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Research Article

Evaluation of Biological Aspects of Baringo Barb *i* (Ruppell 1835) in Lake Baringo

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Abstract: The Baringo barb *Labeobarbus intermsdius* is one of the least studied native fish species in Lake Baringo, a shallow freshwater lake located in the eastern arm of the Rift Valley, Kenya. This study evaluated aspects of its biology to provide baseline scientific information on the species. Fish were sampled using gillnets and their lengths (to the nearest 0.1 cm) and weight (to the nearest 0.1 g) measured on a meter board and electronic balance respectively. Parameters of the length-weight relationship were obtained by fitting the power equation; W=a × Lb to length and weight data. Each fish was dissected to remove the stomach for stomach content analysis. Gonads examined gonads for sexing and determination of maturity stage. Fish size in a total of 280 individual sampled during the study ranged from 6.0 to 36.0 cm total length and 4.3 to 1314 g total weight. The b value of the length-weight relationship was 3.1177 indicate positive allometric growth. Of 254 sexed individuals 107 were males and 147 were female giving a ratio of male to female to be 1:1.38 which was significantly different from the expected 1:1 sex ratio (chi-square test, p<0.05). In this study, all the maturity stages were observed except stages VI and VII in male and VII in females. The most important food items of Baringo barb in Lake Baringo were detritus, algae and seeds but other items were consumed consistently with benthic feeding. There is a need for longer-term studies on the biology of this commercially important species to provide data to guide its sustainable exploitation and conservation.

Keywords: *Labeobarbus intermsdious*; Food and feeding habits; Sex ratio; Lake Baringo

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Introduction

Lake Baringo was once a vibrant fishing ground with a wide range of fish species but of late, the decline in fish catches has been noted. The decline has been associated with several factors which include; degradation of the lake environment and its catchment as a whole, overfishing, predation by birds and crocodiles and lack of food [1]. Before the introduction of *Protopterus aethiopicus in* 1975 by Mlewa and Green [1], *Oreochromis niloticus* was the most dominant species in Lake Baringo but currently Baringo barb *Labeobarbus intermsdius* (Ruppell 1835) is the most dominant fish species in the lake.

The Baringo barb *Labeobarbus intermsdius (*Ruppell 1835) belongs to the class *Actinopterygii* (ray-finned fish), order Cypriniformes (carps) and family *Cyprinidae* (minnows or carps). It is a benthopelagic freshwater fish which is widely distributed throughout Southern Ethiopia, Northern Kenya, and Lake Baringo [2] The species is endemic in Africa-Inland waters [2], where it has been described as one of the potamodromous fishes. Potamodromous migrations occur among different freshwater habitats and take place entirely within the main stem of streams of rivers, between streams and their tributaries and between lakes and their inlet or outlet conditions [3]. Migration occurs for variety of purposes, including feeding, reproduction, and seasonal refuge from severe conditions [3]. Potamodromous species have highly seasonal spawning migrations associated with the flood pulse of rivers [4].

Worthington and Ricardo [5] noted that Baringo barb was abundant over the entire lake and grew to a length of 68.0 cm. During the 1969 survey, 515 specimens of Baringo barb ranging from 8 cm to 35.3 cm (standard length) were caught in gillnets setting various localities of the lake. Baringo barb is predominantly a bottom feeding species this was evident when nets were set at different depths, in open waters bottom set gillnets caught more fish than top gillnets. The catches of Baringo barb were greater in inshore waters than in the off shore waters. It was, however, noted that Baringo barb is of secondary importance in the commercial gillnet fishery but is the dominant species in the subsistence rod-and-line fishery. The sex ratio of Baringo barb in the lake was one female to one male (1:1) according to Ssentongo [6]. Baringo barb together with the members of the genus Barbus [7], are potamodrometic and move into affluent rivers to spawn in vegetated flooded pools [8]. According to Munro [9] fish reproductive process is controlled by environmental cues as well as by endogenous biology rhythms. Reproductive biology of a population of fish provides information on their spawning cycle, fecundity, egg size and sexual maturity which helps in determining the recruitment patterns in such habitats.

The size at first maturity is regarded as the size at which 50% of the fish are mature and should be calculated in males and female separately by determining the proportion of mature fish in different length classes of fish [10].

