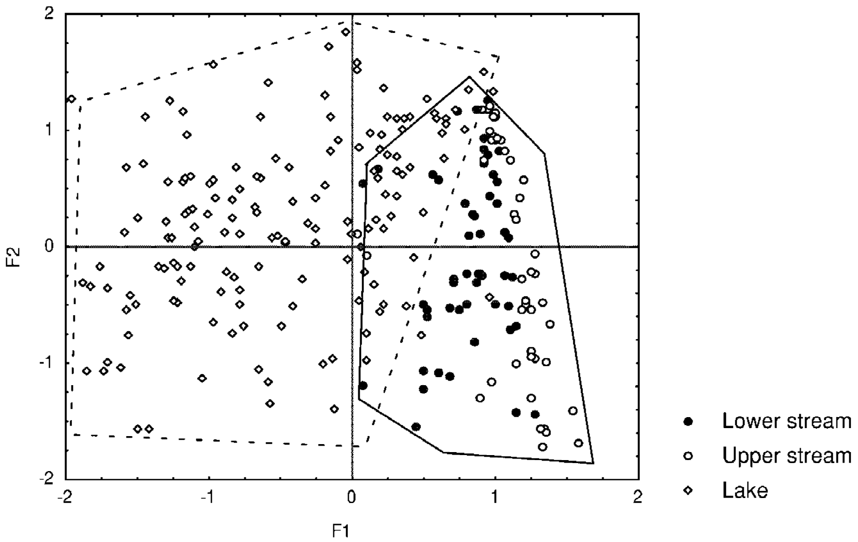

Figure 4. Ordination of *Sarotherodon melanotheron* specimens ($n = 256$) from the Bia River (upper course, lake and lower course) based on a PCA of absolute abundance of 83 prey taxa).

tents. Also, almost all the studied stomachs contained structureless organic matter originating from the mud.

Diet of S. melanotheron *in man-made Lake Ayame*

Diet and size of fishes

Ugwemba & Adebisi (1992) showed that adult *S. melanotheron* feed mainly on blue algae and organic remains while juveniles (with sizes lower than 1.4 cm) have a more balanced food spectrum including zooplankton, insect larvae and organic remains. These authors stressed that the relative importance index (IRI) of *S. melanotheron* preys decreased with increasing size of fish. This result is in agreement with some other studies which indicate that for some cichlid fishes, juveniles feed more on zooplankton whilst the adults feed on insects, phytoplankton or others food sources (Mwebaza-Ndawula, 1994). It is well known that the weight and the body form of fishes change considerably during their development and this variation implies that of the nutritional requirement and the feeding behaviour. Many works have shown such ontogenic changes in African fishes (Paugy & Lévêque, 1999). For some cichlid fishes, the food variation with size is related to that of the dentition (Paugy & Lévêque, 1999). The differences between Ugwemba & Adebisi (1992) and the present study are probably related to the different ranges of selected sizes. Adults and juveniles considered in the present study have a similar food spectrum and this similarity could probably be related to the fact that the differentiation process of the gill-rakers, in those considered as juveniles (45 mm<SL<85 mm) is already accomplished. This is supported by observations made by Kone & Teugels (1999) that the lake Ayame population reaches first sexual maturity at an earlier stage in development.

Seasonality of the diet

Ugwemba & Adebisi (1992) found seasonal variation in the feeding of *S. melanotheron* in small tanks in Ibadan (Nigeria). According to these authors, this variation in diet could be related to seasonal variation of the abundance of the various prey taxa in the environment. Such variations were also observed in *Sarotherodon galilaeus* (Spataru & Zorn, 1978) and *Oreochromis niloticus* (Tudorancea et al., 1988).

We did not observe seasonal variation in the diet of *S. melanotheron* from man-made Lake Ayame. Many authors (Winemiller, 1987; Lauzanne, 1988) suggest that in equatorial environments, fluctuations of the water level constitute the principal factor influencing the quantity of the food of the phytophagous and insectivorous fishes. Under nutrient rich conditions (after rain or increases in flow) phytoplankton can outgrow and become dominant (Mitrovic et al., 2001). Lake Ayame, receiving continuously inflowing water from its upper course can be considered as favourable for an annual plankton growth because of the constant nutrient accumulation from upstream. In

Table 2. Food items, occurrence percentage (% Oc) and relative importance index (%) of *Sarotherodon melanotheron* during rainy and dry season in man-made Lake Ayame (Côte d'Ivoire) from August 1995 to July 1997 (for taxa with occurrence percentage higher than 25%)

