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Original Research Article

Analysis of micro-algae grazing and filtering activity of *Tilapia zillii* in the Ziga reservoir in Burkina Faso (Western Africa)

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From February 2014 to January 2015, 408 water samples were collected in eleven points installed throughout the Ziga dam and in six points of the raw water supply continuum. The analysis of these samples using a Primo Star light microscope equipped with a camera revealed 44 algal groups in the dam lake. In the meantime, 205 *Tilapia zillii* fish were harvested from 11 points installed throughout the dam. Collected fish individuals were eviscerated and the stomach and intestinal contents were stored at 5% formaldehyde in 50 ml pill containers for analysis in the laboratory. Analysis of the contents revealed different groups of algae in the diet of *T. zillii* and according to their numerical importance we have *Chromophyta* (76.50%), *Chlorophyta* (12.43%), *Cyanophyta* (4.67%), *Pyrrophyta* (1.20%) and *Euglenophyta* (0.94%). Helminth eggs (4.27%) were recorded with algal species. The intestinal coefficient of *T. zillii* was identified in the range of 5.1 to 7.4 confirming the position of this fish species in the trophic level as phytophagous fish species. The analysis of the stomach and intestinal contents of *T. zillii* also highlighted preferential preys such as species of *Melosira*, *Cymbella* and helminth eggs; secondary preys such as species of *Cosmarium*, *Nostoc* and *Tribonema*. All identified preys are biological pollutants of water quality and are harmful to human and animal health. From the correlation coefficients, the phytoplanktonophagous feeding habit of *T. zillii* has been established. The species does not change its phytoplankton diet, either according to its size or to the periods of abundance or shortage of preys. According to the characteristics of the prey species, the fish species may be considered as an important biological material to control the quality of polluted water collected into treatment plants to supply drinking water to populations. Using grazing and filtering fish species as *T. zillii* to clean raw water is in one hand, a biological contribution to water pollutants control, and in the other hand, an alternative against chemical treatments for drinking water; chemicals that can cause health hazard to human.

Key words: Tilapia *zillii*, biological control agent, micro-algae, water quality, Ziga dam, Burkina Faso.

INTRODUCTION

In Burkina Faso, 84% of the water resources exploited by the National Office for Water and Sanitation (ONEA) come from open water reservoirs. All these water resources are currently facing significant eutrophication caused by human activities (Neya et al., 2017a). The eutrophic state generates flavors such as putrid tastes and odors of drinking water during the growth periods of certain types of algae (Proulx et al., 2010). Consequently, dislikes and

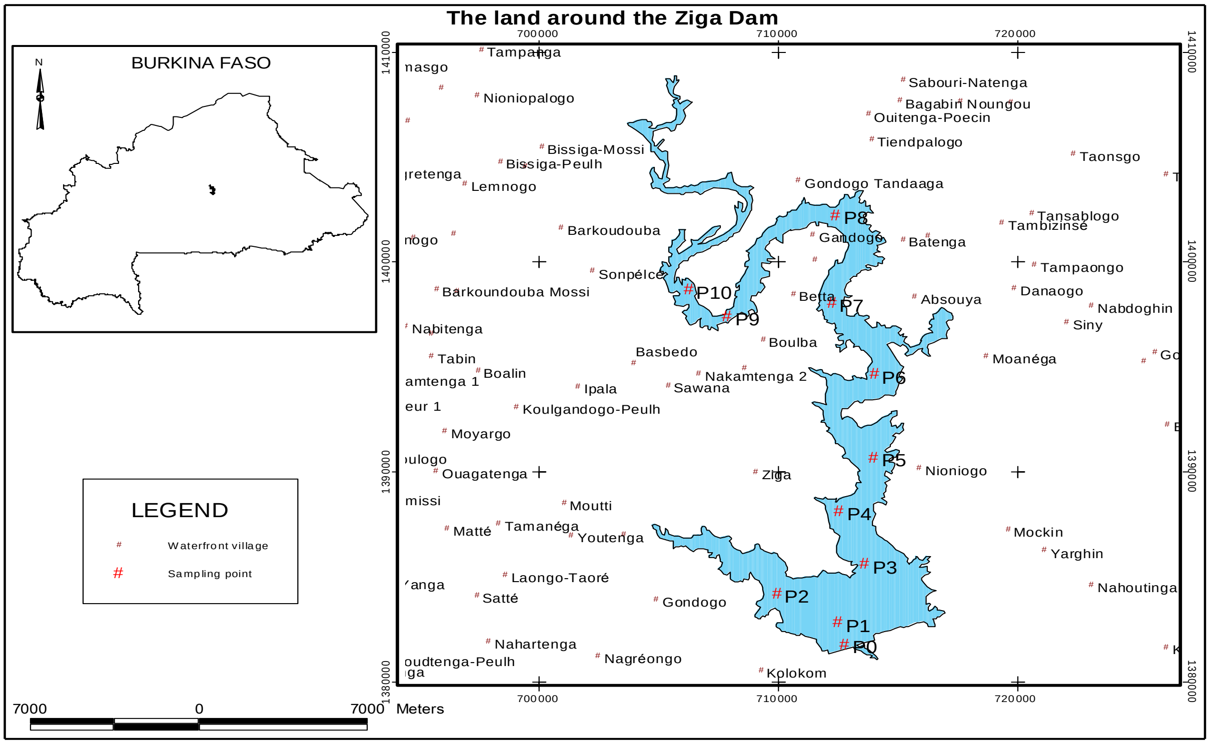

Figure 1: Map of the Ziga dam depicting the algae and *Tilapia zillii* sampling stations (in red #), Burkina Faso (after, Neya et al., 2017)

complains from water consumers are registered during algal bloom periods. In addition many authors reported that several types of algae are known to be harmful to human and animal health and may negatively compromise the development of the food chain (Sivonen and Jones 1999, Chorus and Bartram, 1999, Briand et al., 2003, Lambert et al., 2001, Fujiki et al., 1990, Ito et al., 2002, Devlin et al., 1977, OMS, 1998, 2000, 2003, 2004, Charbonnier, 2006). In most treatment plants chlorine is used for disinfection of water. The reaction of this algaecide with organic material generates trihalomethanes (THMs) such as chloroform, bromoform, dibromochloromethane and bromodichloromethane. These chlorination by-products in water are found to be negative factors for consumer health (Dodds and King, 2001, Nieuwenhuijsen et al., 2000, Mills et al., 1998, Boorman, 1999). It seems clear that the central question is how to solve the dilemma between the impacts of harmful algae or the by-products of chlorination on water quality and the consumer health. Hence, would it not be skillful to introduce fish as biological control agents into the water treatment chain to improve the quality of raw natural water collected in tanks for drinking water purposes? It is well known for thousands of years that the state of balance of ecosystems has been based on the food chain with the predator-to-prey relationships as the backbone. Predator-prey relationships have always played a key role in the dynamic equilibrium within any ecosystem.

