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Hybridization between non-indigenous *Oreochromis niloticus* and native *Oreochromis* species in the lower Kafue River and its potential impacts on fishery

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In the Kafue floodplains, Zambia, a study was done to determine whether meristic and/or other morphological metrics could distinguish putative hybrids (based on color patterns) between non-indigenous *Oreochromis niloticus* (Nile tilapia) and two native species of *Oreochromis andersonii* (three spot tilapia) and *Oreochromis macrochir* (green head tilapia) from the pure parental strains. We also surveyed local fishermen to document their knowledge and beliefs on the spread of *O. niloticus* in the last decade, the occurrence of hybridization, and any changes in catch per unit effort of these and other species. A sample of fifty fish specimens were collected for morphometric and meristic data using gill nets and seine nets, and augments by specimens purchased from the catches of local fishermen. A full standard multi-filament net with mesh sizes ranging from 25 to 150 mm in increments of 12.5 mm mounted in a fleet was used. The seine net used was of 25 mm mesh size, approximately 100 m long and 2 m high at the pocket. We analyzed the morphological and meristic data using the program STATISTICA. Our results confirm that: in the last decade, *O. niloticus* has spread throughout the Kafue floodplains from its initial site of introduction near the eastern end of the Kafue floodplain; putative hybrids between *O. niloticus* and *O. andersonii* cannot be distinguished from parental species based on morphometric or meristic traits; and survey results of local fishermen indicate that they have experienced increases in catch per-unit- effort of *O. niloticus* while simultaneously experiencing decreases in catch per-unit-effort of native tilapia.

Key words: Indigenous knowledge (IK), hybridization, native, invasive species, morphometrics, meristics, Kafue River.

INTRODUCTION

In Zambia, subsistence and commercial fish catches are important for social and economic development of communities and the nation. The fisheries sector contributed 1.24% to the Gross Domestic Product (GDP) between 2002 and 2007 (Musumali et al., 2009) equivalent to US$51- 135 million per annum. The fishery sector plays a pivotal role in the economy through employment especially to the rural poor and provides an affordable animal protein source for many households in Zambia. Over 300,000 people in Zambia earn their income directly as fishers and fish farmers or indirectly as traders, processors and other service providers (Musumali et al., 2009).

The production of fish from aquaculture has been on a steady increase globally. Aquaculture has been noted to be one of the fastest growing food-producing systems in the world (Ahmed and Lorica, 2002). Tilapia culture has seen a rapid global expansion especially in developing countries (El- Sayed, 2006) and it is practiced in over 100 countries globally (FAO, 2004). Due to the environmental challenges associated with terrestrial agriculture, tilapia culture has been promoted as an important source of animal protein that could provide food security especially for developing countries (Canonico et al., 2005). In 2010, approximately 32 million tonnes of farmed tilapia was produced worldwide (FAO, 2012). *Oreochromis niloticus* (Nile tilapia) and its hybrids comprise approximately 80% of the total tilapia aquaculture production in the world (FAO, 2006). While global tilapia production contributes substantially to economic development, the escape or release of tilapia into the waters outside their native range is a concern for a number of reasons (Canonico et al., 2005).

Introduced tilapia species, typically of the genus *Oreochromis,* which establish feral populations can cause adverse ecological impact such as the competition with the native species for food, breeding sites and habitats (Canonico et al., 2005). They may also cause eutrophication especially in intensive tilapia culture due to release of excreta into the water and spread pathogens and parasites to native fish species (Starling et al., 2002; Dabbadie and Lazard, 2010). These factors may cause reduction in biodiversity of the receiving ecosystem and population of native fish species. When formerly isolated tilapia species are brought into contact through introduction mediated by aquaculture, hybridization with closely related native species may occur and have negative genetic impacts by the production of hybrids in the population (D'Amato et al., 2007). This may threaten or even eliminate pure native wild populations that are important genetic resources for future aquaculture breeding programs (Lind et al., 2012). Furthermore, reduced fecundity has been reported in some hybrids, which may eventually lead to lower fish yields (Amarasinghe and De Silva, 2010).

In addition to aquaculture, tilapias have been introduced for biological control of aquatic weeds and insects, as bait for capture fisheries and for re-stocking of capture fisheries (Canonico et al., 2005). Among the tilapias introduced in many parts of Africa, *O. niloticus* (Nile tilapia) and its hybrids account for over 90% of the production (Senanan and Bart, 2010). Since its introduction in Lake Victoria in the 1950s, it has spread to Eastern and Southern Africa as far as the Limpopo River in South Africa due to intentional introduction especially for aqua-culture purposes (Wise et al., 2007). Several reports indicate that in many freshwater systems in Africa where Nile tilapia has been introduced and has established itself and is productive, it has completely eliminated the native *Oreochromis* species (Shipton et al., 2008). *Oreochromis niloticus* has become invasive in many water and wetland systems as a result of intentional introductions or escapes from aquaculture facilities (Gupta et al., 2004). In Lake Victoria, for example, the introduction of Nile tilapia completely eliminated *Oreochromis esculentus* within a period of 30 years (Goudswaard et al., 2002; Wise et al., 2007). The establishment of feral populations of Nile tilapia in an ecosystem is almost impossible to control and the only way to reduce the impact of this species is to prevent its entry into new freshwater habitats (Wise et al., 2007).

According to Schwanck (1995), *O. niloticus* ((locally known as 'Namadama' (fish from the dams) or 'Wamunyima' (name of the manager at Zambia Sugar Estate who kept the fish) was imported together with *Oreochromis aureus* from the University of Stirling in 1982 and in 1988 and introduced into the Kafue catchment area by the Zambia Sugar Estate. However, by 1990 *O. aureus* had disappeared because it did not breed well. At the same time, Kafue Fisheries Ltd cultured the *O. niloticus* further down the Kafue River. Utsugi and Mazingaliwa (2002) reported that during the flood of 1989, fish escaped into the Kafue River. The first catches of Nile tilapia were reported in 1992 in the Kafue River (Shipton et al., 2008), and were spreading in 1994 (Schwanck, 1995).

