PHYTOPLANKTON AND FOOD SELECTIVITY IN NILE TILAPIA REARED IN EARTHEN PONDS UNDER MONOCULTURE AND POLYCULTURE WITH AFRICAN SHARPTOOTH CATFISH

ATHANASIO STEPHANO MBONDE[1], SAMWEL MCHELE LIMBU[2,4], AMON PAUL SHOKO[3], AND YUNUS DAUD MGAYA, [2*]

[1] *Tanzania Fisheries Research Institute, P.O. Box 90, Kigoma, Tanzania*

[2] *Department of Aquatic Sciences and Fisheries Technology, University of Dar es Salaam, P. O. Box 35064, Dar es Salaam, Tanzania*

[3] *Tanzania Fisheries Research Institute, Headquarters, P. O. Box 9750, Dar es Salaam, Tanzania*

[4] *East China Normal University, Department of Biology, School of Life Sciences, Laboratory of Aquaculture Nutrition and Environmental Health, 500 Dong Chuan Road, 200241 Shanghai, China*

ABSTRACT

Phytoplankton availability is one of the most important biotic factors affecting the successful culture of Nile tilapia (*Oreochromis niloticus*, Linnaeus) in semi-intensive ponds. The present study investigated phytoplankton composition, abundance and food selectivity in Nile tilapia *Oreochromis niloticus* (Linnaeus, 1758) reared in monoculture and polyculture system with African sharptooth catfish *Clarias gariepinus* (Burchell 1822) in earthen ponds. Water samples and stomachs of 144 *O. niloticus* were collected from respective pond systems for examination of phytoplankton composition and abundance. The obtained phytoplankton species in water and stomachs were used to determine food selectivity of *O. niloticus*. The results showed significantly higher Chlorophyceae in polyculture than monoculture ponds. The gut contents of *O. niloticus* from both systems were mainly composed of Bacillariophyceae, Euglenophyceae and Cyanophyceae and detritus and insect remains. Bacillariophyceae, detritus and insect remains were selected as food by *O. niloticus* cultured in both systems. Findings from this study show that, under monoculture and polyculture pond systems, *O. niloticus* exhibit selective feeding consuming more Bacillariophyceae, detritus and insect remains.

J. Aqua Trop. Vol. 32, No. (1) 2017, Pages 15-38
© Prints Publications Pvt. Ltd.
Corresponding Author E-mail: yunusmgaya@yahoo.com
http//www.printspublications.com

The results suggest that fish farmers can practice either monoculture or polyculture of *O. niloticus* without affecting its food selectivity.

Keywords: Phytoplankton, Polyculture, Monoculture, Diet, Predator fish.

INTRODUCTION

Nile tilapia (*Oreochromis niloticus*, Linnaeus) is one of the most important cultured species in the world (FAO 2012; Limbu and Jumanne, 2014). The fish provides major sources of animal protein and income (Chakraborty *et al.,* 2011; Yakubu *et al.,* 2012) in the majority of tropical countries (Lowe *et al.,* 2012). Its production in developing countries occurs primarily in semi-intensive earthen ponds which are fed on supplementary feeds and/or fertilized to stimulate growth of phytoplankton (El-Sayed, 2013). In Tanzania, more than 95% of fish farmers culture *O. niloticus* in semi-intensive earthen ponds under mixed-sex culture and to a lesser extent in polyculture with African sharptooth catfish (*Clarias gariepinus*, Burchell) (Shoko *et al.,* 2014) as means of controlling prolific breeding (Limbu *et al.,* 2015) and improving yield and economic benefits (Limbu *et al.,* 2016; Shoko *et al.,* 2016). The successful culture of *O. niloticus* in semi-intensive earthen ponds depends largely on natural food availability such as phytoplankton and abiotic factors among other aspects. In semi-intensive *O. niloticus* ponds, phytoplankton forms the base of food chains and food webs (Shil *et al.,* 2013). Phytoplankton are known to determine the nutritional value present in a pond which influences growth and productivity of the system (Ikpi *et al.,* 2013). Furthermore, phytoplankton reduces the amount of carbon dioxide and produce dissolved oxygen required by fishes for survival and growth in the culture structures (Rapatsa and Moyo, 2013).

Phytoplankton composition and abundance in semi-intensive ponds depend on the biotic and abiotic factors (Bwanika, *et al.,* 2007). The biotic factors include grazing and excretion and egestion by the fish species (Drenner *et al.,* 1984; Bhavimani and Puttaiah, 2014; Roy *et al.,* 2014) while abiotic conditions include water quality parameters, sunlight, and nutrients. The water quality parameters and sunlight in earthen ponds vary diurnally and are less influenced by the cultured species and culture system used (Shoko *et al.,* 2014). On the other hand, nutrients are mostly dependent on natural inputs such as run off and feeding by fish farmers (Leibold, 1999; Crab *et al.,* 2007). When natural inputs are excluded and feeding is isonutritious, nutrient inputs become similar. Under these circumstances, grazing and excretion and egestion by the cultured fish species remain the most important factor affecting composition and abundance of phytoplankton in earthen ponds. Grazing by the cultured fish species modifies the composition and abundance of phytoplankton through consumption related to their feeding habit (Milstein *et al.,* 2003). Moreover, different fish species have different rates of nutrients recycling via excretion and egestion which in turn affect composition and abundance of phytoplankton (Crab *et al.,* 2007). Thus, at any given period, the phytoplankton species found in earthen ponds vary in number of species and taxa (Ikpi *et al.,* 2013).

Despite the fact that *O. niloticus* is considered a filter feeding fish, previous studies in aquaculture have indicated its ability to selectively ingest phytoplankton species (Lu *et al.,* 2004; Rumisha and Nehemia, 2013). Furthermore, studies have shown that filter-feeding may be a relatively unimportant method of ingesting algae by *O. niloticus* (Dempster *et al.,* 1993). Previous studies on phytoplankton species composition and abundance in monoculture *O. niloticus* and its polyculture have yielded diverse outcomes. Chlorophyta, Bacillariophyta and Cyanoprokaryota were identified as dominant species in monoculture of *O. niloticus* and its polyculture with *Macrobrachium rosenbergii* (Danaher *et al.,* 2007). Chlorophyta and Cyanophyta were found to have the most number of genera identified with *Pediastrum* spp. and *Scendesmus* spp., and *Anabaena* spp. as dominant genera/genus, respectively (Kunlasak *et al.,* 2013). In their study, Ikpi *et al.,* (2013) found *Merismopaedia elegans* as the most abundant phytoplankton species and Chlorophyceae was the most dominant taxa. These variations in phytoplankton composition and abundance necessitate further studies.

Our knowledge on composition and abundance of phytoplankton as well as their consumption by *O. niloticus* in semi-intensive monoculture and polyculture with *C. gariepinus* in earthen ponds is patchy and fragmented at best. The links between fish species and phytoplankton are often not determined in nutritional studies despite the importance of the phytoplankton composition and abundance to any aquaculture operation (Kyewalyanga, 2003). The objective of this study was therefore to evaluate phytoplankton composition and abundance in ponds and stomachs of *O. niloticus* cultured in monoculture and polyculture with *C. gariepinus* in semi-intensive earthen ponds. It was hypothesized that water samples and stomach contents of *O. niloticus* cultured in monoculture system exhibit higher phytoplankton composition and abundance than in polyculture.

MATERIALS AND METHODS

Description of the study site

The study was carried out in the Lake Victoria basin at Kimusi village, Tarime District, Mara Region in Tanzania (Figure 1). Tarime is situated between latitudes 1°10"– 1°36" South of the Equator and longitudes 34°08"–35°01" East of Greenwich Meridian (URT, 1998). The district has bimodal rainfall that starts in September to December (short rainy season) and March to May (long rainy season) with an average annual rainfall of 1200 to 1500 mm. The site has an annual temperature range of between 14 °C and 25 °C (URT, 1998).