Length at first maturity is estimated according to Berveton and Holt [11], the sex ratio is also important to establish. The maturity identification procedures are to be based on the size and colour of the gonads. Separation of mature and immature fish is essential for the estimation of the spawning stock biomass; an important indicator of whether or not the stock has reproductive capacity to sustain the population in the future [12].

Food items included benthic diatoms zooplankton and globular colonial algae, weed fragments and some small plant seeds. Invertebrate material included thin cuticles of chironomid larvae and thick chitinous remains of aquatic insects. Fish bones were also noted in the stomachs of Baringo barb. The study of the feeding habits of fish and other animals based upon analysis of stomach content has become standard practice. Stomach content analysis provides important insight into fish feeding patterns and quantitative assessment of feeding habits, which is important in fisheries management.

Dadebo [13] studied food and feeding habits of the African big barb in Lake Koka, Ethopia and found that macrophytes, detritus and insects were the most important food items. Detritus contributed a high percentage followed by macrophytes, but the contributions of phytoplankton, zooplankton, fish scales and ostracods were relatively low. Based on the result of this study it was concluded that Barbus was omnivorous [13].

Manon and Hossain [14] studied food and feeding habits of *Cyprinus carpio var* in a culture pond of Naogaon district (Egypt) and observed that the feeding intensity in mature fish was poor and the feeding intensity was very poor during the spawning period. The feeding intensity of immature fish was found to be active. The food and feeding habits of fishes vary from month to month. This variation is due to changes in the composition of food organism occurring to different in seasons of the year [14].

In fishes, both external (e.g., shape, size and position of mouth, shape of caudal fin) and internal morphology (e.g., stomach shape and size, gut length) provide important information on a species' feeding ecology [15-18].

Cyprinids are known to feed at all trophic levels; higher plants, phytoplankton, zooplankton, zoo benthos, bacteria and attached detritus growing on other fish [2]. They also express seasonal variation on their feeding habits [19].

Larvae feed on zooplankton at early stages of its lifecycle, but as it grows, it gradually shifts from a predominantly animal diet to a more plant one, feeding on detritus, phytoplankton and submerged vegetation [20]. This study is very important because it reveal the state and condition of the fish reservoir and the environment where the fish lives. Also, the biological aspects of the fish can assist researchers, fisheries managers and policy makers on the best management practices to be employed towards sustainable utilization of the fisheries resources. Here present information on the Baringo barb length-weight relationship, food and feeding habits and reproduction.

Materials and Methods

Study area

Fish samples were obtained from Lake Baringo, Kenya. Lake Baringo is a shallow equatorial freshwater lake with a surface area of approximately 130 km^2 located in the eastern arm of the Rift Valley, Kenya. The lake lies between 0°32' and 0°45' N, 36°00' and 36°10' E at an altitude of 975 m above sea level. Lake Baringo has no surface outlet, with its 'freshness' being attributed to the presence of an underground outlet at its northern end [1,6,21]. The Lake's waters level fluctuates every due to high evaporation and unpredictable rainfall [22]. The lake mixes almost daily because of regular winds resulting in high levels of suspended sediment that give it a brownish coloration [1]. The sample were collected in 7 different stations namely; Perkerra River mouth, Molo River mouth, South Endao River, Komolion, Kiserian and Loruk as shown in **Figure 1**.

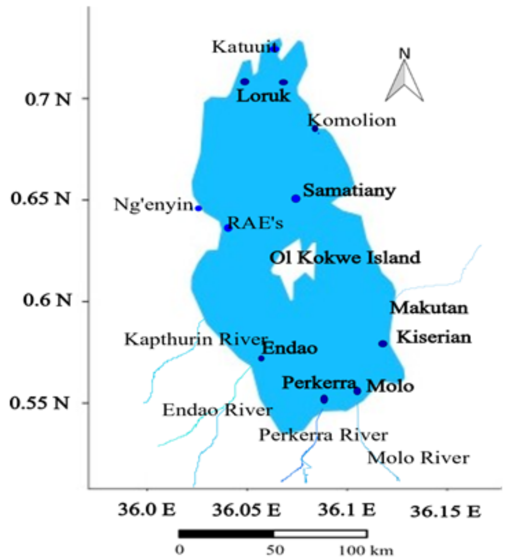

Figure 1: Map of Lake Baringo showing sampling sites.