Clearly, through natural water ecosystems, predator-to-prey relationship was analyzed between the harmful algae recorded in the Ziga dam lake and the phytoplanktonophagous diet of *T. zillii,* an economically valuable fish in the lake. For over a decade, ONEA has been experimenting the phytophagous diet of fish in the Ziga Dam. Therefore, the aim of this work was to use high-performance phytophagous fish adapted for the development of a program seeking to improve the quality of water produced from the open-air tanks operated by the Office. Some fish species like *Oreochromis nilotica* and *Sarotherodon galilaeus* have already been experimented and used in the ONEA drinking chain for biological water cleaing. This work on the phytophagous diet of *T. zillii* was conducted in the same dynamic. The purpose of this present work was finally to contribute to the improvement of ONEA's drinking water quality through the introduction of fish species as biological control agents, a real alternative to the misuse of chemicals in the food chain; chemicals that often causes health hazards to consumers.

METHOD AND MATERIAL

Description of the Ziga water reservoir

The Ziga reservoir (Figure 1) was chosen to study the phytoplankton-eating diet of *T. zilli* as it is the largest lake

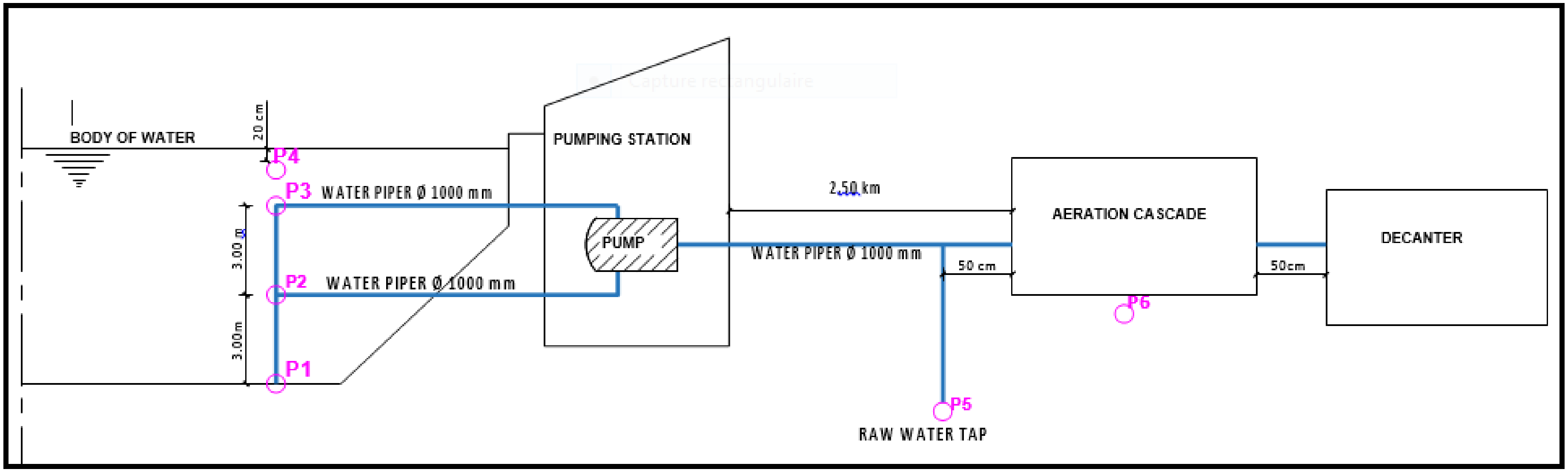

Figure 2: Synoptic diagram of the Ziga raw water supply continuum. 0p1: sampling point bottom of dam (chamber p1)0p2: sampling point, first intake (chamber p2), 0p3: sampling point, second intake (chamber p3), 0p4: sampling point, water surface (chamber p4), 0p5: sampling point, raw water monitoring valve (chamber p5), 0p6: sampling point of aeration cascades (chamber p6), (Neya et al., 2017)

in Burkina Faso for drinking water. The impounded reservoir, in period of flood, has a stocking capacity of 208 million m^3 (ONEA, 1997). It is the main water supplier of the capital of Burkina Faso (Ouagadougou), and provides more than 70% in drinking water to the populations of Ouagadougou. Its surface area is 8872.5 ha and more than 70% of the surrounding area are exploited for market garden crops. The areas used by populations have been for a while subjected to soil erosion that causes eutrophic phenomena in the lake. Indeed, 26 villages are located around the dam and whose human activities cause annual algal pic rate estimated of 5 million cells per milliliter (Neya et al., 2017 b).

Ziga reservoir is located in a Sudanian-type climate that includes two seasons: a dry season going from October to May corresponding to the period in which a significant development of algae (algal bloom) is observed and a rainy season from June to September which corresponds to the decline of algal bloom. Mean rainfall and temperature are respectively 713 mm and 29.1 °C (Neya, 2011).

Sampling of algae

Micro-algae samples were collected in 11 sampling points in strategic areas (p0, p1, p2, p3, p4, p5, p6, p7, p8, p9, and p10) along the Ziga dam as shown in Figure 1 and in the raw water supply continuum chambers (0p1, 0p2, 0p3, 0p4, 0p5 and 0p6) of the treatment station (Figure 2). The 11 points correspond to homogenized and nutrient enrichment points of the dam. Analysis of algae samples from the continuum of the Ziga drinking water treatment plant allowed identifying the nature and the algal concentration in the different chambers. Samples were taken twice a month in all seventeen points. The samples are taken every 15th and 30th of the month in order to take into account the algal development cycle. In addition the sampling was performed between 10 am and 11 am GMT local time; a period of the day when the lighting incident is important allowing an intense activity of the photosynthesis produced by algae.

Samples were collected in 1l bottles and stored in 50 ml bottles containing water with 5% formaldehyde. The contents of the 50 ml bottles were then analyzed in the laboratory with a Primo Star optics microscope. The identification of micro-algae was carried out using dichotomic keys of different authors (Itlis, 1980; Bourrelly, 1985 and 1990). The quantitative analysis of samples was carried out using a Mallassez counting cell coupled to the Primo Star optics microscope equipped with camera. The counting cell is divided in 100 rectangles with a total volume of 1 µl. The following formula was used to calculate algal concentration of each sample.

$$C = \left(\frac{\text{nca} * \text{vc (ml)}}{\text{vtm(ml)}}\right) * \text{f}/1000$$

C: cell concentration in algal cells per milliliter (ml);

- ✓ nca: number of algal cells counted in the 100 rectangles;
- ✓ vc: volume of algae conservation (40ml)
- ✓ vtm: volume of 100 rectangles (0,001ml) of Mallassez counting cell
- ✓ f: dilution factor
- ✓ 1000: conversion factor of the concentration of liter in milliliter.

Sampling of *Tilapia zillii*

The sampling of *T. zillii* was done through fishing around the eleven points (p0, p1, p2, p3, p4, p5, p6, p7, p8, p9, and p10) installed along Ziga Dam (Figure 1) and where algae samples were collected. Gillnets of 10 to 30 mm mesh size knot to knot, are geared in the evening between 18 pm and 18.30 pm and lifted the next morning between 7 am and 12 o'clock. The fish sampling lasted from February 2014 to January 2015 and a total of 205 individuals of fish ranging in size from 85 to 211 mm was registered. Captured fish were eviscerated and stored at 10% formaldehyde for laboratory analysis. The standard size of captured fish was measured using a 1 mm precision ichthiyometer. Stomach and intestinal contents were weighed in the laboratory using a Rawag scale with an accuracy of 0.001 g. Using Mallassez counting cell and the Primo Star optical microscope, algae species in the stomachs and intestines were identified and the cell concentrations calculated. The qualitative and quantitative analyzes were coupled with statistical studies using Statistica software version 7.1 to characterize the phytophagous diet of *T. zillii* in the Ziga dam lake.