Experimental procedures

Six earthen fish ponds each having 150 m^2, mean depth 1.25 m were used in this study. Three ponds were stocked with *O. niloticus* in monoculture while the other three ponds were stocked with *O. niloticus* and *C. gariepinus* in polyculture. For polyculture treatment a stocking ratio of 3:1 for *O. niloticus* and *C. gariepinus* was adopted. In both culture ponds fingerlings of mean

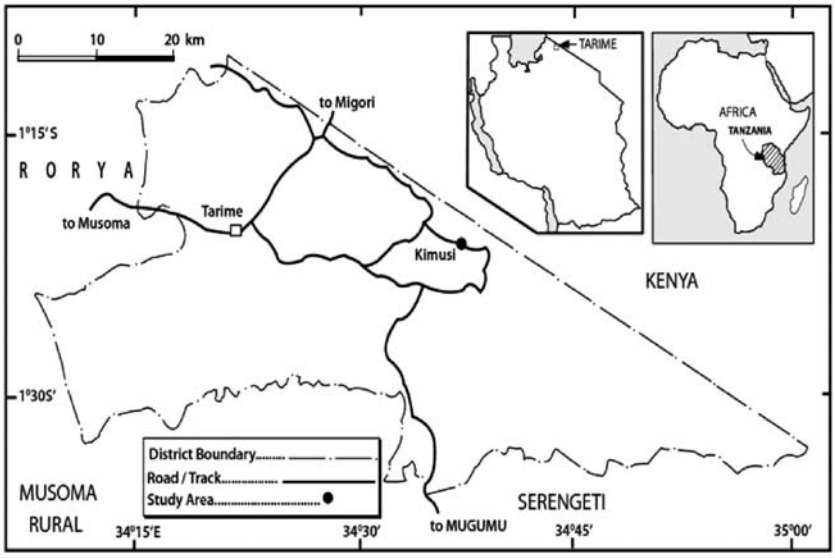


Figure 1: Map of Tarime district, Tanzania showing study site (source: University of Dar es Salaam Cartographic Unit)

(± SE) initial weight of 5.01 ± 0.01 g were stocked at a stocking density of 9 fish m^{-2}. Stocking of similar mean weights of *C. gariepinus* in polyculture ponds was delayed for 30 days to allow *O. niloticus* to grow to a size (12.26 ± 9.49 g) such that *C. gariepinus* were unable to prey on. The high stocking density of 9 fish m^{-2} where phytoplankton data were collected was part of the general objective of a study aimed to establish the optimum density that will give higher yield and economic benefits of *O. niloticus* in monoculture and polyculture of *O. niloticus* and *C. gariepinus* (Shoko *et al.,* 2016).

The main source of water to the ponds was a permanent stream originating from Mori River, one of the main rivers that supply water to Lake Victoria. Water levels in each pond were monitored weekly and maintained at the same level to avoid effect of water level fluctuations. Any decrease in water level in the ponds due to evaporation and/or leakage was offset by abstraction of water from Mori River, which flows nearby the site of the ponds. During weekly monitoring, about 30 per cent of water was exchanged to remove organic debris accumulated on the pond bottom to improve water quality parameters.

Before stocking, ponds were limed at a rate of 0.25 kg m^{-2} (Engle and Neira, 2005) to regulate pond water pH and water chemistry in general. Fish were fed on a 297.50 g kg^{-1} crude protein diet made using locally available cotton seed cake, 683.40 g $kg^{-1}$and maize bran 316.60 g kg^{-1} of dry feed (Table 1) adopted from Shoko *et al.,* (2016). They were fed at a constant daily ration of 5% body weight for *O. niloticus* or of the combined body weights of *O. niloticus* and *C. gariepinus* in

the case of polyculture. The use of a constant daily feeding rate (5% body weight) throughout the study was done intentionally to reflect the practice by rural fish farmers in Tanzania. The ration was divided into two and fed twice a day in the morning between 09:00 hrs and 10:00 hrs and evening between 15:00 hrs and 16:00 hrs. The experiment lasted for four months.

Table 1. Formulation and proximate composition (dry matter basis) of feed used in the study

Ingredients	**Composition (g kg^{-1}) dry feed**
Cotton seed cake	683.40
Maize bran	316.60
Total	1000.00
Proximate composition of feed	
Dry matter	924.70
Crude protein	297.50
Crude lipid	136.70
Crude fibre	109.60
Ash	68.10
Carbohydrate	388.10

Evaluation of phytoplankton species composition and abundance

At each pond, 100 ml water samples were taken using a van Dorn sampler for the phytoplankton species composition and abundance. The samples were fixed with 0.7% Lugol's solution and after one hour were preserved in 2.5% formalin solution. Identification and counting of phytoplankton groups were done using an inverted microscope at 400x magnification according to morphological criteria based on available freshwater phytoplankton keys given by Utermohl (1958) and John *et al.,* (2002). All specimens were distributed over at least two transects from the sedimentation chamber and counted. Different species were counted as numbers of filaments, colonies and cells depending on the nature of the species. The phytoplankton species identified in a given sample was used to estimate the composition. Phytoplankton abundance was calculated according to Greenberg *et al.,* (1992) using the formula:

i. $$Abundance = \frac{C\ x\ At\ \ x\ \ v}{Af\ x\ F\ x\ \ V\ x\ \ Vi}$$

where, C = number of organisms counted, At = total area of bottom of settling chamber (mm^2), v = volume of concentrated sample (20 ml), Af = area of field (mm^2), F = number of fields counted, V = volume of sample observed (2 ml) and Vi = volume of the sedimented sample.

Oreochromis niloticus gut content analysis

Six *O. niloticus* with relatively similar size were sacrificed every month from each pond by hypothermia through immersing them in an ice-slurry for stomach content analysis. Stomachs of 144 *O. niloticus* were removed soon after capture and preserved in specimen bottles containing 4% formalin and instantly transferred to the laboratory for analysis. In the laboratory the stomachs were analyzed for food content basing on the modified Amundsen *et al.,* (1996) point method. Each individual fish was dissected, stomach opened and its content emptied into a petri dish and uniformly mixed with some freshwater. The mixture was then transferred to a slide for microscopic investigation. The food items observed were identified and assigned percentages on the basis of their relative abundances. The percentages were converted into points indicated on the probability tables to give the individual contribution of the specific food item. The various points scored by each item were pooled together and their relative percentages calculated to give constituent contribution of the various items. The data collected were used to calculate Ivlev's index (E) according to Strauss (1979) using the formula:-

ii. $$E = \frac{(ri - pi)}{(ri + pi)}$$

where, *ri* = proportion of *i* food item in fish stomach, *pi* = proportion of *i* food item in the water sample. The index has a possible range of -1 to +1, with negative values indicating avoidance or inaccessibility of the prey item, zero indicating random selection and positive values indicating active selection (Lechowicz, 1982). E values of -1 and +1 indicate complete avoidance and exclusive feeding respectively (Rumisha and Nehemia, 2013).

Water quality and nutrients analysis

Sampling of water temperature, transparency, dissolved oxygen (DO) and pH were done twice daily at 0900 hrs in the morning and 1700 hrs in the evening using a Multimetric kit (model KTO, HQ, 40D PHC 101-LD 101-01 by Hach Company Ltd, USA). Water transparency was measured by using a secchi disc. During the same sampling hours, water samples for nutrient analysis were collected from the middle of ponds in triplicate at about 30 to 35 cm below water surface by using a 250 ml wide-mouthed plastic bottle. Nitrite nitrogen (NO_2-N), nitrate nitrogen (NO_3-N), un-ionized ammonia (NH_3-N) and soluble reactive phosphorus (SRP) were analysed by using standard methods and procedures (APHA, 2005).

Oreochromis niloticus growth performance

During the experiment, 30 fish were randomly seined on a monthly basis from each pond for individual body weight and length measurements to the nearest 0.01 g and 0.01 cm respectively. Weight was measured using a sensitive weighing balance (Electronic Precision Balance Model EJB-KD-3000g, Endel Global Weighing Company) and length was recorded using a measuring board. The weight data were used to calculate individual daily weight gain (DWG, $gday^{-1}$) and

specific growth rate (SGR, %). Fish weight and feed data were used to determine feed conversion ratio (FCR). The following formulae were used to calculate the above parameters:

iii. $$DWG\ (gday^{-1}) = \left(\frac{Wf - Wi}{Time\ (days)} \right)$$

where *Wf* and *Wi* are the final and initial mean weights for each sampling occasion respectively.

iv. $$SGR\ (\%) = \left(\frac{\ell nWf - \ell nWi}{Time\ (days)} \right) x\ 100$$

v. $$FCR = \frac{Total\ \ amount\ of\ \ dry\ \ feed\ \ fed\ (g)}{Total\ \ wet\ weight\ \ gain\ of\ \ \ fish\ (g)}$$

Statistical analyses

The means of all individual values of phytoplankton abundances in culture systems and stomachs and growth of *O. niloticus* are presented with the standard error (SE) of the mean. Data were tested for homogeneity of variance using Levene's test to guard against violation of the assumptions for parametric statistics. This was followed by two-sample t-test to evaluate any significant differences in the measured parameters between monoculture and polyculture systems. All statistical analyses were performed using SPSS 20 for Windows (Landau and Everit, 2004). Significant differences were judged at a probability level of $p < 0.05$ (Zar, 2010).

