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"Where there is water there is fish" – Small-scale inland fisheries in Africa: dynamics and importance

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Abstract

The importance of fish, and in particular small fish, for sustainable and healthy livelihoods in Africa, as well as their strong relationship with climate driven water dynamics are generally undervalued and little understood as most are consumed locally and go unrecorded in catch statistics. Fish are vital providers of animal protein and indispensable micronutrients in many African societies, but modern food production and policies is almost unilaterally associated with terrestrial agriculture and livestock production. The majority of fish species are carnivores and by primarily targeting large adult fish, such as e.g. Nile perch in Lake Victoria, humans feed about two trophic levels higher in water than on land, which in terms of energy is a very inefficient utilization of available food. Small fish are lower in the food web and much more abundant and productive but their capture is inhibited by old fashioned selectivity regulations. Small fish are ubiquitous in all aquatic environments from large lakes to seasonal ponds and productivity is highly correlated with rainfall patterns and water level fluctuations. Catching small fish, which are sun-dried and consumed whole, is the most high-yielding, eco-friendly and nourishing way of utilizing the natural food that aquatic ecosystem provide. Maintaining healthy aquatic ecosystems are more important than traditional fishery management.

Introduction

The role and importance of fish in securing food and nutrition for humans, particularly in developing countries, has frequently been overlooked. Fisheries and aquaculture are often arbitrarily separated from other parts of the food and agricultural systems in governance, food security studies and policy-making (HLPE 2014). Furthermore, nourishment is no longer only a question of calorie availability and access: food security should be broadened to include alimentary aspects as well. There is now robust evidence that lack of essential micronutrients such as zinc and vitamin A affect hundreds of millions of malnourished people around the world (IPCC 2014). Nutritional value is particularly important in Sub-Saharan Africa where approximately 28% of all deaths are attributed to malnutrition (Benson 2008). Fish is especially rich in essential omega-3, long-chain polyunsaturated fatty acids and micronutrients, including bioavailable calcium, iron and zinc (HLPE 2014, Longley et al 2014), which all play a critical role in cerebral development, immune defence systems and general health. Fish is an important source of animal protein in human consumption (Delgado et al 2003), and features prominently in the diet of many people in large parts of Africa. But even when per

capita fish consumption is low, small quantities of fish can have a significant positive nutritional impact by providing essential amino acids, fats, and micronutrients that are scarce in vegetable-based diets (FAO 2012). However, the importance of fish in the sustenance and household economy is largely neglected (Béné et al. 2006).For the most part, fisheries policies are approached from the connotations of fish stocks being overfished, exploited unsustainably and in dire need of management (Allan et al. 2005). But in fact we have only limited knowledge about the actual status of inland African fisheries and the important interplay between climate, water dynamics, fisheries and food production. Fish provides the main source of animal protein for some 200 million people on the African continent (Heck et al 2007). Fisheries also provide a direct source of livelihoods to over 10 million Africans, while 5 to 10 times more engage in fisheries as a secondary activity for food security in rural areas. The official statistics of inland landings in Africa are around 2.5 mill tonnes per year; of which Lake Victoria alone produces 1 million tonnes. But the actual total catches are likely to be significantly higher (around 20 million tonnes), assuming that the total area of freshwater resources (lakes, rivers, reservoirs, floodplains and swamps) on the continent is approx. 1.3 million km^2 (Lehner and Döll 2004, de Graaf et al. 2012) and the average annual production of fish is around 150 kg/ha (Marshall and Maes 1994, Kolding and van Zwieten 2006). As a rough rule of thumb it is highly probable that the official records are underestimated by an order of magnitude. Inland fisheries and aquaculture contribute at least 25% to the world's production of fish at the global level (Dugan et al. 2007) produced from a tiny proportion (approximately 0.2 %) of the global aquatic surface area (Kolding and van Zwieten 2006).

Water, food and fish

In this chapter we will outline and document the importance of fish and fisheries for sustainable and healthy livelihoods in Africa, as well as their close relationship with climate driven water dynamics. Actually, the environment plays a much more important role for fish production than the largely futile attempts of regulating fishing activity. On the contrary, current dominant management approaches, based on the ideology of controlling the fishing pattern, mainly have adverse effects on both the ecosystem resilience and the potential production (Kolding and van Zwieten 2011, 2014). This may have serious consequences for the growing focus on food security and ecosystem resilience in face of climate change. One of the key recommendations of the latest IPCC Assessment Report is that key adaptations for fisheries and aquaculture shall include policy and management to maintain ecosystems in a state that is resilient to change (IPCC 2014). The overwhelming ecosystem dependent factor for fisheries is basically water, and how natural processes around water resources are distributed, managed and conserved. After all, in Africa, like in Asia (Van Zalinge et al. 1998), the saying goes "where there is water, there is fish".