Characterization of the phytoplanktonophageal diet of *Tilapia zillii*

The recorded preys were used to reconstitute and characterize the phytoplanktonophageal diet of *T. zillii* and to identify the criteria required for its classification in the register of biological predator and controller agent. In the present study, three criteria were used to consider *T. zillii* as a biological controller agent: a) *T. zillii* is found in the trophic guild of phytophagous fish, b) preferential and secondary prey of *T. zillii* are detrimental to water quality and harmful to human health, c) *T. zillii* has an ontogenetic phytophagous diet. The determination of these criteria was based on the results of quantitative and qualitative optical microscopy analyzes, coupled with statistical studies performed using the Statistica software. These analyzes were used to determine the criteria that guided the choice of the fish as a biological controller agent after specifying preferential, secondary and accessory preys of the predator species. In addition, the type, the seasonal frequency, the size, the concentrations of preys in the intestines and stomachs were used to confirm that *T. zillii* can be considered as a biological controller agent of water quality in the Ziga dam water treatment station or not.

Statistical analysis of data

According to the literature, several methods are used for the analysis of the diet of a predator. There are calorimetric methods to give value to each constituent prey of the predator diet (Bowen, 1983) and methods based on dietary indices (Hureau, 1970, Holisova, 1975, Lauzanne, 1975, Hyslop, 1980, Zander, 1982, Rosecchi and Nouaze, 1987) using a combination of simple indices and mixed indices for predator prey classification. For the present study, we use these dietary indices because they have the merit of depicting a hierarchy ordination of the prey of the studied diet (Rosecchi et al., 1987). They were calculated according to the different formulas termed:

(a) Frequency Index or Relative Frequencies F: the number of stomachs containing a category of prey is counted and expressed as a percentage of the Total Number (NT) of stomachs containing at least one prey (Hyslop, 1980). F can be calculated as:

F% itemi = Ni / NT × 100; where F% itemi is the frequency of the itemi, Ni is the number of stomachs containing item i and NT is the number of stomachs containing at least one prey.

(b) Numerical Abundance Index Ni:

The total number of individuals in the food category (prey) in all (ni) stomachs is recorded and expressed as a percentage of the total number of individuals (NT) of all prey categories (Hyslop 1980). Ni = ni / NT × 100.

(c) Pi abundance index Pi:

This is the percentage composition of the weight of the diet. According to Hyslop (1980); Paugy and Lévêque (1999), Pi is determined according to the following formula: Pi = pi / Pt × 100 where pi is the mass of prey i and Pt is the total mass of prey.

(d) Vacancy coefficient (Cv):

It represents the percentage of empty stomachs in relation to the total number of stomachs examined. Cv = Nv / Nt × 100 with Nv the number of empty stomachs and Nt the total number of stomachs examined.

(e) Intestinal Coefficient (IC):

Paugy (1994), on the basis of the intestinal coefficient, classifies fish trophic levels by the following expression: Ci = Li / Ls with LI intestine length and LS standard length of fish

Main Food or Hand Food Item (MFI):

Zander (1982), characterizes the diet by combining three indexes namely the abundance index (Pi), the numerical index (Ni) and the relative frequency (Fi). This grouping of prey according to their index value is used to classify them in order of importance that is preferential, secondary and accidental preys. This grouping justified the following formula: MFIi = $\sqrt{Pi\,\frac{(Fi+Ni)}{2}}$

Rocecchi and Nouaze (1987) express the MFI as a percentage (MFI %). According to the authors, this classification scale allows a good distribution of prey in the different categories, when they are numerous and of similar abundances. To better separate preferential preys from others such as secondary and accessory preys, the MFI values for a given species are ranked in descending order. Starting from Tier 1 prey, the indices of each preys are added in order to obtain 50% or more for the total index and the prey is called preferential prey. When the sum of percentages of preys added in order reach an index of at least 75%, the prey is called secondary prey. The last category of preys in the list are considered as accessories. The formula proposed by the authors is then the following:

$$MFIi\,\% = \frac{MFIi}{\sum_{i=1}^{n} MFIi} \times 100$$

For the ontogenetic study of *T. zillii* and the variation of its diet by size and season, a Principal Component Analysis using a regression of the abundance of preys consumed by juveniles and adults during dry season and during rainy season was done. The intestinal coefficient of *T. zillii* was used to characterize the trophic level of the species (Paugy, 1994).

RESULTS

Algal groups in the species diet

A number of 195 and 205 *T. zillii* fish individuals ranged in size from 85 to 211 mm total length and had respectively full stomachs and empty stomachs with a void coefficient of 5.128. Analysis of stomach and intestinal contents indicated four different algal groups in the diet of *T. zillii*: Chromophyta (76.50%), Chlorophyta (12.43%), Cyanophyta (4.67%), Pyrrophyta (1.20%) and Euglenophyta (0.94%) (Figure 3). Helminth eggs were also found and represented 4.27% of the total preys.

The phytoplanktonophageal diet of *Tilapia zillii* based on dietary indices

Analysis of the 408 samples collected from the raw water yielded 44 genera of algae in the Ziga water body. In contrast the analysis of the stomach and intestinal contents all the year long revealed 34 prey types which include 33 genera of algae and helminth eggs (Table 1). In the diet of *T. zillii*, two kinds of primary algae eaten by the species composed of *Melosira, Cymbella* were found and were associated with helminth eggs; three kinds of secondary algae in the diet were recorded and composed of *Cosmarium, Nostoc* and *Tribonema*. The other 28 genera are considered as accessory preys.

In term of seasonal diet, during the dry season, 182 individuals of *T. zillii* fish were harvested. In total, 173 full stomachs and 9 empty stomachs were observed. The vacancy coefficient computed was 5.202%. During this period, 34 preys (Table 2) were recorded in the diet of *T. zillii*. Preferred preys consist of species belonging to *Melosira, Cymbella* and helminth eggs. Secondary prey includes: *Cosmarium*, *Ulothrix* and *Pinnularia*. The remaining 28 preys are accessory preys. During the rainy season, 23 *T. zillii* fish were caught. Analysis of stomach and intestinal contents revealed 22 full stomachs and an empty stomach. The vacancy coefficient at this time was 4.545%. Thirteen preys were counted including seven preferential preys: *Cosmarium, Cymbella*, *Gyrosigma, Melosira*, *Microcystis, Mougeotia, Navicula* and only one secondary preys, *Nostoc*. The remaining 5 preys are accessory preys (Table 3).

In term of diet composition related to fish size or length class, two size groups were used: 85 to 100 mm and 101 to 211 mm. Analysis of 39 fish between 85 and 100 mm in size revealed 22 preys (Table 4) consumed. Among these preys, *Cymbella, Synedra* and *Cosmarium* were preferential preys; *Navicula* was the only secondary prey. The other 18 preys were accessories. No empty stomachs and intestines were found at this time in the fish. In the size class between 101 and 211 mm, 166 fish individuals were harvested. Among recorded individuals, 156 full stomachs and 10 empty stomachs were noticed with a void factor of 6.410%. In this class, 32 preys (Table 5) were recorded in the phytoplanktonophagous diet of the species. Preferential preys included species from *Melosira, Cymbella*. Preferential preys also included helminth eggs and the cosmic genera of *Ulothrix* and *Tribonema*. The remaining 26 preys were classified as accessories.

