Accepted: 11 May 2017
DOI: 10.1111/aje.12438

SHORT COMMUNICATION

WILEY African Journal of Ecology

Feeding pattern and size at first maturity (Lm_{50}) of the exotic African catfish *Clarias gariepinus* (Clariidae) in Lake Naivasha, Kenya

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Funding information
Netherland Fellowship Programme (NFP)

1 | INTRODUCTION

The African Catfish *Clarias gariepinus* (Burchell, 1822) is distributed widely in Africa ranging from the Nile River Basin to West Africa and Algeria in the North (Solak & Akyurt, 2001).The African catfish is also generally considered to be one of the most successful fish species in tropical aquaculture due to their faster growth (Nyamweya, Mlewa, Ngugi, & Kaunda-Arara, 2010). *Clarias gariepinus* is an exotic fish species in Lake Naivasha and was observed for the first time by Kenya Marine Fisheries Research Institute (KMFRI) in 2012, during regular fish stock assessment (Keyombe, Waithaka, & Obegi, 2015). The incidental introduction of catfish in the lake could probably has come through the inflowing rivers; Malewa, Gilgil and Karati into the lake. As catfish is non-native to the Lake, its ecological consequences on the fish assemblage and other biota are not known. Fish biology-based studies are, therefore, necessary for understanding the trophic relationships of the fish and for sustainable utilization of the fishery resources as well.

Determining the feeding behaviour and how diet affects the nutrition and growth of fish is crucial in considering the ecological role of the population in aquatic systems. Feeding methods of *Clarias* range from benthic omnivory, piscivory and also include specialists in seed and wood eating (German, 2009). In early life stages, catfishes are invertebrativores depending on aquatic insects and crayfish as food, but as they mature they completely become carnivores, feeding mainly on live fish (Brewster, 2007; Omondi, Yasindi, & Magana, 2013).

Length at first maturity (Lm_{50}) is the length at which 50% of the fish are mature. Correct estimation of length at first maturity (Lm_{50}) also gives vital information to fisheries managers in setting mesh sizes that will target mature fish, which have contributed to the new generation and gives juvenile fish time to grow and mature (Karna et al., 2012). Due to the fact that fishing rates are usually set to keep a certain percentage of spawning females in a population, size and age at maturity are important parameters that must be monitored in stock assessment (Karna et al., 2012).

The biology and ecology of *C. gariepinus* are relatively well studied in the lakes of Africa including Lakes Victoria and Baringo in Kenya (Kwak, Porath, Michaletz, & Travnichek, 2011). However, very little is known about the species in Lake Naivasha apart from recent studies on its length–weight relationships and condition factor in the lake (Keyombe et al., 2015). This study, therefore, provides baseline data on the feeding pattern and length at first maturity of *C. gariepinus* in the lake. The results obtained may provide vital information on proper management and utilization of catfish stocks in the Lake.

2 | MATERIALS AND METHODS

2.1 | Study area

Lake Naivasha is a shallow freshwater lake in a closed basin in the Great Rift Valley of Kenya. Its freshness is attributed to surface water inflow, biogeochemical sedimentation and underground seepage (Gaudet & Melack, 1981). The lake has a surface area that ranges between 120 and 150 km^2 subject to the dry and wet seasons respectively, with a mean depth of 4–6 m (Njiru, Morara, Waithaka, & Mugo, 2015). The water and air temperature are relatively constant throughout the year and have a mean value of 22 ± 3°C. The main geographical, hydrological and physical characteristics of Lake Naivasha have been summarized by Mireri (2005). The lake fishery activities are based on introduced fish species (Hickley, Britton, Macharia, Muchiri, & Boar, 2015).

In the year 1995, Lake Naivasha was declared a Ramsar wetland giving it international importance due to its freshness and diverse ecology.