RESULTS

Phytoplankton species composition in monoculture and polyculture ponds

Throughout the study period, the monoculture and polyculture pond systems were composed of similar phytoplankton species (Table 2). The monoculture system was dominated by Euglenophyceae (46.19%) followed by Cyanophyceae (24.25%), Chlorophyceae (18.43%), Bacillariophyceae (10.80%) and Chrysophyceae (0.33%). In the polyculture system, Chlorophyceae (39.29%) dominated the phytoplankton species followed by Euglenophyceae (30.46%), Cyanophyceae (20.70%), Bacillariophyceae (9.27%) and Chrysophyceae (0.28%).

Phytoplankton abundance in monoculture and polyculture ponds

The abundance of the phytoplankton groups between the two culture systems is shown in Figure 2. Polyculture system had significantly higher Chlorophyceae species than the monoculture

Table 2: Phytoplankton species composition and abundance in monoculture of Nile tilapia (*Oreochromis niloticus*) and its polyculture with African sharptooth catfish (*Clariasgariepinus*) in earthen ponds

	Pond water				Stomach contents			
Phytoplankton species	**Abundance (Individuals ml^{-1})**		**Percentage composition**		**Abundance (Individuals ml^{-1})**		**Percentage composition**	
Culture system	**Monoculture**	**Polyculture**	**Monoculture**	**Polyculture**	**Monoculture**	**Polyculture**	**Monoculture**	**Polyculture**
Chlorophyceae								
Ankistrodesmus falcatus	104.38	120.90	0.73	0.84	0.00	0.00	0.00	0.00
Ankistrodesmus sp.	16.93	360.03	0.12	2.51	0.00	0.00	0.00	0.00
Ankistrodesmus spiralis	0.00	80.60	0.00	0.56	0.00	0.00	0.00	0.00
Closterium acutum	23.51	0.00	0.17	0.00	0.00	0.00	0.00	0.00
Closterium sp.	0.00	18.81	0.00	0.13	0.00	0.00	0.00	0.00
Coelastrum sp.	28.21	118.22	0.20	0.82	0.00	0.00	0.00	0.00
Kirchneriella contorta	0.00	23.51	0.00	0.16	0.00	0.00	0.00	0.00
Kirchneriella sp.	0.00	322.41	0.00	2.25	0.00	0.00	0.00	0.00
Lagerheimia sp.	0.00	141.06	0.00	0.98	0.00	0.00	0.00	0.00
Oocystis sp.	0.00	164.57	0.00	1.15	0.00	0.00	0.00	0.00
Pediastrum duplex	14.11	131.65	0.10	0.92	0.00	0.00	0.00	0.00
Pediastrum simplex	47.02	211.58	0.33	1.47	0.00	0.00	0.00	0.00
Pediastrum sp.	0.00	23.51	0.00	0.16	0.00	0.06	0.00	0.43
Pediastrum tetras	61.12	42.32	0.43	0.29	0.00	0.00	0.00	0.00
Scenedesmus acuminatus	537.89	699.91	3.78	4.88	0.00	0.00	0.00	0.00
Scenedesmus alternans	244.50	304.28	1.72	2.12	0.00	0.00	0.00	0.00
Scenedesmus bijugatus	23.51	136.69	0.17	0.95	0.00	0.00	0.00	0.00
Scenedesmus costato-granulatus	94.04	0.00	0.66	0.00	0.00	0.00	0.00	0.00

Scenedesmus cummunis	0.00	23.51	0.00	0.16	0.00	0.00	0.00	0.00
Scenedesmu sobliquus	0.00	117.55	0.00	0.82	0.00	0.00	0.00	0.00
Scenedesmus opoliensis	122.25	1015.94	0.86	7.08	0.00	0.00	0.00	0.00
Scenedesmus perforatus	0.00	23.51	0.00	0.16	0.00	0.00	0.00	0.00
Scenedesmus quadricauda	344.72	574.63	2.42	4.01	0.00	0.00	0.00	0.00
Scenedesmussp.	868.43	702.93	6.10	4.90	0.00	0.00	0.00	0.00
Selenastrum sp.	16.93	101.09	0.12	0.70	0.87	0.23	5.88	1.59
Sphinctosiphon polymorphus	0.00	37.61	0.00	0.26	0.00	0.00	0.00	0.00
Staurastrum sp.	33.85	120.90	0.24	0.84	0.00	0.00	0.00	0.00
Tetraedron trigonum	40.44	18.81	0.28	0.13	0.00	0.00	0.00	0.00
Subtotal	2621.83	5636.52	18.43	39.29	0.87	0.29	5.88	2.02
Cyanophyceae								
Anabaena flosaquae	2115.84	1161.36	14.87	8.09	0.00	0.00	0.00	0.00
Anabaena sp.	98.74	0.00	0.69	0.00	0.00	0.00	0.00	0.00
Anabaenopsis tanganyikae	0.00	70.53	0.00	0.49	0.00	0.00	0.00	0.00
Chroococcus sp.	122.25	728.79	0.86	5.08	0.39	0.00	2.61	0.00
Merismopedia punctata cells	0.00	211.58	0.00	1.47	0.00	0.00	0.00	0.00
Merismopedia sp.	33.85	169.94	0.24	1.18	0.00	0.00	0.00	0.00
Merismopedia tenuissima	836.93	199.83	5.88	1.39	0.00	0.00	0.00	0.00
Microcystis flosaquae	191.84	400.33	1.35	2.79	0.00	0.00	0.00	0.00
Microcystis sp.	51.72	28.21	0.36	0.20	1.85	1.46	12.56	10.08
Planktolyngbya sp.	0.00	0.00	0.00	0.00	0.12	0.00	0.84	0.00
Oscillatoria sp.	0.00	0.00	0.00	0.00	0.04	0.00	0.26	0.00
Subtotal	3451.16	2970.57	24.25	20.70	2.40	1.46	16.27	10.08

Bacillariophyceae								
Cyclotella sp.	296.22	212.59	2.08	1.48	0.00	0.00	0.00	0.00
Fragilaria sp.	28.21	70.53	0.20	0.49	0.31	0.36	2.12	2.51
Navicula sp.	378.25	385.55	2.66	2.69	1.02	1.14	6.90	7.90
Nitzschia acicularis	58.77	94.04	0.41	0.66	0.00	0.00	0.00	0.00
Nitzschia palea	14.11	0.00	0.10	0.00	0.00	0.00	0.00	0.00
Nitzschia sp.	350.63	179.34	2.46	1.25	0.08	0.20	0.52	1.41
Pinnularia sp.	28.21	23.51	0.20	0.16	1.12	2.25	7.62	15.55
Stephanodiscus sp.	56.42	0.00	0.40	0.00	0.00	0.00	0.00	0.00
Surirella sp.	70.53	94.04	0.50	0.66	1.54	2.20	10.40	15.26
Synedra acus	112.84	0.00	0.79	0.00	0.00	0.00	0.00	0.00
Synedra sp.	28.21	82.28	0.20	0.57	0.00	0.00	0.00	0.00
Synedra ulna	113.93	188.07	0.80	1.31	0.00	0.00	0.00	0.00
Subtotal	1536.34	1329.95	10.80	9.27	4.07	6.16	27.56	42.63
Euglenophyceae								
Euglena acus	709.49	333.83	4.99	2.33	0.00	0.00	0.00	0.00
Euglena proxima	70.53	0.00	0.50	0.00	0.00	0.00	0.00	0.00
Euglena sp.	324.43	1444.48	2.28	10.07	0.33	1.24	2.25	8.57
Phacus agilis	355.46	0.00	2.50	0.00	0.00	0.00	0.00	0.00
Phacus helicoides	14.11	0.00	0.10	0.00	0.02	0.00	0.10	0.00
Phacus sp.	492.46	260.95	3.46	1.82	1.27	0.55	8.60	3.77
Phacusundulatus	1040.35	327.79	7.31	2.28	0.09	0.00	0.62	0.00
Trachelomonas abrupta	65.83	28.21	0.46	0.20	0.00	0.00	0.00	0.00
Trachelomonas allorgei	221.93	14.11	1.56	0.10	0.00	0.00	0.00	0.00
Trachelomonas gracilis	16.93	56.42	0.12	0.39	0.00	0.00	0.00	0.00

Trachelomonas hispida	40.44	70.53	0.28	0.49	0.00	0.00	0.00	0.00
Trachelomonas sp.	2811.36	1589.23	19.76	11.08	1.66	0.57	11.24	3.96
Trachelomonas volvocina	409.06	244.50	2.87	1.70	0.00	0.00	0.00	0.00
Sub total	6572.36	4370.04	46.19	30.46	3.37	2.36	22.80	16.31
Chrysophyceae								
Mallomonas sp.	0.00	40.30	0.00	0.28	0.23	0.00	1.59	0.00
Dinobryon sp.	47.02	0.00	0.33	0.00	0.27	0.00	1.81	0.00
Sub total	47.02	40.30	0.33	0.28	0.50	0.00	3.40	0.00
Others								
Detritus	**N**	**N**	**N**	**N**	2.53	3.38	17.12	23.43
Insects remains	**N**	**N**	**N**	**N**	1.03	0.80	6.97	5.54
Subtotal					3.56	4.18	24.09	28.96
Grand total	14228.71	14347.38	100.00	100.00	14.76	14.44	100.00	100.00

NI = Available, but were not identified in the pond water

system ($t_{(110)}$ = -2.540, p = 0.012). The other phytoplankton groups did not differ significantly between monoculture and polyculture system ($t_{(16)}$ = 0.201, p = 0.843 for Cyanophyceae, $t_{(22)}$ = 0.338, p = 0.738 for Bacillariophyceae, $t_{(2)}$ = 0.108, p = 0.924 for Euglenophyceae and $t_{(24)}$ = 0.657, p = 0.517 for Chrysophyceae).