Correlation between prey and predator

The regression analysis performed between *T. zillii* intestines and its standard size gave a correlation coefficient r = 0.76 (Figure 4). Between the phytoplankton diet of the dry season and that of the rainy season gives a correlation coefficient of 0.75 (Figure 5). The regression between the size class of 85 to 100 mm and the size class of 101 to 211 mm, revealed a correlation coefficient of 0.92 (Figure 6). The intestinal coefficient of *T. zillii* ranged from 5.14 to 7.46.

DISCUSSION

The study of Lagler et al. (1962) states that there is a

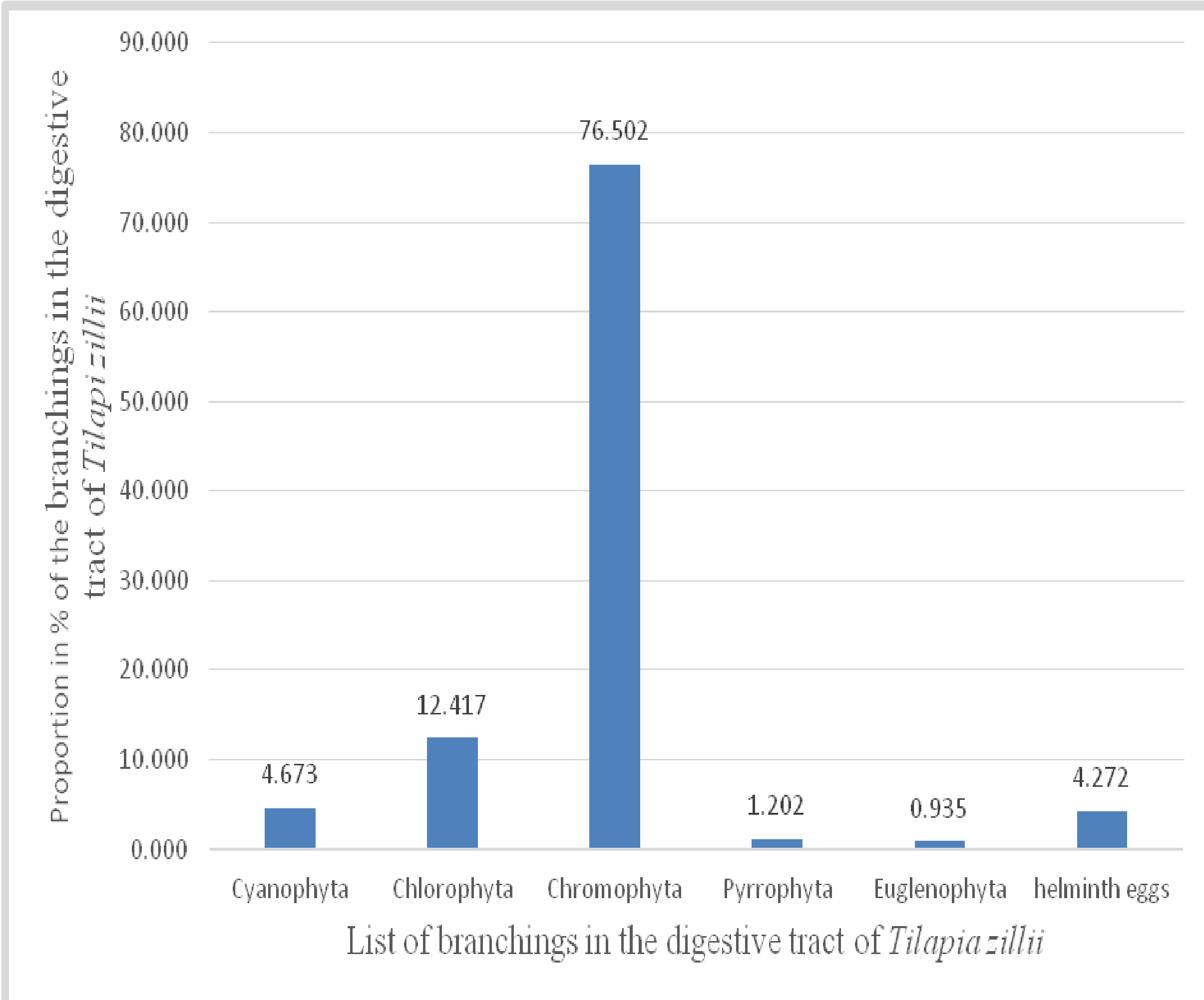

Figure 3: Proportion of algal groups and helminth eggs in the stomach and intestinal contents of *Tilapia zillii* caugth from the Ziga dam lake, Burkina Faso

relationship between the intestine and the standard size of predators. Indeed, the regression of the standard size on the length of the intestine of *T. zillii* was 0.76. This coefficient indicates that there is a perfect relationship between the standard size of T. *zillii* and the length of its gut. Paugy (1994), used this report called intestinal coefficient (Ci) to characterize the trophic gild of some predators. They determined the intestinal coefficients of omnivorous (0.8 to 1.3), ichthyophagous (0.78 to 1.10), zooplankton (0.70 to 0.80) and macro / microphagous (1.83 to 7.00). The intestinal coefficient of T. zillii is in the range of 5.14 to 7.46. This class covers the macro / microphage range (1.83-7.00) of Paugy 1994, indicating that *T. zillii* is a macro / microphytophagous trophic level predator.

Among 44 genera of algae recorded in the Ziga dam lake, *T. zillii* consumed 33 genera (Table 1) corresponding to 75% of the algal biomass of the dam lake with a relatively low vacancy coefficient (4.878%). This coefficient indicates the ability of *T. zillii* to search for these preys despite their scarcity. This ability was also noticed during rainy season diet where 13 of 34 preys were counted with a void coefficient of 0%. Among the genera of algae consumed in a general way, the phytoplanktonophageal diet of *T. zillii* is characterized by preferential and accessory preys that are detrimental to water quality and harmful to human and animal health. Among the preferential preys, the genus *Melosira* has been recognized being a kind of algae that produce tastes and odors in water (Lins, 1977) and species of *Cymbella* genus recognized to cause problem of clogging and thereby can stop to filtering system in the water treatment station (APHA, 1985). In the secondary preys, species of *Cosmarium* has been described as a kind of algae producing tastes and odors in water and the species of *Nostoc* that produce toxins harmful to human and animal health. In addition to the degradation of the water quality induced by these algae, they cause significant treatment costs to the treatment stations because the clogged filters must be cleaned often at close intervals. Helminth eggs are a public health problem in countries with moderate

Table 1. Composition of the phytoplanktonophageal diet all year long of *Tilapia zillii* with the values of the indices