The presence of introduced *O. niloticus* in the Kafue River, and its hybridization with at least two native species (*Oreochromis andersonii* and *Oreochromis macrochir*), has been documented with genetic analysis (Deines et al., 2014). In particular, individuals with both the vertically barred tail of *O. niloticus* and the lateral black spots of *O. andersonii* were confirmed to be hybrids between the two species (Figure 1D). In this paper, we extended these results by: surveying local fishermen to qualify their assessment of the occurrence of *O. niloticus* and hybrids in the Kafue floodplain, and their assessment of any changes in catch-per-unit-effort of *O. niloticus* and native species; and test whether putative hybrids (with both the barred tails and lateral spots) can also be distinguished

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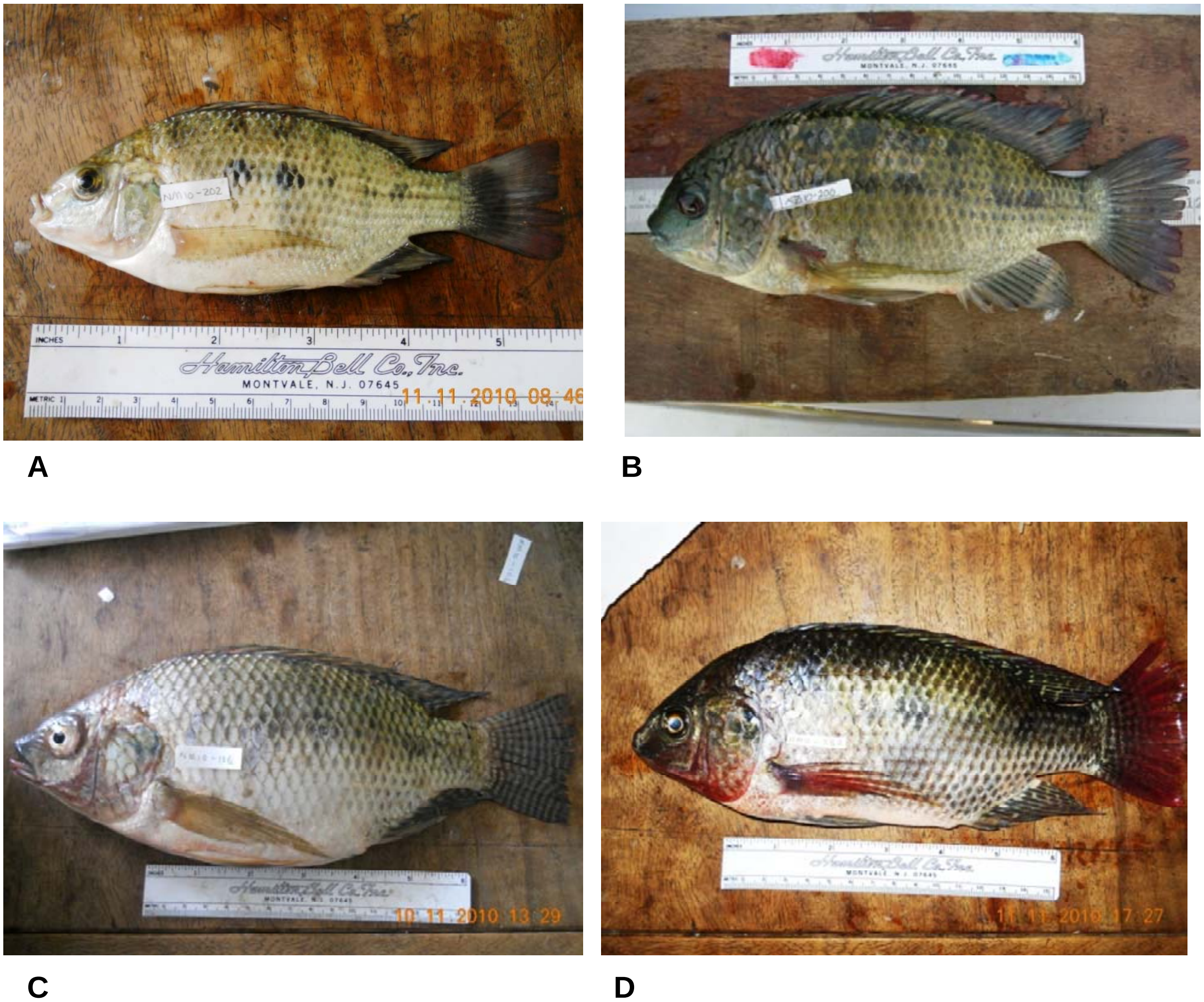

Figure 1. Fish species: (A) *Oreochromis andersonii*, (B) *Oreochromis macrochir*, (C) *Oreochromis niloticus*, (D) Putative hybrid (*O. andersonii* x *O. niloticus*).

from parental species on the basis of morphometric or meristic traits.

METHODS

Study area

The Kafue River system supports an extensive fishery in Zambia. It covers a stretch of about 1,576 km and an area of 152,000 km^2. The Kafue flood plains themselves are 250 km long and 60 km wide covering an area of approximately 6,500 km^2 (Figure 2) (Chabwela and Mumba, 1988). The Kafue fishery is mainly exploited by artisanal fisherfolks using fibre glass and dug-out canoes. They use a variety of fishing nets such as gill nets and seine nets as well as hooks to catch fish. Their nets range in size from 1" – 7" (2.54 cm – 17.78 cm) mesh. Illegal fishing methods are very common such as the use of explosives and 'Kutumpula' bashing water to drive fish towards the nets.

The fish species composition of ten most important fish species in the Kafue fishery for the period 1985 to 2005 included: *Clarius gariepinus, Schilbe intermedius, Marcusenius macrolepidotus, Serranochromis angusticeps, Serranochromis macrocephalus, Oreochromis andersonii, Clarius ngamensis, Synodontis kafuensis, Hepsetus odoe* and *Sargochromis condringtoni* (Nyimbili, 2006). Over the years, there has been a decrease in catch per unit effort of these species.

