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## Sustainable exploitation and participative conservation of Mormyridae fishes in the Malebo Pool, Congo River, Kinshasa

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### Abstract

Mormyridae fish, which make up 20 to 25% of the catches in the Malebo Pool, are subject to pressure from local fishermen. This pressure on the resource is the basis of the decrease in catches, which has an impact on the social situation of the people involved in the sector. The objective of this study is to evaluate the exploitation of Mormyridae fish in the Malebo Pool and to propose conservation measures for sustainable management. The data was collected using the survey method with the interview technique. The results obtained confirm overfishing with a decrease in catches, which has consequences on the social situation of fishermen, fishmongers, processors and consumers. Thus, in order to reduce overfishing to a sustainable exploitation, co-management between the manager and the stakeholders, compliance with regulations, awareness raising and training in conservation and sustainable exploitation based on a series of biological and socioeconomic indicators accepted by all stakeholders are necessary.

**Keywords:** Exploitation, Fishmonger, Mormyridae, Fisherman, Malebo Pool, Overfishing

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## 1. Introduction

The fishes Mormyridae constitute one of the largest families of endemic freshwater fishes in Africa (Stiassny et al., 2007). The work of Hanssens et al. (2008) and Mbadu (2011) in the Malebo Pool determined 10 genera and 46 species for this family.

This resource is under pressure from a poorly known group of fishermen from the surrounding sites of Pool Malebo (Maluku, Ngamanzo, Kinkole, Kingabwa and Kinsuka fisher) (Ntumba et al., 2022a) which needs to be interactively characterized for sustainable management. This intensified anthropic pressure on the fisheries resource, which is accompanied by the deterioration of environmental conditions, is a consequence of the galloping population growth in these riverside settlements, poverty, unemployment and the struggle for survival (Kasigwa et al., 2020; Mbadu, 2011; and Vanga, 2011).

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The results of this study should provide solutions to the problem of managing Mormyridae stocks and will serve to raise the awareness of stakeholders for a sustainable exploitation of this remarkable natural heritage.

### 2.1. Study sites

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Given the lack of information on the number of people involved in fish exploitation in the Malebo Pool, a sample of 138 individuals was selected during the period July to August 2020. These included fishermen (70), fishmongers and traders (37), processors (16), public administration resource persons and consumers (15).

### 2.3. Methods

A survey questionnaire was developed and pre-tested to collect information on the mode of exploitation of the fish, the fisherman's perception of the aquatic environment, the fishing sites, the catches and sizes of the different species of Mormyridae, the techniques and gear used.

Field observations at the landing of the pirogues were also carried out to confirm the information from the interviewed stakeholders on the gear and techniques used, the catches and identification of Mormyridae fish during the study period. For the resource persons, the interview survey technique as used by Luhusu and Micha (2013) and Vanga (2011) was employed. These surveys were conducted by ourselves with the help of three interviewers.

Semi-structured interviews with fishermen in focus groups were conducted in each site to verify the information obtained individually from the fishermen and to obtain answers to questions for which it is not easy to obtain precise answers by questionnaire (Mukabo Okito et al., 2017).

### 2.4. Statistics

Data from the collected surveys were interpreted using SPSS version: 25 on Microsoft Windows 10.

