Policy Brief

A promising perspective for the management of African inland fisheries: the balanced harvesting approach

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EXECUTIVE SUMMARY

The potential of African inland fisheries is largely underestimated. However, fully harnessing its potential is essential to meet the continent's growing demand for food of high nutritional value.

The management of these fisheries has been strongly influenced by models emerging from industrial marine fisheries, based on the principle of selectivity of catches, with the aim of avoiding catching small fish. It appears that these models do not optimize the use of resources and in fact lead to imbalances in ecosystems.

In contrast, the fishing strategies traditionally used throughout Africa in freshwater environments encourage the exploitation of all components of fish populations according to their productivity, enabling much higher levels of production while still preserving the integrity of ecosystems.

These exploitation profiles are very close to the principle of balanced harvesting, which has recently been developed but whose application requires a revision of the political and regulatory frameworks relating to the management of inland fisheries.

01 Introduction

Africa is experiencing the highest demographic growth in the world, with its total population expected to reach between 2.2 and 2.6 billion people by 2050 (Tabutin & Schoumaker 2020). At the same time, the quality of life in both urban and rural areas is improving. This improvement is based on better access to basic services, but above all on improved food and nutrition. Of particular importance is an increase in the consumption of fish, which has proven high nutritional qualities, especially important for women and children (Adu-Afarwuah et al. 2017).

Nevertheless, according to a recent study by the African Development Bank (ANRC 2022a), Africa will face a fish deficit of around 12 million tonnes by 2050 if it wishes to maintain the current average availability of 10 kg of fish per capita per year. The AfDB study analyses potential measures to address this deficit, which include improving fisheries management, restoring aquatic ecosystems to their highest productive level, reducing fish exports from the continent in favour of intra-African trade, improving processing and marketing to reduce post-harvest losses, and further developing aquaculture.

However, these measures mainly concern marine fisheries, while the potential of inland fisheries is still largely underestimated. Recent studies show that the official estimates of the global inland fisheries catch of 11.5 million tonnes in 2020 (FAO 2022) may be underestimated by as much as 50% (Fluet-Chouinard et al. 2018; Ainsworth et al. 2022). For Africa, estimates could be one million tonnes higher than the official figure of 3.3 million tonnes in 2021 (FAO 2022) and the true potential is likely to be even higher (Kolding et al. 2016a). These underestimates include both large lakes and river basins with flood plains.

Developing the potential of inland fisheries is a major challenge, but also can be viewed as an opportunity to meet Africa's growing need for fish and hence, better nutrition. However, to fully realize this potential, measures to support the aim of sustainable fishery growth must be identified, and the necessary supportive policy and strategic frameworks developed. As with marine fisheries, restoring productive ecosystems and reducing post-harvest losses are essential requirements. But in terms of the management required, there is a need for a thorough review of conventional approaches to regulating fishing pressure and fully utilising the productive capacity of freshwater systems.


Pella

02 Framework of International Conventions Governing Fishing

The FAO Code of Conduct for Responsible Fisheries (CCRF) (FAO 1995) and the United Nations Convention on the Law of the Sea (UNCLOS 1982) define fisheries management objectives aimed at "maintaining or restoring populations of harvested species at levels that will produce the maximum sustainable yield (MSY)". This objective of maximizing biological productivity and food production has been adopted by most countries. It was reaffirmed at the World Summit on Sustainable Development (WSSD 2002) and again in 2015 in the UN Sustainable Development Goal 14 on life below water for achievement by 2030. Reaching the maximum sustainable yield is also consistent with Sustainable Development Goal 2 to eradicate hunger, ensure food security and improve nutrition. However, defining MSY in a multispecies fishery is no longer viewed as a single figure, but a variable trade-off that depends on how the fishing patterns are targeted and allocated over the entire system (Fulton et al. 2022).

The CCRF and UNCLOS also require that, while achieving the MSY objective for stocks, states should also consider the conservation of ecosystems. This ecological objective is emphasized by the Convention on Biological Diversity (CBD 1998) and the FAO's Ecosystem Approach to Fisheries (FAO 2003). The CBD guidelines for the ecosystem approach state that "conservation of ecosystem structure and function, in order to maintain ecosystem services, should be a priority target of the ecosystem approach" (SCBD 2014). The key principle of the ecosystem approach is that the function and resilience of ecosystems depends on dynamic relationships within species, between species, and between species and their abiotic environment, so that conserving these interactions and processes becomes more important for the long-term maintenance of biological diversity than simply protecting species (the so-called "Malawi principles"[1]) (CBD 1998).

Global acceptance of the need to consider the impact on ecosystems and the transition to an ecosystem approach after 2001 means that the ecological aims for exploited aquatic ecosystems can no longer be ignored.

[1] *http://www.cbd.int/ecosystem/principles.shtml*

The overriding question has become: what is the strategy for achieving the dual objective of high production while maintaining the ecosystem structure?

The balanced harvesting approach, which proposes to distribute moderate fishing pressure over the widest possible range of species, stocks and sizes in an ecosystem, in proportion to their natural productivity, so that the relative size and composition of species is maintained (Garcia et al. 2012; Zhou et al. 2019), is fully in line with the ecosystem-based approach to fisheries management. It also supports development objectives on improving food security and nutrition and people's quality of life.

03 A Critical Review of Conventional Approaches to Fisheries Management

For more than 40 years, conventional single species fisheries management has been widely criticized for failing to prevent overfishing, lacking control over the continuous increase in fishing capacity or the technological developments that went with it. Another criticism, already old (Larkin 1977; Pope 1991) but increasingly important in the context of the erosion of biodiversity, is that conventional fisheries management fails to take account of the interactions between species and that the structure of ecosystems, by focusing heavily on target selectivity, has been severely impacted despite all the conservation measures implemented. The sole reason for this situation is that conventional fisheries management was conceived and developed in large-scale western fisheries which target a single species and is based on reasoning derived from the management of terrestrial fauna. This thinking suggests that it is essential to "allow the fish to grow" and "reproduce at least once" before catching them (Kolding and van Zwieten 2011). As a result of this core idea, management measures are essentially and, in many countries, almost solely focused on the selectivity of catches. The minimum size of fish caught is controlled by a minimum mesh size of nets (or hooks) and other measures to control size and life stage selection.