Interviews of fishermen

With the approval of the Zambian Department of Fisheries, and following the approach of Schwanck (1995), we conducted interviews on 14 fishermen in 7 of the sampling sites (Choongo, Musa Gate, Chitobolo, Namwala, Nyimba, Kapongo and Cheba) (Figure 2) to qualify their assessment of how the occurrence of *O. niloticus* changed over time, and any changes in catch-per-effort of *O. niloticus* and native species. Fishermen were selected with the aid of local authorities who identified them as experienced and

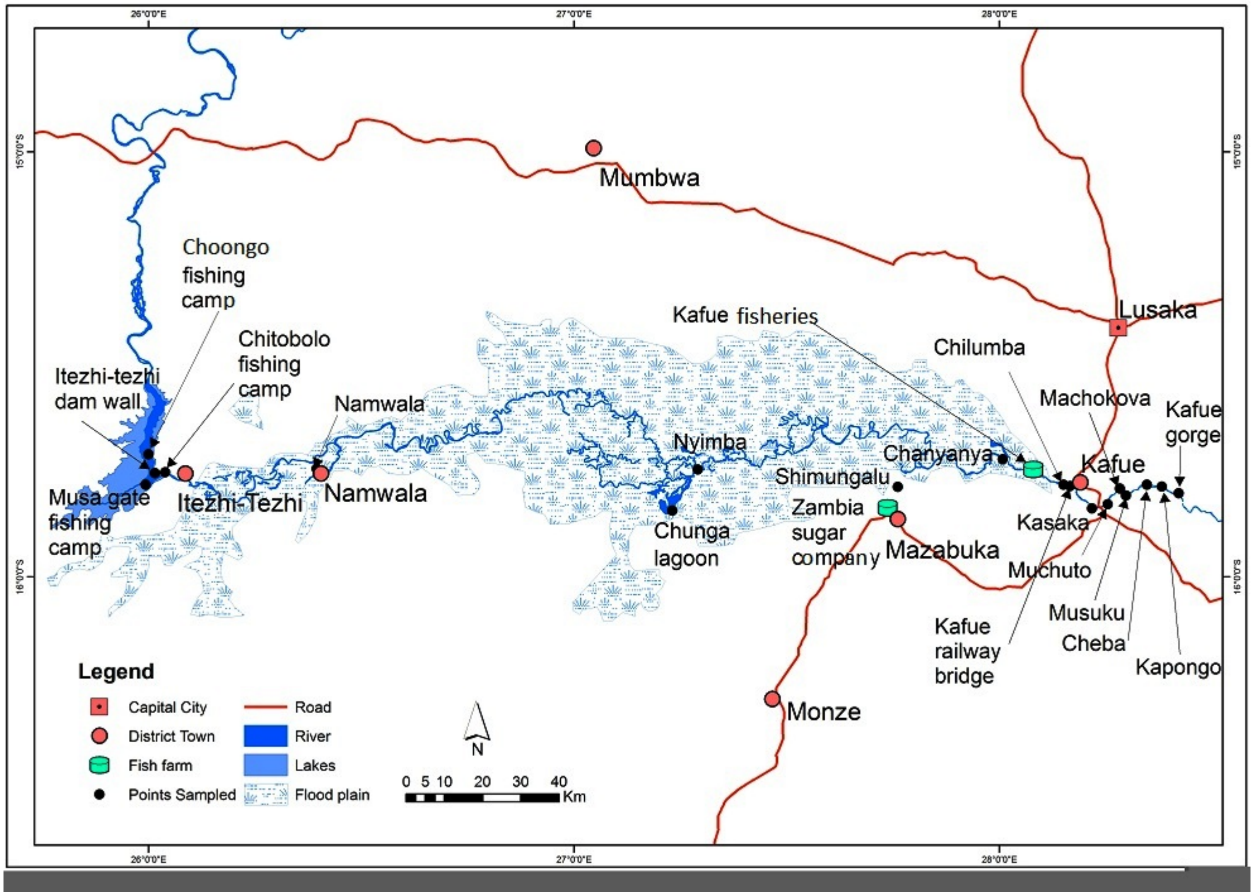

Figure 2. Fishing camps and actual sites sampled on the Kafue floodplains.

having been in the industry for more than 10 years. The questionnaire was administered in the local dialect and the responses were written by the questioners who included the author and the local fishery personnel. The responses used in this paper were: the person's fishing location, fishing method, type of species targeted, what species they have observed to be increasing or decreasing. The questionnaires were also designed to find out how much information the fishermen had on *O. niloticus*. The information on *O. niloticus* included; whether they have caught the species before, which year they made their first catch if they have caught it before, the catch per effort of the species and whether they have observed any changes in the catch per effort of native *Oreochromis* species since its introduction.

Fish sampling

Sampling was done in six sites and additional samples were collected from fishermen in four other different sites. *Oreochromis niloticus*, *O. macrochir* and *O. andersonii* were identified using Skelton (2001). The putative hybrids were identified as individuals with the distinct vertical stripes of *O. niloticus* on the caudal fin and either the three or four conspicuous black mid-lateral blotches of *O. andersonii* or the steep rounded head profile of *O. macrochir* (Trewavas, 1983) (Figure 1).

A total of 50 individuals were sampled for morphometric measurements and meristic counts from 10 sampling sites along the length of the Kafue floodplains (Figure 2 and Table 1). *Oreochromis niloticus* had previously been detected at some of the sampling sites (Schwanck, 1995). Sites at Choongo and Musa Gate are above the Itezhi-tezhi Dam where there is no indication that *O. niloticus* is present.

