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Original Article

Comparative assessment of diet and condition factor of *Cyprinus carpio* and *Oreochromis leucostictus* in Lake Naivasha, Kenya

James Last Keyombe*[1, 2], Yasindi W. Andrew[2], Oyugi O. Dalmas[3]

[1]Lake Turkana Research Station, Kenya Marine and Fisheries Research Institute, P.O. Box 205 - 30500, Lodwar, Kenya.
[2]Department of Biological Sciences, Egerton University, P.O. Box 536 - 20115, Egerton, Kenya.
[3]Migori County, Fisheries and Livestock Development, P.O. Box 210 - 40400, Suna-Migori, Kenya.

Abstract: The study compared and assessed the diet and condition factors of two fish species, *Oreochromis leucostictus* and *Cyprinus carpio*, in Lake Naivasha. Fish samples were collected monthly using gill nets (35-70 mm mesh size) from July to December 2013. Stomach contents of all the specimens were analysed using the point method. Results indicated that detritus was the most abundant food item in the diet of both *O. leucostictus* and *C. carpio* accounting for 50% and 63%, respectively, while benthic macroinvertebrates contributed the least with each fish having 2%. Rooting and digging behaviour of the carp probably led to both *C. carpio* and *O. leucostictus* ingesting the suspended detritus as their main source of food with *C. carpio* outcompeting *O. leucostictus* due to its prolific nature and better adaptability to benthic conditions. Fulton's condition factor of all the fish samples had values of >1. A comparison of the two fish species showed *C. carpio* had a condition factor of 1.51 while *O. leucostictus* had 1.32. The higher condition factor of *C. carpio* in Lake Naivasha is an indication that the fish have better tissue energy reserves, greater reproductive potential and higher survival rates compared to *O. leucostictus* with a lower condition factor.

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Introduction

The blue spotted tilapia, *Oreochromis leucostictus,* is an exotic species of Lake Naivasha. It established itself quickly when it was first introduced, unintentionally, in the lake in 1956 from Lake Victoria Basin and has been present to date (Njiru et al., 2006). Reason for its quick establishment after the introduction has not been exhaustively studied. Currently, it is the most abundant tilapiine fish species in the lake (Oyugi et al., 2011). Other tilapiine species introduced in the 1950s were *Tilapia zillii*, *Oreochromis niloticus* and *O. spirulus niger* (Gunther) (Hickley et al., 2008). There was a hybrid produced between *O. leucostictus* and *O.s. niger* (Gunther) which became abundant in the early 1960s but due to back crossing with *O. leucostictus,* it disappeared by 1972 (Hickley *et al.*, 2008). The purpose for the introduction of *O. s. niger* was to provide a forage fish for the American largemouth bass, *Micropterus salmoides. O. leucostictus* and *T. zillii* used to form an important fishery in the lake (Muchiri and Hickley, 991), with both species being commercially exploited using gill nets by fishermen. They have however been replaced from the commercial fishery by the invasive common carp, *Cyprinus carpio* (Oyugi et al., 2014).

The common carp which was accidentally introduced in the year 1997 from a fish farm at the catchments of River Gilgil has the largest populations and is the main component in the lake's commercial fishery (Oyugi et al., 2014). Among the commercially important fish species of the lake, *O. leucostictus* is the most desired by the local community for consumption. This is because it has fewer bones in its flesh compared to *C. carpio* and is tastier (Waithaka et al., 2015). However, its population has been on a decrease probably due to the invasion by the *C. carpio*