Both the Code of Conduct for Responsible Fisheries (FAO 1995) and the Ecosystem Approach to Fisheries (FAO 2003) recommend increasing species and size selectivity to prevent overfishing, reduce bycatch and rebuild collapsed fisheries. More surprisingly, this recommendation is shared by conservation biologists (e.g. Worm et al. 2009) even though, by definition, any type of selective removal at any level within a community (whether it is species, population, trophic level, sex, or size class) will alter the composition and demography of that community, with cascading effects on ecosystem structure and function. The systematic removal of large, mature adults can even lead to a change in the life traits of a population, particularly a reduction in size at sexual maturity and a decrease in growth rate. The existence of this phenomenon is increasingly being supported by a large body of empirical evidence (Garcia et al. 2012; Natugonza et al. 2022).

In conventional single species fisheries management, the concept of "growth overfishing" remains a dominant concern. The idea that fishing juveniles depletes stocks has become widely accepted and almost dogmatic, even among non-specialists, often without substantial efforts to verify it (Kolding and van Zwieten 2011). As a result, fisheries that lack regulation in terms of selectivity are perceived as indiscriminate, destructive, wasteful and harmful to the ecosystem. Consequently, the non-targeted and often discarded portions of catches have become a major concern for managers in large-scale, industrial fisheries. Considerable efforts are being made to minimize the capture of unwanted species or sizes driven by economic, ethical or conservation motives.

The most serious consequence of this conventional approach, dominated by the principle of increasing selectivity, is evident in its application to small-scale and traditional fisheries in many developing countries. For over 50 years, the introduction of regulation on catch sizes and mesh sizes of fishing gear has been systematic, affecting every type of fishery, whether marine or inland. This widespread implementation has been further encouraged by the fact that administrations often lack the resources to design and implement management plans specifically tailored to these highly diverse and dispersed small-scale fisheries spread over vast territories.

Inspecting fishing gear and the size of fish caught is one of the simplest and least expensive measures to apply, even for officers untrained in fisheries management, compared to regulating total catches or the numbers of people fishing. There are numerous examples of campaigns to confiscate and destroy fishing gear in communities heavily dependent on fishing for their survival. Few countries, particularly in Africa, remain unaffected.

In the current context of widespread overfishing and increasing demand for fishery products, the incompatibility between the objectives of fisheries management and ecosystem conservation should encourage international, regional and national organisations to rethink the foundations of conventional management, which are based predominantly on selectivity (Garcia et al. 2012).

04 Elements of Fisheries Ecology

4.1 Functioning of aquatic ecosystems

Aquatic ecosystems differ radically from terrestrial ecosystems for several reasons. Firstly, the differences are physico-chemical, characterized by a dense, but fluid environment containing numerous dissolved elements and influenced by three-dimensional currents. Secondly, the differences are evolutionary, with mostly free-floating suspended organisms possessing extremely diverse physiologies, each uniquely adapted to this particular environment.

Energy storage

Carbohydrates are scarce in aquatic ecosystems, primarily because they are soluble in water (Kolding et al. 2023). Therefore, energy storage in these environments must rely on non-soluble macronutrients. So, while the energy base in a terrestrial food chain relies on carbohydrates produced by plants such as leaves, tubers, and seeds, the aquatic food chain primarily depends on proteins and lipids (Ahlgren et al. 1992). In aquatic settings, most primary producers are microscopic algae known as phytoplankton. Their immediate consumers, the herbivores, are tiny animals called zooplankton. Consequently, all higher trophic levels, including the smallest fish, are essentially carnivorous. Thus, generally speaking, most fish are predators. On average, phytoplankton contains only 13.6% carbohydrates, 33.5% lipids, and 52.8% protein (Roy 2018). As a result, aquatic animals are not well-adapted to assimilating carbohydrates. In fact, even so-called 'herbivorous' fish do not effectively metabolize plants. Instead, they consume bacterial films that develop on the surfaces of plants or on organic debris found in inland aquatic environments.

Reproduction, growth and natural mortality of fish

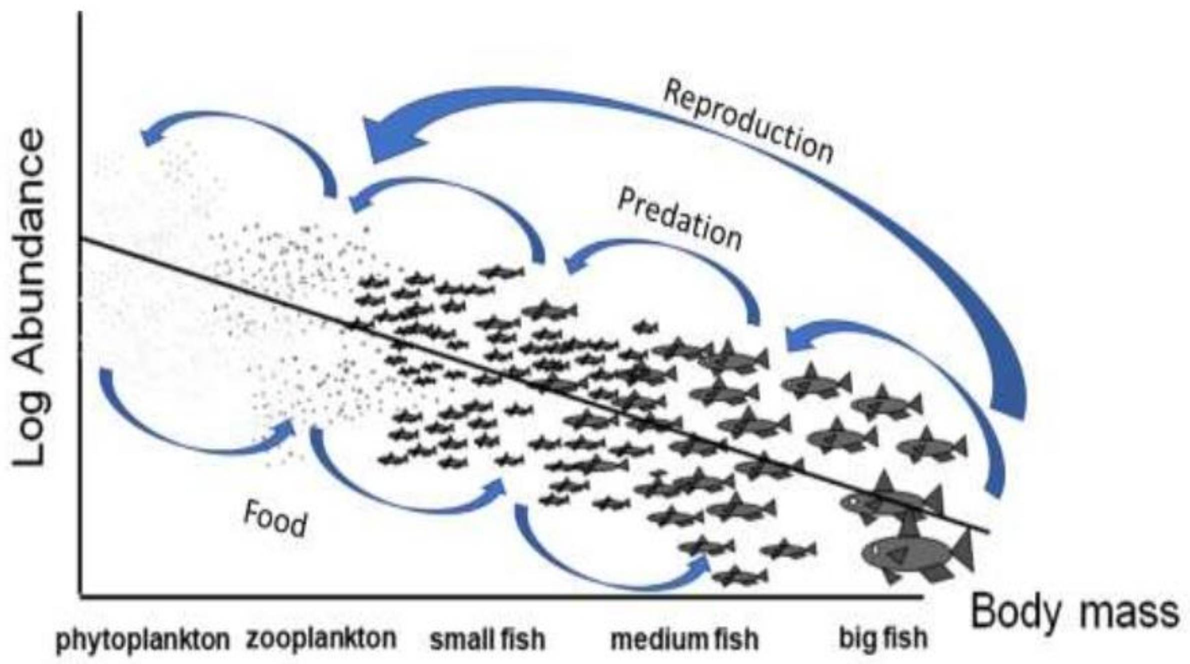
All bony fish[2] begin life as small eggs, which develop into larvae and then into young fish. The egg and larval stages are particularly vulnerable. In fact, all fish, even large predators such as tuna or Nile perch, start their lives as prey (Kolding et al. 2015). To compensate for the high mortality rate of the young[3], female fish