Oreochromis niloticus gut content and phytoplankton selectivity

The gut contents of *O. niloticus* from both monoculture and polyculture pond systems were mainly composed of similar species of phytoplankton namely Bacillariophyceae, Euglenophyceae

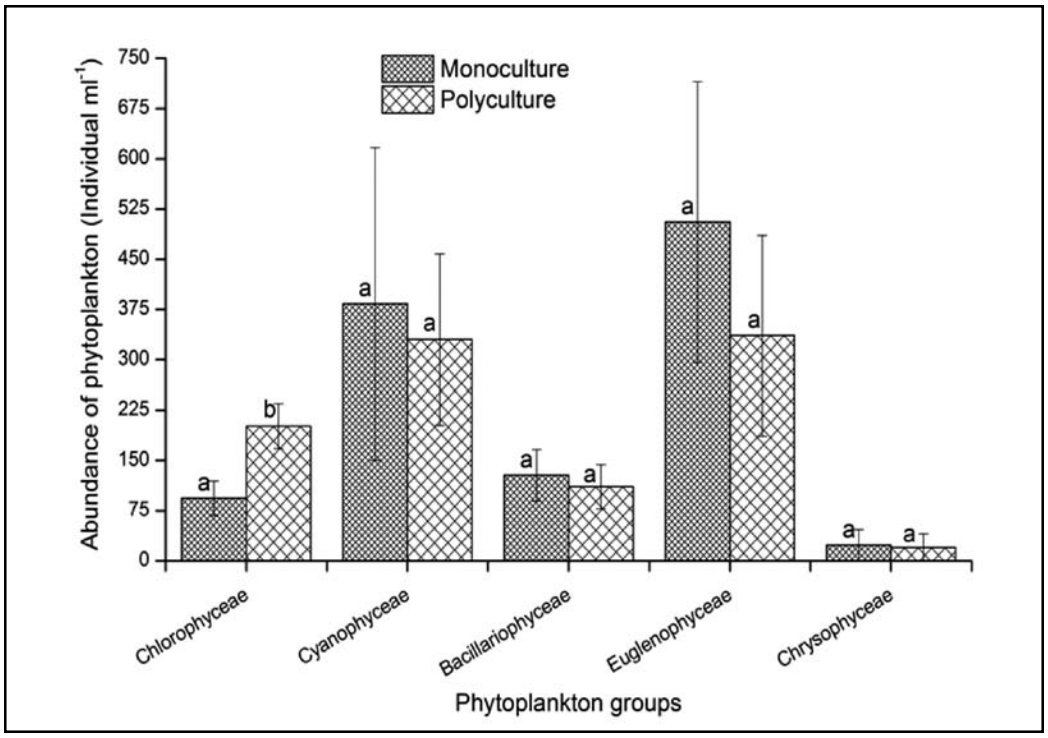


Figure 2. Phytoplankton abundance (individual ml^{-1}) between monoculture and polyculture pond systems.

Values are mean ± standard error (SE) of the mean.
Different letters above bars in each phytoplankton group indicate significant difference ($p < 0.05$).

and Cyanophyceae and detritus and insect remains, although at different percentages. Chlorophyceae and Chrysophyceae, contributed less than 10% of the diet for *O. niloticus* and the latter was virtually absent in the stomachs from polyculture system (Figure 3).

The comparison in abundance of the food items identified in the gut content of *O. niloticus* is

shown in Figure 4. The abundance of Chlorophyceae in the gut content of *O. niloticus* reared in monoculture system was significantly higher than those reared in polyculture ($t_{(22)}$ = 2.162,

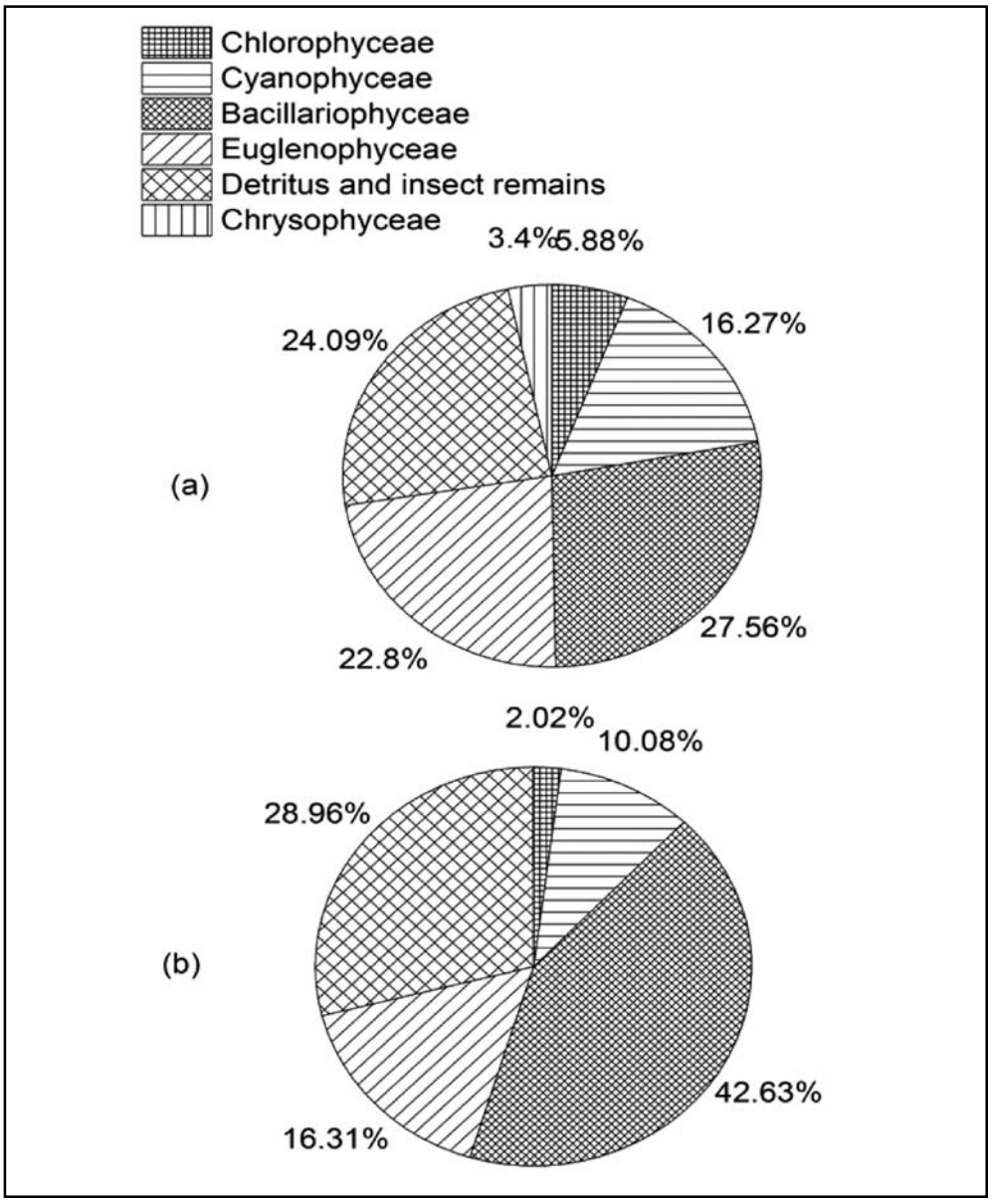


Figure 3. Phytoplankton gut contents of Nile tilapia (*Oreochromis niloticus*) cultured in monoculture (a) and polyculture with African sharptooth catfish (*Clarias gariepnus*) (b).