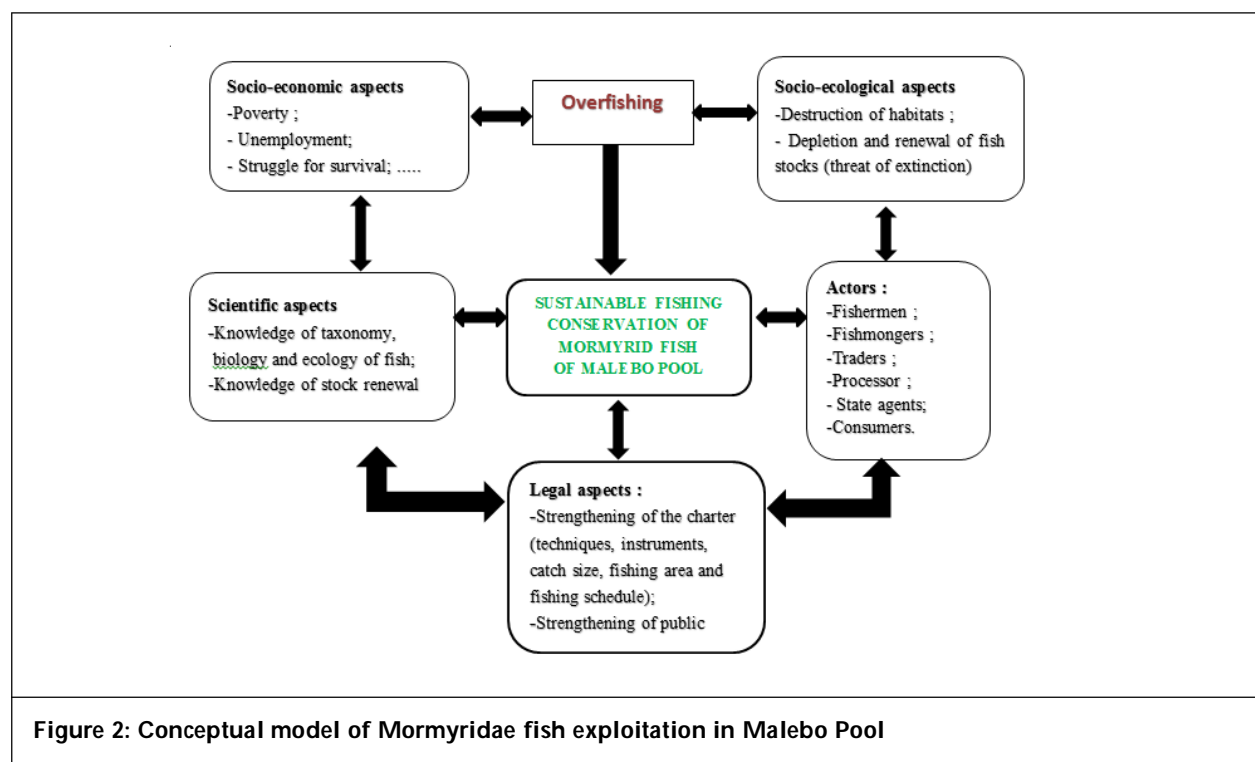
## 3. Results

### 3.1. Conceptual model on the exploitation of Mormyridae fish in the Malebo Pool

In a systemic approach, this study includes all the actors involved in the fishing sector in the Malebo Pool. It identifies the causes that have led to the overexploitation of the resource and proposes a global solution to the problem with a view to sustainable exploitation.

Thus, the model presented in Figure 2 shows the interactions between four important aspects, namely, socioeconomic, scientific, legal and socioecological. These aspects have a more or less important feedback with each other and with the multi-stakeholders involved in the exploitation of fish, leading to overfishing.

Scientific information on the taxonomy of the Mormyridae, the renewal of their stocks and ecological aspects inform and reinforce the provincial fishing regulations. The application of these regulations by the managers in collaboration with the local monitoring committees and their respect by the multi-stakeholders involved in fishing in the Malebo Pool can reduce overfishing to a sustainable fishery ensuring the conservation of fish species.



### 3.2. Socioeconomic characteristics of fishermen

Fishing in the Malebo Pool is mainly a male activity (98.6%), while the sale of fish at the market and processing are mainly done by women (100%). These fishermen have an average age of  $41 \pm 9$  years, with a minimum and maximum of 20 and 65 years respectively. They are mostly married (97.3%) with household sizes of 2 to 4 persons (5.4%), 5 to 6 persons (32.4%), 7 to 9 persons (45.9%), 10 persons and more (16.2%). Few singles (2.7%) were identified.