The importance of small fish

One reason for the high level of production in African inland fisheries is the focus on small fish, many of which go unreported into the local markets. The most productive African fisheries are all aimed at small fish species weighing only one to a few grams. The 'Kapenta' (*Limnothrissa miodon* and *Stolothrissa tanganicae*) fishery in lakes Tanganyika, Kariba, Cahora Bassa and Kivu is the most important in all these lakes. Likewise the 'Chisense' (a mixture of *Potamothrissa acutirostris*, *Microthrissa stappersii* and *Poecilothrissa moeruensis*) fishery in Lakes Mweru, Bangweulu and

Mweru-Wa-Ntipa, the 'Usipa' (*Engraulicypris sardella*) and 'Kambuzi' (many small demersal haplochromine species) fisheries in Lake Malawi, Chilwa and Malombe, the 'Dagaa', 'Omena' or 'Mukene' (*Rastrineobola argentea*) fishery in Lake Victoria, 'Mazeze' (mainly small sized cyprinids) in the Okavango Delta and likewise 'Kapesa' in the Bangweulu swamps (Figure 1), are all high yielding, extremely important for the local consumption and most go unrecorded in catch statistics. Post processing and conservation is straightforward as they are simply sundried in a few days, in contrast to larger fish which needs gutting, salting or smoking for preservation. The simple preservation technology and easy transportation makes them available at most local markets at low cost where they are sold in small portions by weight, fetching the same price as large fish (Brummett 2000) and thus highly accessible (Figure 1). Heaps of small fish are ubiquitously found on local markets far from the original source: Lake Victoria Dagaa is found all over the riparian countries (Hoffman 2010); Lake Mweru Chisense and Lake Kariba Kapenta is found in all large cities in Zambia and southern Democratic Republic of Congo (Overå 2003,IOC 2012). As small fish are sundried whole, with heads, bones and organs, they are a concentrated source of multiple essential nutrients, in contrast to large fish which are usually not eaten whole and therefore do not contribute as much to micronutrient intake (Longley et al 2014).

The controversial "fishing down process"

In addition to the targeted fisheries on the small, mostly pelagic, high productive fish species listed above, a general feature of African small-scale fisheries is the so-called fishing down process (Welcomme 1999), which also results in catching small fish. This process is based on the serial reduction in the sizes of individual fish and fish species as fishing pressure increases, by a corresponding successive reduction in mesh sizes, and diversification of fishing gears and methods. The process is induced by the inevitable decline in individual catch rates as the number of people and thereby fishers increase (Jul-Larsen et al. 2003, Kolding et al. 2014a). The individual decline, however, is accompanied by a corresponding rise in the total catch from the combined fishery as smaller, faster growing, more productive species and sizes replace larger, slower growing, less productive ones. In addition, as many fish eating predators are among the larger species, the reduction of these will boost the abundance of species and sizes lower in the food chain (Figure 2). There is therefore strong evidence that targeting small fish will give much higher yields than targeting only large fish (Kolding et al. 2003 a,b). Unfortunately, however, the general process of 'fishing down' is interpreted as a sign of a deteriorating and unsustainable situation (Pauly et al. 2008), with the added complication that an increasing number of fishing methods become technically illegal as they target smaller and smaller fish. As the regulation of fishing effort (numbers of fishers) is difficult to implement in Africa for socio-political reasons, the fishery regulations in most African fisheries consist of technical measures, such as minimum legal mesh sizes to prevent fishing on small juveniles and the general condemnation of unselective fishing gears such as beach seines (Kolding and van Zwieten 2011). The fishing down process therefore causes increasing conflicts between fishers and managers (Misund et al. 2002) and a snowballing perception that the fisheries are 'doomed' and fishers are destroying their own resources in line with "The tragedy of the commons" doctrine (Welcomme and Lymer 2012). As shall be elaborated below, however, the fishing down process is not only a rational response of the fishers (Plank et al. 2015), but also a precondition for maximizing food production while maintaining the health and structure of the fished ecosystem (Kolding and van Zwieten 2014).