* Corresponding author: James Last Keyombe
E-mail address: katalitsa@yahoo.com
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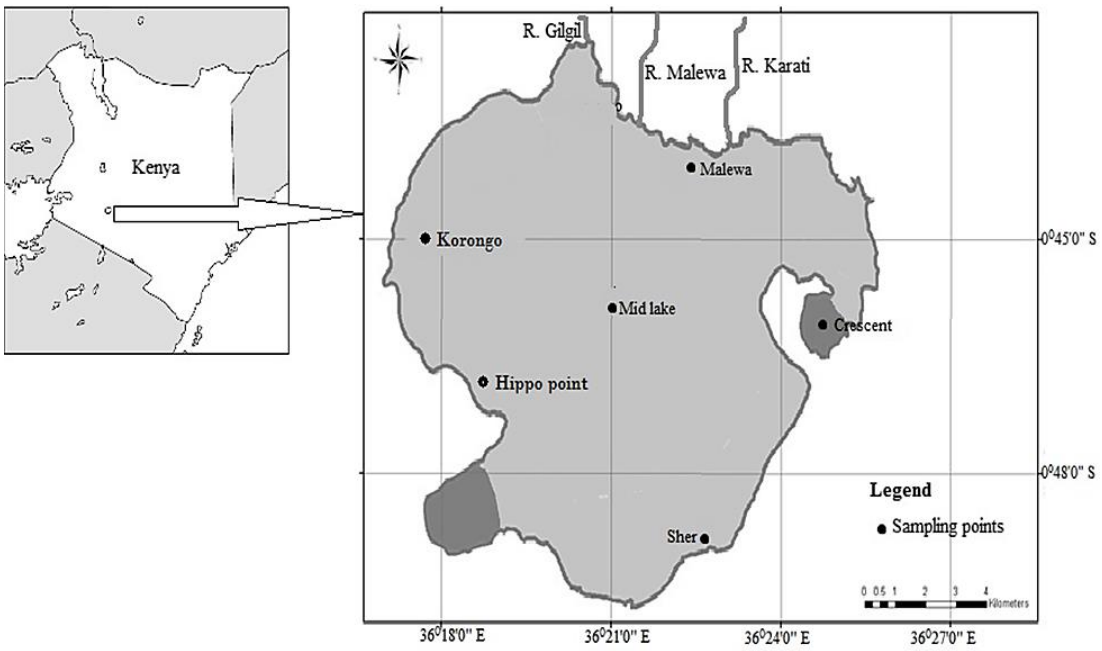

Figure 1. A map of Lake Naivasha showing the sampling sites.

in the lake (Oyugi et al., 2014). The *C. carpio* interfered with the *O. leucostictus* breeding grounds through increasing turbidity of the water when feeding, and this could have reduced *O. leucostictus* spawning areas (Oyugi et al., 2014).

Interactions between fish species and between them and planktonic organisms are frequently revealed through dietary studies. Gut content analysis which provides evidence of whether the invading population has increased pressure on prey items or increased competition for resources (Britton et al., 2007), is also lacking in this lake. Similarly, common carp has had various impacts in Lake Naivasha ecosystem since its introduction (Oyugi et al., 2012). However, knowledge of the effects of their interaction with *O. leucostictus* is limited. Therefore, the aim of this study is to assess the diet and condition factor of *O. leucostictus* and *C. carpio* in Lake Naivasha, to facilitate informed decision making processes for effective management of the fisheries resources.

Materials and Methods

Study area: Lake Naivasha is a shallow freshwater body, situated in the eastern arm of the Great Rift Valley in Kenya (0°46'S, and 36°20'E). It lies at an altitude of about 1890 m above the sea level. The Lake covers a surface area varying between 120 Km^2 and 160 Km^2 depending on the dry and wet seasons, respectively (Harper and Mavuti, 2004). The lake's mean depth varies between 4-6 m (Hickley et al., 2008). It lies in an endorheic basin but its freshness is mainly maintained by the inflows from the catchment area, biogeochemical sedimentation and the underground seepage (Hickley et al., 2008). Lake Naivasha is a complex basin consisting of four lakes that include Oloidien, Crescent Lake, the main Lake Naivasha and Sonachi. Rivers Malewa and Gilgil are the most important feeders of the lake (Fig. 1). Karati River flows into the lake intermittently. The lake is surrounded by a *Cyperus papyrus* swamp which covers an area of 64 km^2, but this can vary largely depending on rainfall intensity, livestock and prevailing wildlife populations in the riparian zone (Harper and Mavuti, 2004).