Samples of *Oreochromis* species were collected using a standard gillnet survey, seine nets and from fishermen during the 2010 low-water season (August-September). Gillnets set was carried out for three consecutive nights in six sampling sites. A full standard multi-filament net with mesh sizes of 25, 37.5, 50, 62.5, 75, 87.5, 100, 112.5, 125, 137.5 and 150 mm mounted in a fleet was used. Each net used measured 45 m and the fleet used was, therefore 495 m long. The setting of the nets was done at approximately 6 pm and removed the following day at 6 pm.

Fish samples were supplemented using beach seine nets at Choongo and Namwala sites. The seine net used was of 25 mm mesh size, approximately 100 m long and 2 m high at the pocket and was dragged by six men over a period of about 20 to 30 min. Two hauls were made consecutively. Other fish samples were collected from the local fishermen after carefully studying their catches. Most of their catches were mainly from seine nets. Collections supplemented from fishers took place at Chitobolo, Chilumba, Kasaka and Kapongo (Figure 2).

A colour photograph of each fish sampled was taken. Each fish was then individually placed in a polythene bag and preserved in 10% formalin in 20 L buckets according to species for further processing as described below.

Morphometric measurements and meristic counts

Morphometric measurements and meristic counts of each fish were obtained according to methods of Barel et al. (1977) and Snoeks

Table 1. Fish sampled for morphometric measurements and meristic counts

Specie	Sampling site	Total length range (mm)	Total fish sampled
Oreochromis andersonii	Choongo, Namwala, Chunga lagoon, Nyimba, Shimungalu, Chanyanya, Kasaka, Kapongo	141-274	18
Oreochromis macrochir	Namwala, Chunga lagoon, Nyimba, Shimungalu, Chilumba, Kasaka	69-380	14
Oreochromis niloticus	Chitobolo, Chunga lagoon, Nyimba, Shimungalu, Chilumba	122-256	12
Putative *O. andersonii* x *O. niloticus*	Namwala, Shimungalu, Kapongo	192-246	6

(1994). These measurements were taken using a vernier calliper to the nearest 0.01. The meristic counts were done under a dissecting microscope.

The morphological measurements taken were: Lachrymal depth (LacrD) defined as preorbital depth (POD), snout length (SnL), lower jaw length (LJL), premaxillary pedicel length (PPL), cheek depth (ChD), horizontal eye diameter/eye depth (EyD), vertical eye diameter/eye length (EyL), inter-orbital width (IOW), head width (HW), head length (HL), standard length (SL), body depth (BD), dorsal fin base length (DFB), anal fin base length (AFB), pectoral fin base length (PFL), predosal distance (PrD), prepelvic distance (PrP), prepectoral distance/preventral distance (PrV), preanal distance (PrA), caudal peduncle length (CPL), caudal peduncle depth (CPD)

The meristic counts taken included: the upper and lower jaw teeth numbers (UJT and LJT), inner tooth rows, dorsal fin spiny rays (DSPIN) and dorsal fin soft rays (DSOFT), anal fin spiny rays (ASPIN) and anal fin soft rays (ASOFT), upper and lower lateral line scales (ULL and LLL), lateral line to anal fin scales (LLA), pelvic/ventral fin scales (PV), number of scales between the dorsal fin and the upper lateral line (DLL), scales around the caudal peduncle (CP) and cheek scales (CK).

Data analysis

Interviews

The information provided by the fishermen on the questionnaires was analysed to reveal the general understanding the fishermen had on introduction of *O. niloticus*. We found this was possible because Nile tilapia were easily distinguished by fishermen from other tilapia by the presence of stripes on the caudal fin, a characteristic not possessed by other species of tilapia (Trewavas, 1983).

Morphometric and meristic data handling

The morphometric and meristic data were analyzed using STATISTICA Version 5 (StatSoft, Inc., 1997). The raw morphometric data were transformed into logarithms and subjected to PCA to extract principle components.

The data were then used to plot relationships among the fish species based on principal component (PC) 2 and PC 3. Principal component 1 was not used in morphometric analysis because in multivariate allometry PC 1 represents the size and shape as all the characters are correlated positively with this component (Lleonart et al., 2000). Meristic count data where analyzed based on PC 1 and 2. This is because meristic counts are not influenced by allometry on PC 1. The factor loading was used to identify which of the morphometric and meristic characters were causing most variations among the fish.

RESULTS

Distribution of *Oreochromis* species in the Lower Kafue River

The invasive species *O. niloticus* was found along the whole 250 km stretch of the Kafue floodplains. It was however, absent in the stretch of the Kafue River upstream of the Itezhi-tezhi Dam during this study. The local fishermen also confirmed that they had not caught *O. niloticus* in the Kafue River upstream the Itezhi-tezhi Dam wall. They also indicated that their first catch of *O. niloticus* on the Kafue River below the Itezhi-tezhi Dam wall was around the year 2002. The information from the local fishermen indicated that by 2004 *O. niloticus* was present in all areas in the Kafue floodplain.

During this study, *O. niloticus* catch was higher than both *O. andersonii* and *O. macrochir* catches for almost all the sampling done using both seine and gill nets. Our observations of a subset of catches by fishermen were consistent with the pattern reported by the fishermen: *O. andersonii* was the least frequent in most of the catches. In Shimungalu, Chunga lagoon and Nyimba, *O. andersonii* was very rare.

Survey results

Twelve of the fishermen interviewed were using dug-out canoes as fishing vessels while two were using small engine boats. They were using both seine nets and gill nets with mesh sizes ranging mainly between 1-3½ inches (25.4 to 88.9 mm).