Figure 1. Top left. Kapesa (mixture of small fish) being sundried in Bangweulu swamps, Zambia. Top right and center left: Dagaa being sundried and packed at Lake Victoria, Tanzania. Center right: Packed sundried dagaa distributed to loacal markets. Bottom left: Sundried dagaa on local market, Tanzania. Bottom right: Traditional dish of sundried omena in Kenya with maize porridge (Ugali). (Photo credits: Top left; Carl Huchzermeyer, Bottom right; reproduced with permission from Msupa, Nairobi http://www.msupa.com/ , remaining pictures by Modesta Medard)

Thus, in spite of rules and regulations, the overall result of these ongoing processes is that African inland fisheries are increasingly providing large amounts of small fish (sizes and species), which from a nutritional point of view is highly beneficial (Kawarazuka and Béné2011, Beveridge et al 2013, Longley et al. 2014). It is also highly advantageous from an ecological point of view as catching small fish conserves the aquatic ecosystem structure (Law et al. 2012, 2014, Kolding and van Zwieten, 2014), as well as maintains the terrestrial ecosystem by reducing the cutting of firewood necessary

for smoking and preserving large fish. There are even indications that access to affordable fish protein is contributing to the conservation of endangered mammal species hunted for bush meat (Wilkie et al 2005, Junker et al. 2015). Still, the major governance focus on inland fisheries at the moment is not on their essential contribution to food security, but on their alleged self-inflicted destruction of the resources from overfishing and illegal fishing methods. Most management effort at present seems oriented at constraining fishing, particularly on small juvenile fish, instead of studying and understanding the dynamics of local fishing patterns, and quantifying their importance for nutrition and impact on the ecosystem.

The terrestrial and aquatic food chain

Humans have been both farmers and fishers for millennia, but modern food production is almost unilaterally associated with terrestrial agriculture. Most people are predominantly vegetarians; the average trophic level is 2.21 (Bonhommeau et al. 2013), which means that around 80% of our food is from trophic level 1 (plants), and the rest is mainly meat based (trophic level 2 and higher) from our domesticated animals. It is therefore easily forgotten that the life history of fish is quite different from the farmed creatures we use in animal husbandry all over the world. All the livestock we farm for food are relatively large herbivores that can feed directly on primary vascular vegetation, or so-called higher plants, which dominates the terrestrial ecosystem. The agricultural food chain is therefore short, consisting chiefly of two trophic levels (Figure 2), and nobody would dream of farming terrestrial carnivores for human food production as we lose about 90% of the available energy each time we move one trophic level up the chain. The aquatic food chain, however, is fundamentally different. Most importantly, the majority of primary producers (plants) are microscopic suspended algae, and only small amounts of larger vascular macrophytes inhabit the fringes of the aquatic ecosystems. In general, organisms have to be small to consume minuscule algae, and the major herbivores (cows and goats) of the waters are therefore tiny filter-feeding zooplankton, though there are some important categories of fish that can feed on detritus and algae (e.g. tilapia and carp species). However, the majority of all fish species are primarily carnivorous but, in contrast to terrestrial predators, they have very high fecundities and minuscule progenies that all start their life at the bottom of the food chain. In short, fish breed like plants with lots of seeds but feed like lions. Consequently, aquatic communities are different from terrestrial in that nearly all fish, even the largest predators, start their life as small prey for larger fish (Kolding et al. 2014b). This means that most fish during their ontogeny often traverse across several trophic levels before reaching adulthood. By primarily targeting large adult fish, such as e.g Nile perch in Lake Victoria, humans feed about two trophic levels higher in water than on land, which in terms of energy is a very inefficient utilization of available food. Nearly half of the global primary production is aquatic, and yet only about 2% of the global human food is derived from fisheries and aquaculture (FAO 2006). In theory this discrepancy should envisage a huge potential for increase, but looking at the difference between the aquatic and terrestrial food chain (Figure 2), it is only possible if we target lower trophic levels, which means 'fishing down' and catching small sizes, as they do in Africa.