Prey items	F%I	NI%	FMI	PI%	FMI%	FMI% Cumule	Diet
Melosira	27.692	7.210	26.251	39.487	25.432	25.432	Primary
Cymbella	82.564	21.495	21.675	9.030	21.000	46.432	Primary
Helminth eggs	16.410	4.272	16.527	26.412	16.011	62.443	Primary
Cosmarium	48.205	12.550	9.256	2.820	8.967	71.410	Secondary
Nostoc	5.641	1.469	3.193	2.869	3.094	74.504	Secondary
Tribonema	13.846	3.605	3.131	1.124	3.034	77.537	Secondary
Ulothrix	7.692	2.003	3.020	1.882	2.926	80.463	Accessory
Pinnularia	7.692	2.003	2.939	1.782	2.847	83.311	Accessory
Navicula	43.077	11.215	2.620	0.253	2.539	85.849	Accessory
Mougeotia	15.897	4.139	2.488	0.618	2.411	88.260	Accessory
Rhizoclonium	1.538	0.401	2.342	5.656	2.269	90.528	Accessory
Synedra	65.641	17.089	1.801	0.078	1.745	92.273	Accessory
Peridinium	4.103	1.068	1.786	1.234	1.730	94.004	Accessory
Cladophora	1.026	0.267	1.730	4.632	1.676	95.680	Accessory
Merismopedia	2.564	0.668	0.925	0.529	0.896	96.576	Accessory
Epithemia	0.513	0.134	0.578	1.033	0.560	97.136	Accessory
Microcystis	5.128	1.335	0.491	0.075	0.476	97.611	Accessory
Euastrum	5.641	1.469	0.414	0.048	0.401	98.012	Accessory
Trachelomonas	3.590	0.935	0.411	0.074	0.398	98.410	Accessory
Pseudanabaena	3.590	0.935	0.260	0.030	0.251	98.661	Accessory
Gyrosigma	8.718	2.270	0.232	0.010	0.225	98.886	Accessory
Surirella	0.513	0.134	0.228	0.161	0.221	99.107	Accessory
Diatoma	1.538	0.401	0.173	0.031	0.167	99.274	Accessory
Spirogyra	0.513	0.134	0.132	0.054	0.128	99.402	Accessory
Nitzschia	1.538	0.401	0.102	0.011	0.099	99.501	Accessory
Lyngbya	0.513	0.134	0.100	0.031	0.097	99.598	Accessory
Eudorina	1.538	0.401	0.100	0.010	0.097	99.695	Accessory
Staurastrum	2.564	0.668	0.075	0.004	0.073	99.768	Accessory
Volvox	0.513	0.134	0.058	0.010	0.056	99.823	Accessory
Xanthidium	1.538	0.401	0.054	0.003	0.053	99.876	Accessory
Closterium	1.026	0.267	0.043	0.003	0.042	99.918	Accessory
Sphaerocystis	0.513	0.134	0.034	0.004	0.033	99.951	Accessory
Coelastrum	0.513	0.134	0.027	0.002	0.026	99.977	Accessory
Gymnodinium	0.513	0.134	0.024	0.002	0.023	100.000	Accessory

sanitation (ANOFEL, 2014). These eggs were found as preferential preys in *T. zillii* despite their low number in the present investigation (Figure 3). The absolute frequency of these eggs in the stomach and intestinal contents of *T. zillii*, corroborates the work of Berg (1979) who defined preferential prey as a feed whose lack in a medium interferes or handicaps with certain functions (development, reproduction) of the predator that consumes them. These eggs are pollutant of water quality and harmful to human and animal health and are however recognized difficult or impossible to be eliminated during the treatment of water by conventional methods (sedimentation-coagulation, filtration and disinfection). In the perspective of the specific selection of these eggs by this fish, it could be used as a biological control agent of these pests, which are prevalent in most multi-users of water reservoirs in sub-Saharan Africa (Neya et al., 2107c).

The Principal Component Analysis (Figure 5) of the diet by doing the regression between prey abundances of dry season (high abundance period) and prey abundances during rainy season (low abundance and scarcity season) revealed a high correlation coefficient r = 0.75. This high correlation coefficient indicates that there is no significant change in phytoplankton diet of the fish during both seasons (Tables 2 and 3).

The linear regression between low sizes and high sizes of stomachs (e.g., the size class from 85 mm to 100 mm and the one of 101 to 211 mm) also gave a correlation coefficient r = 0.85 (Figure 6).

The high correlation coefficient indicates that *T. zillii* diet does not vary in both size groups (Tables 4 and 5). Tables 1, 2, 3 and 5 indicate that *Melosira* and *Cymbella* genera are

Table 2. Composition of the phytoplanktonophageal diet of *Tilapia zillii* according to the dry season based on the values of the indices

Prey items	FI%	NI%	PI%	MFI	MFI%	MFI% Cumule	Diet
Melosira	29.121	7.496	47.428	29.468	28.161	28.161	Primary
Cymbella	80.769	20.792	10.603	23.204	22.175	50.336	Primary
Helminth eggs	15.385	3.960	14.293	11.758	11.236	61.572	Primary
Cosmarium	50.549	13.013	3.361	10.335	9.877	71.449	Secondary
Ulothrix	8.242	2.122	2.274	3.433	3.281	74.729	Secondary
Pinnularia	8.242	2.122	2.153	3.340	3.192	77.921	Secondary
Navicula	45.055	11.598	0.300	2.917	2.787	80.709	Accessory
Tribonema	12.088	3.112	1.057	2.834	2.708	83.417	Accessory
Mougeotia	16.484	4.243	0.705	2.703	2.583	86.000	Accessory
Rhizoclonium	1.099	0.283	6.835	2.173	2.077	88.077	Accessory
Peridinium	4.396	1.132	1.491	2.030	1.940	90.017	Accessory
Synedra	68.681	17.680	0.091	1.979	1.892	91.908	Accessory
Cladophora	1.099	0.283	5.598	1.967	1.879	93.788	Accessory
Merismopedia	2.747	0.707	0.640	1.051	1.005	94.792	Accessory
Nostoc	4.396	1.132	0.318	0.937	0.896	95.688	Accessory
Eudorina	1.648	0.424	0.487	0.710	0.679	96.367	Accessory
Epithemia	0.549	0.141	1.248	0.657	0.628	96.994	Accessory
Surirella	0.549	0.141	0.713	0.496	0.474	97.468	Accessory
Euastrum	6.044	1.556	0.058	0.470	0.449	97.918	Accessory
Microcystis	4.945	1.273	0.057	0.420	0.401	98.319	Accessory
Trachelomonas	2.747	0.707	0.062	0.326	0.312	98.631	Accessory
Pseudanabaena	3.846	0.990	0.036	0.295	0.282	98.913	Accessory
Gyrosygma	8.242	2.122	0.010	0.229	0.219	99.132	Accessory
Diatoma	1.648	0.424	0.037	0.196	0.188	99.319	Accessory
Spirogyra	0.549	0.141	0.065	0.150	0.143	99.463	Accessory
Nitzschia	1.648	0.424	0.013	0.116	0.111	99.574	Accessory
Lyngbya	0.549	0.141	0.038	0.114	0.109	99.682	Accessory
Staurastrum	2.747	0.707	0.004	0.086	0.082	99.764	Accessory
Volvox sp	0.549	0.141	0.012	0.065	0.063	99.827	Accessory
Closterium	1.099	0.283	0.004	0.049	0.047	99.874	Accessory
Sphaerocystis	0.549	0.141	0.004	0.038	0.037	99.910	Accessory
Xanthidium	1.099	0.283	0.002	0.036	0.034	99.945	Accessory
Coelastrum	0.549	0.141	0.003	0.031	0.030	99.974	Accessory
Gymnodinium	0.549	0.141	0.002	0.027	0.026	100.000	Accessory