[2] Bony fish include all freshwater and marine fish with the exception of rays and sharks.

[3] More than 99% of juvenile fish on average will die naturally (mostly eaten by other organisms) long before reaching maturity (Le Pape and Bonhommeau 2015).

exhibit extremely high fecundity, the highest in the animal kingdom, amounting to thousands or even millions of eggs per spawning[4]. This fecundity also increases with age, as fish continuously grow, and the oldest and therefore largest females[5] can have a fecundity several dozen times greater than that of young females. It is therefore noteworthy that the systematic removal of large fish by fishing leads to the elimination of the most fecund females, thereby reducing the reproductive capacity of a population or stock (Hixon et al. 2014).

FIGURE 1: Illustration of the general life cycle of a fish within a population and the position of individuals being both predator and prey at each stage of this cycle. (From Kolding et al. 2023)



Aquatic ecosystems are strongly size-structured (Hatton et al. 2021). Over the course of its life, each individual fish gains in size and weight. This growth is made possible by the initial consumption of zooplankton and later of smaller fish. In an ecosystem at equilibrium, the growth of predator individuals is balanced by the consumption of prey individuals. Within each size class, considering all species, the gain in biomass (production) is offset by the mortality due to predation by the larger size class (Figure 1).

Fish cannot chew and therefore swallow their prey whole. Predation between the different size classes is therefore determined by the size of the fish's mouth, so

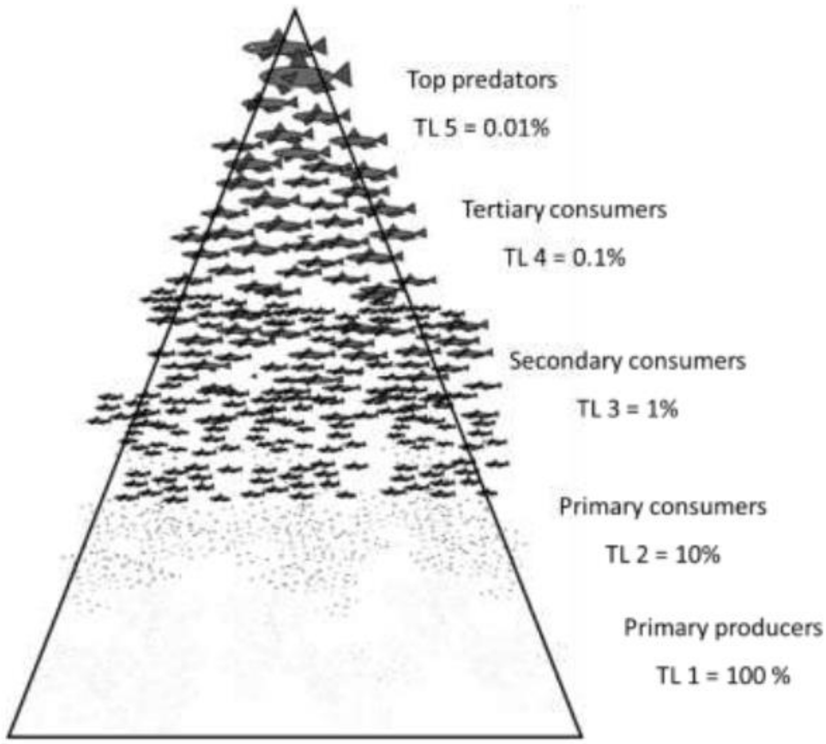
[4] *Except for fish that guard their eggs, such as some tilapia, which only lay a few hundred eggs.*
5 These old, highly fertile females are known by the acronym BOFFFFs, which stands for Big Old Fat Fecund Female Fish.

each size corresponds to a certain range of potential prey, which generally cannot be longer than a third of the predator's length (Scharf et al. 2000). Fish, in general, are therefore both prey and predator, and cannibalism is common in many species.

Trophic levels and productivity

Inland aquatic environments generally contain a large number of fish species, typically around a hundred in tropical lake and riverine environments. The maximum size that an individual can reach varies depending on its species, ranging from a few centimetres to over a meter, but the vast majority of all freshwater species, more than 80%, are less than 15 cm total length (Kolding et al. 2023). Therefore, the environment is populated by a multitude of fish of all sizes. However, the number of individuals in each size class is inversely proportional to their size. In other words, the number of small fish, whether they are adults belonging to small species or juveniles of larger species, is often 1,000 to 10,000 times greater than the number of larger individuals (Figure 2).

FIGURE 2: A schematic diagram of the trophic pyramid showing the relative numbers (on a logarithmic scale) of individuals at the different trophic levels and the rule for transferring 10% of the energy from a given level to the next higher level. From Kolding et al. (in prep).