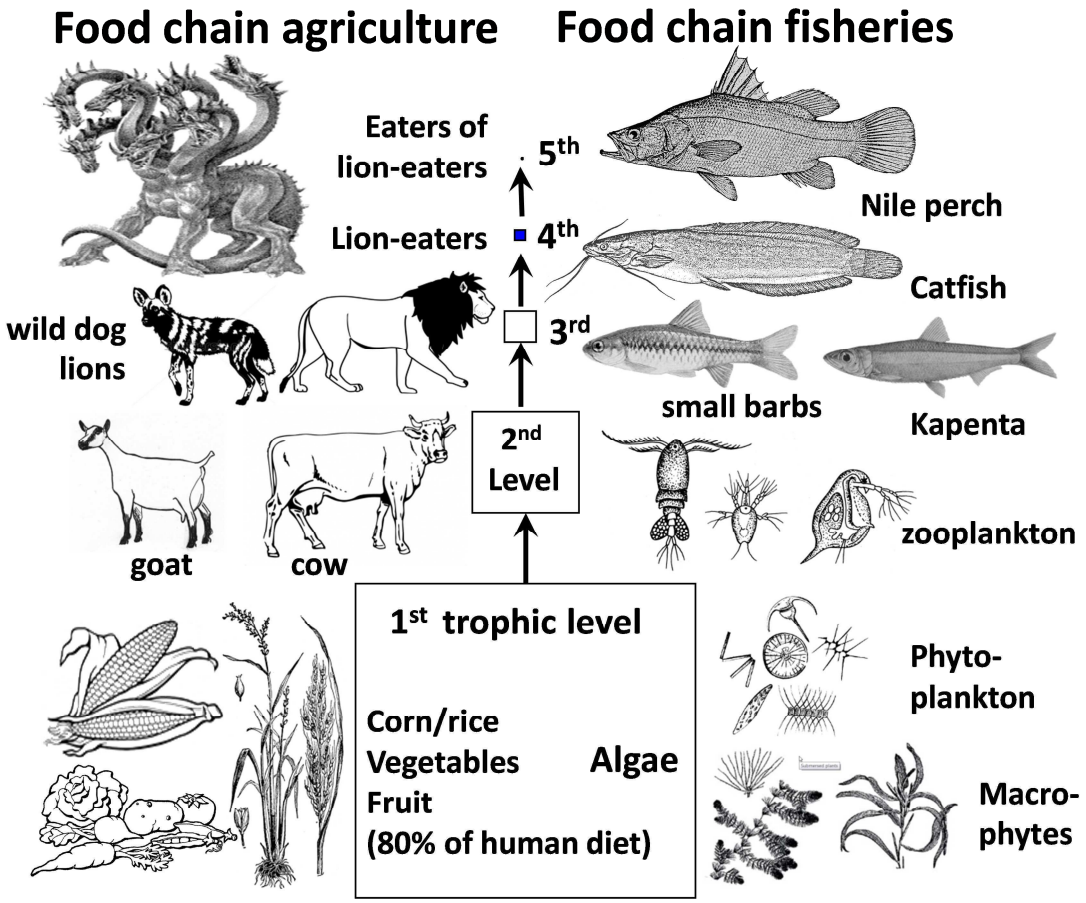

Figure 2. A comparison of the terrestrial agricultural and the aquatic fisheries food chains. The average human trophic level (TL) is 2.21 (Bonhommeau et al. 2013), meaning we are about 80% terrestrial vegetarians (only slightly higher than aquatic zooplankton). In contrast, we are feeding about two TLs higher in most fisheries targeting large fish, resulting in around 99% of the corresponding energy being lost in transfer inefficiency. Modified from Duarte et al. (2009).

The doomsday perceptions, threats and lack of recognition

Notwithstanding the fact that the reported African inland capture fisheries are still steadily rising at about 3.7 percent per year, there is a general pessimistic view of the future of inland fisheries following the numerous threats to aquatic ecosystems posed my man's activities (Welcomme and Lymer 2009). This "inland fisheries are doomed" view is supported by many individual studies and reports from all continents including Africa (Allan et al. 2005, Friend et al. 2009). Catches are alleged to be falling, species disappearing and many of the symptoms of chronic overfishing at the level of individual species or whole communities are being reported (Allan et al. 2005, Welcomme et al. 2010). The problem of many of these statements, however, is that they are based on ambiguous indicators (Kolding et al. 2014a). The omnipresent reports of 'declining catches' are a typical example. The statement almost never differentiates between individual catches (which will always decline as more and more fishers share the same resource), and the total catches (which mostly increase and rarely decline). When asking a fisher if his catches have declined, he will almost invariably agree as this is in accordance with his own personal observations: fishers live in a world of