The six sampling stations in both the main Lake Naivasha and crescent lake which were used in this study are indicated in Figure 1. These stations are Malewa (00°43'49.9"S 036°21'32.1"E), Korongo (00° 44'22.6"S 036°19'28.9"E), Hippo Point (00°47'14.0"S 036°18'56.8"E), Mid Lake (00°46'30.8"S 036°20' 49.9"E), Sher 00°49'19.1"S 036°21'49.4"E) and Crescent (00°45'39.8"S 036°24'31.2"E). Malewa and Korongo sampling stations are located approximately 100 m from the shore and characterized by floating

Table 1. The ovarian maturity stages of *Oreochromis leucostictus* and *Cyprinus carpio* (Witte and Van Densen, 1995; Bonneau, 1999; Donkers, 2004).

	Description	
Maturity stage	***O. leucostictus***	***C. carpio***
I	Cannot differentiate sex	Immature, gonad tissue developing
II	Small ovary, tube like. Eggs not visible	Gonad non-vascularised
III	Ovary larger, occupies 1/3 of body cavity. Eggs visible as yellow granules	Eggs/milt visible
IV	Ovary dull grey. Occupies ½ of body cavity. Eggs visible as yellow granules	Mature, vascularised but not running
V	Ovary large. Greenish in colour. Occupies almost entire body cavity	Running ripe
	Golden green eggs extruded on applying pressure to abdomen	
VI	Red wrinkled ovary	Spent

mats of water hyacinth (*Eichhornia crassipes*), salvinia (*Salvinia molesta*) and papyrus (*C. papyrus*) vegetation. They are characterized by muddy substrate, decayed plant materials and silt. The average depths of the stations are 3 and 3.5 m, respectively. Sher Bay and Crescent Lake are fairly sheltered from the wave action of the main lake and are characterized by calm waters occasionally invaded by the floating mats of *E. crassipes* and detached *C. papyrus* especially during strong winds at high water levels. The average depths in these stations are 2.5 and 3 m, respectively. The substrate is mainly silt and sand.

Sampling and data analyses: Fish samples were collected monthly using gill nets (mesh size OF 35, 40, 50, 60 and 70 mm) from Malewa, Korongo, Hippo Point, Mid Lake, Sher and Crescent sampling stations between July and December 2013. The variation in net mesh sizes allowed fish of different sizes to be caught. The nets were set at the first sampling station of the day at 7:00 am and hauled six hours later at 1:00 pm. The nets were then set at 1:30 pm and hauled at 7:30 for the second station of the day. Two stations were sampled per day. Six hours was the adequate time to ensure enough fish for sampling were caught in the nets during the day.

Immediately after retrieving the net, each fish caught was weighed in grams using an electronic weighing scale (Digitron T745) to the nearest 0.1 grams. The total length of each fish was measured to the nearest centimeter using a measuring board. The sampled fish were then eviscerated and their sex determined according to Witte and Van Densen (1995) as outlined in Table 1. In the laboratory, fish stomachs were removed, fullness index determined using the modified method of Hyslop (1980), and preserved in labeled plastic vials with 5% formalin for further analysis. Condition factor (K) was estimated following Le Cren (1951):

$$K = W/L^{b}$$

Where K is the condition factor, W is the total body weight of fish in grams, L the total length in centimeters and *b* is the regression slope.

Data on gut contents was tested for normality and homogeneity of variance using MS Excel 2010 and chi-square. The differences in the contribution of each food item were tested using Quadratic fit. Descriptive and inferential data analysis was conducted using MS Excel 2010. In all the analyses, 95% level of significance was used as the critical point for rejection of the null hypotheses.

Results

Contribution of food items: During the period of July to December 2013 the gut contents of 153 *O. leucostictus* and 162 *C. carpio* were analysed. Detritus, algae and zooplankton were the most abundant food types in the guts of the two fish species,