All the fishermen interviewed were aware of the presence of *O. niloticus.* By 2004, *O. niloticus* had spread upstream as far as the Itezhi-tezhi Dam and downstream to Kapongo (Kafue Gorge Dam) (Table 2). All except one of the fishermen interviewed reported observing high catch-per-effort of *O. niloticus* in their fishing areas, and the species is among the three most targeted fish species,

Table 2. Results from interviews of fishermen conducted during the study. Sites are ordered from west to east (see Figure 2)

Site	Number of fishermen interviewed	Type of fishing vessel	Type of nets used	Mesh size (mm)	Year started fishing	First catch of *O. niloticus*
Choongo	1	Dug-out canoes	-	-	-	No *O. niloticus*
Musa gate	1	Dug-out canoes	-	-	-	No *O. niloticus*
Chitobolo	1	Dug-out canoe			-	2002
Namwala	5	Dug-out canoes	Seine nets Gill nets Hooks	1¼" - 3½"	1979, 1994, 2004	1996, 2001, 2004
Nyimba	4	Small engine Fibre glass Dug-out canoes	Seine, Gill Rod and line	1.0" - 6.0"	1976, 1992, 1994	1994, 2000, 2001
Cheba	1	Dug-out canoes	Seine	1¼"	1978	1995
Kapongo	1	Dug-out canoes	Seine	1¼"	1982	2004

and among the three most commonly caught species together with *Tilapia rendalii* and *Barbus* species (Figure 3).

Oreochromis niloticus was one of the fish species that fishermen reported increasing in catch-per-effort together with Redbreast tilapia (*T. rendalii*) (Figure 4). Fishermen identified *O. andersonii* and *O. macrochir* as fish species for which the catch-per-effort had declined (Figure 4). Fishermen reported catching fish possessing features of both *O. niloticus* and *O. andersonii,* suggesting potential hybridization between these species.

Morphometric and meristic results

A total of 50 specimens sampled from the Kafue floodplain were assigned species identification according to morphology and colour patterns: *O. niloticus, O. andersonii, O. macrochir* and putative hybrids between *O. niloticus* and *O. andersonii*.

Overall, the PCA results provided clear discrimination among the three parental species, but the putative hybrids always clustered with *O. niloticus*. PCA results distinguished *O. andersonii* from *O. niloticus* on PC 2 although a few individuals from both species overlap. *Oreochromis andersonii* is similar to *O. macrochir*. On PC 3, *O. macrochir* is different from *O. andersonii* but similar to *O. niloticus* and the putative hybrids.

The three morphometric characters that showed most significant variations between putative species along PC 2 included: Premaxillary pedicel length (0.4007), lower jaw width (-0.3492), and caudal peduncle length (-0.2876). The variations between species along PC 3 were mainly due to: vertical eye diameter/eye lengthy (-0.2987), horizontal eye diameter/eye depth (-0.2762) and anal fin base length (0.2357) (Figure 5).

The meristic results indicate that the fish species could only be separated on PC 2 where *O. macrochir* is different from both *O. andersonii* and *O. niloticus* and the putative hybrids. Again, the putative hybrids clustered together with *O. niloticus*.

The three meristic characters that showed the most significant variations along the PC 1 include: Upper lateral line scales (0.8293), anal fin soft rays (0.7688) and lower lateral line scales (0.6555). On PC 2 they include: Number of scales between the anal fin and upper lateral line (-0.3971), caudal peduncle scales (-0.3249) and dorsal fin soft rays (0.3038) (Figure 6).

DISCUSSION

Indigenous knowledge of the distribution of *O. niloticus*

This study has revealed that *O. niloticus* is now distributed along the whole of the 250 km stretch of the Kafue floodplains. Schwanck (1995) survey found *O. niloticus* confined within a stretch of 75 km between Muchuto and Kachola in the eastern region of the floodplain. However, he rightly predicted that *O. niloticus* would expand its range upstream, being finally restricted by the Itezhi-tezhi Dam wall. The sampling done at Choongo upstream before the dam wall and the study of the fishermen catches at Musa Gate also before the dam wall revealed no presence of *O. niloticus*. This means that the dam wall has acted as a geographical barrier preventing further spread of the *O. niloticus* upstream.

The sampling conducted during this study at different sites and the study of tilapia catches from fishermen along the floodplain showed higher catches of *O. niloticus* followed by *O. macrochir* and *O. andersonii* which was least. A study by Chikopela et al. (2011) in three major habitats of the Kafue floodplains revealed that *O. niloticus* had the highest index of relative importance (IRI) and contributed most to the diversity and evenness of the floodplain as compared to *O. andersonii* and *O. macrochir*. *Oreochromis niloticus* had not only established its popu-

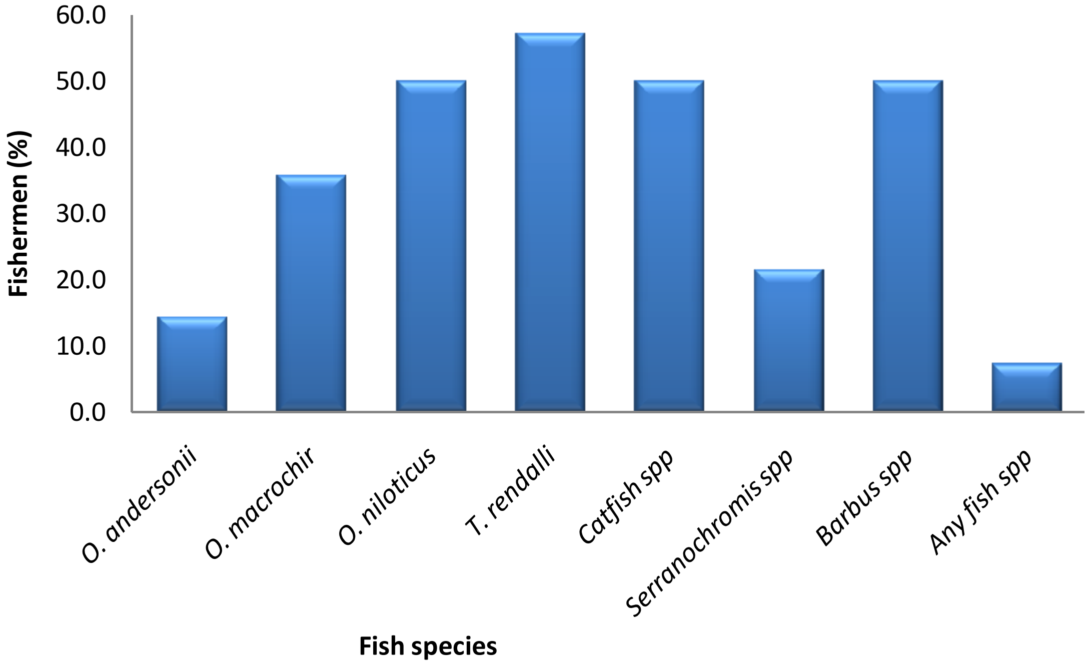

Figure 3. Fish species caught by local fishermen interviewed.

