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# Challenges in fisheries management in the Zambezi, one of the great rivers of Africa

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**Abstract** Almost all fisheries in the Zambezi River system have experienced severe declines in catch rates, loss of larger, most valuable fish species, and increased use of environmentally damaging active fishing gears. The fisheries of the Barotse, Caprivi and Kafue floodplains, and lakes Kariba (Zambian sector), Malawi and Malombe are all fished down. The concept of balanced harvesting with moderate effort has no relevance to these African inland fisheries, where rapid human population growth and lack of alternative livelihoods for small-scale fishers means they have no choice but to continue fishing despite dwindling returns. In some areas, e.g. Liuwa Plain National Park in Zambia and conservancies in Namibia, comanagement with local communities has potential for success, but other fisheries, e.g. Lake Malombe in Malawi, are so severely fished down that there is no prospect of recovery without radical restructuring of exploitation patterns coupled with habitat restoration.

KEYWORDS: African fisheries, comanagement, cpue, fisheries exploitation, floodplains, lakes.

## Introduction

The Zambezi River is, at 2574 km, the fourth longest river in Africa, encompassing eight countries with a catchment area of 1.39 million km$^2$. Subsistence and commercial fishing, and angling tourism, are major activities throughout the system, which includes several large lakes and numerous, highly productive floodplains (Tweddle 2010).

As is the case in many inland fisheries (Allan *et al.* 2005; Welcomme *et al.* 2010), those of the Zambezi are economically overfished (Weyl *et al.* 2010). Catch rates are decreasing, fish communities are changing, and larger, more valuable, species are being replaced by smaller, much less valuable species (FAO 1993; Tweddle *et al.* 1995; Weyl *et al.* 2004b, 2005b, 2010; Peel *et al.* 2013; and see section on Lake Kariba below). As a result, impoverished rural fishing communities have become trapped in a cycle of declining individual catches resulting from increased effort, reduced mesh sizes and ultimately use of environmentally destructive

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fishing gears such as large beach seine nets lined with cloth to catch the few remaining small fish species that can survive the intense, unrelenting effort.

Welcomme (1999) discussed evaluation of exploitation levels in multispecies inland fisheries, a review of direct relevance to all Zambezian fisheries. He concluded that three basic strategies can be adopted for management in inland fisheries, that is (1) manage the fishery only for large species of high commercial value, (2) maximise yields, but conserve the fish assemblage as far as possible and (3) allow the fishery to become fished down.

Strategy 1 states that although the yield would be less than maximal, the catch value may offset this. Control of effort is needed together with gear restrictions on fishing for smaller fish in case this impacts on the target species. Welcomme (1999) stated that on the whole this strategy proves unsuccessful when demand for fish is high, as in the Zambezian fisheries described below.

Strategy 2 is optimal in that it allows for the taking of a maximum yield without allowing a fishing down process to occur. In reality, as Welcomme (1999) stated, such a strategy is difficult to implement, but a solution is to transfer responsibility for the fishery to the fishing communities through a system of comanagement. He stressed that to be effective this entails education of the fishing communities and support for locally oriented fishing strategies.

Strategy 3 is disastrous in that such fisheries constantly deliver less than their former potential. It has been argued that observed declines in Zambezi fisheries may be due to environmental changes (e.g. Van Zwieten *et al.* 2003; for Lake Malombe in Malawi) and that overfishing cannot occur because if catches drop too low then fishers will simply stop fishing and take up other economic opportunities (Kolding & van Zwieten 2012, 2014). These perceptions, however, do not take into account that in impoverished communities fishers are forced to continue fishing despite severe declines in quantity and quality of fish catches, simply to survive. Quantitative and qualitative proof of failures in fisheries management in the Zambezi system presented here show that most currently fall under Strategy 3, despite progressive legislation in riparian countries that promotes comanagement of the fisheries and should therefore allow for management scenarios that promote Strategy 2.

It is accepted that in many circumstances, particularly in floodplain fisheries, regulations preventing the capture of the numerous, small pioneering species are misguided (Kolding & van Zwieten 2014) and that government perceptions of river and floodplain fishery management needs are flawed and need modification. In the majority of cases, however, the desire of the riparian and lakeshore communities to manage their fisheries for their own food security and economic benefits should be given over-riding priority.

The aim of this study was to review the status and trends in the fisheries of the Zambezi River and the challenges facing management of the fisheries to meet the needs and aspirations of the riparian communities.

## The Zambezi River system

Moore *et al.* (2007) and Tweddle (2010) described the river system, including the geological history in relation to fish distribution. The river is divided into the Upper Zambezi from its source in northwest Zambia down to Victoria Falls, below which the Middle Zambezi encompasses two major hydroelectric dams; the second, Cahora Bassa, marks the boundary with the Lower Zambezi that drains into the Indian Ocean.

Several tributaries are considered major rivers in their own right, including the Kabompo River in the upper reaches that has numerous tributaries that support a distinct ichthyofauna (Tweddle *et al.* 2004). Many large tributaries enter the Zambezi from the Angolan highlands in the west where high rainfall is the major source of the annual flood. The Kafue and Luangwa tributaries enter the Middle Zambezi, while the Lower Shire drains from Lake Malawi into the Lower Zambezi.

The Zambezi River system includes many large floodplains. Among these are the Central Barotse Floodplain (250 km long and up to 50 km wide), Caprivi floodplains (a complex system incorporating 120 km of the Upper Zambezi and also the Chobe River) in the upper Zambezi, the Kafue River Flats floodplains (440 km long and 60 km wide) in the middle Zambezi, and the Elephant and Ndinde marshes on the Lower Shire tributary and the Zambezi Delta, which, from its apex 120 km from the mouth, forms a large triangle with the Indian Ocean coast, extends 200 km along the coast and covers about 12 000 $km^2$.