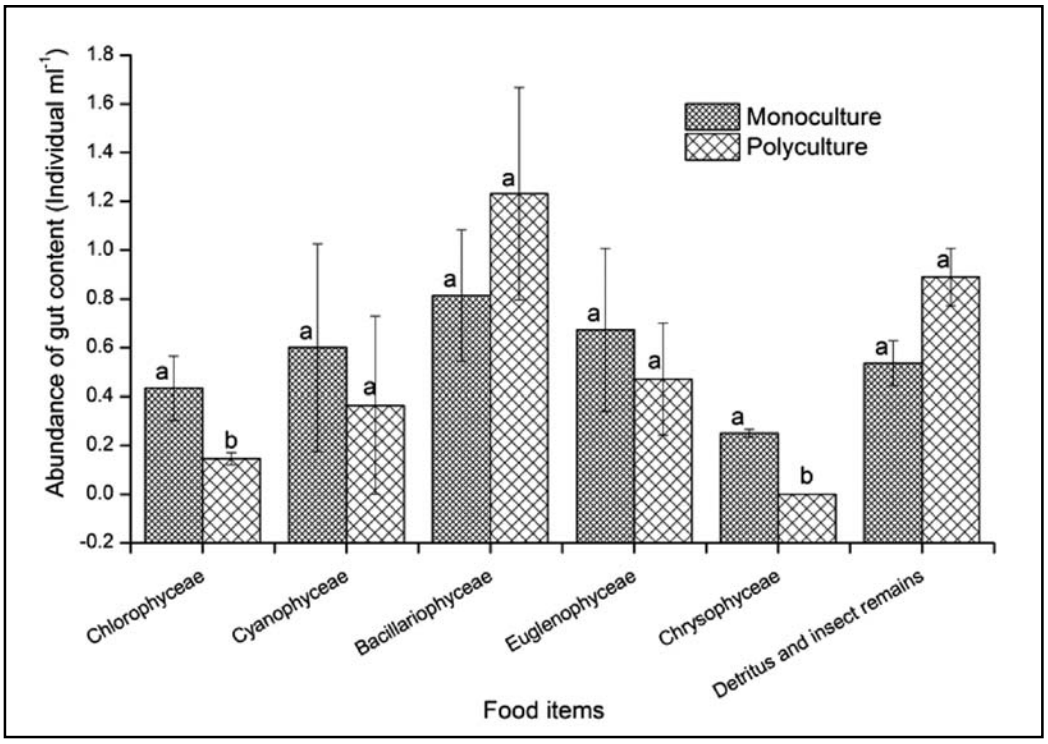


Figure 4. The abundance of the food items identified in the gut content of Nile tilapia *Oreochromis niloticus* raised in monoculture and polyculture

Different letters above bars in each phytoplankton group indicate significant difference ($p < 0.05$).

$p = 0.042$). Likewise, Chrysophyceae abundance in monocultured *O. niloticus* was significantly higher than their counter parts in polyculture ($t_{(2)} = 15.667$, $p = 0.004$). However the abundance of Bacillariophyceae ($t_{(8)} = -0.815$, $p = 0.438$), detritus and insect remains ($t_{(2)} = -2.361$, $p = 0.142$), Euglenophyceae ($t_{(8)} = 0.500$, $p = 0.630$) and Cyanophyceae ($t_{(2)} = 0.423$, $p = 0.687$) were the same between gut contents of *O. niloticus* in monoculture and polyculture.

O. niloticus cultured in monoculture and polyculture exhibited food selectivity according to Ivlev's index results (Table 3). The fish consumed comparatively more food items in monoculture (four items) as compared to polyculture (two items). Only Bacillariophyceae and detritus and insect remains were equally selected as food by *O. niloticus* cultured in both systems. Chlorophyceae and Chrysophyceae were selected in monoculture system, but not in polyculture. Chrysophyceae was completely avoided as food by *O. niloticus* cultured in polyculture. Cyanophyceae and Euglenophyceae were relatively less selected as food by *O. niloticus* cultured in both systems.

Table 3. Electivity indices (Ivlev's indices) of food items consumed by Nile tilapia (*Oreochromis niloticus*) cultured in monoculture and polyculture pond systems

Food group	Ivlev's index monoculture	Ivlev's index polyculture
Chlorophyceae	0.07	-0.71
Cyanophyceae	-0.44	-0.59
Bacillariophyceae	0.23	0.44
Euglenophyceae	-0.50	-0.51
Chrysophyceae	0.45	-1
Detritus and insect remains	1	1

Water quality and nutrients analysis

Water temperature was 22.91 ± 0.89 °C in polyculture ponds and 23.78 ± 0.74 °C in monoculture ponds with no significant difference between culture systems ($t_{(34)} = 0.749$, $p = 0.459$). The water temperatures in the two ponds were lower than the acceptable limits (25 to 32 °C) for warm water fish growth in aquaculture pond waters (Boyd and Tucker, 1998). Dissolved oxygen was above the minimum level required (5.00 mgL^{-1}) with a value of 8.82 ± 1.38 mgL^{-1} in polyculture ponds and 9.39 ± 1.38 mgL^{-1} in monoculture ponds, equally with no significant difference between the two culture systems ($t_{(34)} = 0.309$, $p = 0.760$). Water pH was stable and close to neutral throughout the study with values of 7.79 ± 0.21 in polyculture and 7.84 ± 0.18 in monoculture. No significant difference existed in pH between the two culture systems ($t_{(34)} = 0.210$, $p = 0.7835$). Dissolved oxygen and pH were within the recommended levels for *O. niloticus* survival and growth (Boyd and Tucker, 1998). Water transparency was 52.17 ± 0.95 cm in monoculture and 37.73 ± 1.51 cm in polyculture ponds. Monoculture ponds had significantly higher water transparency compared to polyculture ponds ($t_{(34)} = 8.094$, $p = 0.001$). However, water transparency in both culture systems was within the range (30 - 80 cm) recommended for good fish health in ponds (Bhatnagar and Devi, 2013; Gupta and Dey, 2013).

The levels of NO_2-N were $4.73 \times 10^{-3} \pm 2.78 \times 10^{-3}$ mgL^{-1} and $0.98 \times 10^{-3} \pm 0.98 \times 10^{-3}$ mgL^{-1} for monoculture and polyculture ponds respectively and did not differ significantly between the two culture systems ($t_{(34)} = 1.272$, $p = 0.212$). For NO_3-N the levels were $6.98 \times 10^{-6} \pm 3.45 \times 10^{-6}$ mgL^{-1} and $1.97 \times 10^{-6} \pm 1.35 \times 10^{-6}$ mgL^{-1} in monoculture and polyculture respectively with no significant difference between the two systems ($t_{(34)} = 1.451$, $p = 0.186$). These levels were within the recommended limits of less than 0.3 mgL^{-1} and 0.2 to10 mgL^{-1} for NO_2-N and NO_3-N respectively for aquaculture pond waters (Boyd and Tucker, 1998). NH_3-N was 0.23 ± 0.07 mgL^{-1} in monoculture and 0.26 ± 0.08 mgL^{-1} in polyculture with no significant difference between the two culture systems ($t_{(34)} = -0.313$, $p = 0.756$). However, NH_3-N levels obtained are much higher than 0.05-0.1 mgL^{-1} recommended for aquaculture pond waters (Boyd and Tucker, 1998). The levels of

SRP were statistically similar in the two culture systems ($t_{(34)}$ = 0.018, p = 0.986) with values of 1.33 x 10^{-2} ± 0.54 x 10^{-2} mgL^{-1} in monoculture and 1.32 x 10^{-2} ± 0.50 x 10^{-2} mgL^{-1} in polyculture. The SRP levels obtained are lower than the maximum recommended level of 0.2 mgL^{-1} for aquaculture (Boyd and Tucker, 1998).

Oreochromis niloticus growth performance

The DWG of *O. niloticus* in polyculture system was 0.39 ± 0.04 $gday^{-1}$ while in monoculture system was 0.43 ± 0.08 $gday^{-1}$. SGR was 1.49 ± 0.20% in polyculture and 1.67 ± 0.32% in monoculture. FCR was typically high with values of 4.69 ± 0.42 in monoculture and 5.04 ± 0.40 in polyculture. All the growth performance parameters measured did not differ between *O. niloticus* raised in monoculture and polyculture ($t_{(22)}$ = 0.544, p = 0.592 for DWG, $t_{(22)}$ = 0.496, p = 0.624 for SGR and $t_{(22)}$ = -0.605, p = 0.551 for FCR).