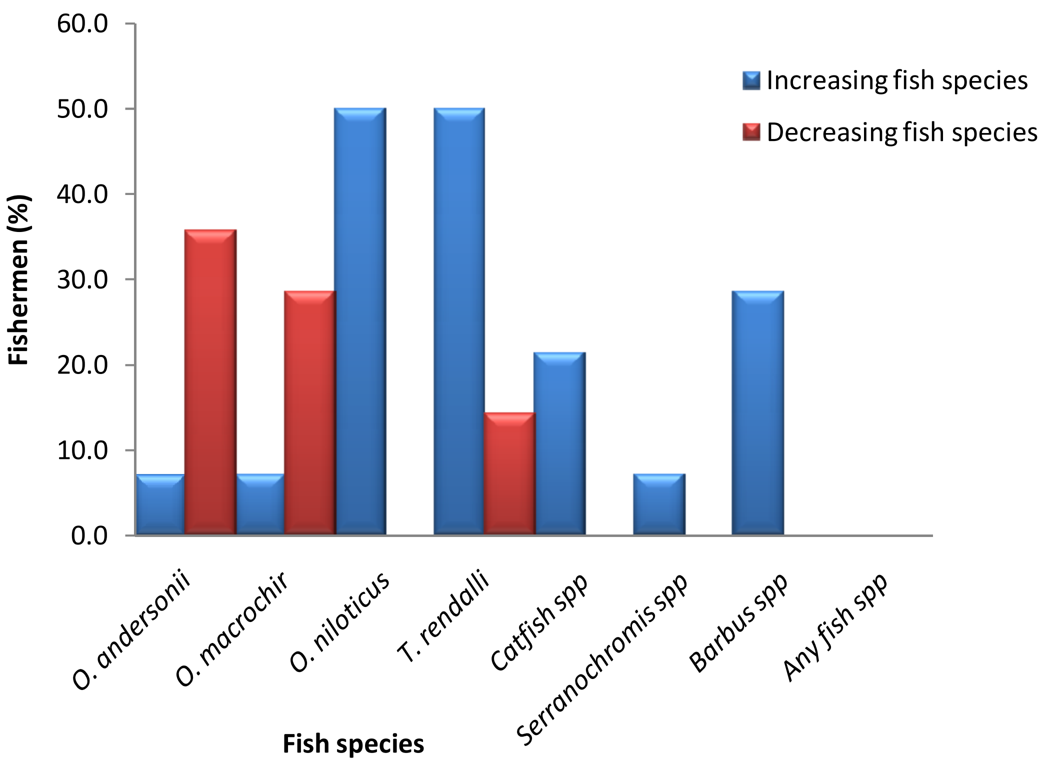

Figure 4. Increasing and decreasing fish species as reported by the local fishermen interviewed.

lation in the Kafue but has dominated the numbers among the mouth brooding tilapiines (Chikopela et al., 2011). The local fishermen interviewed have also reported a decrease in catch-per-effort of both *O. macrochir* and *O. andersonii* catches since the introduction of *O. niloticus*. This seems to indicate that the introduction of