Sample collection

Fish samples were collected using a gang of multifilament gillnets of various mesh sizes ranging from 1-8" with incremental of 0.5" joined together. The nets were set in 5 different stations namely; Pekerra River mouth, Molo River mouth, south Endau River, Komolion, Kiserian and Loruk. The nets were set in the evening between (4.30 pm to 6.00 pm) and retrieved in the morning from 6.30 am to 8.00 am. Nets were set parallel to the shoreline. At lifting time fish was sorted to species level and labelled according to mesh sizes.

Sample analysis

Size: After fish retrieval from the net they were sorted according to the net mesh sizes *in situ*. The samples were then placed in a cooler box to reduce spoilage rate and also to minimize post-harvest digestion. The Length was measured on a meter board to the nearest 0.1 cm and weight was measured using electronic balance to the nearest 0.1 grams.

Length and Weight Relationship (LWR): Parameters of the length weight relationship were obtained by fitting the power equation: $W=a \times L^b$ to length and weight data where: (W) is the total wet weight (g), (a) is a constant determined empirically, (T.L.) is the total length (cm) testing according to Biswas [23] in order to verify if calculated b was significantly different from 3. A least squares regression was employed to estimate the parameters of LWR [24], as was the coefficient of determination (r^2). Statistical comparison of LWR between sexes was performed by applying a t-test. The significant difference was observed, LWR was estimated for each sex and finally the LWR was estimated for the combined sexes [25].

Food and feeding habits of Baringo barb: In the laboratory after taking the length and weight measurements of the fish, the specimen were dissected using a pair of scissors and stomach fullness were observed, after the stomach fullness study the guts were opened using scalpel then stomach contents transferred to a Petri dish for identification of food items using a magnifying glass (Magnification 5x, 10x) according Bowen [26], the fullness of the stomach was identified. **Table 1** below shows the criteria which was used for determining the stomach fullness index.

Stomach contents were examined and individual food organisms sorted, identified and recorded for each stomach so as to analyse frequency of occurrence [27]. The number of stomachs in which each type of food item occurs is expressed as a percentage of the total number of stomachs examined. The stomach fullness was identified as full, 3/4 full, 1/2 full, 1/4 full or empty.

Sexual maturity stages and sex ratios of Baringo barb: Each specimen was sexed by visual examination of the gonads after dissecting the fish through the vent. A microscope and hand lens was used in the examination of gonads which was not be discernible to the naked eyes as described by Olurin and Odeyemi [28] in their study on the reproductive biology of fishes of Owa streams in Nigeria.

The maturity identification procedure was based on the size and colour of the gonads [29]. The maturity stages were assigned according to Hopson [30]. According to the scheme VI stages in male and VII in females are recognized, with maturity stage beginning at stage IV in males and III in females [26]. The stages of maturity of the gonads was determined according to Nikolskii and Hopson [30,31] as shown in **Tables 2 and 3**.

Table 1: Criteria for determining stomach fullness**.**

Criteria	Fullness index
1. Stomach content empty	0
2. Very little food present	¼
3. Half full stomach	½
4. Stomach nearly full but wall not bulging, food fills to about 3/4 when stomach is pressed from anterior to distal	¾
5. Stomach full distended with food from anterior to distal	1

Results

Size of fish

Of 280 individual sampled during the study, the shortest individual was 6.0 cm and the longest was 36.0 cm Total Length and 4.3 g and 1314 g Total Weight. The mean length of female and male were found to be different with female having mean size of 16.06 ± 5.07 and males have 13.89 ± 3.37 hence females were larger than male, the analysis of covariance revealed significant difference between sexes for the sizes for both length (t-test, P=0.000057) and weight (t-test, P=0.044) ($P<0.05$).

Length weight relationship

The value of b found in this study was 3.1177 which indicate positive allometric growth. The degree of adjustment of the model studied was assessed by the coefficient of determination (r^2) 0.8803 (**Figure 2**). This

Table 2: Maturity stages for male fish.