DISCUSSION

The present study has shown dominance of Euglenophyceae, Chlorophyceae and Cyanophyceae in the two culture pond systems. The present findings are supported by similar results reported by Degefu *et al.* (2011), Mette *et al.* (2011) and Ssanyu *et al.* (2011). The dominance of Cyanophyceae in both culture systems was due to their robustness. Cyanophyceae are known to outcompete other algal species because they are buoyant and can form larger colonies that can rise to the surface more quickly and benefit from harnessing available light (Sitoki *et al.,* 2012; Rumisha and Nehemia, 2013). Ultimately, they outcompeted other algal species and became dominant in the two culture systems.

The dominance of Chlorophyceae in the two culture systems is related to their tolerance to unfavorable conditions. It has been shown that Chlorophyceae are tolerant to a variety of conditions and they usually do well at high light intensity (Mette *et al.,* 2011). This corresponds to the conditions that prevailed in the ponds where monthly sampling by seining using nets disturbs the water thus creating harsh environment for phytoplankton existence giving a chance for Chlorophyceae to flourish due to their ability to tolerate harsh conditions.

Euglenophyceae dominance in the ponds was due to their ability to form blooms which inhibit growth of other algal species (Rahman *et al.,* 2012). Euglenophyceae are responsible for the occurrence of red sticky scum on the surface of ponds in day time. Their bloom inhibits light penetration for other species as well as utilizes most of the nutrients from the water body for their growth. Consequently, other phytoplankton species decrease markedly in aquaculture ponds leading to their dominance.

The present results showed similar phytoplankton species composition in the two pond systems.

The similarity in phytoplankton composition was due to existence of similar concentrations of nutrients, water quality and light availability in the two culture pond systems. Nutrient availability, water quality and light are primary factors controlling phytoplankton productivity in fish ponds (Mette *et al.,* 2011; Roy *et al.,* 2014). It is generally accepted that nutrients availability regulate phytoplankton composition (Peretyatko *et al.,* 2007). Among the important nutrients, phosphorus and nitrogenous compounds such as PO_3 and NO_3 usually show significant positive correlation with phytoplankton composition (Garg and Bhatnagar, 1999). In the present study, the amount of SRP and NO_3-N were similar between the two ponds. Consequently, similar species of phytoplankton were stimulated in the two culture ponds.

Furthermore, the distribution and composition of phytoplankton species depend upon the physico-chemical parameters in the culture system. The physico-chemical parameters like dissolved oxygen, water temperature and pH are usually positively correlated with phytoplankton present in the pond (Shakila and Natarajan, 2011; Hasan *et al.,* 2013). The similarity in dissolved oxygen, water temperature and pH in the present study signifies that the composition of phytoplankton species were not affected in the two culture systems. Apart from water quality and nutrients, light is also known to be one of the most important factors affecting composition of phytoplankton in fish ponds (Mette *et al.,* 2011). Although light intensity was not measured in the present study, all ponds were free from aquatic vegetation and were well exposed to sunlight, thus had equal access to light. Consequently, since the two pond systems had similar nutrients levels, water quality parameters and equal access to light, they ended up having similar phytoplankton species composition.

The study has shown significantly higher Chlorophyceae species in gut content of *O. niloticus* raised in polyculture system than the monoculture system. Similar lower Chlorophyceae in monoculture ponds stocked with tilapia has been obtained by Danaher *et al.* (2007). The higher abundance of Chlorophyceae species in polyculture was due to their avoidance as food by *O. niloticus*. It was shown in the present study that, Ivlev's index for Chlorophyceae in monoculture was positive (0.07) while in polyculture was negative (-0.71). Therefore, *O. niloticus* fed actively on Chlorophyceae in monoculture which ultimately depleted their abundance and became significantly higher in polyculture.

The gut contents of *O. niloticus* from both monoculture and polyculture pond systems were mainly composed of similar taxa namely Bacillariophyceae, detritus and insect remains, Euglenophyceae and Cyanophyceae although at different percentages. Kaggwa *et al.* (2009) and Rumisha and Nehemia (2013) obtained similar results whereby Bacillariophyceae, Euglenophyceae, Cyanophyceae and detritus constituted the bulk of the fish diet. The existence of these types of food items in the stomachs were due to the selective feeding behavior of *O. niloticus* (Kaggwa *et al.,* 2010).

O. niloticus are considered efficient in feeding on certain types of phytoplankton in ponds (Danaher *et al.,* 2007) thanks to their ability to filter and digest them at very low stomach pH of 1.25 (Turker *et al.,* 2003; Figueredo and Giani, 2005). They feed on certain types of phytoplankton cells which are recognized to contain good quality protein, polyunsaturated fatty acids and vitamins (Rahman *et al.,* 2014). Thus, despite the presence of other food items in pond water of the two culture systems, *O. niloticus* exhibited selective feeding. The food selectivity of *O. niloticus* confers a competitive advantage over other fish species. The food selectivity of *O. niloticus* according to the environment makes them suitable species for pond aquaculture because phytoplankton and detritus are usually abundant in fish ponds.

Furthermore, this study has shown that Bacillariophyceae and detritus and insect remains were selected as food by *O. niloticus* cultured in both systems. Similar results were obtained by Kaggwa *et al.* (2009) who found that the stomach contents of *O. niloticus* were dominated by detritus and algal material. The selection of Bacillariophyceae and detritus in both culture systems is due to their relatively larger size. Filter feeding fish including *O. niloticus* preferentially feeds on bigger algae and detritus and insects because during the crossflow filtration, their branchial arch are able to capture food item based on size (Smith and Sanderson, 2013). Relatively larger sized particles have higher retention inside the fish oropharyngeal cavity than smaller ones (Smith and Sanderson, 2013). Consequently, based on the comparatively larger sizes of the Bacillariophyceae and detritus and insect remains than other food types, they were retained more easily by branchial arch of *O. niloticus* and thus were abundant in the stomach as food in the two pond culture systems.

The present study showed that, Chlorophyceae and Chrysophyceae were selected in monoculture system, but not in polyculture. Chrysophyceae were completely avoided as food by *O. niloticus* cultured in polyculture. Similar avoidance of Chlorophyceae has been obtained by Figueredo and Giani (2005). The avoidance of Chlorophyceae and Chrysophyceae in polyculture is probably due to the feeding behaviour of the *C. gariepinus* in polyculture ponds which leads to suspension of sediments into the water column hence decreasing water transparency (Kadye and Booth, 2012). Indeed, the present study showed higher water transparency in monoculture compared to polyculture ponds. *C. gariepinus* has been shown to cause low secchi disc transparency when cultured in earthen ponds (Toko *et al.,* 2007). Previous research by Saeed and Batran (2014) showed a similar higher turbidity in polyculture than monoculture due to the presence of *C. gariepinus*. Bottom feeding habit by *C. gariepinus* re-suspends sediments into the water column decreasing water transparency which in turn obstructs selection of *O. niloticus* and enhances the escape ability of small-sized Chlorophyceae and Chrysophyceae taxa (Turker *et al.,* 2003). Under turbulent conditions it was difficult for *O. niloticus* to select the small-sized Chlorophyceae and Chrysophyceae in its food leading to their avoidance.

The present study has shown that Cyanophyceae and Euglenophyceae were relatively less selected as food by *O. niloticus* cultured in both systems despite their relatively higher abundance

in pond water than other groups. Bacillariophytes were selected by *O. niloticus* in both culture systems, despite their relatively lower abundance compared to Cyanophyceae. Similar results have been obtained by Rumisha and Nehemia (2013). The avoidance of Cyanophyceae and Euglenophyceae is related to their inedibility compared to large and colonial phytoplankton species (Mette *et al.,* 2011). Accordingly, although Cyanophyceae and Euglenophyceae were present in the stomachs of *O. niloticus,* the presence of other large groups of phytoplankton shadowed their selection as food relative to their abundance in pond water. Thus, regardless of their existence in water and stomach content, their selective indices were negative showing avoidance as food by *O. niloticus*.

The present study showed similar growth performance between *O. niloticus* raised in monoculture and polyculture. Similar growth performance of *O. niloticus* has also been obtained in previous study by Shoko *et al.,* (2014). The similarity in growth performance was due to similar conditions in the two culture systems. During this study the food items present in the two systems were similar and water quality parameters and nutrients did not differ. Similar growth performance of *O. niloticus* also indicates the compatibility of the two species for polyculture. *O. niloticus* and *C. gariepinus* differ in their feeding habit and do not compete in their feeding niche. *C. gariepinus* is an omnivore with a preference for animal protein and small fish (Bruton, 1979). *O. niloticus* on the other hand, is generally herbivorous and detritivorous (Njiru *et al.,* 2004; Oso *et al.,* 2006; Ssanyu *et al.,* 2011).