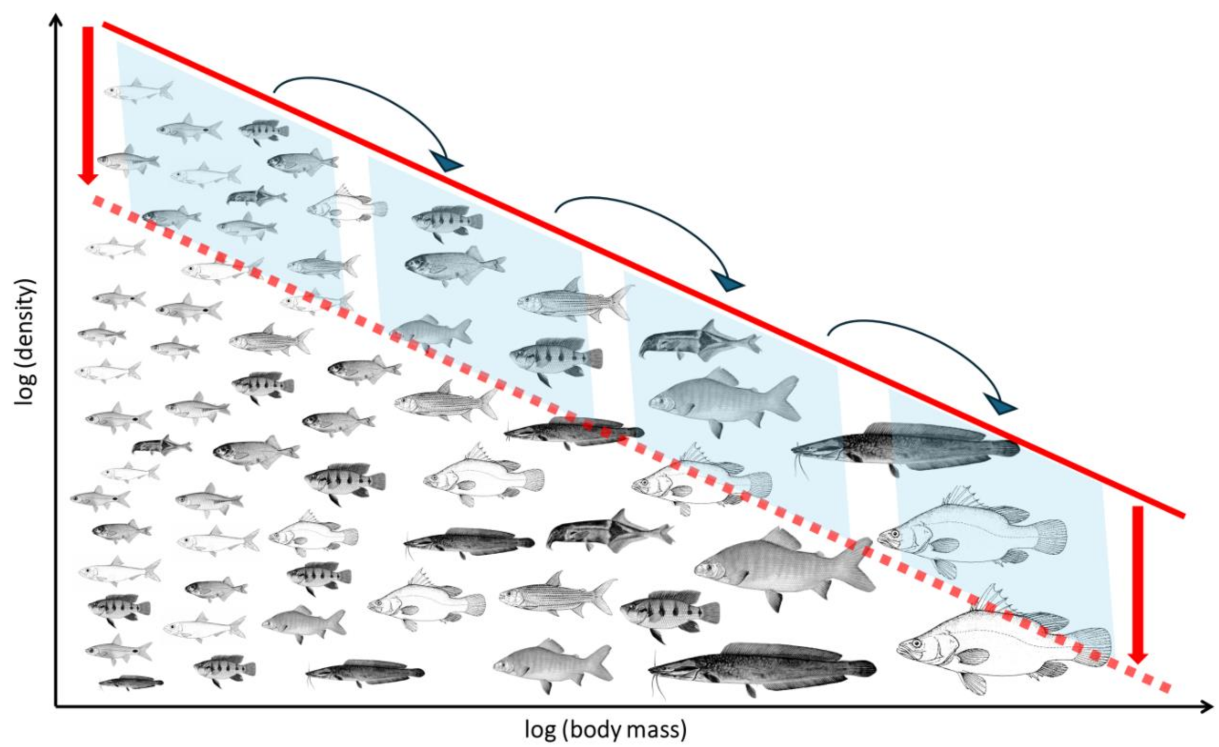


Some fish are primary consumers and are classified at trophic level 2, with trophic level 1 being that of primary producers, i.e. vegetal plankton. The predators of level 2 fish belong to trophic level 3 and, in turn, are consumed by fish from trophic level 4. In a phenomenon unique to aquatic ecosystems, some fish grow to sizes that categorize them as super-predators of trophic level 5. This is akin to terrestrial animals preying on the predators of lions, a scenario not seen in the terrestrial ecosystems.

On average, the transfer of energy from one trophic level to the next level above is around 10 percent of the energy consumed. To produce one kilogram of a level 5 predator, there must be the consumption of 10 kilograms of level 4 fish, or equivalently, 100 kilograms of level 3 prey and 1000 kilograms of level 2 prey.

A direct consequence of this energy transfer relationship is that productivity, i.e. the production (P) per biomass unit (B) over a given period of time, is inversely proportional to the size of the fish, regardless of the species under consideration. Productivity (P/B) is expressed in units per year. For example, the productivity of different species of freshwater sardines is 4 to 6 per year, compared with 1 to 2 per year for Nile perch and 0.8 per year for large catfish species.

FIGURE 3: Illustration of the spectrum of fish size in an equilibrium community and representation of the principle of balanced harvesting by equitable harvesting from each size class (redrawn after Zhou et al. 2019)



4.2 Consequences of fish resource exploitation strategies

According to the conventional management approach, commercial fisheries primarily target large fish and avoid catching small specimens to prevent growth overfishing. In industrialized countries, the market values of large fish, especially bigger predators like cod, tuna, and Nile perch, are much higher than those of smaller species, particularly the small abundant pelagic species (such as anchovies and sardines), which are frequently used to produce meal for feeding farmed animals, including fish like salmon and sea bream.

This strategy leads to negative economic, environmental and food consequences. Consuming predators from higher trophic levels means that their energy cost has been multiplied by 10, 100 or 1,000 compared to consuming their prey directly. Moreover, the search for and capture of the largest fish is increasingly unsustainable for fishing companies, which have to expend more energy and use more efficient technologies to catch fewer fish. Furthermore, as highlighted earlier, systematic fishing of the largest fish reduces the overall reproductive capacity of the population and can even lead to irreversible collapses through so-called recruitment overfishing, the overfishing of adult, mature, fish. Finally, industrial value chains use large fish inefficiently, whether in canning or filleting processes, producing more waste than finished products. Conversely, there are many advantages to eating small fish. For the same quantity of fish caught, the cost to the ecosystem is far lower (10, 100 or 1000 times lower) than with large predatory fish at trophic level 4 and 5. These resources are much more abundant and, importantly, more productive, capable of supporting greater fishing efforts and thus creating jobs and livelihoods for more people.