Stage	Size	Colour	Other features
I (Immature virgin)	Very small	Translucent	Thin, narrow ribbon
II (Developing virgin)	Length less than 1/2 body cavity	Becoming opaque, white	Slightly lobed and coiled
III (Early mature)	Length 3/4 body cavity	Whitish-grey	Strongly coiled, blood vessels visible
IV (Late mature)	Length 3/4 body cavity, swelling	Opaque, white	Strongly coiled
V (Ripe)	Filling body cavity	Opaque, creamy-white	Tightly convoluted lobes, milt does not flow
VI Running	Filling body cavity	Creamy-white	Milt easily extruded
VII (Spent)	Length less than 1/2 body cavity	White, bloodshot	Crinkled and shrunken

Table 3: Maturity stage for female fish.

Female (ovary)			
Stage	**Size**	**Colour**	**Other features**
I (Immature virgin)	Length less than 1/4 body cavity	Translucent, white	Small, oval sac
II (Developing virgin)	Length 1/3 body cavity	Reddish-orange or translucent	Small, oval sac
III (Early mature)	Length 1/2 body cavity	Pinkish-white	Opaque eggs clearly visible
IV (Late mature)	Length 2/3 body cavity	Whitish-yellow	Opaque eggs clearly visible
V (Ripe)	Very swollen	Pale yellow	Some eggs transparent, not easily extruded
VI (Running)	Very swollen	Transparent	Eggs easily extruded
VII (Spent)	Length 1/2 body cavity	Bloodshot	Flaccid and shrunken

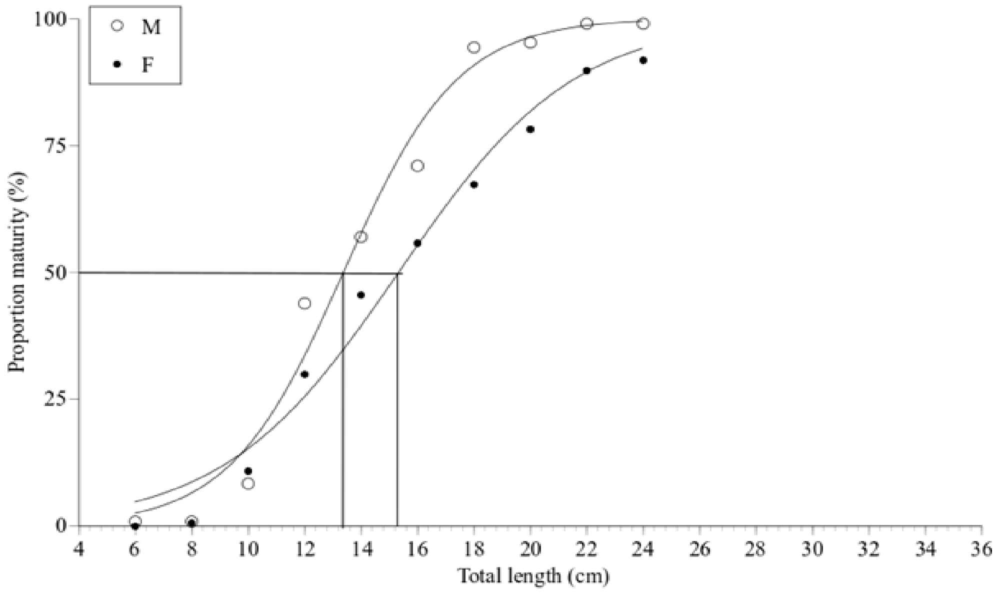

Figure 2: Strong positive relationship between length and weight.

Table 4: The length weight characteristics.

Sex	Weight and length characteristics		Parameters of LWRs		
	L mean ± SD	W mean ± SD	a	b	r^2
Male	13.89 ± 3.37	39.89 ± 113.55	0.0089	3.0271	0.8659
Female	16.05 ± 5.07	75.63 ± 169.17	0.0064	3.1754	0.8681
Both	15.00 ± 4.56	57.84 ± 142.62	0.0073	3.1177	0.8803

shows a strong positive relationship between Length and weight. It shows that 88.03% of the variability experienced in weight is explained by the variability in length.

The weight and length characteristics, as well as, the parameters of the LWR (W=aLb) for the Baringo barb caught in the Lake Baringo waters SD is the standard deviation; a and b are the parameters of the weight–length relationship; r^2 is the coefficient of determination of growth; Both is the combined sample of male and female (**Table 4**).