It is generally recognized that, the interaction between fish and food organisms is the most important aspect in polyculture (Wahab *et al.,* 2011). Optimum growth can only be obtained using appropriate combinations of species that utilize available resources in the pond system efficiently through synergistic relationships while minimizing antagonistic ones (Milstein, 1992). Thus, the polyculture of these two fish species seem to play mutual trophic benefits, providing better growth for economic return to fish farmers than in monoculture system (Shoko *et al.,* 2016). Based on the present environmental conditions and growth performance, fish farmers within the Lake Victoria basin and similar environments can practice both monoculture and polyculture to obtain comparable growth rate of *O. niloticus*.

CONCLUSION

This study revealed dominance and composition by Euglenophyceae, Chlorophyceae and Cyanophyceae in the two culture pond systems. Non selection of the Chlorophyceae as food by *O. niloticus* in polyculture system caused their higher abundance. Under pond culture system, *O. niloticus* exhibit selective feeding habit consuming more Bacillariophyceae, detritus and insect remains than other types. However, selective feeding behaviour in *O. niloticus* does not alter its growth performance in the two culture systems. Fish farmers can practice either monoculture or polyculture of *O. niloticus* without affecting its phytoplankton food selectivity.

ACKNOWLEDGEMENTS

The authors express their sincere thanks to the Inter-University Council for East Africa (IUCEA) through Lake Victoria Research Initiative (VicRes) for provision of a research grant. We are grateful to rural fish farmers for the cooperation and commitment they rendered during the experimental phase of the study.

REFERENCES

Amundsen P. A., Gabler, H. M. and Staldvik, F. J. (1996) A new approach to graphical analysis of feeding strategy from stomach contents data-modification of the Costello (1990) method. *J. Fish Biol.* **48**, 607-614.

APHA (2005) *Standard methods for examination of water and wastewater, 21st edition*. American Public Health Association, American Water Works Association, Water Pollution Control Federation, New York, USA.

Bhatnagar A. and Devi, P. (2013) Water quality guidelines for the management of pond fish culture. *Int. J. Environ. Sci.* **3**, 1980-2009.

Bhavimani H. and Puttaiah, E. (2014) Fish culture and physico-chemical characteristics of Madikoppa pond, Dharwad Tq/Dist, Karnatak. *Hydrol. Curr. Res.* **5**, 1-3.

Boyd C. E. and Tucker, C. S. (1998) *Pond Aquaculture Water Quality Management*. Kluwer Academic Publishers, Norwell, Massachusetts, United State of America.

Bruton M. (1979) The food and feeding behaviour of *Clarias gariepinus* (Pisces: Clariidae) in Lake Sibaya, South Africa, with emphasis on its role as a predator of cichlids. *Trans. Zool. Soc. London* **35**, 47-114.

Chakraborty S. B., Mazumdar, D., Chatterji, U. and Banerjee, S. (2011) Growth of mixed-sex and monosex Nile tilapia in different culture systems. *Turk. J. Fish. Aquat. Sci.* **11**, 131-138.

Crab R., Avnimelech, Y., Defoirdt, T., Bossier, P. and Verstraete, W. (2007) Nitrogen removal techniques in aquaculture for a sustainable production. *Aquaculture* **270**, 1-14.

Danaher J. J., Tidwell, J. H., Coyle, S. D., Dasgupta, S. and Zimba, P. V. (2007) Effects of two densities of caged monosex Nile tilapia, *Oreochromis niloticus*, on water quality, phytoplankton populations, and production when polycultured with *Macrobrachium rosenbergii* in temperate ponds. *J. World Aquacult. Soc.* **38**, 367-382.

Degefu F., Mengistu, S. and Schagerl, M. (2011) Influence of fish cage farming on water quality and plankton in fish ponds: A case study in the Rift Valley and North Shoa reservoirs, Ethiopia. *Aquaculture* **316**, 129-135.

Dempster P. W., Beveridge, M. C. M. and Baird, D. J. (1993) Herbivory in the tilapia *Oreochromis niloticus*: a comparison of feeding rates on phytoplankton and periphyton. *J. Fish Biol.* **43**, 385-392.

Drenner R. W., Mummert, J. R., deNoyelles Jr, F. and Kettle, D. (1984) Selective particle ingestion by a filter-feeding fish and its impact on phytoplankton community structure. *Limnol. Oceanogr.* **29**, 941-948.

El-Sayed A.-F. M. (2013) Tilapia feed management practices in sub-Saharan Africa. In: *On-farm feeding and feed management in aquaculture* (eds by M.R. Hasan & M.B. New), pp. 377-405. FAO Fisheries and Aquaculture Technical Paper No. 583, Rome Italy.

Engle C. R. and Neira, I. (2005) *Tilapia Farm Business Management and Economics: A Training Manual. Aquaculture CRSP*. Oregon State University, Corvallis, Oregon, USA.

FAO (2012) *The State of World Fisheries and Aquaculture*. Food and Agriculture Organization of the United Nations, Rome, Italy.

Figueredo C. C. and Giani, A. (2005) Ecological interactions between Nile tilapia (*Oreochromis niloticus*, L.) and the phytoplanktonic community of the Furnas Reservoir (Brazil). *Freshwater Biol.* **50**, 1391-1403.

Garg S. K. and Bhatnagar, A. (1999) Effect of different doses of organic fertilizer (cow dung) on pond productivity and fish biomass in stillwater ponds. *J. Appl. Ichthyol.* **15**, 10-18.

Greenberg A. E., Clesceri, L. S. and Eaton, A. D. (1992) *Standard Methods for the Examination of Water and Wastewater*. American Public Health Association, Port City Press, Baltimore, Maryland.

Gupta T. and Dey, M. (2013) Hydro biological characteristics of some semi-intensive fish culture ponds of Lumding Town of Nagaon District, Assam. *Curr. World Environ.* **8**, 107-115.

Hasan K., Shahabuddin, A., Ahmed, R., Siddiqa, A., Khan, M. and Haque, M. (2013) Study on phytoplankton ecology of earthen catfish ponds in Bangladesh. *Int. Sci. Invest. J.* **2**, 1-11.

Ikpi G. U., Offem, B. O. and Okey, I. B. (2013) Plankton distribution and diversity in tropical earthen fish ponds. *Environ. Nat. Resour. Res.* **3**, 45-51.

John D. M., Whitton, B. A. and Brook, A. J. (2002) *The freshwater algae flora of the British Isles: an identification guide to freshwater and terrestrial algae*. Cambridge University Press, Cambridge, United Kingdom.

Kadye W. T. and Booth, A. J. (2012) Integrating stomach content and stable isotope analyses to elucidate the feeding habits of non-native sharptooth catfish *Clarias gariepinus*. *Biol. Invasions* **14**, 779-795.

Kaggwa R., van Dam, A., Balirwa, J., Kansiime, F. and Denny, P. (2009) Increasing fish production from wetlands at Lake Victoria, Uganda using organically manured seasonal wetland fish ponds. *Wetlands Ecol. Manage.* **17**, 257-277.

Kaggwa R. C., Van Dam, A. A., Kipkemboi, J. and Denny, P. (2010) Evaluation of nitrogen cycling and fish production in seasonal ponds ('Fingerponds') in Lake Victoria wetlands, East Africa using a

dynamic simulation model. *Aquacult. Res.* **42**, 74-90.

Kunlasak K., Chitmanat, C., Whangchai, N., Promya, J. and Lebel, L. (2013) Relationships of dissolved oxygen with chlorophyll-a and phytoplankton composition in tilapia ponds. *Int. J. Geosci.* **4**, 46.

Kyewalyanga M. S. (2003) Assessment of types and abundance of live food for fish farming in Makoba earthen ponds, Zanzibar, Tanzania. *West. Indian Ocean J. Mar. Sci.* **2**, 45-56.

Landau S. and Everit, B. S. (2004) *A Hand Book of Statistical Analyses using SPSS*. Chapman and Hall/CRC Press LLC, London, UK.

Lechowicz M. J. (1982) The Sampling Characteristics of Electivity Indices. *Oecologia* **52**, 22-30.

Leibold M. A. (1999) Biodiversity and nutrient enrichment in pond plankton communities. *Evol. Ecol. Res.* **1**, 73-75.