Lakes in the Zambezi catchment range from extensive areas of small seasonal and semi-permanent pans (e.g. 300+ in the Liuwa Plain National Park) through ephemeral lakes such as the >100 $km^2$ Lake Liambezi on the Zambezi/Chobe floodplain and the 6500 $km^2$ Kafue Flats floodplain, to the large man-made impoundments – Itezhitezhi, Kariba and Cahora Bassa. Lake Malawi, one of the Great Lakes of Africa at 30 000 $km^2$, also drains to the Zambezi via the Shire River and Lake Malombe.

## The fisheries

### *Central Barotse Floodplain (CBF) – low-value species*

Few studies have been made on the CBF fishery despite its enormous area and dependence of the local population on the fish resources. Apart from outdated reports (FAO 1968, 1969, 1970), a descriptive report by Bell-Cross (1974) and fish ecology studies by Winemiller (1991) and Winemiller and Kelso-Winemiller (1994, 1996), little information was available on the Barotse Floodplain fishery until three fish biodiversity surveys were conducted in 2002–2003 (Tweddle *et al.* 2004). They briefly discussed the fisheries of the floodplain and stated that the Barotse Royal Establishment and local fishing community leaders had great concern about declining yields and, more worryingly, inappropriate fishing methods. Observations during the three surveys suggested that fishing pressure was intense, particularly in areas of relatively high human population. It was apparent that the concentration of fishermen was much higher than reported previously (Welcomme 1985). Since then the situation has deteriorated further, and new observations on the fishery in and around the Liuwa Plain National Park on the western edge of the CBF are reported here.

The fishery in the 300+ pans in the Liuwa Plain National Park is well managed through long-established ownership of fishing rights to individual pans by local families (Peel *et al.* 2013). The pans are seasonal, filling during the rains (November to April) and shrinking or drying up during the long dry season. Fish (mostly clariid catfishes) recruit into the pans during annual floods. Timing of harvesting of individual pans and fisher participation is decided by the family head, and permits are issued by the Traditional Authorities in agreement with the National Park management. Most pans are harvested late in the dry season, allowing for growth of the catfish and ensuring maximum fishery yields. All fish present in the pans can be harvested because recruitment is from external sources.

Outside the park in the very different riverine and large lagoon environments of the Luambimba and other tributaries of the Zambezi on the Barotse floodplain, experimental gillnet catches yielded no adult specimens of any of the economically important large cichlid species (Peel *et al.* 2013). Fishing activities observed were seine nets and small-meshed gillnets (25- to 50-mm-stretched mesh). Many of the seine nets used, called *sefa-sefa*, were made of shade cloth, with the bunts lined with cotton cloth. Observations of fish on sale in Kalabo Market agreed with the observations on catches from the fishers in the area and were indicative of a fishery that was excessively exploited, forcing a shift to fishing for small, low-value fishes in the absence of the large, valuable cichlids that were formerly the focus of the fishery. The large numbers of smoked and dried juvenile *Synodontis* species in both Kalabo market and on the banks of the Luambimba River were particularly noteworthy, reflecting fishery dependence on very low-value fish in the absence of formerly common valuable cichlid species. Recognising the serious situation facing the cichlid fishery, the Barotse fishing communities have independently established the Zambezi Fish Conservation Association and also a fish traders' association and are currently (early 2014) engaged with the Zambian Department of Fisheries, the Traditional Authority (Barotse Royal Establishment), and NGOs (WorldFish, AAS, NNF/EU) to implement comanagement activities and source donor funding for a major comanagement programme.

### *Decreasing catch rates on the Caprivi floodplain*

The fishery of the Caprivi floodplain is shared between Namibia and Zambia. Fishing communities in Namibia are seriously concerned about the major increase in fishing effort from Zambia. A frame survey in 2008 (van der Waal *et al.* 2011) found that more than 50% of fishers were Zambian despite the greater part of the floodplain being in Namibia. *Sefa-sefa* are now widely used in this fishery, but of much more serious concern is the increase in fishing effort including a change from multifilament to monofilament nets, used as both gillnets and as seine nets. Formerly universally banned in the Zambezi region, the Zambian authorities started to allow the import of monofilament gillnets of stretched mesh size 5" (127 mm) and higher, in the belief that only large fish would be caught. Inevitably, the 5" limit was disregarded and nets down to 3" (76 mm) mesh are widely available. From the late 2000s, monofilament rapidly replaced multifilament, and by 2012, nearly 100% of gillnets used in the Upper Zambezi were monofilament (Fig. 1a). The monofilament nets are >3 times as effective as multifilament in this fishery (Simasiku 2014), but gillnet CPUE recorded by community fish monitors demonstrated a decline from 7 kg net night$^{-1}$ to just over 1 kg net night$^{-1}$ between 2010 and 2012 (Fig. 1b), despite a series of five high flood years from 2007 to 2011 that should have produced high recruitment. The decline is supported by fisheries independent data from experimental research net catches by the Namibian Ministry of Fisheries and Marine Resources (Fig. 1c) and by a major decline in catches by anglers fishing the Nwanyi Angling Club's annual Zambezi Classic International Angling Competition in 2013 (D. Tweddle, personal observation). These combined dependent and independent catch data suggest a stock decline of the targeted large cichlid species of more than 90% from 2010 to 2012.

Communities in Namibia are increasingly looking to take control of their own natural resources through establishing conservancies; Fish Protection Areas are being established and protected by fish guards appointed by the conservancies (Tweddle 2014a,b; Cooke *et al.* in press).