eternally decreasing individual catches as overall effort increases. He is rarely aware of the fact that the summed catches over all the fishers in the system at the same time has increased. Although underestimated, reported inland catches in Africa are still increasing linearly (FAO 2012), and there are no examples of decreasing total catches from any system outside the North Atlantic region that can be attributed unequivocally to fishing. When total catches in small scale fisheries are falling, it is always in association with decreased amounts of water or deteriorating water quality and aquatic habitats (droughts, floodplain conversion, river regulation, abstractions and dams). Another example is the typical observed decrease in the size of fish caught (as described above), which in general is interpreted as a sign of overfishing (Kolding et al. 2014a). A decrease in size, as in the common "fishing down process", may be a sign of fishing, but not necessarily a sign of overfishing. Actually, it can just as well be interpreted as a healthy sign of a redistribution of fishing effort over larger parts of the fish community and thereby keeping the structure intact (Essington et al 2006, Kolding and van Zwieten 2014). Still, the general perception favours a sense of hopelessness that leads to the neglect of the sector as a whole and renders policy makers to focus on other, more optimistic, sectors for growth and development (Welcomme and Lymer 2009). As a result, the important and beneficial contribution of wild caught inland fish to food security has been largely ignored and undervalued (Mills et al. 2011), priorities for food studies have been switched to other sectors, and aquaculture is being promoted as the solution to sustain production in the face of the perceived inevitable decline and eventual disappearance of freshwater fish stocks (Welcomme and Lymer 2012). This view is prominent in many African countries and together with the general unawareness of the importance of fish for human nutrition (HLPE 2014), has led to a lack of means assigned to inland fisheries, a lack of informed approaches on managing many aspects of the resources, as well as an apparent failure to include the sector in national and regional development policies (Welcomme and Lymer 2012, FAO 2012, HLPE 2014).

Adding to this pessimistic view on small-scale fisheries in Africa, as elsewhere, is the large number of anthropogenic threats to inland aquatic systems. Foremost among these are (Welcomme and Lymer 2012):

a) Poor fishery management - including uncontrolled and excessive fishing, increasing use of illegal gears (catching small fish!), and introductions of invasive exotic species.

b) Water abstractions - There is a growing trend in Africa for rivers to be regulated and flows to be diverted for irrigation either directly or from reservoirs (Dudgeon et al. 2006, Richter et al. 2010).

c) Land drainage - There is an increasing trend to drain wetlands and separate floodplains from the river channel. This results in a loss of living and breeding areas of many fish species and will negatively affect productivity (Kolding and van Zwieten 2012).

d) Dam construction – With the rising demands of energy there is a surge in proposals and constructions of large dams. The impacts of such dams on the fish fauna downstream are rarely assessed although there is often a compensatory effect with the creation of new fisheries in the reservoirs upstream (Kolding and van Zwieten 2006, Richter et al. 2010).

e) Pollution/eutrophication- Pollution has important local effects in rivers and in lakes. In lakes eutrophication is an increasing threat from the growing levels of human population

around their shores, a lack of proper waste water treatment system or ancient agricultural practices involving seasonal burning of vegetation on fallow land (Tamatamatah et al. 2005). Lake Victoria, the largest lake in Africa, is a typical example of this development (Kolding et al. 2008)

f) Climatic variability/change- Climatic variation has always been a severe problem especially in the drought prone belts of the Sahel and southern African region. There is a clear correlation between fish productivity and rainfall in all African water bodies (Jul-Larsen et al. 2003, Kolding and Zwieten 2012).

"Fish come with the rain"

For local fishers, the biggest concern is about water. "Where there is water there is fish" or "Fish come with the rain" are often heard statements when asking African fishers about the drivers of fish production. A good example are the many isolated endorheic water bodies in Africa, such as Lake Ngami (Botswana), Lake Chilwa (Malawi), Lake Mweru Wa' Ntipa (Zambia) or Lake Liambezi (Namibia), which periodically dry out completely (Figure 3), becoming muddy swamps or even dust pans. Upon refilling, however, during years of good rains, the fishery immediately bounces back and resumes very high productivity within a very short time – usually less than a year. At the moment, both Lake Ngami, which was dry from 1982 to 2002, and Lake Liambezi, which was dry between 1986 and 2009, are highly productive characterized by outstanding fish yields. Currently, both fisheries are exporting large quantities of fish to Zambian and the Democratic Republic of Congo markets. These lakes are typical examples of how rain and water are the main factor controlling fish production in inland fisheries (Jul-Larsen et al. 2003). Africa is well known as the continent with some of the largest lakes in the world (Victoria, Tanganyika, Malawi and Turkana), but in relative terms the high number of small, often ephemeral, water bodies, dams, swamps, marshes and floodplains are much more important in terms of food production (Anderson 1989, Marshall and Maes 1994). Due to the high surface to volume ratio, small shallow water bodies, are much more productive and have a much higher standing fish biomass per unit area than large lakes (Marshall and Maes 1994). However, following the prevailing climatic conditions, large parts of Africa have fluctuating and often unpredictable rainfall patterns (Nicholson 1996, Figure 3), which together with a high evaporation rate make many small water bodies liable to dry out intermittently, or at best result in pronounced water level fluctuations. Such unstable environments which constantly undergo successive resetting, are only inhabitable for small, short-lived and fast growing species with high generation overturn, and consequently the fisheries in small water bodies are characterised by small fish and high seasonal and inter-annual variability. However, alternating wet and dry conditions seems only to boost productivity as it recycles nutrients through oxidation and leaching (Kolding and van Zwieten 2006, van Zwieten et al. 2011). Another example is the floodplain fisheries, which are considered among the most productive in the tropics. Here the strong positive relationship between hydrology and fish production has long been recognised (Welcomme, 1979; Junk et al. 1989, Welcomme et al. 2006). More recently also the general dependency of larger lakes and reservoirs to the ambient hydrological regime has been documented (Kolding and van Zwieten 2012). In general, for all water bodies, there is evidence that fish productivity increases exponentially with the amplitude of annual water fluctuations relative to the mean depth.