2.2 | Sampling procedures

The study was conducted in four different stations in Lake Naivasha (Figure 1). The stations were as follows: (i) Oserian Bay, (ii) Crescent Island, (iii) Mouth of Malewa River and Central Beach. Crescent Island is a station in the Crater Lake located in the eastern side which occasionally separate from the main lake during low water levels (Ndungu, Augustijn, Hulscher, Kitaka, & Mathooko, 2013). Oserian Bay is located in the open water and characterized by occasional invasion of floating mats of water hyacinth (*Eichhornia crassipes*) and papyrus (*Cyperus papyrus*) vegetation. Malewa River Mouth is located in the northern side and contributes 80% of discharge into the lake (Ndungu et al., 2013). Central Beach station is close to wetlands in the north of the lake, which is the shallow part and characterized by sandy silt, muddy substrate with decayed plant materials. The average depths of the Oserian Bay, Crescent Island, Malewa River Mouth and Central Beach stations were 4.5, 12.2, 2.6 and 1.4 m, respectively.

Samples of *C. gariepinus* were collected three times a month from November 2015 to January 2016, by setting gill nets of mesh size 50–200 mm at the four sampling stations. Gillnets were usually set during the afternoon and retrieved the following morning. In addition,

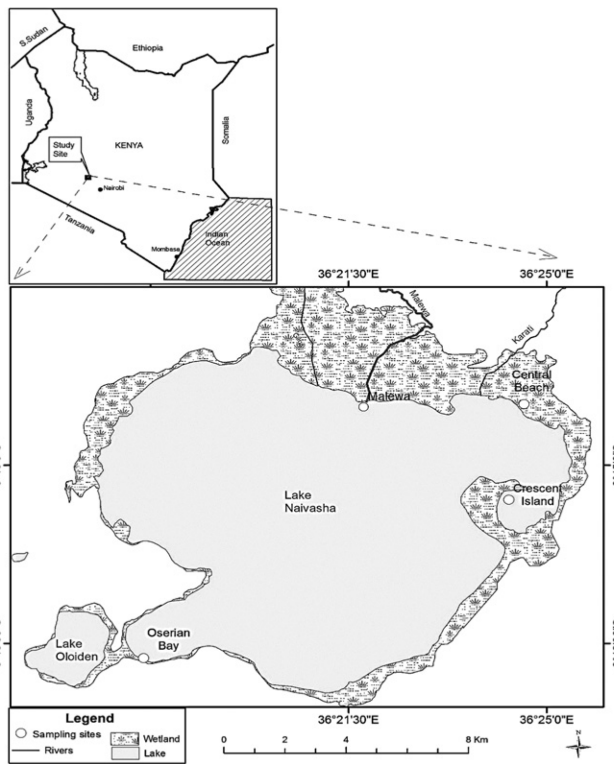

FIGURE 1 A map of Lake Naivasha showing the sampling stations (Source: Topographic Map of Kenya, scale 1:50,000)

mosquito nets were also used to get small fishes from the shallow littoral area. Immediately after capture, each fish was weighed to the nearest gram (g) using an electronic balance (Sartorius ED4202S), and total length was measured to the nearest cm using a measuring board. Individual fish were placed in labelled vials and preserved in 4% formalin. In the laboratory, the fishes were dissected, guts removed, and the sex of individual fish was determined based on the method of Murua et al. (2003) and Muchlisin (2014). The gut contents were analysed using a modified point method according to Hynes (1950) as reviewed by Hyslop (1980). In the laboratory, stomach contents were emptied into a Petri dish, and food items were sorted into categories using a binocular (×50) microscope. Large food items such as fish were identified visually. Smaller food items were sorted and counted using the inverted compound microscope (×400). Stomach contents were assessed separately and put into 10 cm length groups. The percentage contribution of each food item to stomach fullness in each length group was calculated on the basis of the awarded points using the equation by Zacharia (1974):

$$\% \text{ contribution} = A/B \times 100$$

where, *A* is the point given for each food item, and *B* is total points given for all food items in each stomach.

Size at first maturity was determined from the relationship between the percentage of male and female fish with mature gonads plotted against different length classes using the least square regression method. Kolmogorov–Smirnov test was used to compare the maturity difference among sexes. Fish maturity stages IV and V were used for Lm_{50} calculation.