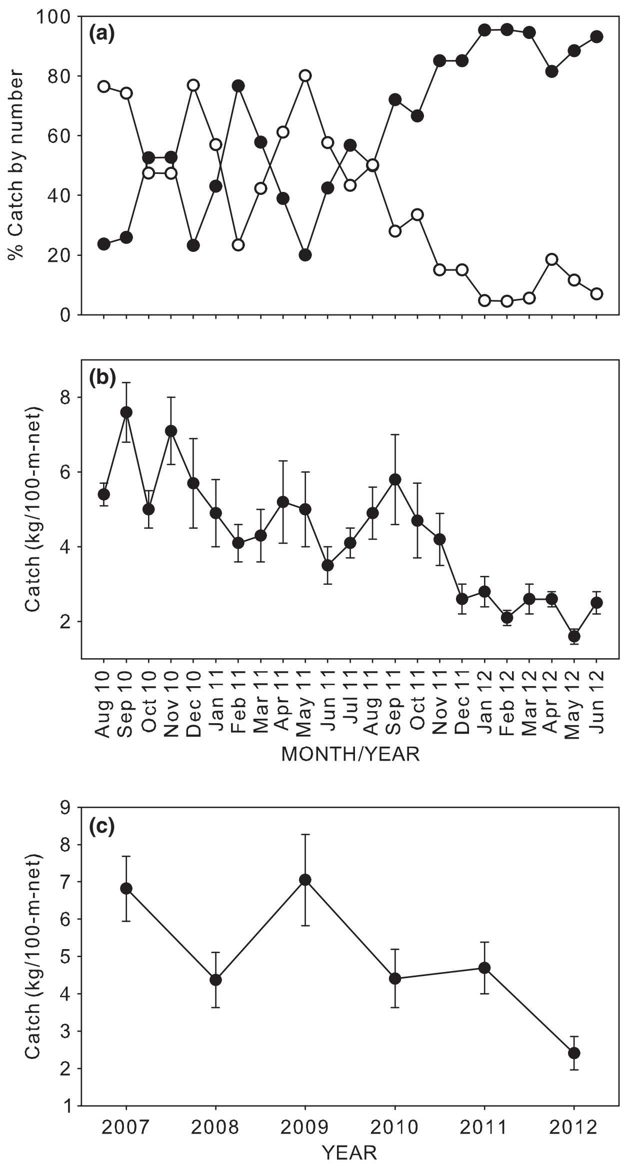


**Figure 1.** Evidence for decline in CPUE in the Upper Zambezi River fishery in the Caprivi floodplain area. (a) Change from multifilament to monofilament netting, demonstrated by the percentage of fish caught in each mesh type, data from community monitors. (b) Decline in CPUE in the fishery, all netting combined as passive and active gears not adequately differentiated (data recorded by community monitors). (c) Decline in CPUE in MFMR experimental gillnet catches at standard stations along the Zambezi River.

### *Lake Liambezi – exporting wealth to the detriment of locals*

Lake Liambezi is a Namibian ephemeral lake that filled up from the Zambezi in 2009 after being largely dry since the mid-1980s. A new fishery based on tilapiine cichlids was rapidly established, and within a year, the newly refilled lake was yielding substantial catches, increasing to an estimated 2700 t annually by 2011/2012 (R. Peel, personal observation). This is greatly in excess of the estimated 600 t yr$^{-1}$ that the lake yielded when full in 1974 (van der Waal 1980), but there are problems in the operation of the current fishery that were not present in the 1970s. Attempts were made by the local community in the Muyako area of the lake to assume control of the fishery as it developed through establishment of a fishing committee (Tweddle *et al.* 2011), with registration of fishers restricted to local community members, restrictions on minimum gillnet mesh size to protect the tilapiine stocks and a ban on active fishing gears. Marketing of fish was performed primarily by women from the area, who delivered the fish fresh on ice to the nearest urban market in Katima Mulilo. Although initially successful, commercial greed took over, with non-local businessmen hiring fishers, mainly from Zambia, to fish for them and ignoring the locally agreed rules. The fish are processed by salting and drying and are now marketed directly by businessmen through Zambia to the Democratic Republic of Congo. The lakeshore communities are not, therefore, deriving similar benefits from the fishery as they were in the past.

Experimental CPUE of monofilament gillnets in 2012 was less than half that recorded in the multifilament gillnets used in the 1970s, despite the greater efficiency of monofilament nets. Passive gillnetting was no longer profitable and the use of ‘bashing’ to drive fish into nets was introduced from Zambia. The use of illegal seine nets became widespread. The numerous islands in the lake were all occupied by fishing camps set up by foreign nationals, with no hygiene facilities, and were reportedly (M. Saisai, personal communication) the focus of other criminal activities. Security operations were carried out jointly by MFMR, Police, Customs, Immigration and the Namibia Defence Force in 2013 and 2014. In initial operations, Zambian fishers were simply deported, but they immediately returned, and therefore, in March 2014, they were arrested, taken to court and heavily fined (Sanzila 2014).

Lake Liambezi is therefore an example of a Zambezi fishery that is producing high yields, but for the benefit of outside businessmen and migrant fishers, to the detriment of the livelihoods and food security of the local population.

### *Lake Kariba – unmanaged fisheries result in decreased catch rates and species changes*

Lake Kariba is situated along the border of Zimbabwe and Zambia. The fishery on the Zimbabwean side was actively managed with limited access, closed areas and gear mesh size restrictions (Malasha 2003), while fishing on the Zambian side has been unrestricted since the very beginning (Kolding *et al.* 2003). It has been argued that there is no evidence of overfishing on the Zambian side of the lake (Kolding *et al.* 2003; Kolding & van Zwieten 2011, 2014), despite both experimental and fishers' CPUE being very much lower than on the Zimbabwe side of the lake. These authors argued that although catch rates are lower in Zambia, this is simply the effects of fishing. They argue that species diversity is similar and that the overall community size structure is relatively the same. Their data suggest otherwise. Two features of their experimental gillnet catch data illustrate the adverse economic impact of the heavy fishing pressure on the Zambian side of the lake. For example, based on the comparison of the relative biomass-size distribution between the unfished Lakeside station on the Zimbabwe side of the lake and the exploited Sinazongwe station on the Zambian side (Fig. 2), Kolding *et al.* (2003) concluded that 'although the absolute stock abundance is clearly different between the unfished and fished areas, the overall community size structure is relatively the same'. Their interpretations are, however, based on species-combined length data, and more than half of the dataset is based on species larger than 50 cm TL, which in Kariba are mostly clariids and *Hydrocynus vittatus* (Castelnau), species that are largely resilient to exploitation and that have been shown to undertake large movements (Merron 1993; Økland *et al.* 2005). Species that seem particularly depleted are those between 35 and 50 cm, the size range of the larger cichlid species. In addition, a marked difference in abundance of the larger fish species was prevalent (Fig. 3). On the Zimbabwe side of the lake, the economically most important tilapiine and serranochromine cichlids, together with the tigerfish *H. vittatus*, the prime target for the important tourism angling sector, continued to comprise well over 50% of the catch expressed in terms of relative importance (IRI). In Sinazongwe, Zambia, however, the small, very low-value *Synodontis* species comprised over 70% of the IRI by 1993. Although the authors stated that the experimental fishing was confined to the Zongwe estuary area after 2004, the increase in relative importance of the *Synodontis* species preceded this change. A dominance of *Synodontis* in catches, particularly in non-selective experimental gears, is evidence of a severely degraded fishery resource.