These fishermen have a secondary education with or without a diploma (83.8%) and primary education (16.2%). They live in the quarters and communes of Kinkole (40.5%), Kingabwa (16.2%), Nsele (16.2%), Ngaliema (13.5%), Ngamanzo (5.4%), Masina and Kingasani (8.1%). The dominant tribes encountered are the Lokele (28.5%), Mongo (27.1%), Kongo (7.1%), Bangala (7.1%), Mbunza (5.7%) and Yaka (5.7%). The other tribes encountered were the Sakata (4.3%), the Songe (4.3%), the Ngombe (2.9%), the Topoke, the Tetele, the Libinza, the Ekonda and the Ngwaka, each representing 1.4%.

### 3.3. Declining catches and the social situation of fishermen

In the Malebo Pool, fish catches per fishing team vary from 3 to 4 kg per day (55.7%) and 5 to 7 kg per day (38.6%). Minimum catches of 1 to 2 kg per day (4.3%) and maximum catches of 8 to 10 (1.4%) are rare. The fishing effort is 3 to 6 h (22.8%), 6 to 8 h (31.4%) and 8 to 12 h (45.7%) per day at a work rate of 3 to 4 days per week (50.0%) and 5 to 6 days per week (44.3%). Fishermen who work every day and those who work 1-2 days per week represent 4.3% and 1.4% respectively.

Mormyridae, which represent 20 to 25% of the catches according to 55.2% and 28.6% of the fishermen interviewed respectively, are caught almost every day at a rate of 1 to 1.5 kg per fishing team, the number of which is not known. Catches are good in the dry season and low in the rainy season as confirmed by 82.8% of respondents. Seven percent of the fishers observed a decrease in catches between the years 2000 and 2005; 34.4% between 2006 and 2009; 30.1% between 2010 and 2014 and 28.5% between 2015 and 2019.

The low fish catches as indicated in Figures 3; 4 and 5 lead to low incomes among the fishermen and negatively influence their socioeconomic situation and further impoverish them. 12.9% of the fishers estimate their daily income to be between 5 and 10\$, 47.1% estimate between 10 and 15\$, 18.6% estimate between 15 and 20\$ and 1.4% estimate to get 20\$ or more. The rest are difficult to calculate and it depends on the quantity and quality of the catch.

To supplement their income and meet their social and economic needs, 42.9% of the fishermen resort to complementary activities (agriculture 11.4%; petty trade 8.6%; masonry and handicrafts 8.4%; carpentry 1.4%; whaleboat construction 2.8%; making of fishing nets 1.4%; musical and plastic arts 4.2%; driving 4.7%). But 77.1% of these fishermen confirm that these activities are less profitable than fishing.



Figures 3; 4 and 5: Mormyridae catches at Kinsuka and Kinkole sites

### 3.4. Causes of reduced catches

In the Malebo Pool, the causes of the decrease in catches resulting in the exploitation of small specimens are non-stop overfishing using non-selective and unauthorized gear (62.8%), the use of habitat-destroying techniques and gear (passive nets with a mesh size of less than 3 cm between knots, mosquito nets, Sambwisa



fishing (18.5%)), which prevent good natural recruitment of fish stocks, and the use of small-mesh nets (18.5%). Thus, this situation inevitably leads to a decrease in their biomass and therefore in the yield of fishing units.

Other causes of this decrease in catches are the increase in the number of fishermen in the Malebo Pool who have free access to the resource, the lack of monitoring of fishing regulations and the high demand for fish by consumers.

### 3.5. Fishing gear and techniques

As the Ngamanzo site is characterized by the deep waters of the Malebo Pool (Ntumba et al., 2022a), the results of the surveys presented in Table 1 and the field observations show that drift netting with a mesh size greater than or equal to 3 cm is the most common method of fishing (66.7%), followed by still netting (14.2%). A small proportion of fishermen fish with hawks and nets for aquarium fish. Few fishermen (9.5%) practise Nduka fishing in the dry season. The Nduka technique involves fencing off a grassy stretch of bank with nets of at least 2.5 cm mesh and leaving it for two months, then harvesting the fish trapped there while cutting and clearing floating and submerged weeds.

At the Kinkole site, most fishers (42.1%) use a set net, followed by a drift net (15.8%). The Nduka and Sambwisa fishing techniques are practiced in the dry season by 10.5% of the fishers respectively. The Sambwisa technique consists of encircling part of the floating and submerged vegetation with a net with a mesh size of 1.5 to 2.5 cm, then using a machete, cutting and removing the weeds, tightening the net and harvesting the fish.