3 | RESULTS AND DISCUSSION

3.1 | Diet composition

Of the 400 stomachs of *C. gariepinus* examined, 25% were completely empty. From the rest of 75% stomachs, 13.5% were fingerlings and juveniles (4.5–11.5 cm length). All fingerlings collected had full stomachs. The main consumed food items were zooplankton (24.6%), fish (23.1%) and insects (21.4%). The commonest ingested zooplankton was *Daphnia pulex* followed by *Chydorus* sp and *Ceriodaphnia* (Table 1). The most eaten free-living insects were the Notonectidae *Micronecta scutellaris*, followed by Chironomid larvae. The presence of empty stomachs in this study could be due to sampling methodology and time. Vinson and Angradi (2011) found that the percentage of getting empty stomachs in fishes is higher for passive capture methods (e.g. *gillnets)* due to longer lag time between capture. Moreover, due to the fact that most fishes are continuous feeders rather than strictly nocturnal, the observed empty stomachs during this study could probably due to fishes were collected earlier in their period of most active feeding. The ingestion of a wide variety of diet observed in this study could be due to its morphological adaptations (big mouth, marginal and pharyngeal teeth, tough and muscular stomach and short intestine) and omnivorous feeding habit, where *C. gariepinus* could switch from one

TABLE 1 The percentage occurrence of different food items identified from the stomachs of 400 individuals of *Clarias gariepinus* in Lake Naivasha

Food item			
Insects		Rotifers	
Noumectidea	10.3	*Filinia Pejleri*	2.7
Naucohdae	1.7	*Tricocerca*	2
Chironomid larvae	6.7	*Keratella*	1.4
Chironomid pupae	2.7	*Polyarthra*	1.3
Total insects	21.4	Zooplankton	24.6
Cladoceras		Others	
Ceriodaphnia	3.4	Detritus	10.1
Diaphanosoma	2.2	Insect remains	7.9
Daphnia pulex	5.6	Fish scales	3.9
Moina micrura	1.8	Plant material	2.1
Chydorus sp.	4.2	Fish	23.1
		Mollusc	4
		Fish eggs	2.9

type of food item to the other depending on availability (Dadebo, 2009; Yalcin, Solak, & Akyrut, 2001). In a study on the feeding habits of five fish species (*Oreochromis leucostictus*, *Coptodon zillii*, *Micropterus salmoides*, *Barbus amphigramma and Poecilia reticulata*) in Lake Naivasha, Hickley et al. (2002) concluded that zooplankton, phytoplankton and benthos especially chironomids were underutilized. This study has, therefore, revealed that, those food items that were previously underutilized are intensively consumed by *C. gariepinus* there by filling the niche gap in the basic food web in the Lake. Omnivore feeding habit of *C. gariepinus* and lack of major competition from the existing species in the Lake may have led to easy establishment of the species in the lake.

3.2 | Ontogenic shift

A change in the diet with increasing size was observed. Small fishes of between 0 and 15 cm Total Length (TL) fed on high proportions of phytoplankton and insects while fish of >15 cm TL fed more on zooplankton, fish (*Oreochromis niloticus*) and crayfish (Figure 2). Phytoplankton were absent in the diet of *C. gariepinus* in the range from 31 to 40 cm TL, while they were the major food of *C. gariepinus* in size range from 0 to 30 cm TL. Ontogenic shift observed during study could be due to changing capabilities of fish. Generally, fish grow in a pattern of level from eggs to adults and their feeding habit changes markedly throughout the life time thus, they become more effective at manipulating larger, more beneficial prey as they grow big (Hildrew, Raffaelli, & Edmonds, 2007). Adult *C. gariepinus* in size range of ≥40 cm TL mainly fed on fish, which is in agreement with studies by Omondi et al. (2013) in Lake Baringo. Younger fish also fed on a higher proportion of insects probably in bid to satisfy specific protein demand due to a higher specific growth rate and greater specific metabolism at the stage.

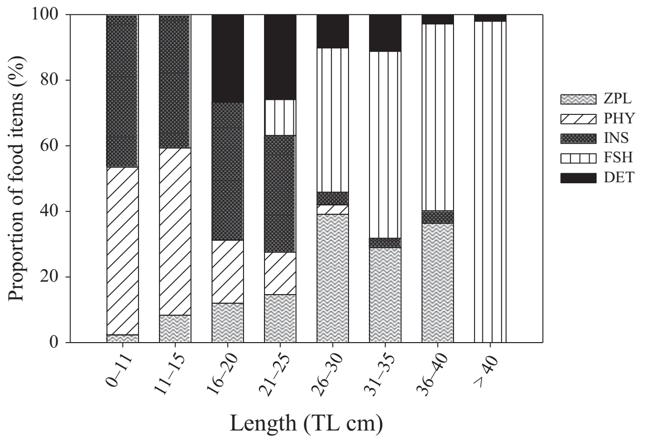

FIGURE 2 The percentage contribution of different food items consumed by *Clarias gariepinus* in different length groups (ZPL-zooplankton, PHY-phytoplankton, INS-insects, FSH-fish, DET-detritus)