### *Kafue Flats floodplain - decline in cpue*

The Kafue River basin lies on the Central African plateau and is a principal subcatchment of the Zambezi River. It lies completely within Zambia and with an area of 156 995 km$^2$ comprises about 20% of the total land area of the country. The Kafue Flats floodplain lies between Itezhi-tezhi dam and the Kafue Gorge dam and is characterised by floodplain swamps and marshlands. Its close proximity to Lusaka means that production and output from the region has a ready market.

The Kafue River system fishery makes an important contribution to national fish production and supply and

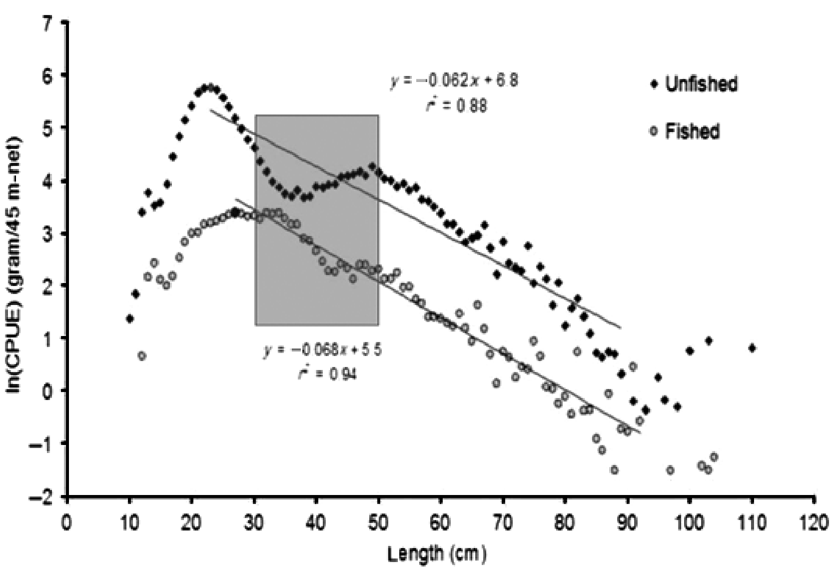


**Figure 2.** Relative biomass-size distribution, based on CPUE in experimental gillnets, between the unfished Lakeside station on the Zimbabwe side of the lake and the exploited Sinazongwe station on the Zambian side. The shaded box highlights the size range of the valuable large cichlids, where there is evidence of marked depletion on the Zambian side of the lake. (Redrawn from Kolding *et al.* 2003).

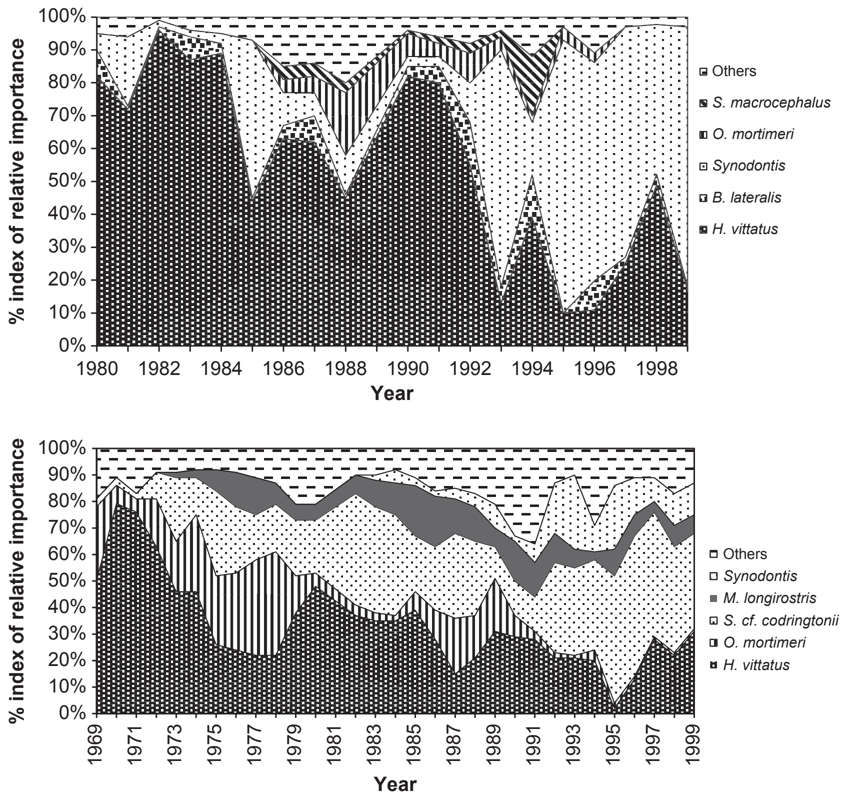


**Figure 3.** Comparison of species composition of experimental gillnet catches on Lake Kariba, Zambia (top) and Zimbabwe (bottom), showing the absence of large cichlids and dominance of low-value *Synodontis* species in the former (Redrawn from Kolding *et al.* 2003).