Limbu S. M. and Jumanne, K. (2014) Effect of restricted and re-feeding regime on feeding cost, growth performance, feed utilization and survival rate of mixed sex Nile tilapia *Oreochromis niloticus* cultured in tanks. *Int. J. Fish. Aquat. Stud.* **2**, 118-123.

Limbu S. M., Shoko, A. P., Lamtane, H. A., Kishe-Machumu, M. A., Joram, M. C., Mbonde, A. S., Mgana, H. F. and Mgaya, Y. D. (2016) Fish polyculture system integrated with vegetable farming improves yield and economic benefits of small-scale farmers. *Aquacult. Res.*, http://dx.doi.org/10.1111/are.13188.

Limbu S. M., Shoko, A. P., Lamtane, H. A., Shirima, E. D., Kishe-Machumu, M. A., Mgana, H. F. and Mgaya, Y. D. (2015) Effect of initial stocking size of the predatory African sharptooth catfish (*Clarias gariepinus*) on recruits, growth performance, survival and yield of mixed-sex Nile tilapia (*Oreochromis niloticus*) in concrete tank culture system. *Int. Aquat. Res.* **7**, 63-73.

Lowe M. R., Wu, W., Peterson, M. S., Brown-Peterson, N. J., Slack, W. T. and Schofield, P. J. (2012) Survival, growth and reproduction of non-native Nile tilapia II: Fundamental niche projections and invasion potential in the Northern Gulf of Mexico. *PLoS ONE* **7**, 1-10.

Lu J., Takeuchi, T. and Satoh, H. (2004) Ingestion and assimilation of three species of freshwater algae by larval tilapia *Oreochromis niloticus*. *Aquaculture* **238**, 437-449.

Mette E. M., Vanni, M. J., Newell, J. M. and González, M. J. (2011) Phytoplankton communities and stoichiometry are interactively affected by light, nutrients, and fish. *Limnol. Oceanogr.* **56**, 1959-1975.

Milstein A. (1992) Ecological aspects of fish species interactions in polyculture ponds. *Hydrobiologia* **231**, 177-186.

Milstein A., Azim, M. E., Wahab, M. A. and Verdegem, M. C. J. (2003) The effects of periphyton, fish and fertilizer dose on biological processes affecting water quality in earthen fish ponds. *Environ. Biol. Fishes* **68**, 247-260.

Njiru M., Okeyo Owuor, J., Muchiri, M. and Cowx, I. (2004) Shifts in the food of Nile tilapia, *Oreochromis niloticus* (L.) in Lake Victoria, Kenya. *Afr. J. Ecol.* **42**, 163-170.

Oso J., Ayodele, I. and Fagbuaro, O. (2006) Food and feeding habits of *Oreochromis niloticus* (L.) and *Sarotherodon galilaeus* (L.) in a tropical reservoir. *World J. Zool.* **1**, 118-121.

Peretyatko A., Teissier, S., Symoens, J.-J. and Triest, L. (2007) Phytoplankton biomass and environmental factors over a gradient of clear to turbid peri-urban ponds. *Aquat. Conserv.: Mar. Freshwat. Ecosyst.* **17**, 584-601.

Rahman M. M., Hossain, M. D., Saha, A. K. and Islam, M. S. (2014) Effects of euglenophytes supplemented feed on the growth and carcass composition of common carp (*Cyprinus carpio* var. *specularis*). *Res. J. Agricult. Environ. Manag.* **3**, 137-144.

Rahman M. S., Shahjahan, M., Haque, M. and Khan, S. (2012) Control of euglenophyte bloom and fish production enhancement using duckweed and lime. *Iran. J. Fish. Sci.* **11**, 358-371.

Rapatsa M. M. and Moyo, N. A. G. (2013) Performance evaluation of chicken, cow and pig manure in the production of natural fish food in aquadams stocked with *Oreochromis mossambicus*. *Phys. Chem. Earth Parts A/B/C* **66**, 68-74.

Roy K., Chari, M., Gaur, S. and Thakur, A. (2014) Ecological dynamics and hydrobiological correlations in freshwater ponds - Recent researches and application. *Int. J. Environ. Biol.* **4**, 112-118.

Rumisha C. and Nehemia, A. (2013) Feeding selectivity of wild and pond-cultured Nile tilapia *Oreochromis niloticus* in the Lake Victoria basin in Mara, Tanzania. *Afr. J. Aquat. Sci.* **2013**, 1-6.

Saeed S. M. and Batran, A. M. (2014) Evaluation of water quality parameters in two different fish culture regimes. In: *4th Conference of Central Laboratory for Aquaculture Research (CLAR): Aquaculture between Science and Application. 11-12 March 2014* , *Egyptian Journal for Aquaculture,* Egypt*,* pp. 17-33.

Shakila H. and Natarajan, S. (2011) Phytoplankton diversity and its relationship to the physico–chemical parameters in the Temple pond of Thiruporur, Chennai. *Int. J. Environ. Biol.* **2** 81-83.

Shil J., Ghosh, A. K. and Rahaman, S. M. B. (2013) Abundance and diversity of zooplankton in semi intensive prawn (*Macrobrachium rosenbergii*) farm. *SpringerPlus* **2**, 1-8.

Shoko A. P., Limbu, S. M., Mrosso, H. D. J. and Mgaya, Y. D. (2014) A comparison of diurnal dynamics of water quality parameters in Nile tilapia (*Oreochromis niloticus*, Linnaeus, 1758) monoculture and polyculture with African sharp tooth catfish (*Clarias gariepinus*, Burchell, 1822) in earthen ponds. *Int. Aquat. Res.* **6**, 1-13.

Shoko A. P., Limbu, S. M., Mrosso, H. D. J., Mkenda, A. F. and Mgaya, Y. D. (2016) Effect of stocking density on growth, production and economic benefits of mixed sex Nile tilapia (*Oreochromis niloticus*) and African sharptooth catfish (*Clarias gariepinus*) in polyculture and monoculture. *Aquacult. Res.* **47**, 36-50.

Sitoki L., Kurmayer, R. and Rott, E. (2012) Spatial variation of phytoplankton composition, biovolume, and resulting microcystin concentrations in the Nyanza Gulf (Lake Victoria, Kenya). *Hydrobiologia* **691**, 109-122.

Smith J. C. and Sanderson, S. L. (2013) Particle retention in suspension-feeding fish after removal of filtration structures. *Zoology* **116**, 348-355.

Ssanyu G., Rasowo, J., Auma, E. and Ndunguru, M. (2011) Evaluation of plankton community structure in fish refugia acting as *Oreochromis niloticus* propagation and nursery units for rice/fish trials. *J. Aquacult. Res. Dev.* **2011**, 2-4.

Strauss R. E. (1979) Reliability estimates for Ivlev's electivity index, the forage ratio, and a proposed linear index of food selection. *Trans. Am. Fish. Soc.* **108**, 344-352.

Toko I., Fiogbe, E. D., Koukpode, B. and Kestemont, P. (2007) Rearing of African catfish (*Clarias gariepinus*) and vundu catfish (*Heterobranchus longifilis*) in traditional fish ponds (whedos): Effect of stocking density on growth, production and body composition. *Aquaculture* **262**, 65-72.

Turker H., Eversole, A. G. and Brune, D. E. (2003) Filtration of green algae and cyanobacteria by Nile tilapia, *Oreochromis niloticus*, in the partitioned aquaculture system. *Aquaculture* **215**, 93-101.

URT (1998) United Repubic of Tanzania (URT). Mara Region Socio-Economic Profile: The Planning Commission Dar es Salaam and Regional Commissioner's Office Mara. pp. 224.

Utermohl H. (1958) Zur Vervollkommnung der quantitativen Phytoplankton-methodik. Mitteilungen-Internationale Vereinigung fur. *Theoret. Angew. Limnol.* **9**, 1-38.

Wahab M., Kadir, A., Milstein, A. and Kunda, M. (2011) Manipulation of species combination for enhancing fish production in polyculture systems involving major carps and small indigenous fish species. *Aquaculture* **321**, 289-297.

Yakubu A. F., Obi, A., Okonji, V. A., Ajiboye, O. O., Adams, T. E., Olaji, E. D. and Nwogu, N. A. (2012) Growth performance of Nile tilapia (*Oreochromis niloticus*) as affected by stocking density and feed types in water flow through system. *World J. Fish Mar. Sci.* **4**, 320-324.

Zar J. H. (2010) *Biostatistical Analysis*. Prentice Hall Inc., New Jersey, USA.

*Corresponding Author:

Yunus Daud Mgaya – Department of Aquatic Sciences and Fisheries Technology, University of Dar es Salaam, P. O. Box 35064, Dar es Salaam, Tanzania.

Received : 08.01.2017

Accepted : 01.03.2017