Items	Rainy season		Dry season	
	% Oc	% IRI	% Oc	% IRI
Phytoplankton				
Cyanophyceae				
Merismopedia	26.32	0.07	75.38	0.26
Gomphosphaeria	49.47	1.94	55.38	0.91
Microcystis	93.68	5.89	100.00	3.40
Anabaena	31.58	1.06	32.31	0.21
Lyngbya	74.74	1.68	93.85	3.95
Euglenophyceae				
Trachelomonas	67.37	0.72	67.69	1.02
Phacus	44.21	0.09	53.85	0.09
Chlorophyceae				
Tetraedron	58.95	0.24	67.69	0.32
Closteriopsis	71.58	1.41	80.00	2.79
Monoraphidium	73.68	0.68	78.46	1.46
Ankistrodesmus	72.63	1.92	83.08	4.69
Coelastrum	70.53	1.04	67.69	0.37
Scenedesmus	66.32	0.48	72.31	0.79
Tetrastrum	27.37	0.04	47.69	0.22
Crucigeniella	27.37	0.20	44.62	0.26
Pediastrum	40.00	0.13	53.85	0.15
Conjugatophyceae				
Closterium	73.68	0.58	81.54	0.67
Staurastrum	92.63	1.25	89.23	1.49
Staurodesmus	53.68	0.14	58.46	0.19
Xanthophyceae				
Centritractus	22.11	0.02	41.54	0.04
Bacillariophyceae				
Aulacoseira	97.89	19.46	95.38	10.32
Asterionella	102.11	27.08	98.46	31.30
Frustulia	49.47	0.20	41.54	0.10
Pinnularia	41.05	0.07	35.38	0.05
Navicula	36.84	0.08	36.92	0.04
Zooplankton				
Cladocera				
Diaphanosoma	37.89	5.52	30.77	3.67
Moina	31.58	8.40	43.08	8.76
Bosmina	57.89	18.52	58.46	21.15
Copepods				
Thermocyclops	25.26	0.41	30.77	0.55

Table 3. Food items, occurrence (% Oc), numeric (%N), volumetric (%V) and relative importance (% IRI) indexes of *Sarotherodon melanotheron* in the lower course (Aboisso) of the Bia River (Côte d'Ivoire) from August 1995 to July 1997

Items	% Oc	% N	% V	% IRI
Phytoplankton				
Cyanophyceae				
Merismopedia	21.15	0.51	0.00	0.10
Gomphosphaeria	5.77	0.06	0.00	0.00
Chroococcus	1.92	0.01	0.00	0.00
Microcystis	21.15	0.11	0.01	0.02
Anabaenopsis	1.92	0.01	0.00	0.00
Anabaena	1.92	0.02	0.00	0.00
Oscillatoria	1.92	0.01	0.00	0.00
Lyngbya	98.08	57.88	11.22	62.37
Plectonema	13.46	0.29	0.00	0.04
Euglenophyceae				
Trachelomonas	69.23	2.03	0.09	1.36
Euglena	40.38	1.99	0.09	0.77
Phacus	36.54	1.63	0.35	0.67
Lepocinclis	25.00	3.81	0.18	0.92
Chlorophyceae				
Tetraedron	5.77	0.03	0.00	0.00
Schroederia	7.69	0.40	0.00	0.03
Closteriopsis	17.31	0.27	0.00	0.04
Monoraphidium	40.38	0.80	0.00	0.30
Ankistrodesmus	32.69	0.47	0.00	0.14
Coelastrum	7.69	0.04	0.00	0.00
Scenedesmus	23.08	0.18	0.00	0.04
Tetrastrum	17.31	0.19	0.00	0.03
Crucigenia	3.85	0.08	0.00	0.00
Crucigeniella	5.77	0.02	0.00	0.00
Pediastrum	21.15	0.12	0.28	0.08
Oedogoniophyceae				
Oedogonium	1.92	0.01	0.00	0.00
Conjugatophyceae				
Mougeotia	21.15	0.14	0.25	0.08
Closterium	32.69	0.26	0.30	0.17
Cosmarium	1.92	0.01	0.00	0.00
Staurastrum	69.23	1.47	0.07	0.99
Euastrum	1.92	0.01	0.00	0.00
Xanthidium	1.92	0.02	0.00	0.00
Staurodesmus	19.23	0.28	0.01	0.05
Xanthophyceae				
Centritractus	1.92	0.01	0.00	0.00
Bacillariophyceae				
Aulacoseira	75.00	6.34	0.17	4.49
Amphora	23.08	0.25	0.02	0.06
Fragilaria	23.08	0.19	0.03	0.05
Terpsinoe	86.54	3.17	4.88	6.41
Asterionella	55.77	2.65	0.02	1.37
Eunotia	36.54	0.93	0.04	0.33
Cocconeis	1.92	0.01	0.00	0.00

Continued on p. 82

Table 3. contd.