statistical records suggest production fluctuated over a 7-year cycle between about 3000 and 10 000 t $yr^{-1}$ before the closure of the upstream Itezhi-tezhi Reservoir in 1987, but has stabilised around 6000 t $yr^{-1}$ in recent years (Fig. 4a), although this is considered a gross underestimate – it is likely the annual harvest in the Kafue Flats will be in excess of 20 000 t $yr^{-1}$. The dominant fishing gear used in the Kafue fishery is gillnets (often using in conjunction with beating the water), but longlines, baskets/traps and seine nets are also used. Some 47% of gillnets in use have mesh sizes below the permissible mesh size and mosquito mesh seine nets are used widely in this fishery. These illegal gears are used to catch tilapia and catfish species.

This increase in illegal gears is coupled with a large increase in number of fishers and their gears over the past 10–15 years thus the relatively stable catches suggest CPUE has declined. This assumption was supported by feedback from fishers during consultation who unanimously indicated that catches per gillnet have declined in recent years, thus driving each fisher to increase the number and length of gillnet set to maintain catches.

Further evidence of the decline in CPUE was available from the experimental gillnet surveys carried out in the Chunga lagoon (Nyimbili 2006). CPUE (weight of fish caught per gillnet) has declined rapidly since the mid-1980s from 3 kg per set to stabilise during the 1990s but to decline further since the year 2000 to 0.2 kg per set (Fig. 4b). In terms of number of fish caught per gillnet, CPUE has dropped drastically from 20 fish per set in 1986 to 2 fish per set in 2005. The situation was not different when one considers size of fish caught per setting. The CPUE is accompanied by a fall in maximum size of fish caught, although there is little evidence of a change in mean size of fish caught, a scenario that may be linked to rapid spread of Nile tilapia, *Oreochromis niloticus L.*, that has escaped from fish farms in the area (Cowx *et al.* 2011). These trends in falling CPUE and maximum size of fish caught are consistent across the main commercial species caught (Nyimbili 2006). This is consistent with the fishing down process typically found in floodplains linked to loss of the larger individuals, especially higher value species such as the tilapias. In summary, continuous increase in fishing effort potentially arising because of the open-access nature of the fishery has caused a drastic drop in catch rates and average size of the fish caught. However, it should be noted that the fishery is under

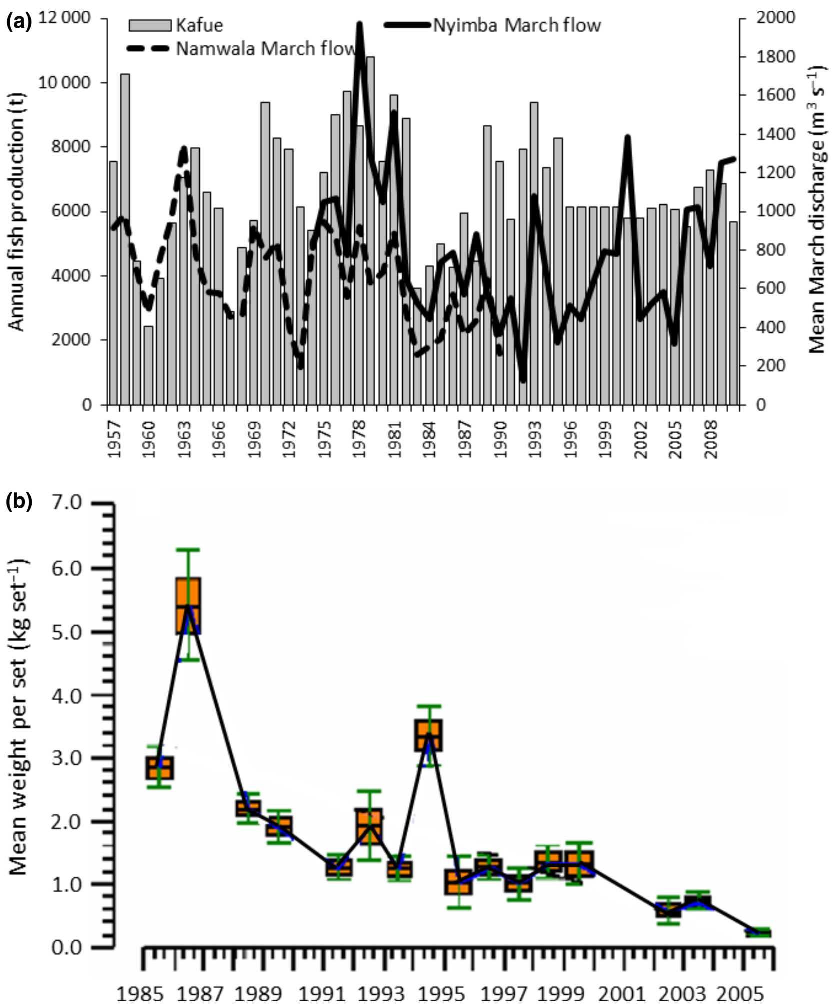


**Figure 4.** (a) Trends in total fish catches (*t*) from the Kafue Flats and relationship with mean march discharge at Itezhi-tezhi (Source data: Zambian Department of Fisheries). (b) Mean annual CPUE (kg per set) of all species over the period 1985 to 2005. The error bars represent 95% confidence level (Source dat: Nyimbili 2006).

great threat from the introduction of Nile tilapia (escaped from local fish farms) that now dominates the catch, but more so from proposed hydropower development at the upstream Itezhi-tezhi dam that will modify the flows in the downstream Kafue Flats floodplain and disrupt the natural flooding regime (Cowx *et al.* 2011). Ultimately, it is likely that the fisheries in the floodplain will be completely transformed with the loss of considerable species diversity.