Table 3. Composition of the phytoplanktonophageal diet of *Tilapia zillii* in the rainy season based on the values of the indices cumulated

Prey items	FI%	NI%	PI%	MFI	MFI%	MFI% Cumule	Diet
Cosmarium	9.091	5.128	0.216	1.239	2.000	2.000	Primary
Cymbella	68.182	38.462	1.473	8.863	14.309	16.309	Primary
Gyrosigma	9.091	5.128	0.008	0.233	0.376	16.685	Primary
Melosira	4.545	2.564	1.335	2.178	3.517	20.202	Primary
Microcystis	4.545	2.564	0.153	0.739	1.192	21.395	Primary
Mougeotia	4.545	2.564	0.191	0.824	1.331	22.725	Primary
Navicula	9.091	5.128	0.024	0.416	0.671	23.396	Primary
Nostoc	13.636	7.692	14.410	12.396	20.014	43.410	Secondary
Helminth eggs	13.636	7.692	80.654	29.328	47.350	90.760	Accessory
Synedra	13.636	7.692	0.018	0.443	0.715	91.476	Accessory
Trachelomonas	4.545	2.564	0.130	0.679	1.096	92.572	Accessory
Tribonema	18.182	10.256	1.379	4.428	7.149	99.720	Accessory
Xanthidium	4.545	2.564	0.008	0.173	0.280	100.000	Accessory

preferential and constant preys of *T. zillii* throughout its life. However, these two kinds of algae, according to our work, are listed as confirmed causes of clogging of the filters in water treatment stations of the Ziga reservoir.

The rainy season is the period of shortage of algae. From different prey species belonging to 34 genera recorded in

Table 4. Phytoplanctonophageal diet of *Tilapia zillii* as a function of size (85 <ls <100 mm)

Prey items	FI%	NI%	PI%	MFI	MFI%	MFI% Cumule	Diet
Cymbella	74.359	23.387	8.440	6.991	12.194	12.194	Primary
Synedra	61.538	19.355	0.008	6.360	11.093	23.286	Primary
Cosmarium	30.769	9.677	2.280	4.497	7.844	31.130	Primary
Navicula	30.769	9.677	0.671	4.497	7.844	38.974	Secondary
Merismopedia	28.205	8.871	43.386	4.306	7.510	46.484	Accessory
Tribonema	15.385	4.839	0.859	3.180	5.546	52.030	Accessory
Helminth eggs	12.821	4.032	9.567	2.903	5.063	57.093	Accessory
Microcystis	7.692	2.419	0.092	2.249	3.922	61.015	Accessory
Mougeotia	7.692	2.419	0.321	2.249	3.922	64.937	Accessory
Anabaena	5.128	1.613	0.038	1.836	3.202	68.139	Accessory
Euastrum	5.128	1.613	0.039	1.836	3.202	71.341	Accessory
Gyrosigma	5.128	1.613	0.005	1.836	3.202	74.543	Accessory
Nostoc	5.128	1.613	0.019	1.836	3.202	77.746	Accessory
Peridinium	5.128	1.613	8.811	1.836	3.202	80.948	Accessory
Pinnularia	5.128	1.613	1.446	1.836	3.202	84.150	Accessory
Melosira	2.564	0.806	0.037	1.298	2.264	86.414	Accessory
Nitzschia	2.564	0.806	0.114	1.298	2.264	88.679	Accessory
Rhizoclonium	2.564	0.806	4.649	1.298	2.264	90.943	Accessory
Spirogyra	2.564	0.806	16.115	1.298	2.264	93.207	Accessory
Staurastrum	2.564	0.806	0.484	1.298	2.264	95.471	Accessory
Trachelomonas	2.564	0.806	0.102	1.298	2.264	97.736	Accessory
Ulothrix	2.564	0.806	2.517	1.298	2.264	100.000	Accessory

Table 5. Phytoplanktonophageal regime of *Tilapia zillii* as a function of size (101 <ls <211 mm)

Prey items	FI%	NI%	PI%	MFI	MFI%	MFI% Cumule	Diet
Melosira	27.564	6.880	38.822	25.857	24.720	24.720	Primary
Cymbella	84.615	21.120	9.063	21.889	20.926	45.646	Primary
Helminth eggs	17.308	4.320	28.486	17.551	16.779	62.425	Primary
Cosmarium	52.564	13.120	2.875	9.716	9.289	71.714	Secondary
Ulothrix	8.974	2.240	1.794	3.172	3.032	74.746	Secondary
Tribonema	13.462	3.360	1.163	3.128	2.990	77.736	Secondary
Navicula	46.154	11.520	0.269	2.785	2.663	80.399	Secondary
Pinnularia	8.333	2.080	1.416	2.716	2.596	82.995	Accessory
Nostoc	5.769	1.440	2.023	2.700	2.582	85.577	Accessory
Mougeotia	17.949	4.480	0.609	2.613	2.498	88.075	Accessory
Cladophora	1.282	0.320	5.188	2.039	1.949	90.024	Accessory
Rhizoclonium	1.282	0.320	4.326	1.862	1.780	91.803	Accessory
Synedra	66.667	16.640	0.075	1.769	1.691	93.494	Accessory
Peridinium	3.846	0.960	1.202	1.699	1.625	95.119	Accessory
Merismopedia	2.564	0.640	0.581	0.965	0.923	96.042	Accessory
Eudorina	1.923	0.480	0.451	0.736	0.704	96.746	Accessory
Epithemia	0.641	0.160	1.157	0.681	0.651	97.397	Accessory
Trachelomonas	3.846	0.960	0.079	0.435	0.416	97.813	Accessory
Euastrum	5.769	1.440	0.049	0.421	0.402	98.215	Accessory
Microcystis	4.487	1.120	0.044	0.349	0.334	98.549	Accessory
Surirella	0.641	0.160	0.180	0.269	0.257	98.806	Accessory
Gyrosigma	9.615	2.400	0.010	0.249	0.238	99.044	Accessory
Pseudanabaena	3.205	0.800	0.029	0.239	0.229	99.273	Accessory
Diatoma	1.923	0.480	0.034	0.203	0.194	99.467	Accessory
Lyngbya	0.641	0.160	0.035	0.118	0.113	99.580	Accessory
Nitzschia	1.282	0.320	0.010	0.088	0.084	99.664	Accessory
Staurastrum	2.564	0.640	0.003	0.069	0.066	99.730	Accessory
Volvox	0.641	0.160	0.011	0.068	0.065	99.795	Accessory
Xanthidium	1.923	0.480	0.003	0.064	0.061	99.856	Accessory
Closterium	1.282	0.320	0.003	0.051	0.049	99.905	Accessory
Sphaerocystis	0.641	0.160	0.004	0.040	0.038	99.943	Accessory
Coelastrum	0.641	0.160	0.003	0.032	0.031	99.973	Accessory
Gymnodinium	0.641	0.160	0.002	0.028	0.027	100.000	Accessory