Items	% Oc	% N	% V	% IRI
Gyrosigma	32.69	0.86	0.10	0.29
Gomphonema	48.08	0.45	0.01	0.20
Cymbella	44.23	0.55	0.03	0.23
Frustulia	75.00	6.68	0.15	4.71
Neidium	5.77	0.11	0.00	0.01
Pinnularia	63.46	2.84	0.05	1.69
Stauroneis	5.77	0.07	0.01	0.00
Navicula	57.69	0.93	0.02	0.50
Hantzschia	13.46	0.30	0.01	0.04
Nitzschia	7.69	0.04	0.01	0.00
Surirella	1.92	0.00	0.00	0.00
Dinophyceae				
Peridinium	13.46	0.29	0.01	0.04
Rhodophyceae				
Audouinella	13.46	0.19	0.00	0.02
Zooplankton				
Rotifers	11.54	0.00	0.25	0.03
Cladocera				
Kurzia	1.92	0.00	0.50	0.01
Copepods				
Thermocyclops	1.92	0.00	0.99	0.02
Others				
Chironomid larvae	15.38	0.00	79.83	11.30

addition, man-made Lake Ayame is located in an important agricultural region. According to Moss (1991) the change from mostly forest to mostly agriculture environment leads to an increase in the neighbouring rivers of the concentration of some nutrients (phosphorus, soluble orthophosphate, nitrate, ammonium) which are known to be important in phytoplankton growth. These reasons could justify the absence of notable seasonal variations in the phytoplankton and the zooplankton of Lake Ayame and as a result in the diet of *S. melanotheron* from that lake.

Diet comparison between riverine and lacustrine environment

Qualitative differences appear in the composition of the phytoplankton between the fishing stations.

Phytoplankton composition of an aquatic ecosystem is affected by biological (planktivorous fish), physical (light and temperature) and chemical (nutriments) parameters. This suggests a variation in phytoplankton from one site to another, and during the same year (Wetzel, 1983).

Table 4. Food items, occurrence (% Oc), numeric (%N), volumetric (%V) and relative importance (% IRI) indexes of *Sarotherodon melanotheron* in the upper course (Bianouan) of the Bia River (Côte d'Ivoire) from August 1995 to July 1997

Items	% Oc	% N	% V	% IRI
Phytoplankton				
Cyanophyceae				
Merismopedia	4.08	0.03	0.00	0.00
Microcystis	10.20	0.26	0.01	0.04
Lyngbya	91.84	29.52	2.23	39.64
Plectonema	22.45	0.50	0.00	0.15
Euglenophyceae				
Trachelomonas	30.61	0.53	0.04	0.24
Euglena	20.41	0.11	0.01	0.03
Phacus	8.16	0.03	0.01	0.00
Chlorophyceae				
Eudorina	8.16	0.11	0.23	0.04
Schroederia	4.08	0.02	0.00	0.00
Closteriopsis	8.16	0.48	0.00	0.05
Monoraphidium	8.16	0.27	0.00	0.03
Ankistrodesmus	8.16	0.82	0.00	0.09
Coelastrum	2.04	0.04	0.01	0.00
Scenedesmus	8.16	0.29	0.00	0.03
Tetrastrum	2.04	0.02	0.00	0.00
Pediastrum	4.08	0.05	0.00	0.00
Oedogoniophyceae				
Bulbochaete	2.04	0.02	11.64	0.32
Conjugatophyceae				
Mougeotia	22.45	5.09	3.90	2.74
Closterium	24.49	0.49	2.23	0.91
Cosmarium	2.04	0.01	0.00	0.00
Staurastrum	8.16	0.08	0.01	0.01
Bacillariophyceae				
Aulacoseira	20.41	13.42	0.42	3.84
Coscinodiscus	2.04	0.73	0.18	0.03
Amphora	20.41	0.33	0.06	0.11
Fragilaria	34.69	0.80	0.06	0.41
Terpsinoe	12.24	0.05	0.22	0.05
Asterionella	20.41	9.12	0.05	2.54
Eunotia	36.73	0.52	0.02	0.27
Cocconeis	4.08	0.13	0.00	0.01
Gyrosigma	65.31	2.69	0.53	2.86
Gomphonema	53.06	5.63	0.06	4.10
Cymbella	53.06	2.02	0.15	1.57
Frustulia	67.35	4.89	0.17	4.63
Neidium	2.04	0.02	0.00	0.00
Pinnularia	67.35	8.85	0.10	8.19
Stauroneis	2.04	0.07	0.01	0.00
Navicula	69.39	8.31	0.31	8.12
Rhopalodia	2.04	0.01	0.00	0.00

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Table 4. contd.