### *Collapse of the high-value chambo fisheries in Malawi*

In Lakes Malawi and Malombe, catch rates have declined, fish communities are changing, and larger, more valuable, species are being replaced by smaller, much less valuable species (Weyl *et al.* 2004b, 2005b, 2010). The depletion of chambo, a collective name for three large tilapia species comprising the *Oreochromis 'Nyasalapia'* species flock (Trewavas 1983), which command prices at least twice as high as those for comparably sized other cichlids (Weyl *et al.* 2010), has been a concern for many years (e.g. Lowe 1952; Lewis 1990; Banda *et al.* 2005). The historical assessment of the collapse of the fishery based on good long-term data (Weyl *et al.* 2010) is a prime example of the implications of non-selective fisheries (e.g. Garcia *et al.* 2012) on African livelihoods.

The main fishing grounds for chambo in Malawi are the southern parts of Lake Malawi and the smaller Lake Malombe. Chambo were traditionally exploited by artisanal gillnet and beach seine fishers (Turner *et al.* 1995) and were considered fully exploited soon after the initiation of industrial purse seining in 1942 (Lowe 1952). Fisheries assessments in the 1960s demonstrated that haplochromine cichlids were underexploited, and a trawl fishery was subsequently developed (Tarbit 1972). This fishery rapidly depleted larger, slower growing, late maturing species (Turner 1977; Banda *et al.* 1996) and began to fish in shallower waters where chambo were a common bycatch (Weyl *et al.* 2005b). As the fishing effort increased, and catches of larger species decreased, the artisanal fishery changed from targeting primarily large cyprinids and tilapia to fishing for small haplochromine cichlids (Weyl *et al.* 2005b). The resultant gear modifications, such as the use of small-meshed gillnets and light attraction increased the harvest pressure on immature chambo, particularly in southern Lake Malawi where the 1+ year-class chambo, previously relatively unexploited, contributed heavily to the catch in the light attraction *kauni* fishery (Weyl *et al.* 2004a, 2005a,b).

It was most likely this additional pressure, that is a well-developed fishery for adult chambo coupled with an increased bycatch of juveniles in the small mesh fishing gears, which caused the crash of the chambo fishery in southern Lake Malawi from 5000 t $yr^{-1}$ in 1992 to <2000 t $yr^{-1}$ by 1999 (Weyl *et al.* 2010). Environmental variability is also possibly a factor; for example, Tweddle and Magasa (1989) showed that declining lake levels boosted chambo juvenile survival, probably due to wind-induced mixing of nutrient-rich deep water improving survival of planktivorous juvenile fish, but the main driver of biomass is fishing effort (Tweddle & Magasa 1989), and effort has exceeded the level that allows maximum sustainable yield for chambo since 1976 (Bell *et al.* 2012).

Lake Malombe is a prime example of the loss of economic value resulting from the depletion of a high-value species in an African fishery. This 390 $km^2$, warm (26.5 °C), shallow (max. depth 7 m) and highly productive lake consistently yielded ≈4000 t $yr^{-1}$ of chambo until the mid-1970s (Fig. 4). Chambo were harvested using mostly large-meshed gillnets. The introduction of a small-meshed purse seine (*nkacha* net) in the mid-1980s in combination with continued fishing on adults initially increased chambo catches, to ≈8000 t $yr^{-1}$ by 1982 as the small immature fish were now also being caught. This, however, resulted in a crash of chambo catch to less than 200 t $yr^{-1}$ in 1992 (Fig. 5). This decline was initially compensated for by an increased harvest of small haplochromine cichlids in the seine net fishery, which by the mid-1990s had almost completely replaced the chambo fishery (Fig. 4). Tweddle *et al.* (1995) assessed the small-meshed seine fishery in 1990 and warned that the increasing reliance on tiny, immature fish could lead to a collapse. Partly as a result of this warning, a participatory fisheries management approach was initiated for the fishery in 1994 (Scholz *et al.* 1998). This initiative put great emphasis on the

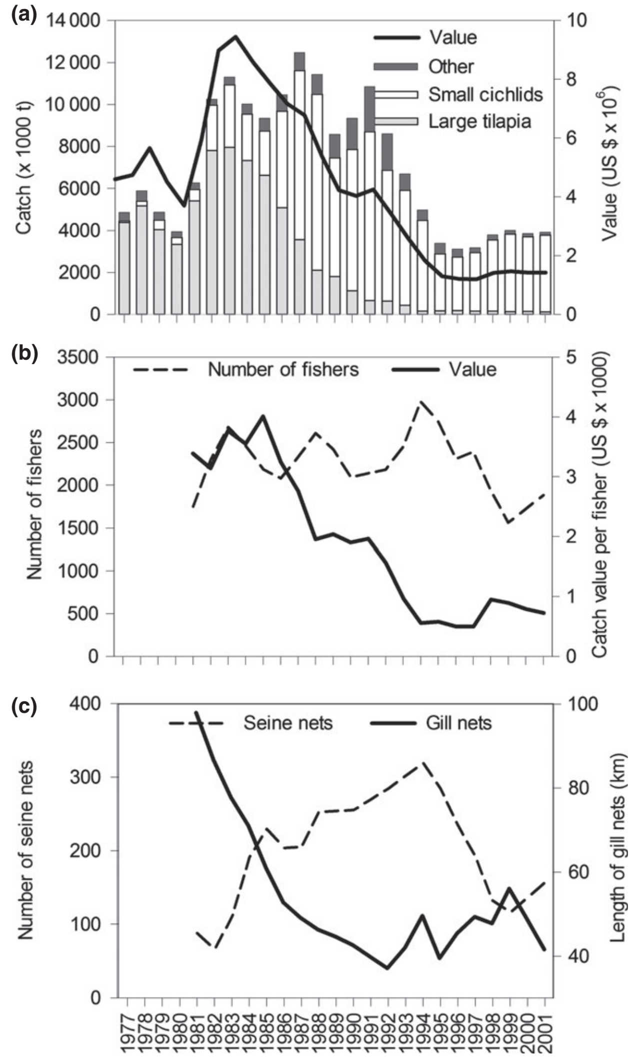


**Figure 5.** Demise of the fishery for large tilapias in Lake Malombe, Malawi. (a) Catch of large tilapias vs small haplochromine cichlids and corresponding catch value calculated using the fish price from 2000; (b) Number of fishers on the lake remained relatively constant but the catch value per fisher decreased dramatically as (c) the gillnet fishery was replaced by a small-meshed seine net fishery. (Source data Malawi Department of Fisheries).