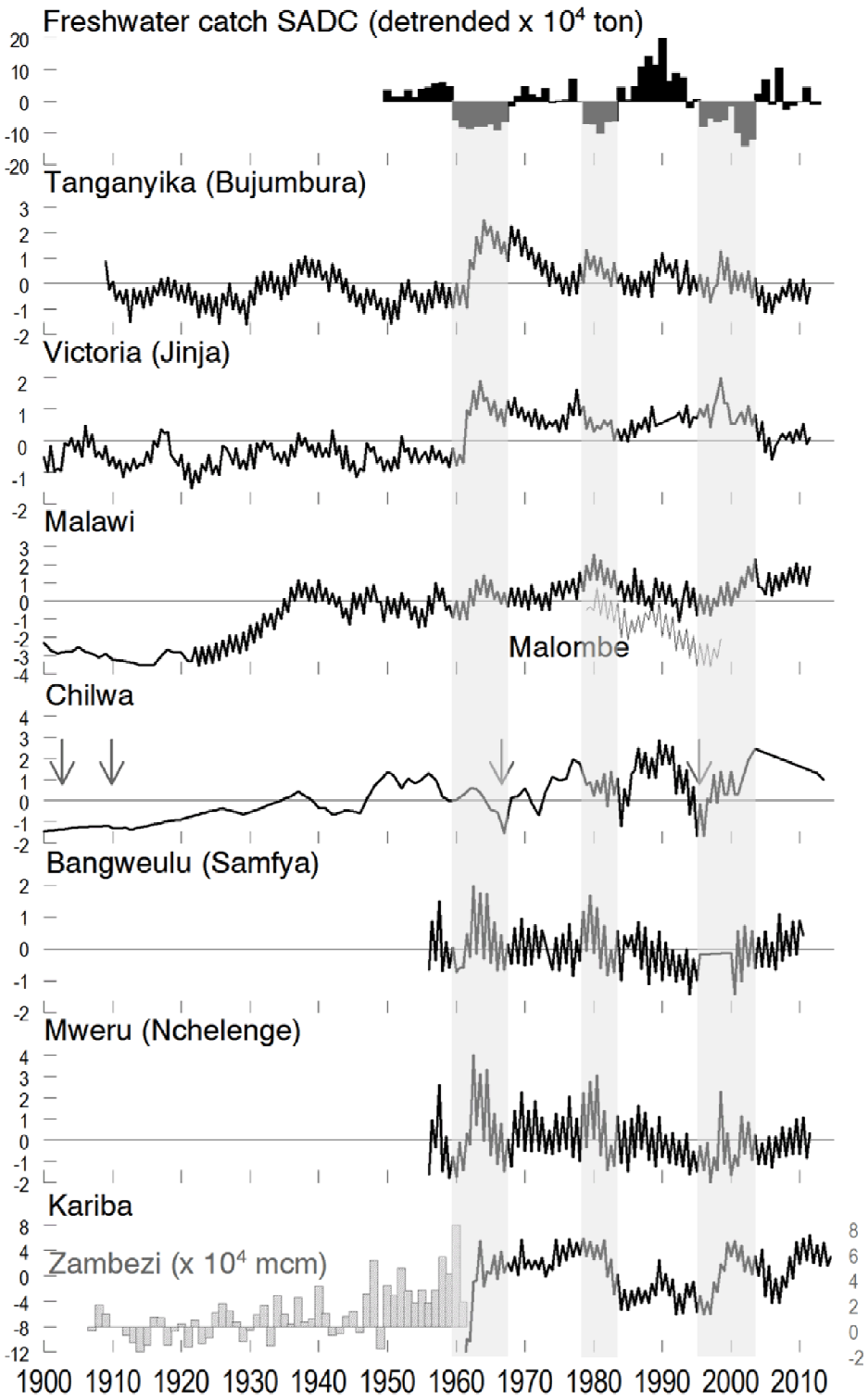

Figure 3. Relative water levels of Lakes, Tanganyika, Victoria, Malawi, Malombe, Chilwa, Bangweulu, Mweru and Kariba expressed as deviations from the long-term mean of annual mean levels over the period for which data were available. Light gray bars are the deviations of the 89 year mean annual total inflow of the Zambezi at Victoria falls (mcm = million cubic meter). Arrows indicate the years Lake Chilwa was reported to be dry. Malombe is hydrologically considered a satellite of Malawi: when this lake has low stands Malombe completely dries up. The top panel shows the variability around the trend of the total fish catches of the SADC region with grey bars comparing periods of low catches relative to the trend. Updated from Jul-Larsen et al. (2003).

Thus, water alone is not enough for high productivity; a greatly enhancing effect is seasonal oscillations (driven by the rain pattern) with intermittent periods of floods intercepted with fallow periods of low water levels to expose the shorelines for terrestrial conditions and rejuvenation (Kolding and van Zwieten 2006, 2012). In terms of fisheries, this means that high productivity is achieved at the expense of high seasonality, where yields are fluctuating and most rewarding during the receding water phase. Small-scale inland fisheries, however, are adapted to – and even take advantage of – these fluctuations by shifting between agricultural activities, such as ploughing and planting at the onset of the rainy season while growing and harvesting is combined with fishing at receding water levels during the dry season. Most small-scale African fishers thus have a mixed economy, and only few are full time commercial fishers (FAO 2014). This feature is maybe another reason why fishing in general has received so little attention in rural household economy, as many 'fishers' can just as well be considered as small-scale farmers. The "Fish comes with the rain" aphorism is not only indicating the deep local knowledge of the dynamics between hydrology and productivity, but also the interconnection between fishing and farming as an integrated livelihood strategy in many African communities.

The legislative separation between fishing and farming.

While fishing and farming, and sometimes also fishing and pastoralism, are often integrated activities for food security all over Africa, the governance, policies and management of these activities are mostly segregated. Inland fisheries are usually located under the same administrative umbrella as wildlife, tourism- or game departments in most (land-locked) African countries, and therefore more considered an intermittent hunting activity than a stable food supplier. The reason for this political separation is difficult to pin down, but appears to be