Items	% Oc	% N	% V	% IRI
Hantschia	40.82	1.67	0.06	0.96
Nitzschia	10.20	1.11	0.02	0.16
Surirella	6.12	0.03	0.01	0.00
Rhodophyceae				
Audouinella	36.73	0.85	0.02	0.43
Zooplankton				
Rotifers				
Testudinella	6.12	0.00	1.68	0.14
Cladocera				
Moina	4.08	0.00	23.27	1.29
Others				
Chironomid larvae	22.45	0.00	52.28	15.95

In general, change in riverine flow rate is accompanied by altered water volumes and velocities, and sometimes by changed levels of nutrients, suspended particulate matter, dissolved organic matter, temperature, conductivity, dissolved oxygen and turbidity (Morshuizen et al., 1996). The construction of the dam on the Bia River, which created the lake and two distinct riverine parts definitely contributed to differences of these parameters between the different environments. Ouattara (2000) demonstrated that phytoplankton abundance is considerably higher in man-made Lake Ayame compared to upper and lower courses. Physicochemical data (Table 6) recorded during this study show important differences between mean values of nitrite, nitrate and phosphorus for the different environments. These parameters are essential for primary producers. Thus the difference in the food composition of *S. melanotheron* between upper course, lake and lower course of the Bia River is probably related to the fact that, at least, some of the physicochemical parameters, in particular those related to nutrient production, are different.

According to Kone & Teugels (1999), the landlocked population of *Sarotherodon melanotheron* in Lake Ayame, became well adapted to that freshwater environment: (1) condition factors are comparable to those in its natural (brackish water) environment populations, (2) they reproduce all year round and (3) the species represented more than 50% of the commercial catches in 1997.

The tilapias are known for their ability to effectively colonise the unstable ecosystems in tropical and subtropical areas (Lowe-McConnell, 1979). Their suc-

Table 5. Food items, occurrence (% Oc), numeric (%N), volumetric (%V) and relative importance (% IRI) indexes of *Sarotherodon melanotheron* in man-made Lake Ayame (Côte d'Ivoire) from August 1995 to July 1997

Items	% Oc	% N	% V	% IRI
Phytoplankton				
Cyanophyceae				
Merismopedia	32.93	0.40	0.00	0.10
Gomphosphaeria	51.83	3.73	0.00	1.50
Chroococcus	23.17	0.17	0.00	0.03
Microcystis	93.29	6.40	0.04	4.66
Anabaena	31.10	2.72	0.00	0.66
Oscillatoria	0.61	0.00	0.00	0.00
Lyngbya	82.32	4.15	0.01	2.66
Plectonema	2.44	0.06	0.00	0.00
Euglenophyceae				
Trachelomonas	65.24	1.66	0.01	0.85
Euglena	12.20	0.04	0.00	0.00
Phacus	47.56	0.24	0.00	0.09
Lepocinclis	10.37	0.04	0.00	0.00
Chlorophyceae				
Pandorina	1.22	0.00	0.00	0.00
Eudorina	4.88	0.01	0.00	0.00
Tetraedron	61.59	0.57	0.00	0.27
Schroederia	0.61	0.00	0.00	0.00
Closteriopsis	84.15	3.52	0.00	2.30
Monoraphidium	75.61	1.79	0.00	1.05
Kirchneriella	0.61	0.00	0.00	0.00
Ankistrodesmus	77.44	5.34	0.00	3.21
Selenodictyum	12.20	0.06	0.00	0.01
Nephrocytium	6.71	0.02	0.00	0.00
Micractinium	1.22	0.04	0.00	0.00
Dictyosphaerium	1.22	0.00	0.00	0.00
Dimorphococcus	4.88	0.03	0.00	0.00
Coelastrum	68.90	1.35	0.01	0.73
Scenedesmus	67.07	1.18	0.00	0.61
Tetrastrum	34.76	0.38	0.00	0.10
Crucigenia	26.22	0.46	0.00	0.09
Crucigeniella	34.15	0.88	0.00	0.23
Actinastrum	16.46	0.04	0.00	0.01
Pediastrum	44.51	0.35	0.04	0.13
Elakatothrix	4.27	0.01	0.00	0.00
Oedogonium	0.61	0.00	0.00	0.00
Conjugatophyceae				
Mougeotia	1.83	0.00	0.00	0.00
Closterium	75.00	1.05	0.00	0.61
Cosmarium	17.68	0.05	0.00	0.01
Staurastrum	90.24	1.95	0.02	1.38
Micrasterias	0.61	0.06	0.03	0.00
Euastrum	22.56	0.08	0.00	0.01
Xanthidium	11.59	0.04	0.00	0.00
Staurodesmus	54.27	0.38	0.00	0.16
Sphaerozosma	7.93	0.10	0.00	0.01
Spondylosium	20.12	0.11	0.00	0.02

Continued on p. 84

Table 5. contd.