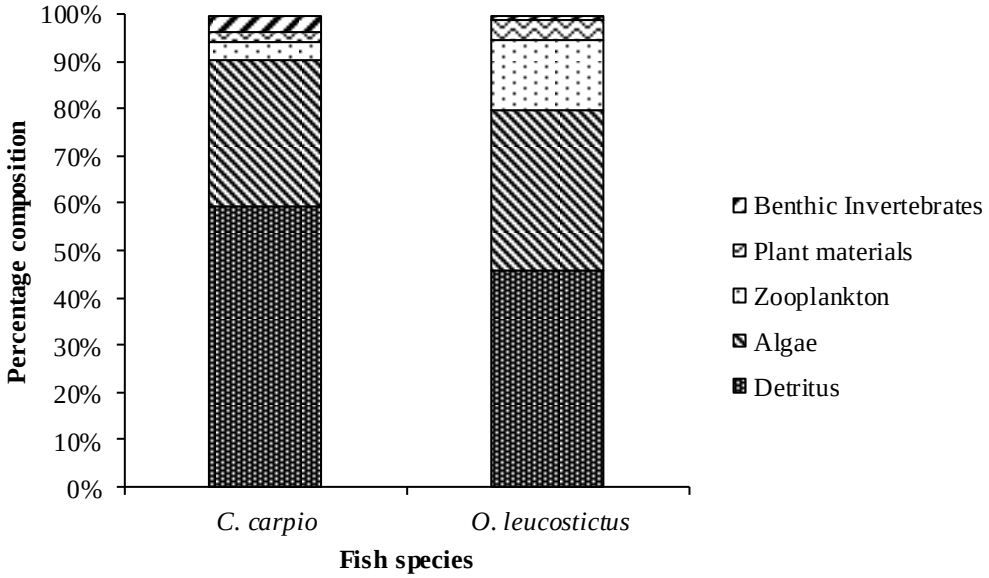

Figure 2. The dietary composition of (a) *Cyprinus carpio* and (b) *Oreochromis leucostictus* in Lake Naivasha from July to December 2013.

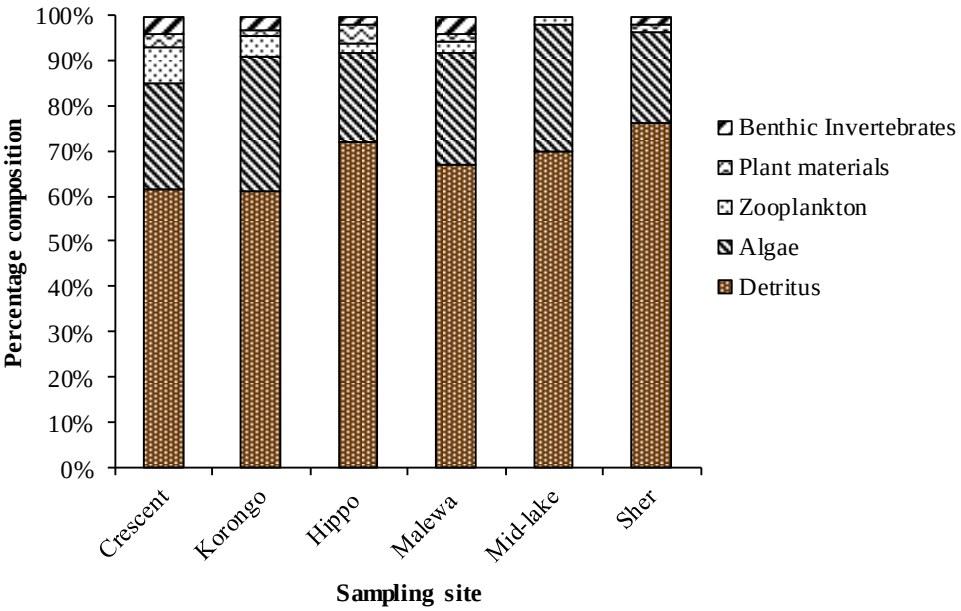

Figure 3. The relative food contribution in the guts of *Cyprinus carpio* at different sampling stations in Lake Naivasha from July to December 2013.

with fish of all sizes including the dietary items in their diet (Fig. 2). Detritus contributed the highest proportion in the diet of both *O. leucostictus* and *C. carpio* in all the sampling stations. Despite *O. leucostictus* and *C. carpio* having diversified their feeding habit to include mainly detritus and phytoplankton, higher plant materials still contributed significant portion of food items consumed by the fish in Lake Naivasha.