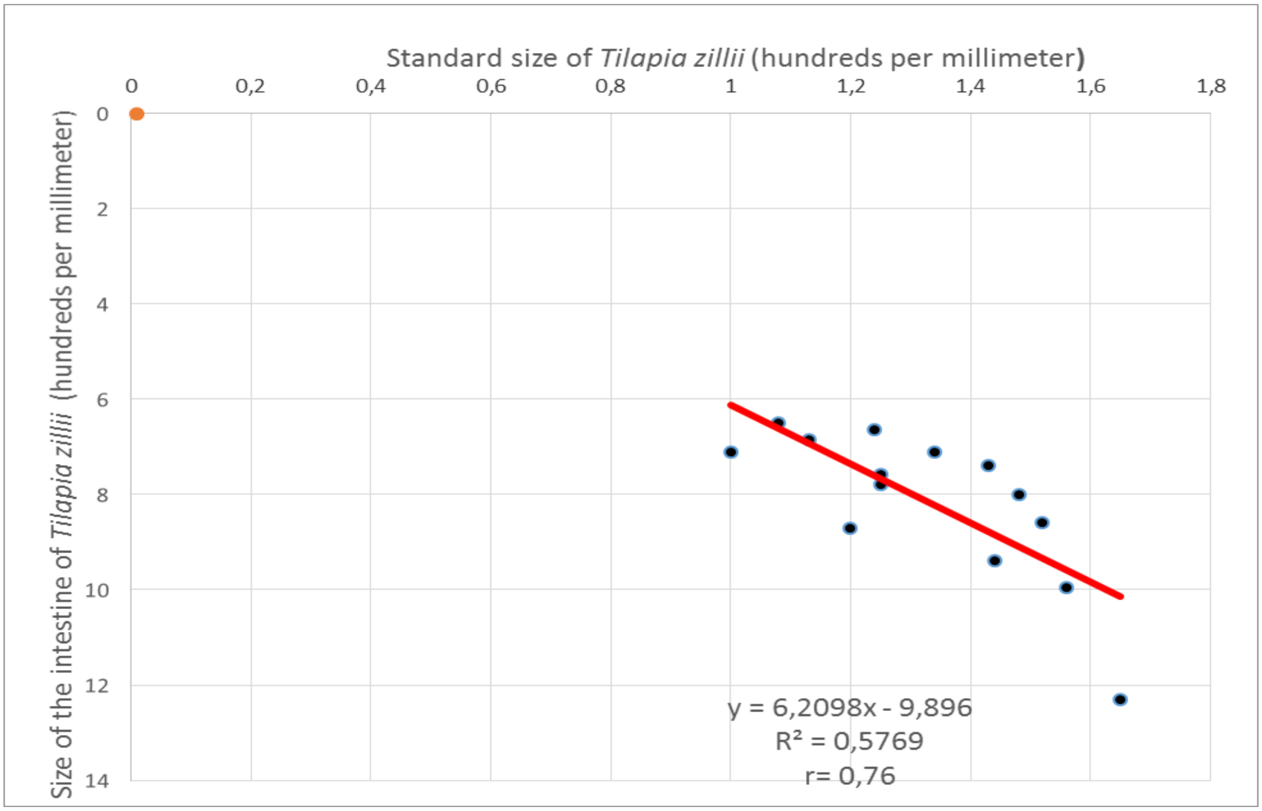

Figure 4: Correlation between intestine and standard size of *Tilapia zillii*

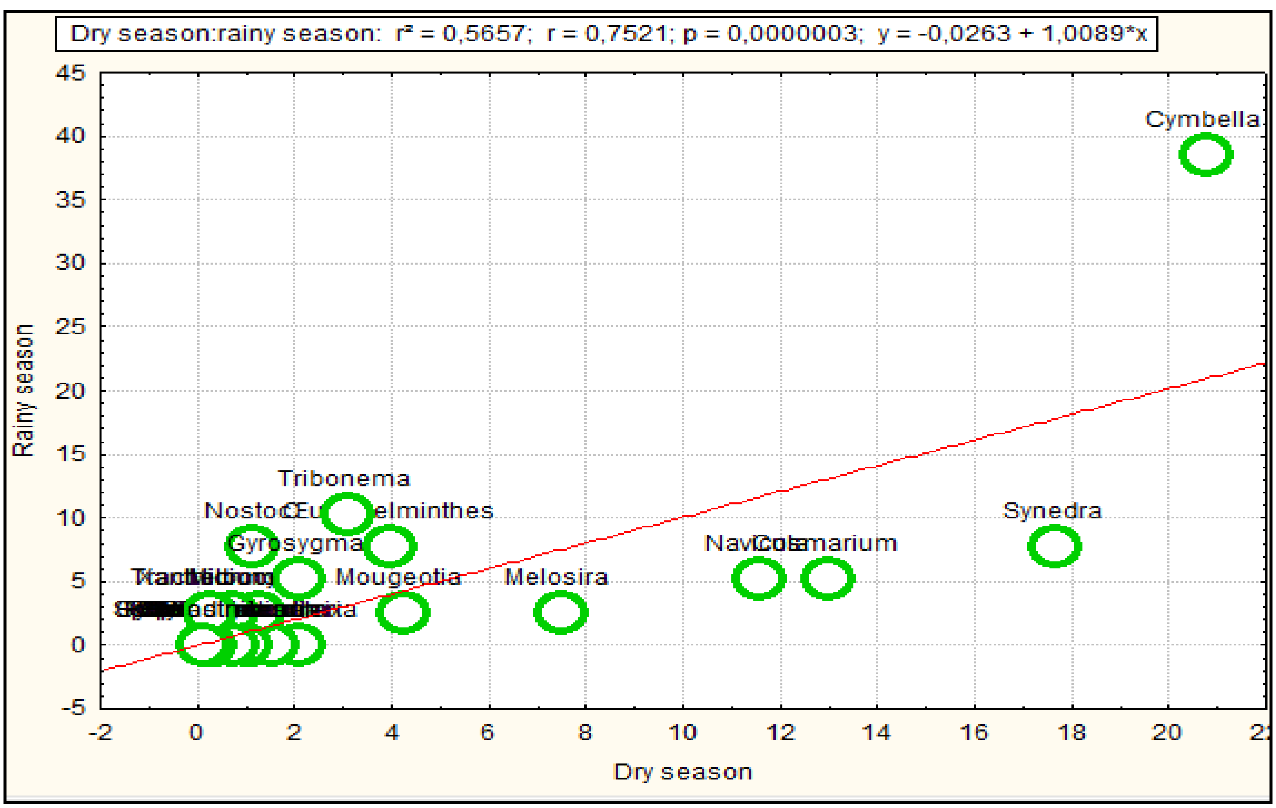

Figure 5: Correlation coefficient of prey ingested by *Tilapia zillii* in relation to the dry season and the rainy season, based on relative size class of the fish; numbers on the two axis are relative sizes.