In addition, small fish have considerable preservation and consumption advantages. They can be quickly and easily preserved (for example, by sun drying), and are more commonly eaten whole, offering significant nutritional benefits due to the micronutrients (such as calcium, iron, zinc and vitamin A) contained in parts not usually consumed in large fish (Dey et al. 2017; Belton et al. 2022; Bavinck et al. 2023). The consumption of whole small fish is understood to make a significant contribution to reducing malnutrition in much of the developing world (Hicks et al. 2019). However, it is important to note that fishing strategies in most traditional fisheries, particularly in Africa, differ vastly from those in commercial fisheries. Traditional fisheries, primarily focused on subsistence and local and regional demand, do not specifically target large fish or certain species. Instead, they have developed a diversified set of techniques adapted to catching different species and sizes of fish depending on their environmental availability and abundance. This means that fishers exploit various groups of species and sizes at different times of the year, aligning with the seasonal variability of the environment, using a wide range of fishing methods. Instead of exclusively seeking the largest fish of a single species year-round, this form of fishing is generally unselective and exploits many different components of the fish community in the ecosystem overall.

The imposition of mesh size regulations from the conventional approaches to fisheries management means that many traditional fishing techniques have been declared illegal, including the use of mosquito nets or weirs of traps placed in the channels of receding waters of flood plains, a very ancient fishing method. However, most illegal gear does not necessarily lead to overfishing. For instance, very small-mesh nets are essential for catching sardines and the many small pelagic species found in African freshwater systems (Kolding et al. 2019). It has also been shown that mosquito nets, often replacing traditional baskets, never catch large fish, which helps to protect the reproductive potential of these species (Short et al. 2018). Additionally, the ease of acquiring mosquito nets provides the poorest fishers, often including women, with easy access to a protein source. Research suggests the impacts of these issues should be carefully investigated and analysed before declaring such fishing gear illegal (Tilley et al. 2020).

In general, traditional fisheries have often been held responsible for overfishing without considering the historical, institutional, social and cultural processes of fishers that enable them to overcome temporary scarcity and, consequently, avoid overfishing through adaptive decision-making (Finkbeiner et al. 2017).

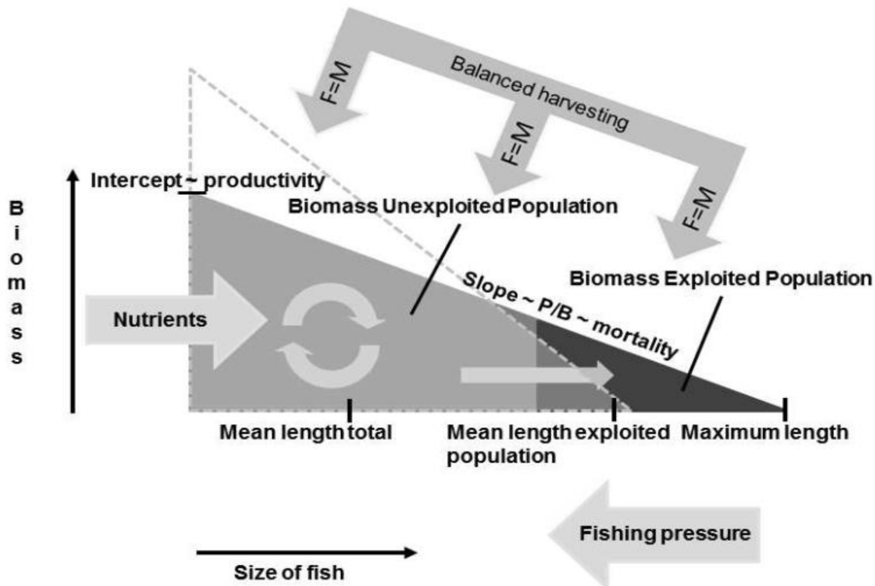
4.3 Conditions and limits for implementing balanced harvesting

The conditions for implementing balanced harvesting have been widely debated in recent years (Pauly & Froese 2020), and it is clear that in the context of marine fisheries many issues remain unresolved. This is particularly due to the great complexity of ecosystems and commercial fisheries with specific demands on certain species and sizes (Garcia 2015). However, when considering the application of this approach to inland fisheries, the evidence supporting its feasibility is much more established (Kolding & Zwieten 2014).

The principle of balanced harvesting can be summarized in Figure 4. It illustrates that by applying a fishing effort proportional to the productivity of each fish size class, the biomass is reduced, but the structure of the ecosystem remains intact, and overall yield increases. In contrast, conventional fisheries exert fishing pressure mainly on large fish, leading to systematic overfishing and leaving a significant biomass of small fish unexploited.

The methods for assessing the state of a fishery from the perspective of balanced harvesting are less developed than those based on the conventional approach. However, there are a few relatively simple indicators that can be effective and illustrative, even in data-poor situations. The primary indicator concerns the exploitation profile relative to the productivity of the fish population.