Spatial variation in diet composition: There was minimal spatial variation in the composition of the food items consumed by both *C. carpio* and *O. leucostictus* in Lake Naivasha. Detritus dominated *C. carpio* diet in both the inshore (Crescent, Korongo, Malewa, Sher, Hippo point) and offshore (Mid lake) sampling stations. The lowest composition of detritus was at Korongo and the highest at Sher sampling stations at 61% and 75%, respectively. The other important food items in the guts of *C. carpio* were zooplankton, benthic invertebrates and plant

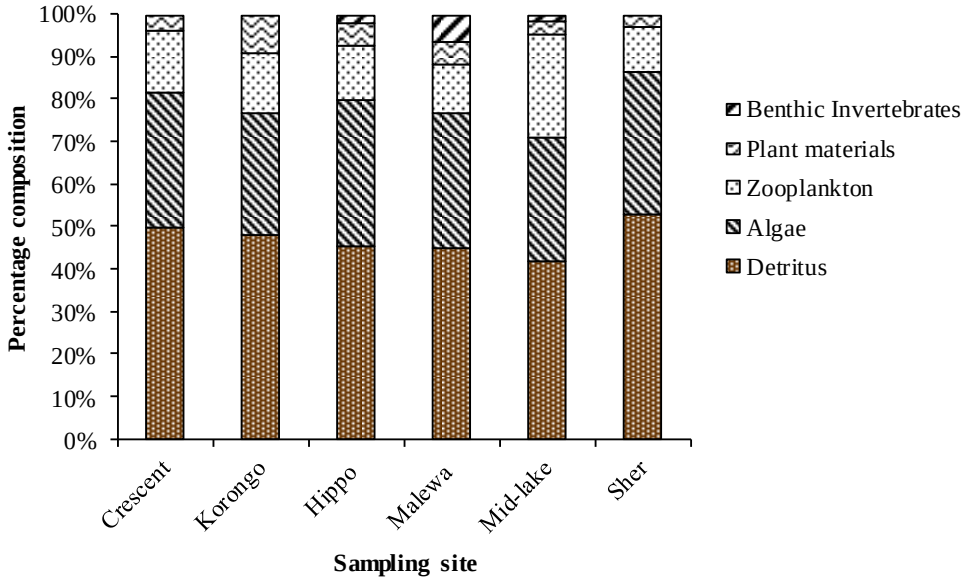

Figure 4. The relative contribution of food items in the guts of *Oreochromis leucostictus* at different sampling stations in Lake Naivasha from July to December 2013.

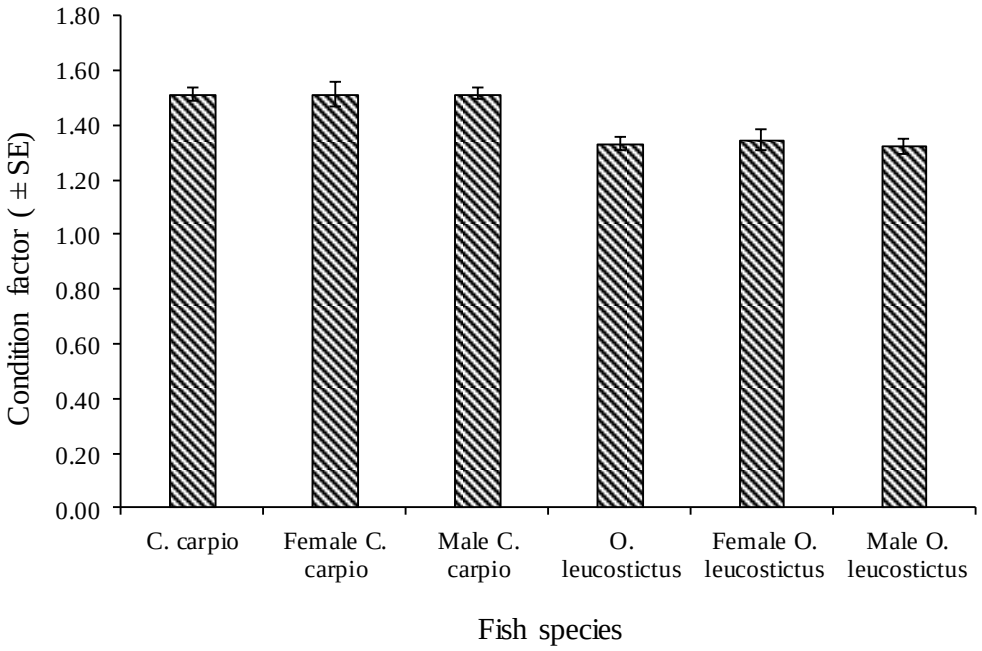

Figure 5. The condition factor of *Oreochromis leucostictus* and *Cyprinus carpio* in Lake Naivasha from July to December 2013.

materials.