sensitisation of fishing communities about, among other things, the consequence of using inappropriate and destructive fishing gears, such as seine nets with mosquito netting. The programme was, however, unable to implement a reduction in fishing effort and the use of small-meshed nets continued (Weyl 2008). This excessive effort resulted in the decrease of annual nkacha net yields from more than 12 000 t in the 1980s to less than 5000 t in the 1990s (Fig. 5). Assessments of gear utilisation showed that limited compliance with Beach Village Committee as well as Fisheries regulations (e.g. less than 5% of the nkacha nets and gillnets were of the legal minimum mesh size) and effort reductions in seines was a result of emigration in response to decreasing economic returns (Weyl 2008).

A re-assessment of catch and effort data in 2001 showed that there had been no increase in the annual catch since 1992 and that short-term fluctuations in the fishery between 1995 and 1998 that had been reported as project successes (Weyl 2008) were most likely due to environmental variability because, as was the case in the assessment of the fishery in Lake Malawi, fishing effort was again the most powerful explanatory variable for catch rate (Van Zwieten *et al.* 2003). The haplochromine cichlid stock is also overfished and has not recovered from its collapse in the early 1990s, most likely because the small-meshed nkacha nets were harvesting even the small haplochromine cichlids at unsustainable sizes and rates (Weyl *et al.* 2005a).

The real loss, however, has been economic. The 2001 mean beach price for chambo was US\$ 1.04 $kg^{-1}$ while the mean for other fishes was US\$ 0.36 $kg^{-1}$ (Department of Fisheries, unpublished data). Using this price differential, the value of the overall catch value decreased from more than US\$9.4 million $yr^{-1}$ to <US \$2 million $yr^{-1}$ (Fig. 4). The biggest losers were the ≈2200 fishers because decreases in catch rate and value have resulted in a reduction of the overall value of the catch from US\$4 000 $fisher^{-1}$ $yr^{-1}$ to US\$720 $fisher^{-1}$ $yr^{-1}$ after the collapse. The lack of alternative livelihoods for small scale fishers means that they have had no choice but to stay in the fishery (Allison & Ellis 2001), resulting in relatively stable fisher numbers despite dwindling economic returns.

## Discussion

The status of the Zambezi fisheries reviewed here can be considered in relation to Welcomme's (1999) evaluation of exploitation levels in multispecies fisheries and three strategies for management in inland fisheries, that is (1) managing the fishery only for large species of high commercial value, (2) maximising yields, but conserving the fish assemblage as far as possible and (3) allowing the fishery to become fished down. The Zambezian riparian communities are mostly dependent on natural resources, particularly fish, for food security and livelihoods, and thus allowing Strategy 3 to occur has serious implications for the health and wealth of the fishing communities.

This high dependence of Zambezi riparian communities on their fisheries, including the Malawi lakes, contrasts with the views of Jul-Larsen *et al.* (2003), who stated: 'There is considerable mobility of people in and out of the fishery sector' and 'People's flexible adaptation to the ecological and economic environment through frequent entries into and exits out of the fishery sector, facilitates the function of SADC (Southern African Development Community) freshwater fisheries as a "safety valve" or, in other words, as a buffer against poverty'. Also Kolding and van Zwieten (2011)stated 'there seems to be no logical reason, why fishers, at least those with limited technology, should behave fundamentally different from other predators: thus their density should be regulated by the productivity of (or profit from) the fish. In other words, when the individual catch rate of a fisher becomes too low for them to sustain a livelihood, they must leave, switch resources or increase their efficiency'. They go on to say 'It appears that most African inland fisheries, with their yet relatively low technological level, behave largely as natural predators, that is the density of fishers to a large extent seems regulated by the environmentally driven natural productivity of the ecosystem'. These statements appear fundamentally inaccurate based on the Zambezian experience, and indeed elsewhere, with the dependence of communities on their fish resources, primarily for food security but also as an economic resource.

The problems in the Zambezian artisanal fisheries are common to the majority of African freshwater fisheries, including unemployment, hardship and rapid human population growth. Mobility of fishers is also a major problem. There are migrant fishers who do behave as Kolding and van Zwieten (2011) suggest and move about to maximise profit. These fishers often use destructive fishing methods to maximise their gain quickly with little regard for the resource or the high proportion of resident fishers that remain in the fishery. The resident fishers, who are the predominant group, have to continue to scratch out a livelihood and, with resource depletion, move even further towards the use of destructive fishing gears and fish down the fish communities to small, low-value species (Welcome 1999).

The failure to deal with open-access fisheries operated by impoverished rural communities has resulted in the collapse of the majority of the economically valuable Zambezian fisheries based largely on large cichlid species, such as the tilapiine fisheries in the Malawi lakes. Rapid population growth results in competition for fishery resources, leading to high fishing pressure, declining catches, disappearance of large valuable fishes, introduction of small-meshed, active fishing gears to maintain catch rates and economic deterioration of the fisheries.

Kolding and van Zwieten (2014) stated that 'a fishing pattern that distributes a moderate mortality across the widest possible range of species and sizes in an ecosystem in proportion to their biological production, so-called *balanced harvesting* (Garcia *et al.* 2012), will satisfy both fishery objectives and conservation objectives'. Unfortunately, this is not the case in most Zambezian fisheries, where uncontrolled fishing effort targeting the larger, more valuable species results in mortality rates very much higher than 'moderate mortality'. The uncontrolled effort is neither economically nor biologically resource efficient and is unsustainable in the long term. This is the complete antithesis of the balanced harvest concept but is the reality in many of the fisheries of the Zambezi system and elsewhere in the developing world.