Food and feeding habits of Baringo barb of Lake Baringo

The food items of Baringo barb of Lake Baringo were classified into 6 groups and others that were identified only once in one or two fishes. Out of the total number of 274 fish samples collected, 252 (91.97%) were non-empty while the remaining 22 (8.03%) were completely empty (**Table 5**). Out of the 274 sample gutted, 117 stomachs were full, 73 half full, 52 a quarter full, 22 were empty, 1 three quarter full and 10 digested hence you could not identify the type of food in the stomach.

Table 5: Number of empty and non-empty stomachs.

Stomach content	Number	Percentage (%)
Empty stomach	22	8.03
Stomach with food	252	91.97
Total	274	100%

The food items identified were; detritus, insects, seed, fish, algae, molluscs and others those were in small numbers and were not easy to identify. Among the food items detritus, algae and seeds were most dominant with percentage of 56.0%, 15.7% and 10.0%, respectively followed by molluscs, fish then insects with a percentage of 3.9%, 1.7% and 0.23%, respectively. Results in **Figure 3** below show that detritus, algae, seed occurred in high number of guts and constituted the bulk of (81.73%) of food consumed. The remaining food items accounted for only 18.27% of the total volume of food items. Regardless of the sites used during sampling, detritus dominated the diet compositions. Detritus occurred in 72.85% of the guts and accounted for 56% of the total food volume; algae occurred in 28% of the stomachs and accounted for 15% of the total volume food

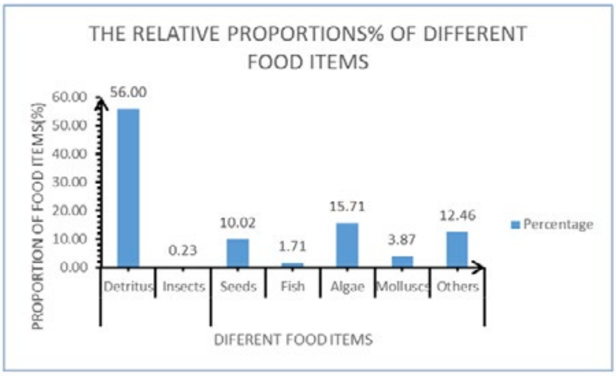

Figure 3: Relative proportions of different food items in the diet of Baringo barb using frequency of occurrence method from Lake Baringo.

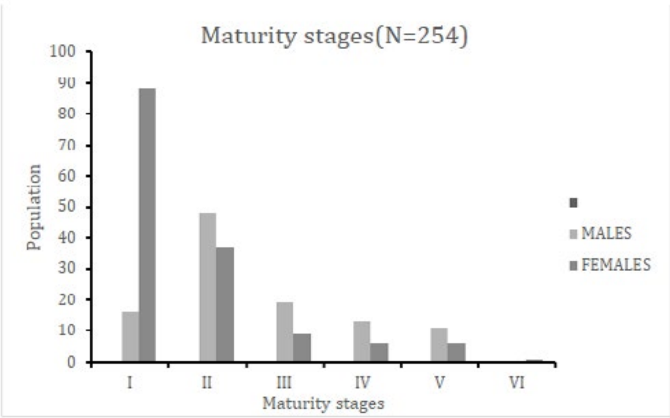

Figure 4: Graph of proportions of maturity stages.

consumed.

Sexual maturity stages and sex ratios

A total of 254 samples were sexed and 107 were males and 147 were female giving a ratio of male to female to be 1:1.37, the $p \leq 0.05$. Chis-square test results show significant difference in sex ratio ($p=0.012$) from the expected ratio of 1:1. In this study all the maturity stages were observed except stages VI and VII in male and VII in females as shown in **Figure 4** below.

Among 107 male samples 43 males (40%) were mature and 64 (60%) were immature while in female 147 samples were sexed and 22 females (15%) were mature while 125 females (75%) were immature all these translate to total 65 (25.6%) mature and 189 (74.4%) immature. In total 65 out of 254 were mature and among the 65, 43 were males while 22 were female. The size at first sexual maturity L50 of male is 13.40 cm ($r^2=0.98$) of total length and 15.36 cm ($r^2=0.98$) for female.