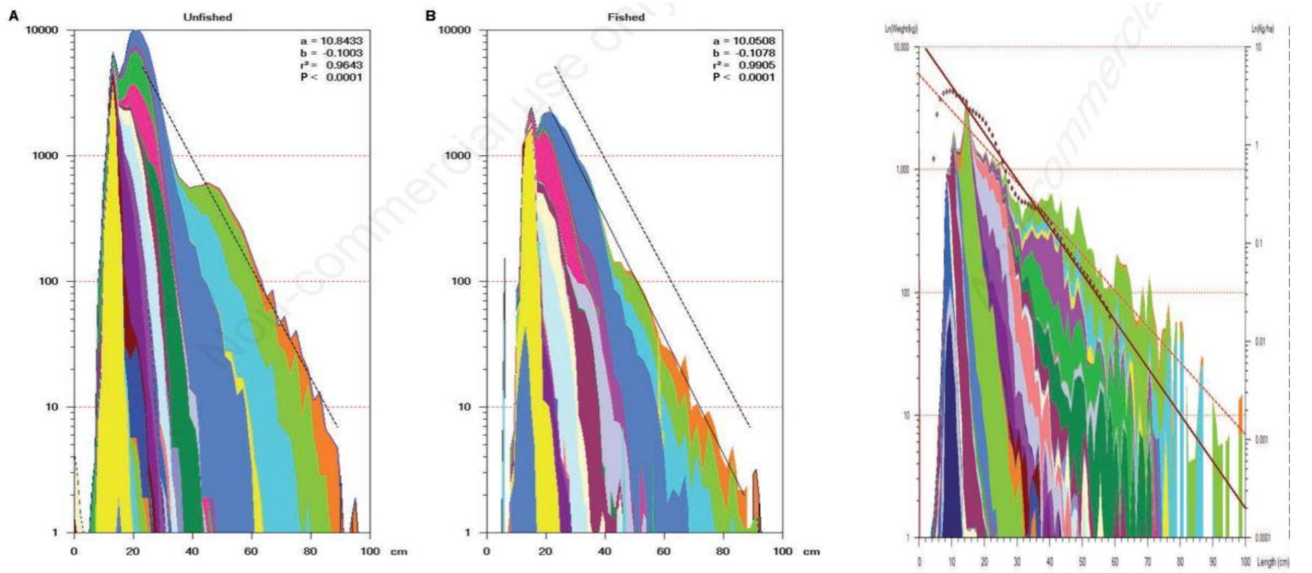
FIGURE 4: Diagram on a logarithmic scale showing the effects of balanced harvesting (arrows indicating fishing pressure) compared with selective harvesting (dotted triangle) on biomass for different size classes of fish. (Kolding and Zwieten 2014)



The method involves plotting biomass as a function of fish length for all catches, using a logarithmic scale with base 10 for the biomass. A logarithmic scale is used because small individuals are typically 1,000 times more numerous than larger ones. Figure 5 illustrates the type of curve obtained, where the colours represent different species or groups of species. In an unexploited environment (left), the linear regression of the curve typically has a characteristic negative slope, theoretically close to -1 in a normalized undisturbed size spectrum (Hatton et al. 2021). In a balanced harvested environment (centre), the slope will be similarly negative but positioned lower on the graph. Conversely, the more selective the fishing (right), the steeper the slope of the regression line will be, indicating that large fish constitute the majority of catches (Figure 4).

The first examples showing the effects of a balanced harvesting approach were observed in small-scale African fisheries that had never been subject to conventional fisheries management regulations on selectivity (Jul-Larsen et al. 2003). Initially considered as evidence of destructive fishing due to their non-compliance, these fisheries have since become recognized as examples of ecologically and socially optimal fisheries (Kolding and van Zwieten 2014; Kolding et al. 2015; Kolding et al. 2016b). While the case studies presented here are limited to African inland fisheries, there are other examples, particularly in Asia (Kelkar and Arthur 2022).

FIGURE 5: Representation of the biomass distribution (Log10) by size and species of fish observed in the catches: on the left, in an unfished area, in the centre, in a case of balanced harvesting with parallel slopes comparing unfished and fished situations, and on the right in a case of selective harvesting. (Kolding & Zwieten 2014)



05

Examples of partially balanced fisheries

5.1 Natural large lakes

Lake Victoria (Natugonza et al. 2022)

Lake Victoria, shared by Kenya, Uganda, and Tanzania, is the largest natural tropical lake by both size (68,800 km²) and fish production, with more than 1,000,000 tonnes caught on average over the last decade. The fishery of the Lake Victoria sardine (Rastrineobola argentea) fishery, locally known as dagaa, contributes the largest volume of catches, with an annual harvest of around 600,000 tonnes. This is followed by the Nile perch (Lates niloticus), with around 230,000 tonnes, a species introduced to the lake in the 1950s. Other fisheries produce around 200,000 tonnes a year, mainly of tilapia. Prior to the 1990s, the fishery almost exclusively targeted large Nile perch and tilapia. The fishing effort surged in the 1990s, increasing from 50,000 to 200,000 fishers, with a proportional drop in annual catch rates from 40 to 10 tonnes per boat. This intensified effort was then fairly rapidly directed towards other available resources, particularly young Nile perch aged between one and two years, which are three times more abundant than adults and have no predators other than their own species, and dagaa, which has a considerable productivity (P/B of the order of 4 per year).

Since the 2000s, this situation has stabilized, and a study of catch profiles reveals that all the ecosystem components are exploited to some degree, in proportion to their productivity, despite intense pressure on adult Nile perch in certain areas to meet the demands of processing plants and exporters. The Lake Victoria Fisheries Organisation is currently focused on promoting small pelagic fisheries and their value chains due to their significant contribution to employment and food security.

Lake Mweru (Kolding & van Zwieten 2014)

Lake Mweru, covering an average area of 5,100 km², is shared between the Democratic Republic of the Congo and Zambia. In the 1960s, commercial fishing led to the overexploitation of the endemic tilapia (Oreochromis mweruensis). In the 1970s, a new light attraction fishery was developed to catch the Lake Mweru sardine (Microthrissa moeruensis), locally known as chisense, which has a maximum size of 5 cm and had previously been completely ignored. Then, in the 1990s, fish aggregating devices were introduced to target the previously unexploited small specimens of several species. The shift to smaller mesh sizes and the diversification of fishing methods resulted in a sixfold increase in total yields between 1970 and 2008. Although the relative abundance of large fish has generally declined, no species has disappeared from the system. In fact, the overall reduction in mesh size has been followed by a recovery in the mean size and biomass of the endemic tilapia (Oreochromis mweruensis).

A closer examination of the size structures reveals that since the 1980s, the relative biomass of very large fish (79-82 cm) in the community has remained constant, while that of medium-sized fish (30-40 cm) has slightly increased. This is accompanied by a large increase in catches of the smallest size fish in the community. This trend continued in the 2000s, alongside a doubling in the number of fishers.