Items	% Oc	% N	% V	% IRI
Xanthophyceae				
Ophiocytium	9.15	0.04	0.00	0.00
Centritractus	29.27	0.11	0.00	0.03
Bacillariophyceae				
Aulacoseira	95.73	20.60	0.05	15.34
Cyclotella	2.44	0.00	0.00	0.00
Amphora	4.27	0.02	0.00	0.00
Fragilaria	12.80	0.04	0.00	0.00
Terpsinoe	0.61	0.00	0.00	0.00
Asterionella	96.34	38.02	0.03	28.45
Eunotia	18.90	0.07	0.00	0.01
Cocconeis	0.61	0.01	0.00	0.00
Gyrosigma	1.22	0.00	0.00	0.00
Gomphonema	20.73	0.09	0.00	0.01
Cymbella	14.02	0.03	0.00	0.00
Frustulia	45.12	0.42	0.00	0.15
Neidium	3.66	0.01	0.00	0.00
Pinnularia	37.80	0.20	0.00	0.06
Stauroneis	4.88	0.02	0.00	0.00
Navicula	35.98	0.21	0.00	0.06
Rhopalodia	0.61	0.00	0.00	0.00
Hantzschia	3.05	0.00	0.00	0.00
Nitzschia	0.61	0.01	0.00	0.00
Surirella	3.66	0.01	0.00	0.00
Dinophyceae				
Peridinium	42.07	0.58	0.00	0.19
Zooplankton				
Rotifers				
Brachionus	19.51	0.00	0.03	0.00
Anuraeopsis	3.05	0.00	0.00	0.00
Trichocerca	20.73	0.00	0.01	0.00
Filinia	20.73	0.00	0.00	0.00
Asplanchna	0.61	0.00	0.02	0.00
Keratella	16.46	0.00	0.01	0.00
Lecane	7.32	0.00	0.00	0.00
Platyias	1.83	0.00	0.00	0.00
Polyrathra	0.61	0.00	0.00	0.00
Testudinella	8.54	0.00	0.02	0.00
Hexarthra	2.44	0.00	0.00	0.00
Lepadella	1.22	0.04	0.00	0.00
Cladocera				
Diaphanosoma	34.76	0.00	18.02	4.86
Ceriodaphnia	3.05	0.00	0.28	0.01
Moina	35.98	0.00	32.19	8.99
Bosmina	57.93	0.00	43.36	19.50
Camptocercus	0.61	0.00	0.01	0.00
Kurzia	4.27	0.00	0.15	0.00
Chydorus	0.61	0.00	0.00	0.00
Macrothridae	0.61	0.00	0.00	0.00
Copepods				
Thermodiaptomus	14.63	0.00	2.00	0.23
Thermocyclops	26.83	0.00	2.17	0.45
Copepodites	15.24	0.00	0.42	0.05
Naupliis larvae	16.46	0.00	0.10	0.01

Table 6. Chemical parameters of the sampling sites (Bianouan, Ayame Lake and Aboisso) in the Bia River (Côte d'Ivoire)

Sites		Parameters			
		NO2– (mg/l)	NO3– (mg/l)	PO4– (mg/l)	Ca++ (mg/l)
Bianouan	Mean	0.004	0.34	1.31	11.83
	Minimum	0.001	0.1	0.47	4
	Maximum	0.02	0.7	2.65	18
	Observations	20	18	20	20
Ayame Lake	Mean	110.52	7.37	26	6.37
	Minimum	54	6.7	27.98	3.2
	Maximum	157	8.47	30	11.1
	Observations	38	38	40	40
Aboisso	Mean	0.002	0.35	1.08	11.33
	Minimum	0.001	0.4	0.67	8
	Maximum	0.005	0.8	2.01	18
	Observations	18	18	19	19

cess in these habitats was attributed to their aptitudes to quickly adapt their life-history characteristics and their trophic level in response to the changes in their environment (Bowen & Allanson, 1982). Its presence in the upper course of the Bia River and in man-made Lake Ayame confirms this The present study demonstrates that *S. melanotheron* is able, as other cichlids in general, to adapt its feeding biology to different environmental conditions.

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