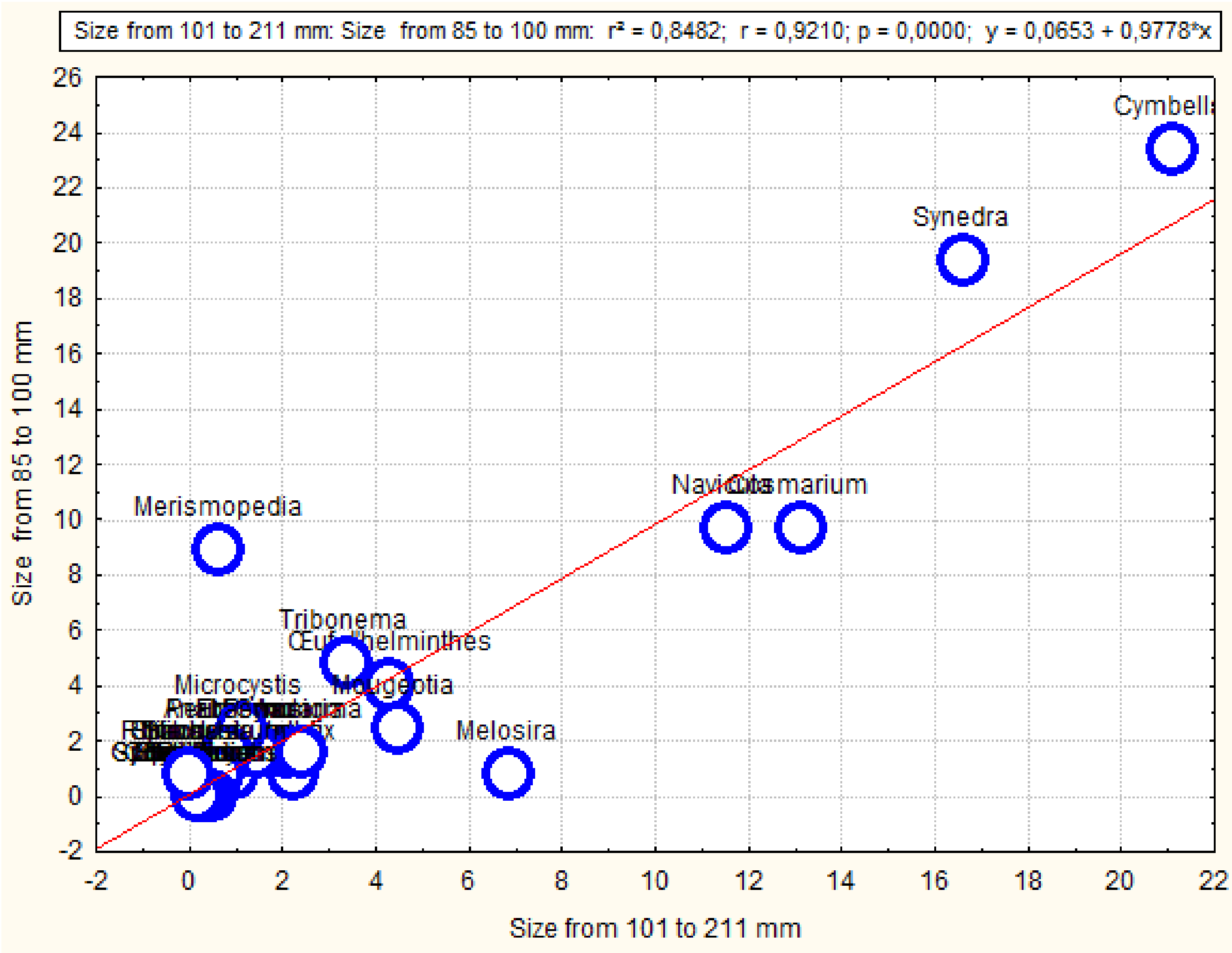

Figure 6: Correlation coefficient of prey ingested by *Tilapia zillii* as a function of size range (85 <ls <100 and 101 <ls <211 mm), based on the relative abundances of preys.

the Ziga reservoir, prey species of 13 genera were found in *T. zillii* diet. As shown in Table 3, during the periods of prey scarcity, some accessory preys such as species of *Nostoc, Navicula, Mougeotia, Microcystis and Gyrosigma*; and secondary preys such as species of *Cosmarium* were converted into preferential preys by *T. zillii* in order to continue performing its physiological and reproductive functions. The scarcity of preys during the rainy season certainly contributed to the decline in the number of *T. zillii* caught during the same period corresponding to 23 individuals fished compared to 182 caught in the dry season.

The reconversion of preys seems to confirm the proof that the diet of *T. zillii* is trongly linked to a category of preys used for its development. This resulted in the reduction of prey number from 34 (Table 1) to 13 (Table 3) different from some fish species such as *Sarotherodon melanotheron* reported by Ugwumba and Adebisi (1992) which adapted their diet to the variability of the prey. Reconverted preys are mainly producers of toxins (*Nostoc* and *Microcystis*), tastes and odors (*Microcystis, Cosmarium*) and filter clogging (*Navicula* and *Microcystis*). The reconversion ability of accessory preys into preferential preys during scarcity periods, proves the important contribution of the species to the management of water quality of the Ziga dam lake.

Compared to the diets of *Orechromis niloticus* and *Sarotherodon galilaeus* species that were previously studied in the Ziga Dam, the preferential preys of *T. zillii* were less extensive. Indeed, according to Neya et al. (2017b and 2017c), among 44 genera of algae recorded in the Ziga dam lake, *T. zillii* consumes 33, *Sarotherodon galilaeus* 36 and *Oreochromis niloticus* 41 genera. However, *T. zillii* was found to be the only species that has an ability to use accessory algae in case of abundance of preferential algae. Because of the ability of this species to change its diet according to the periods and the availability of preys in the lake, *T. zillii* can be particularly used to biologically control raw water quality.

Conclusion

Following the analysis of the phytoplanktonophagous diet of *T. zillii*, it appears that preferential and secondary preys are pests of the quality of water. Some prey species such as *Nostoc* and the helminth eggs found in the digestive tract of the species have harmful consequences on human and animal health. The absence of helminth eggs, found in the empty stomachs of the species, indicates that these eggs constitute a preferential category of prey for *T. zillii* and not an infestation of the species. The principal component analyzes show that *T. zillii* does not change its diet, either in terms of size or in terms of periods of scarcity or abundance of prey.

The characterization of the phytoplanktonophagous diet of *T. zillii* of the Ziga dam lake indicates that this species can be used as a tool in the biological treatment process of drinking water. This approach is an alternative to the misuse of chemicals used for the treatment of water and have in the meantime consequences on the state of aquatic system. This fish reduces the toxins, the tastes and the odors produced by algae and THM contained in drinking water.

T. zillii is the third dominant species in the icthyofauna of the Ziga dam after *Oreochromis niloticus* and *Sarotherodon galilaeus*. In addition, as a biological control agent, *T. zillii* is an important source of income for people of the surrounding villages. Quantitative and qualitative analyzes of the stomach and intestinal contents of *T. zillii* indicated that the species has the faculty of using accessory algae during periods of abundance as preferential algae during periods of hunger. The characterization of the phytoplanktonophagous diet of *T. zillii* of the Ziga dam lake shows that this species can be used in the biological treatment chain of drinking water.

Conflict of interests

The authors declare that they have no conflicting interests.

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