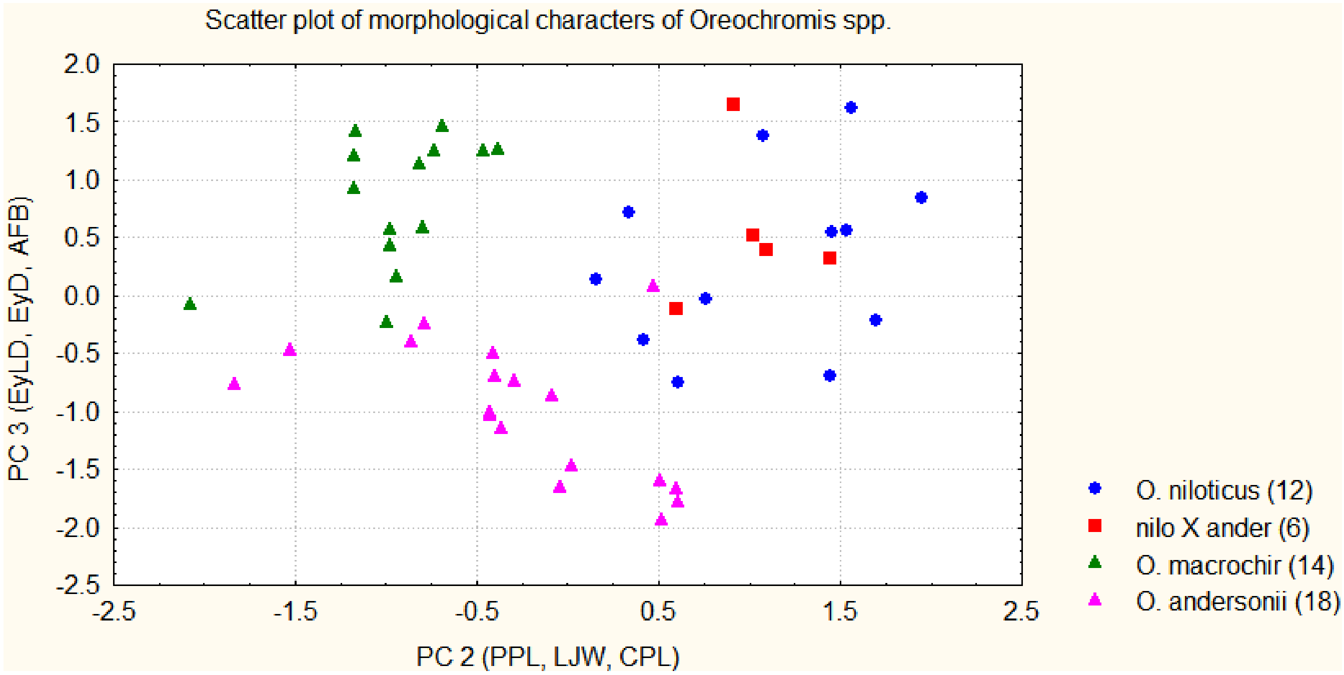

Figure 5. PCA plot of morphometric characters of *O. niloticus, O. andersonii* and *O. macrochir* including suspected hybrids. Each data point represents an individual fish. PPL = Premaxillary pedicel length, LJW = lower jaw width, CPL = caudal peduncle length, EyLD = vertical eye diameter/eye lengthy, EyD = horizontal eye diameter/eye depth, AFB = anal fin base length.

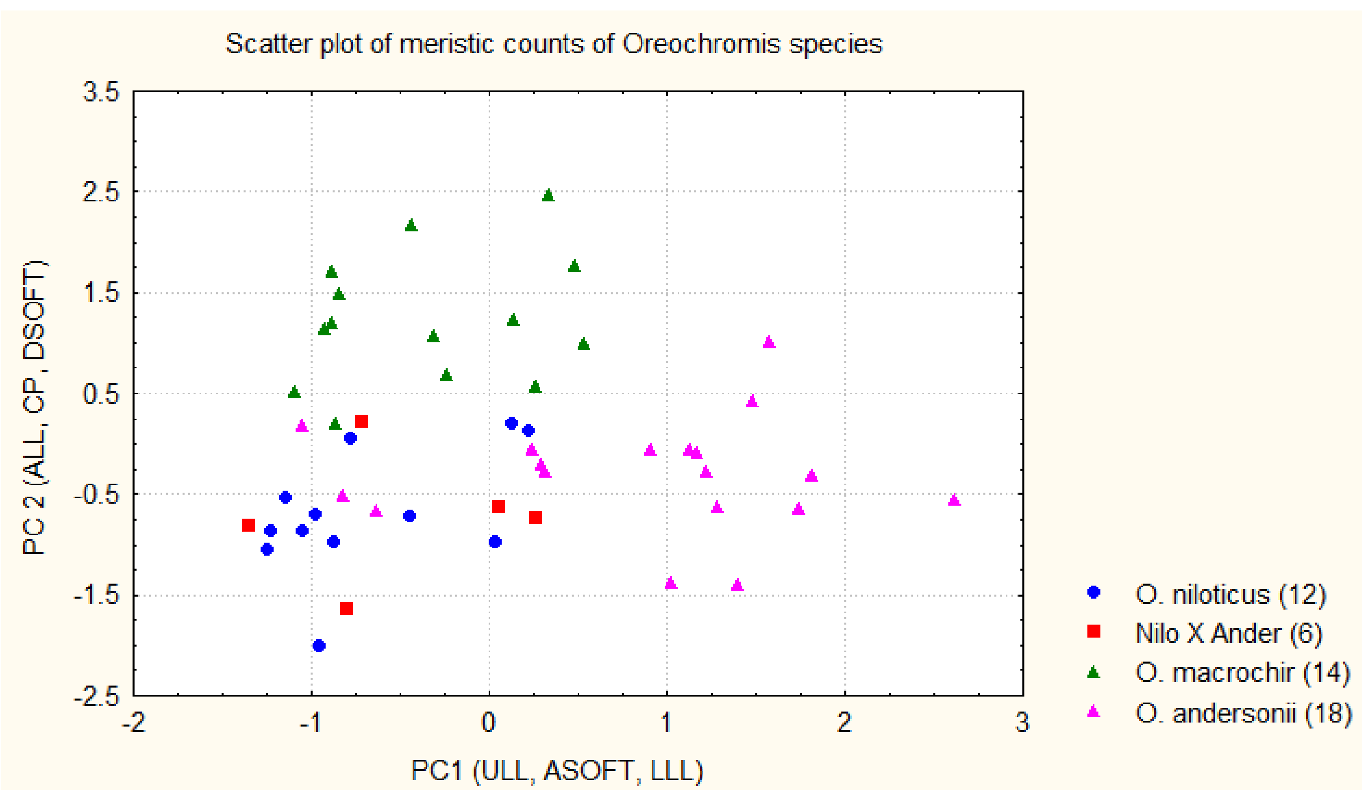

Figure 6. PCA plot for meristic counts of *O. niloticus, O. andersonii* and *O. macrochir* including suspected hybrids. Each data point represents an individual fish. ULL = Upper lateral line scales, ASOFT = anal fin soft rays, LLL = lower lateral line scales, ALL = number of scales between the anal fin and upper lateral line, CP = caudal peduncle scales, DSOFT = dorsal fin soft rays.

the non-indigenous *O. niloticus* may have an impact on the population of other related species like *O. macrochir* and *O. andersonii*. This assumption may not be conclusive since sampling was not done throughout the year. In addition, fishing pressure, introduction of non-indigenous crayfish (*Cherax quadricarinatus*) which three of the fishermen reported, or other unmeasured factors could contribute to the decline in catch-per-effort of native fishes during the spread of *O. niloticus*.

Taken at face value, however, the reduction in catches of *O. andersonii* reported by fishermen, and its apparent absence in areas closest to the point of release of *O. niloticus* like Shimungalu in Mazabuka indicate a strong negative interaction with O. *niloticus* leading to the establishment of the non-indigenous species at the expense of the indigenous species. The probable explanation of this is the potential of *O. niloticus* to hybridize with other *Oreochromis* species followed by the extinction of the hybrids leaving only pure *O. niloticus* strains (Shipton et al., 2008). The takeover is usually preceded by a period of introgressive hybridization (Schwanck, 1995).