5.2 Large reservoirs

Lake Volta (Kolding & van Zwieten 2014)

Lake Volta, created in 1964, is the world's largest reservoir by area, covering 8,500 km² and located entirely in Ghana. Although fishing efforts and landing statistics are not regularly updated, it has been estimated that around 100,000 fishers produce up to 250,000 tonnes per year (van Zwieten et al. 2011). Of the 121 species identified, around 75 are exploited to varying degrees, depending on their seasonal abundance. This variability is linked to the hydrological regime of the river Volta. During periods of flooding, between 150 and 1,800 km² of the land becomes inundated, creating new habitats for fish. This land is often grazed or cultivated during the dry season, contributing to the high productivity of the reservoir after flooding. Average daily catches are around 25 kg, amounting to 7.5 tonnes per pirogue over the year (Zwieten et al. 2011). Since the 1960s, fishers have developed a diverse range of 27 types of fishing gear. According to regulations based on conventional fisheries management, the majority of this gear is technically illegal. However, there is little to no enforcement, and fishers often switch between different gear and habitats throughout the year. Each gear targets a specific length range (mostly between 4 and 35 cm), corresponding to a group of species. Cumulatively, these catches involve all commercial species at various stages of their lives and across the entire exploitable habitat, effectively exemplifying the balanced harvesting approach.

Lake Kariba (Kolding et al. 2016)

Lake Kariba, located on the Zambezi River, is an artificial lake created in 1959, primarily for hydroelectric power generation. The reservoir, covering an area of 5,400 km², is shared between Zambia (45%) and Zimbabwe (55%). The lake supports significant fisheries, which, for historical reasons, have been managed very differently in each country. Zimbabwe has implemented and enforced regulations derived from conventional fisheries management, including effort restrictions, mesh size limits, and the establishment of several natural reserves closed to fishing. In contrast, fishing in Zambia has remained largely open access and unregulated.

Like all tropical basins, fish production in Lake Kariba fluctuates according to the river's hydrodynamic regime. While biomass levels are high and generally stable in Zimbabwe, they have sharply declined in Zambia over the last few decades. The average mesh size used by various fishing units has decreased, leading to a reduction in the average size of the fish caught. However, a comparison of the highly exploited Zambian fish community with an unexploited community in an area permanently closed to fishing in Zimbabwe reveals that the two communities are identical in structure, differing only in terms of biomass (Figure 5, left and centre). Consequently, the gradual shift in Zambia's fishing profile towards smaller but more productive ecosystem components has enabled a balance between fishing and ecosystem productivity while still preserving its structure.

In other words, Zambian fishing, technically illegal and unregulated, appears to align closely to a sustainable ecosystem approach to fishing.

5.3 Floodplains

The fishery on Zambia's vast Bangweulu floodplain is the second largest in the country. Rainfall is the primary factor determining the extent of flooding, and good fishing years follow years of heavy precipitation. During the dry season the water recedes, causing all the fish to concentrate in isolated pools or main channels, including juveniles that previously fed on the flood plains. This leads to a period of high mortality due to predation and declining water quality. Consequently, the biomass mainly consists of small fish under 15 cm. Fishing involves a seasonal rotation of traps and gillnets, the latter often combined with water beating (kusikila). These methods have remained largely unchanged since the 1940s, but under current regulations, traps and most gillnets are illegal because of their fine mesh size. A study of catches by the main fishing gear shows that all 35 species present are caught by at least one type of gear. The results indicate almost balanced catches in relation to the productivity associated with size. An early 2000s stock assessment revealed that the only overexploited stocks were the largest predators caught by legal gear. For gillnets alone, 90% of catches were made in meshes smaller than the legal mesh size yet were only lightly to moderately exploited. The Bengweulu marsh fishing is considered biologically and socially sustainable. By harvesting a seasonal and transient assemblage of species with high levels of productivity and biological turnover, already adapted to high mortality, fishers have maintained stable livelihoods for decades (Huchzermeyer 2013).

Many African floodplain fisheries share characteristics with those in the Bangweulu swamps (ANRC 2022b), but few have been studied in sufficient depth to confirm adherence to balanced harvesting principles. However, partial information, like the diversity of fishing methods used annually, or the species and size of fish composition at markets can be indicative.

In Mali's Inner Niger Delta, over a hundred types of fishing gear have been documented, including very small-mesh nets and traps used in shallow waters. This gear catches very small species or juveniles of larger species. Over several years, catch profiles show that more than 75 different species ranging over different sizes are caught, suggesting balanced harvesting (Quensière 1994). Additionally, fishing has long been insulated from external markets, except for occasional Nile perch demand in major urban centres like Bamako.

In South Africa, on the Pongola River floodplain, fishers reputedly use a wide range of gear types. Some are used collectively, capturing all species present in the environment, including the smallest. Studies on resource state and biodiversity have shown no signs of overexploitation (Britz et al. 2015).

In the middle valley of the Senegal River, the gear diversity allows each species to be targeted at different times of the year. Fishers can predict the successive movements of each species in the receding channels. Some traps are designed to capture a range of species, first attracting the smallest fish, then their predators, and finally the largest predators (Adams-Sow 1996), following the natural trophic chain.

In conclusion, these examples illustrate that conventional management tools, by prohibiting the capture of small species and small sizes, do not maximize yields and also fail to maintain the internal structure of the exploited ecosystem. This approach hinders the achievement of an ecosystem-based approach to fishing.

06

Constraints and challenges to implement balanced harvesting

The implementation of a balanced harvesting approach faces constraints, largely due to the framework of international conventions ratified by most countries. However, the implications and contradictions of these conventions on inland fisheries have not been thoroughly analysed or debated. Biodiversity protection primarily focuses on terrestrial and marine environments, with freshwater environments receiving much less attention.