Zooplankton abundance ranged from 1-8% in all sampling stations. Zooplankton in the guts of *C. carpio*at Crescent, Korongo and Malewa sampling stations constituted 8%, 4% and 3%, respectively. Carps from Mid lake, Sher and Hippo point sampling stations had 2%, 1% and 2% of zooplankton as their gut contents (Fig. 3). The results revealed no significant differences between the food items ingested by *C. carpio* in all the sampling stations (P<0.05).

The important food items of *O. leucostictus*in all sampling stations was detritus at Sher (52%) followed by algae at Hippo point (35%) and zooplankton at Mid lake (24%). Benthic macroinvertebrates and higher plant materials constituted insignificant proportions of *O. leucostictus* food each at 4%. The results showed no significant differences between the food items

ingested by *O. leucostictus* in all the sampling stations ($P<0.005$). No significant spatial variation was detected between the other food items. Further analyses revealed that detritus was the most important food item for *O. leucostictus*in all the sampling stations (Fig. 4).

Condition factor: All the fish samples collected had condition factor value of > 1. *Cyprinus carpio* had a condition factor of 1.51 while that of *O. leucostictus* was 1.32. The females of *C. carpio* had a K-value of 1.53 while female *O. leucostictus* 1.35. Similarly, male *C. carpio* had a K-value of 1.52 while males of *O. leucostictus* had 1.33 (Fig. 5).

Discussion

The highest proportion of phytoplankton was consumed in the open waters compared to the areas closer to the shore. This could be due to the openness and lack of free floating macrophytes in these off shore sampling stations allowing for more light penetration hence more phytoplankton biomass compared to areas closer to the shore where macrophytes shade the water from direct sunlight and inhibiting phytoplankton development.

The higher percentages of plant materials consumed in the near shore areas (Korongo and Hippo point) than in the open deeper areas of the lake (Sher Bay, Oserian and Crescent Island) could be due to the infestation and presence of water hyacinth and other macrophytes as compared to the open lake which only receives floating macrophytes occasionally especially during strong winds. There was no significant difference in the amount of detritus in the diet of both fish in all the sampling stations. However, slightly higher detritus amounts were recorded in the near shore areas. This could be attributed to the decaying of plant materials abundant at the littoral zone. Occasionally, the decayed plant materials and other sediments are usually carried to the deeper waters through lake mixing particularly by wind thus distributing the detritus throughout the lake. This could explain the almost equal contribution of detritus in all the sampling station within the lake.

An earlier study by Njiru et al. (2006) found that *C. carpio* in Lake Naivasha had diversified its diet by feeding on plant materials (40%), plant seeds (17%), detritus (12%) and fish remains (11%). However, according to Muchiri (1990), *O. leucostictus* feed on detritus as the principal component of their diet. Detritus is the most abundant food material available to fish in the lake and its importance has been previously also noted by Malvestuto (1974) and Siddiqui (1977). Of the other dietary constituents, algae, especially planktonic forms, were predominant.

Fish body condition varies seasonally depending on changes in gonadal development, food availability, and other environmental factors (Pope and Willis, 1996). The two fish species had K-values above 1. The results showed that both species were in good condition. According to Braga (1986) and Efitre et al. (2009), values of the condition factor vary according to seasons and are influenced by environmental conditions. The favourable physicochemical parameters in Lake Naivasha may therefore have been a catalyst for the good condition factor of the two fish species.

The physico-chemical parameters of Lake Naivasha measured in this study were within the tolerable range for both *O. leucostictus* and *C. carpio* (Edwards and Twomey, 1982). In a study of *O. leucostictus* in Lake Naivasha, Siddiqui (1977) found all stages of gonad maturation all year round and did not observe any seasonal fluctuation in relative condition factor, which he attributed to a constant proportion of fish with gonads in different stages of development.