3.3 | Size at first maturity

The smallest mature female sampled was 18 cm TL and weighed 90 g and was collected at Oserian Bay, while the smallest mature male caught was of 24 cm TL and weighed 100 g and caught at Crescent Island. The distribution of ripe males and females of *C. gariepinus* in Lake Naivasaha is presented in Figure 3. The overall mean (±*SE*) size at maturity (Lm_{50}) was 21.9 ± 0.52 cm TL and 41.6 ± 3.84 cm TL for females and males, respectively (Figure 3). Females had smaller size at Lm_{50} than males. Also, KS-test revealed significant variations between the sexes ($P < .05$). The maturity size for both males and females in this study was smaller than results reported by Dadebo, Gebre-Mariam, and Mengistou (2011) of 58 cm TL for females and 52 cm TL for males in Lake Chamo, Ethiopia. These variations may be due to environmental factors, such as food availability. The process of maturation is significantly influenced by a number of factors, such as water temperature and food availability (Thorpe, Mangel, Metcalfe, & Huntingford, 1998). The early maturity in fishes was also attributed to maximizing the reproductive success of the species in particular physical habitats and to maintain the suitable spawning stock (Matthews, 2012). Therefore, the early maturity of females of *C. gariepinus* could be due to the fact that the species is new to the Lake Naivasha; thus, rapid production of early offspring helps in establishment of the population. Yet, more detailed studies are, therefore, needed to provide further understanding in to the specific factors affecting maturity of catfish in Lake Naivasha.

This is the first study that provides baseline information on the feeding pattern and length at first maturity of *C. gariepinus*, in Lake Naivasha. There is a probability that *C. gariepinus* may continue to expand its niche in the Lake until it stabilizes. However, this may not be achieved due to the intense fishing pressure currently experienced in the lake and the continued ecosystem degradation (Njiru et al., 2015). It may similarly be significant to use stable isotope techniques to discriminate the quantities of the food items consumed by *C. gariepinus* to ascertain whether they are assimilated and utilized for energy and growth.

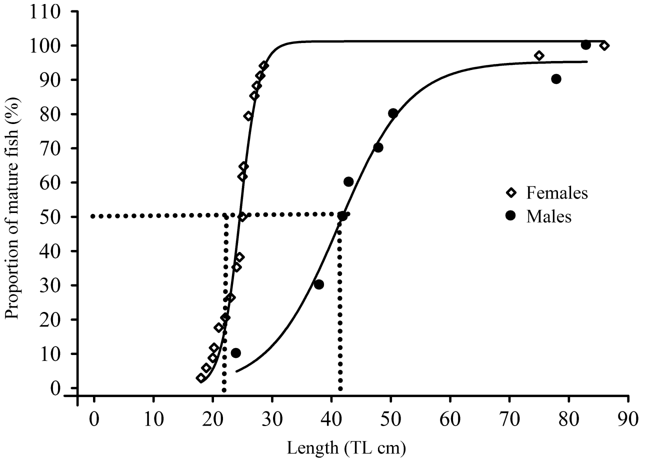

FIGURE 3 The length at first maturity of male and female *Clarias gariepinus* in Lake Naivasha

ACKNOWLEDGEMENTS

The research work was funded by the Netherland Fellowship Programme (NFP). We are grateful to the Department of Biological Sciences, Egerton University for providing laboratory facilities. Our gratitude goes to the technical team from Kenya Marine and Fisheries Research Institute (KMFRI), Lake Naivasha field station, for their support during sample collection.

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How to cite this article: Meri MM, Njiru J, Yasindi AW. Feeding pattern and size at first maturity (Lm_{50}) of the exotic African catfish *Clarias gariepinus* (Clariidae) in Lake Naivasha, Kenya. *Afr J Ecol*. 2018;56:395–398. https://doi.org/10.1111/aje.12438