Moreover, the inland fisheries sector is often overlooked in development policies, partly because it is not directly linked to any sustainable development goal (SDG) beyond its underestimated contribution to SDG2. Additionally, SDG14 is exclusively concerned with marine ecosystems. Consequently, most countries have simply adopted legal frameworks for managing inland fisheries that mirror the principles of conventional industrial marine management developed in the global North (Kolding and van Zwieten 2011). Revising or even abandoning these frameworks necessitates a heightened awareness among the various government departments responsible for these sectors, including both managers and scientific research institutes. These institutes often lack the resources to manage inland fisheries effectively, compared to marine fisheries, and do not possess the information needed for a more critical analysis of prevailing scientific models. Conservationists, often playing a secondary role in managing inland fisheries and aquatic environments, should also be more involved in awareness-raising efforts.

Before reforming the political, regulatory and institutional frameworks, it is crucial to analyse the existing situation pragmatically. If the traditionally managed fisheries align closely to balanced harvesting principles, maintaining them as they are, while strengthening the existing governance framework, may be a viable option. Conversely, if the fisheries have been significantly altered by applying conventional approaches, including market influences which favour the capture of a few species and sizes, then a more proactive approach may be necessary. This could involve promoting those fisheries targeting small species or juvenile fractions of larger species while possibly reducing fishing pressure on the larger sizes of specific targeted species. In the context of fisheries with a commercial component, it may nevertheless be important to limit the overall fishing effort.

The challenges vary by country, depending on the importance attached to developing inland fisheries while applying sectoral policies. A nearly universal challenge is presented by the regulatory frameworks inspired by the conventional fisheries management, which enforce gear selectivity and prohibit the capture of juvenile fish, often without a solid scientific basis and disregarding customary natural resource management laws. The final challenge is reforming institutional frameworks, which are frequently weak yet firmly committed to their prerogatives, despite regular difficulties in enforcement.

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Opportunities for African inland fisheries

There are numerous reasons to maintain and favour a multi-species balanced harvesting approach in inland fisheries, with the most compelling being the significant potential to responsibly increase production. This increase can be achieved by expanding the range of sizes caught and adjusting the fishing effort to match the relative productivity within each size class. The potential for production gains is particularly notable in the African Great Lakes, certain large reservoirs, and river basins that are currently only lightly to moderately exploited, especially in central and southern Africa. With average productivities for various aquatic environments in Africa ranging from 3 to 8 tonnes per km^2 annually (Lymer et al. 2016), there is a possibility to increase these figures by 50% to 100%.

A second advantage of balanced harvesting is its alignment with traditional floodplain management. Fishing communities have developed various techniques over generations to catch fish according to their availability and accessibility in the environment. In many regions, these methods persist or are at least tolerated, particularly where conventional regulatory approaches have not been well implemented or enforced. In such cases, management incurs no cost other than those associated with the customary distribution of access rights and the control of closed fishing seasons and areas.

Conversely, in regions where mesh size regulations have been rigorously imposed and enforced, gradually lifting these restrictions could reduce conflicts between fishing communities and administrative bodies, while also decreasing surveillance costs that often prove challenging to implement. These costs would be notably lower in terrestrial protected areas managed by international conservation organisations, which sometimes exert undue pressure on local communities by equating fishing with hunting. Allowing local communities to engage in balanced subsistence fishing could lessen the pressure on terrestrial fauna without endangering aquatic biodiversity.

Fundamentally, maintaining and developing balanced harvesting approaches could meet the need for improved nutrition through the production of substantial quantities of small fish, which can be easily consumed whole and preserved cheaply by drying. These products require minimal resources for packaging, when employing traditional practices already proven effective in major floodplains, where storage times can extend for several months (Bavinck et al. 2023). This treatment would also reduce post-harvest losses and cut storage and transportation costs by eliminating the need for cold chains.

Finally, shifting the catch profiles in Africa's major fisheries towards a higher proportion of small fish could address the growing demand in the African market for nutrient dense, low-cost, easy-to-preserve products. This shift would significantly reduce the continent's reliance on imports, which currently consists predominantly of small marine pelagic fish and frozen farmed tilapia of less-than-optimal nutritional quality.

Conclusion and Policy Recommendations

African countries possess significant potential for fisheries resources in their freshwater bodies. The contributions of these resources and inland fisheries to the food security, livelihoods and well-being of millions of households should be acknowledged and emphasized in sustainable development strategies. This includes their capacity to adapt to environmental and climate change without altering often ancient fishing techniques or the level of fishing effort.

Countries considering a review of their sectoral policy should aim to develop strategies that reconcile the ecosystem approach to fisheries, the objectives of the Global Framework for Biodiversity, and the sustainable development goals. Such policy frameworks would foster the development of the fisheries sector by optimizing production, enhancing food and nutrition security, and creating jobs, while also preserving biodiversity and traditional fisheries governance and management. Sustainable management policies should, under no circumstances, prioritize the increasing exports of fisheries products outside the African continent.

Awareness-raising programmes about the principles of the ecosystem approach and balanced harvesting should target all stakeholders, including managers of fisheries at both central and decentralized levels, tourism sector stakeholders, conservationists, and civil society organisations. Open communication between institutional and private stakeholders and fishers is crucial for establishing a trust-based relationship free from prejudice.

In countries where a sectoral policy review is not planned, a more tactical approach should be considered. The first step would be to conduct a comprehensive inventory of existing fisheries, taking into account their seasonal variability. This inventory should encompass all components of the fishery - stakeholders, technical resources, and the composition and structure of catches – without the intention to control or suppress practices deemed illegal.

Subsequently, there should be agreement to maintain the status quo for fisheries managed in a balanced or nearly balanced manner. For fisheries with a commercial aspect, it may be viable to conduct pilot experiments by temporarily relaxing regulations on selectivity (Peter and van Zwieten 2022). This approach can be implemented without an immediate overhaul of political and regulatory frameworks, by granting competency to the traditional local authorities. This would facilitate a return to balanced exploitation of the various resource components, in line with practices based on local knowledge.

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