Some fishermen reported that they had seen *O. niloticus* individuals possessing features of other native *Oreochromis* species, especially the three or four spots of *O. andersonii* consistent with the hybridization confirmed by Deines et al. (2014).

While the socio-economic impact arising from the introduction of *O. niloticus* in the Kafue floodplains was not investigated fully in this study, the fishermen interviewed had different views on the effect of *O. niloticus* on their catches. Among the fishermen interviewed, 41.7% of them felt that *O. niloticus* has affected their catches of native tilapia while 33.3% said it did not. Another 25% of fishermen interviewed did not know whether there was an effect or not. The fishermen claimed that the introduction of *O. niloticus* has reduced their sales of native tilapia which are one of the most preferred fish in Zambia which also fetch a higher cost. This is because they are not able to catch large quantities of native tilapia as they used to before *O. niloticus* was introduced. Some felt that their income has reduced because *O. niloticus* cannot be preserved for a longer time as compared to the native tilapia. Some fishermen interviewed confirmed that they have resorted to the use of bad fishing methods like ‘bashing’ the water to drive fish to the set nets in order to catch native tilapia.

These results suggest that establishment and spread of *O. niloticus* throughout the Kafue floodplains may pose a threat to the ecology and existence of local *Oreochromis* species. The invasion of *O. niloticus* may also pose a challenge to the sustainability of the fishery and eventually the livelihoods of people dependent on the fishery. This is because a fishery which usually exploits variety of species is more likely to be sustainable than one which depends on only a few species (Dulvy et al., 2000). As long as catch-per-effort of *O. niloticus* remains high, the fishery may be maintained, but perhaps be moving to an *Oreochromis* monoculture of *O. niloticus*.

Hybrids identification based on morphometrics and meristics

Our analysis demonstrated that morphometric and meristic traits are no use in distinguishing hybrids of *O. niloticus* x *O. andersonii* from parental individuals. Thus where genetic analysis is not possible future studies on hybridization will have to continue to rely on colour patterns to identify hybrids, while acknowledging that not all hybrids and backcrosses possess the mixed colour patterns (Deines et al., 2014). However, any estimate of the prevalence of hybridization will be poor without genetic analysis, especially because genetic analysis from specimens on the Kafue floodplain revealed hybrid mixture of all the three *Oreochromis* species, while colour patterns had suggested hybridization involving only *O. niloticus* and *O. andersonii* (Deines et al., 2014).

Implications

The issue of food security, dietary and nutritional needs of people in local communities illustrates a concern that goes beyond the potential ecological and genetic impacts on biodiversity of escaped tilapias from aquaculture facilities into receiving ecosystems such as dams, rivers, wetlands or lakes (Seaman and Bart, 2010). As noted by the WorldFish Centre (2009), fish is an important food for over 400 million Africans, contributing essential proteins, minerals and micronutrients to their diets. Zambia is no exception. Fish in Zambia is estimated to provide about 40% of the animal protein intake. It therefore, plays an important role in the food and nutrition of the Zambian people more especially the urban poor and people living with HIV and AIDS (Musumali et al., 2009).

Taking the case of the Kafue flood plains, fishing is a major mainstay industry for local communities. The observation in this study of the possibility of hybridisation and its potential threats to native fish species that provided food security, employment, economic security, and self-sustenance for this largely rural part of Zambia raises serious concerns. In this fishery, just as in other fishery areas, fishing provides income almost all year round to men, women and youths who cannot find other sources of income.

The results of this study suggest that the presence of *O. niloticus* in the Kafue floodplain has had an impact on the indigenous *Oreochromis* species. Fishermen reported a reduction in the catch-per-effort of the native *Oreochromis* species which are commercially important and which are widely favoured by most Zambians. The poverty situation is already apparent in the Kafue floodplains as some of the fishermen interviewed were requesting the government to send them relief food, especially during the fish ban period between February and March annually. This is because they cannot catch enough to sustain their families.

Recognising the risks inherent with any species introduction, and the particular risks quantified here on the Kafue floodplain (loss of genetic identity of native tilapia, reported loss of income by fishermen), FAO (1996) advocates that the Precautionary Principal should apply, a consideration relevant to the Zambian Department of Fisheries and similar agencies in other countries to consider with regard to potential future introductions of *O. niloticus*. FAO (2006) recommends that the governments reduce risks of adverse impacts of introduction on capture fisheries to establish corrective or mitigating procedures in advancement of actual adverse effects, and to minimize unintended introduction to wild ecosystems and associated capture fisheries. Loss of native species can lead to loss of genetic diversity necessary for future food security and poverty reduction (Lind et al., 2012). According to Musumali et al. (2009), about 68% of the Zambian population live below the poverty line. It is more rampant in the rural area were about 81% live in poverty.

The poverty and food insecurity in Zambia stems from the over reliance on rain-fed agriculture, and associated effects of frequent unfavourable climatic conditions, along with inadequate incomes, access to markets and transport facilities to enable the transfer or purchase of food. This is compounded by low economic diversification into sectors such as fisheries that could supplement crop production. Food security entails the access to enough amounts of safe, nutritious and quality food. For communities in this study, wild fishing is an important if not the most vital activity by which local families meet their food needs and achieve economic security. Anything that disturbs this vital source of nutrition and economic livelihood is likely to embolden poverty, imperil food security, and thwart self-sustenance aspects of their food security.

Conclusion

This study has revealed that the local fishermen throughout the Kafue floodplain are very aware of the introduction of *O. niloticus* in their fishery. They have reported an increase in catches of *O. niloticus* and associate this increase with the reduction in catches of native *O. andersonii* and *O. macrochir*. Moreover, they have observed apparently hybrid fish that combine characteristics of *O. niloticus* and native *Oreochromis* species.

There are differences in morphological characters of *O. niloticus*, *O. andersonii* and *O. macrochir* consistent with their classification as different species. However, the hybrids between *O. niloticus* and *O. andersonii* could not be distinguished from *O. niloticus* based on the quantifiable morphometric and meristic measurements.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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