According to Nathaniel et al. (1998), the condition factor of gravid females was within the range 1.6 and 2.0 irrespective of the location of sampling in the Victoria reservoir (Uganda). The condition factor of 1.52 for *C. carpio* in this study is in agreement with the results from Victoria reservoir.

Based on the results of this study, it can be concluded that the habit of *C. carpio* of rooting or digging in the bottom has had a negative effect on the environmental condition of Lake Naivasha through increase in turbidity and decrease in oxygen in the water column. This has in turn led to both fish species in the study consuming the suspended detritus as their

main source of food with *C. carpio* outcompeting *O. leucostictus* due to its prolific nature and better adaptability to such conditions. The higher condition factor of *C. carpio* in Lake Naivasha is an indication that the fish have better tissue energy reserves, greater reproductive potential and higher survival compared to *O. leucostictus* with a lower condition factor. It can therefore be concluded that the feeding and reproductive ecology of *C. carpio* has disrupted the natural environmental conditions of Lake Naivasha causing a decline in the numbers of *O. leucostictus* through alteration of its feeding and reproductive strategies. Since *C. carpio* is a better competitor than *O. leucostictus*, the fisheries stakeholders should look into cage culture of *O. leucostictus* as an alternative way of ensuring improved production of the fish species.

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چکیده فارسی

توسعه ارزیابی مقایسه‌ای رژیم غذایی و ضریب چاقی *Cyprinus carpio* و *Oreochromis leucostictus* در دریاچه نایواشا، کنیا

جیمز لست کیومبه[1,2*]، یاسیندی دبلیو. آندرو[2]، اویوگی او. دالماس[3]

[1]ایستگاه تحقیقاتی دریاچه تورکانا، انیستیتو تحقیقاتی علوم دریایی و شیلاتی کنیا، صندوق پستی ۳۰۵۰۰-۲۰۵، لودوار، کنیا.
[2]گروه علوم زیستی، دانشگاه اگرتون، صندوق پستی ۲۰۱۱۵-۵۳۶، اگرتون ، کنیا.
[3]اداره توسعه شیلات و دامداری منطقه میگوری، صندوق پستی ۴۰۴۰۰-۲۱۰، سونا-میگوری، کنیا.

چکیده:

در این مطالعه رژیم غذایی و ضریب چاقی دو گونه ماهی *Cyprinus carpio* و *Oreochromis leucostictus* در دریاچه نایواشا کنیا ارزیابی و مقایسه شد. نمونه‌های ماهی ماهانه با استفاده از تور گوشکیر (فاصله گره تا گره ۷۰- ۳۵ میلی‌متر) از ماه جولای تا دسامبر ۲۰۱۳ صید شدند. محتویات معده تمامی نمونه‌ها با استفاده از روش نقطه‌ای تحلیل شدند. نتایج نشان داد که دیتریت فراوان‌ترین اقلام غذایی در رژیم غذایی هر دو گونه *C. carpio* و *O. leucostictus* به ترتیب با ۵۰ و ۶۳ درصد بود، درحالی‌که بی‌مهرگان کفزی حداقل ۲ درصد را برا هر گونه شامل می‌شدند. رفتار ریشه کنی و نقب‌زنی کپور معمولی احتمالاً منجر به این می‌شود که هر دو گونه *C. carpio* و *O. leucostictus* از دیتریت‌های معلق را به عنوان غذای اصلی استفاده نمایند، با این وجود در این رقابت *C. carpio* به‌علت توانایی ذاتی و سازگاری بهتر به شرایط بستر نسبت به *O. leucostictus* برتری دارد. ضریب چاقی فولتون تمامی نمونه ماهی‌ها بیشتر از ۱ بود. مقایسه ضریب چاقی دو گونه نشان داد که مقدار آن در *C. carpio* ۱/۵۱ و در *O. leucostictus* ۱/۳۲ می‌باشد. ضریب چاقی بالاتر *C. carpio* در دریاچه نایواشا نشان دهنده ذخایر بافتی انرژیتیکی، پتانسیل تولید مثلی و نرخ بقای بالاتر در مقایسه با *O. leucostictus* با مقدار پایین‌تر ضریب چاقی است.

کلمات کلیدی: تغذیه، پوده، جلبک، زئوپلانکتون، فیتوپلانکتون، مواد گیاهی.