Discussion

The parameters of the fish LWRs are affected by a series of factors including season, habitat, gonad maturity, sex, diet, stomach fullness and health by Ali et al. [32]. In this study b>3, then large specimens have increased in weight more than in length, either as the result of a notable ontogenetic change in body shape with size, which is rare, or because largest specimens in the sample were thicker than small specimens, which was in the case of this study in the five sampling sites; Kiserian, Samatian, Loruk, Komolion and Endau. Conversely, b>3, then large specimens have changed their body shape to become more elongated or small specimens were in better nutritional condition at the time of sampling.

Baringo barb fed mainly on detritus, algae and seeds in Lake Baringo. Unlike the present study, the major food items of Africa big barb were mollusks, fish prey and insects in Lake Hawassa [33] and detritus, macrophytes and insects in Lake Koka [13]. Similarly, in Lake Tana the diet of Tana barb was dominated by insect larvae and detritus [33]. The results of the present study are in agreement with the findings of other investigators in different water bodies of Africa where detritus dominate the gut content of the species. Unlike the present study, Desta [34] reported the dominance of gastropods in the diet of *B. intermedius* in Lake Hawassa [34] and he reported that in addition to other food categories Barbus consumed large quantities of mollusks, fish prey and aquatic insects. Similarly, in Lake Tana the diet of Tana barb was dominated by benthic prey organisms' especially insect larvae and detritus [33]. The high occurrence and volumetric contribution of detritus in guts of Africa big barb showed the significant contribution of this food item in their nutrition but dietary studies on big Barbus in different lakes showed that the ingestion of detritus, sand particles and benthic food items indicated the ability of the fish species to possess benthic habitats [13]. Detritus is considered low in nutritional value [26]. Several studies have considered that an increased consumption of detritus is a primer to a decline of higher value primary food resources [26].

The sex ratio of male to female was 1: 1.38. The expected sex-ratio (1:1) was not observed. The overall sex ratio of 1:1.38 in favour of females in the fishery is similar to that observed in other species: Labeo coubie (1:1.67) and Rasbora tawarensis (1:3.39) [35]. The variation of sex ratio from normal can be triggered by quite a number of factors such as population adaption to environmental changes, reproductive behaviour, food availability and feeding habits

[36]. These results might signify that the reproductive strategy of fish species should be the polygamy or an r-selected reproductive strategy where the number of larvae is high but with less parental care. The higher number of female in the sex ratio in the sample may be due to the differential fishing factors related to seasons and schooling of fishes in the feeding and spawning grounds, or to selective fishing for the large fish, rather than reflecting a real population sex ratio. Sex ratio divergence might also be explained by partial segregation of mature individuals through the preference of school formation, rendering one sex more vulnerable to capture [35]. Additionally, once fertilization of eggs is completed, males may move from spawning to feeding areas located in the shallows where they are not easily caught [37]. Although the number of females were higher than the male, the number of mature male (43) were higher than the number of mature female (22) and this could be due to the fact that Baringo barb together with the members of the genus Barbus [7], are potamodrometic and move into affluent rivers to spawn in vegetated flooded pools [8]. The samples were collected during rainy season when the Baringo barb were breeding hence most of the mature female had moved to the rivers to spawn.

The length at first maturity (L50) of Big Barb of Lake Baringo indicates that 15.36 cm and of the female fish were reproductive female were slightly larger in size at maturity than male. This is can be related to environmental factors that has been experienced in the region for some seasons as indicated by Johansson and Svensson.

Conclusion and Recommendation

In Lake Baringo, the growth of Baringo barb is positive allometric growth, with females attaining bigger sizes than males in both length and weight. Sex ratio of males: females are not 1:1, however the biased sex ratio could not be explained due to the short duration of the study. The most important food items of Baringo barb in Lake Baringo were detritus, algae and seeds but other food items were present suggesting the species is largely a benthic feeder. Baringo barb growth in Lake Baringo shows positive allometry (b was greater than 3) b>3. It is recommended that longer term studies covering all seasons are necessary to obtain a clearer understanding of the growth, feeding and reproductive biology of the species in Lake Baringo.

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Compliance with Ethical Standards

All the experiments carried out in the current study comply with the laws of the Republic of Kenya.

Conflict of Interest

The authors declare no conflict of interest

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