partly historical and mainly inherited from Colonial administration (Malasha 2003). Much of the fisheries legislation in Anglophone Africa can be traced back to British game legislation, where hunting and angling were seen as a gentleman sport with the important principle of "giving the game a fair chance" (Malasha 2003). This attitude has important implications for fishing methods that are seen as 'herding', 'indiscriminate', and 'unselective' and considered particularly unethical when immature individuals are targeted. In addition, during the last decade of the Colonial period, a new and ground-breaking fisheries theory was developed in the UK, which rapidly became the doctrine of modern rational fisheries management. The theory (Beverton and Holt 1957) stipulated minimum size limits on exploited species in order to maximize yields, and was soon exported to the colonies (Beverton 1959), resulting in widespread mesh-size regulations and the condemnation of catching small and immature fish (Kolding and van Zwieten 2011). Traditionally, however, African fishers have always targeted all sizes of fish as there is no selective preference for large sizes as in Europe (Tsikliras and Polymeros 2014). Together with the above described 'fishing down process' as a result of increased effort, the overall outcome is increasing conflicts and distrust between managers and fishers (Misund et al. 2002) and an increasing perception in the wider society that the traditional fishing pattern is destructive: fishers are seen as irresponsible law-breaking buccaneers instead of good citizens providing much needed and essential nutritious food to supplement the starch based staples from the fields. If African fishers had followed the regulations, and only fished selectively on the legal large sizes, there would inevitably be a decrease in the average size of fish caught. It is therefore a great paradox in fisheries governance that the expected result of fishing within legal requirements (a decrease in size) is used as a diagnostic of unsustainability and depletion (Kolding et al. 2014a). Ironically, there is now

increasing evidence that the traditional African balanced fishing pattern focusing predominantly on small fish is much more ecologically sustainable and provides more food than predicted by the conventional Western theory (Kolding and van Zwieten 2011, 2014; Law et al 2012, 2013, 2014). Together, this calls for a revaluation of the current legislation and a need for a paradigm shift in management (Mosepele 2014). However, the political division between fishing as a hunting activity in the wild and farming as a domestic food supplier may not only prevent such changes, but also help to explain the negative perceptions and recurrent management problems that African inland fisheries suffer from.