'Balanced harvesting' in the Zambezi fisheries therefore must incorporate management of the riverine, lacustrine and large lagoon systems to ensure optimal exploitation of the large, economically valuable cichlid species, while encouraging diverse fishing methods on the floodplains to exploit the numerous prolific and generally smaller but less economically valuable species. In contrast to the valuable cichlid fisheries in lakes, lagoons and large rivers, fisheries based on floodplain fishes of small adult size are resilient, with such pioneer species adapted to fluctuating environments. Adaptive species traits include rapid growth and maturation, multiple spawning and strong migratory instincts that result in the species occupying all available habitats. Natural mortality is exceptionally high through predation and habitat variability (especially natural desiccation), allowing intensive exploitation when such species are present on the floodplains. This is widely recognised scientifically (e.g. Merron 1991) but is a concept that has yet to be actively promoted in management.

Comanagement, particularly partnerships between government and fishing communities, has been widely promoted in some Zambezi fisheries, with varying degrees of success. Lake Malombe is a notable example of failure (Allison & Ellis 2001; Hara 2006a,b). This can be largely blamed on the underlying issue that, by the time comanagement efforts were implemented, the fishery had collapsed with no prospect of recovery without radical restructuring of the exploitation patterns, coupled with habitat restoration.

In other affected Zambezi riverine and floodplain fisheries, however, there are prospects for successful intervention because of the resilience of floodplain fish communities that allows rapid recovery of overexploited stocks if effective control of destructive fishing methods, especially those targeting juvenile life stages of commercially valuable species, is implemented. Provided governments recognise the capabilities of communities to take responsibility for the management of their own natural resources, successful comanagement is possible. Current government fisheries acts in some Zambezi countries, particularly Malawi, Zambia and Namibia, recognise the role of communities, but capacity building and empowerment remains patchy. However, such management intervention may be largely irrelevant if the fisheries and their habitats are subjected to environment degradation caused by water resource development dams, for example Itezhi-tezhi upstream of the Kafue Flats floodplain, Cowx *et al.* 2011) or alien invasive species such as the Nile tilapia introduced across the developing world (Gozlan *et al.* 2010).

Contrary to the statement of Kolding and van Zwieten (2014) that in most African artisanal fisheries, small fish is often preferred due to availability, ease of preservation, transport, preparation and taste, the riparian communities of the Zambezi floodplains are seriously concerned about the decline in their large cichlid fisheries. In Namibia, conservancies are being established on the Caprivi floodplains, with a mandate to manage their own natural resources. While currently focussed on wildlife resources, conservancies are beginning to take responsibility for fisheries because of their concerns about the declines in their catches and the influx of unsustainable, destructive fishing methods from outside the area. Two Fish Protection Areas are now established and patrolled by conservancy employed guards (Tweddle 2014a,b), a development that would not have been possible without the awareness by the conservancies of the need to look after their fish stocks. Welcomme's (1999) statement that Strategy 2, that is *maximise yields but conserve the fish assemblage as far as possible*, is optimal is directly relevant to the conservancies' goals. The conservancies are community organisations that are prepared to take responsibility for their fisheries. Similarly, the independent establishment of fishers and traders associations on the Barotse and Kafue Flats floodplains is an indication of community action. These fishing communities will continue to need management support and guidance for some time to come, as was recognised by Welcomme (1999), but initial successes are encouraging.

Catch data from Zambezi fisheries are of variable quality, for example Malawi has exceptional, complete commercial data dating back to the start of commercial (as opposed to artisanal) fishing operations in 1946 (e.g. Tweddle & Magasa 1989; Turner *et al.* 1995), whereas Zambezi floodplain fisheries are widely under-recorded (Cowx *et al.* 2011; Tweddle *et al.* 2004; Tweddle & Hay 2011). As a result, the true values of these fisheries are underestimated. One consequence of this is that inland Fisheries Departments are poorly funded by governments and have high staff turnover, which contributes to an inability to manage the fisheries optimally for food security and economic benefits to the riparian communities. Furthermore, there are competing interests for water usage in the Zambezi system, and fisheries are usually low on the priority list (see Kafue case study). Proposed large irrigation schemes using Upper Zambezi water with long feeder canals threaten floodplain fisheries, tourism (through reduced flow over Victoria Falls), hydroelectricity generation and even elephant migration corridors. It is essential that collection of catch statistics is improved to demonstrate the high importance of the fisheries and that the vital role they play in rural livelihoods is more widely recognised. This recognition should include all livelihoods dependent on fish stocks, thus including the important tourism sector.

A balanced ecosystem approach to management of Zambezi fisheries should, therefore, include legitimate human aspiration towards improved livelihoods, thus the concept of maximising yields through 'No Management' at expense of optimum economic returns (e.g. Jul-Larsen *et al.* 2003; Kolding *et al.* 2003) is misguided and likely to lead to Welcomme's Strategy 3, that is *fishing down*. Intensive exploitation of floodplain fishes for food must be balanced against the high economic value (for food, sale and tourism) of larger fishes, particularly cichlids and tigerfish. Conservancies recognise the value of tourism, including allowing catch-and-release angling in their waters, and are entering into partnerships with lodges/clubs to promote this.

The long-term default position for comanagement until now is effectively 'no management' because comanagement is seen as a quick fix solution to failures in traditional governance. Communities are given fisheries to manage, such as Lake Malombe, that are beyond recovery without major management intervention. Comanagement can only work with fisheries that still have existing or potential value, and fisheries that have already been destroyed have to be brought back to stability before being handed over to communities. The current Caprivi floodplain comanagement programme and the successful traditional management system for the Liuwa Plain fishery are examples that can be used to inform management actions elsewhere in the Zambezi system.

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