Governance, livelihoods and the ecosystem approach to fisheries

Freshwater availability is predicted to be a serious constraint to achieve future food requirements (Postel 1998, Molden 2007). As a consequence we are likely to see an upcoming intensified competition for water, and most likely an increased regulation and extraction of natural inland water bodies. Most of the research on increased food production under limited water supply is focused on agriculture, with very little regard to the contribution from fish (Dugan et al. 2007, Molden et al. 2010). However, where there is water there is fish, and fish can often be integrated into water management systems built primarily for agriculture such as reservoirs or irrigation schemes. Wetlands, floodplains and small shallow water bodies are the most productive aquatic systems per unit area, and combined they outsize the larger lakes, reservoirs and rivers (Lehner and Döll 2004, Welcomme et al. 2010), but their relative contribution to food security in Africa is largely unknown. Freshwater fish are probably among the most resilient harvestable natural resources, provided their habitat, including the quantity, timing, and variability of river flow are maintained (Welcomme and Petr 2004, Dugan et al. 2007). Thus, maintenance of wetlands and their livelihood values should be taken into consideration in future appraisals of food production. Water productivity increases with seasonal fluctuations in water level (Kolding and van Zwieten 2012), which indicates that it is important that wetlands and lakes maintain their natural cycles, while man-made dams and reservoirs can be regulated to mimic natural fluctuations, and thus increase productivity.

The livelihood benefits of fisheries are conspicuous but mostly ignored or underestimated, although there is a dawning recognition of the importance of fish in the human diet composition. Small species and juvenile fish have the highest level of biological production (Morgan et al. 1980), the highest level of essential micronutrients since they are consumed whole, and they only need sun drying for preservation. Catching fish in proportion to their productivity, so-called balanced harvest (Garcia et al. 2012), which favours small fish, is also the most sustainable and least disturbing to ecosystem structure and resilience (Law et al 2012, 2013). Catching and consuming small fish traditionally has been practised in Africa for centuries, and there is still no significant price differential between small and large fish at local markets. Catching small fish, however, requires fishing methods, such as small mesh sizes, which are largely prohibited over most of the African continent. Unfortunately, the gear and size regulations are based on theoretical assumptions, which have rarely been verified empirically (Kolding and van Zwieten 2011). On the contrary, there is increasing evidence that the highly selective fishing pattern that current management regulations promote, are having serious adverse effects on the fish communities (Garcia et al. 2012).

Paradoxically, the currently favoured management policy is the so-called ecosystem approach to fisheries (EAF, FAO 2003), where a key feature is conservation of the ecosystem structure and

functioning (UNEP/CBD/COP 1998). EAF is now internationally accepted, and commitments to adopt an EAF are already written into many policy documents (Jennings et al. 2014). However, any selective removal of any parts of the fish community will by definition change the structure. There is thus an underlying incompatibility between the observed results of regulatory imposed selectivity and the aim of EAF. On the other hand, unregulated small-scale fisheries in Africa, or fisheries that defy administrative regulations, seem to adopt a fishing pattern that is largely unselective at the ecosystem level, and which provides high sustainable yields (Kolding and van Zwieten 2014). As fishing effort increase and the individual catch rate decrease, the fishers will naturally adapt by diversifying the fishing methods and targets (more gears and different species) and smaller mesh sizes (smaller individuals). Together these two mechanisms will approach a more balanced harvest that will increase both the ecosystem resilience and the amount of food that can be harvested.

Summary and conclusions

In conclusion, African small-scale inland fisheries are characterised by a high adaptability to seasonal and long-term environmental and climatic changes. They are essential providers of protein and micronutrients to millions of people, and they appear to be the best empirical examples we have of an ecosystem approach to fisheries in terms of keeping structure and function. The latter is mainly because the African market has no particular size preferences, and that small nutritious and prolific fish are in high demand. The anthropogenic threats to African inland fisheries are not so much poor fisheries management in the conventional sense, but rather an ecologically profoundly wrong management approach that needs revision. The most important anthropogenic threats, however, are physico-chemical changes of the aquatic environments in the form of water abstraction, flood regulations, land drainage and eutrophication. As long as the aquatic environments are kept intact and productive, there will always be food. Where there is water there is fish.

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