Site/Techniques	Drift gillnet (%)	Standing gillnet (%)	Beach seine (%)	Nduka fishing (%)	Sambwisa fishing (%)	Fishnet (%)	Sparrowhawk net (%)	Creeel (%)	Total (%)
Ngamanzo	66,7	14,2	0	9,5	0	4,8	4,8	0	100
Kinkole	15,8	42,1	5,3	10,5	10,5	5,3	5,3	5,3	100
Kingabwa	20	33,3	13,3	13,3	6,7	0	13,3	0	100
Kinsuka	0	33,3	0	0	0	0	60	6,7	100

Station/Mesh size of nets	Ngamanzo (%)	Kinkole (%)	Kingabwa (%)	Kinsuka (%)
1.5 ; 2.5 ; 4 cm	0	36.8	0	0
1.5 ; 2.5 ; 3.5 cm et 8 – 4 -12 cm	0	47.4	40	0
24-3-8 cm et 20 – 8 – 16 cm	42.9	5.3	0	0
6-3.5 - 12 cm et 4 ; 1.5 ; 6 cm	9.5	0	26.6	0
4 ; 1.5 ; 6 cm	0	0	33.3	0
3.5 – 6 -10 cm et 16- 8- 25-cm	0	10.52	0	0
6- 4-12 cm et 16- 3 - 25-cm	47.6	0	0	0
1.5 ; 2.5 ; 3.5 cm et 6 ; 10; 16 cm	0	0	0	13.3
2.5 ; 6 ; 8 cm et 8 ; 12 ; 14 cm	0	0	0	60
2.5 ; 6 ; 8 ; 12 cm	0	0	0	26.6
TOTAL %	100	100	100	100



**Figure 6; 7 and 8: Fishing gear at the Kinkole site. Figure 7 shows boats with batteries of nets of different mesh sizes, including mosquito netting**



**Figure 9; 10 and 11: Trammel nets at Kinkole and Ngamanzo, creel at Kinsuka**

Hawk fishing, beach seining, creel fishing and dip net fishing for aquarium fish are each practiced by 5.3% of the fishermen.

At the Kingabwa site, the dormant net technique predominates (33.3%), followed by the drift net (20%). Beach seine, sparrowhawk and Nduka represent 13.3% each. Few fishermen (6.7%) are interested in the Sambwisa fishery.

The Kinsuka site is characterized by high water velocity and rocks (Ntumba et al., 2022a). It is difficult to fish with drift nets. Hawk fishing is more common (60%), followed by still net fishing (33.3%). Net fishing is also practiced by 6.7% of fishermen.

The results of Table 2 on the mesh size and type of nets inventoried at each fishing site indicate that :

- At the Ngamanzo site, fishermen use trammel nets (Figures 9 and 10). More than 90% of these layers of nets have mesh sizes greater than or equal to 3 cm. Less than 10% of respondents admitted to using unauthorized mesh sizes of 1.5 cm among the net layers;
- At Kinkole, the fishermen use either batteries of nets of different mesh sizes (1.5; 2.5; 4 cm and 1.5; 2.5; 3.5 cm presented in figures 6; 7 and 8), or trammel nets (6- 3.5 -10 cm, 8 - 4 -12 cm, 20 - 8 - 16 cm, 16- 8- 25 cm. 84.2% of the fishermen admit to using nets of mesh sizes smaller than 2 cm (including mosquito nets) to capitalize on their harvest;
- At the Kingabwa site, all the fishermen admit to using nets with a mesh size of less than 2 cm in their batteries and in one of three layers of drift nets;
- At Kinsuka, the fishermen use batteries of standing nets and hawk nets with a mesh size of 1.5 to 16 cm. All the fishermen admit to using meshes of less than 2 cm in their nets.

**Table 3: List of Mormyridae caught according to the fishing gears and techniques inventoried in the four sites surveyed in Pool Malebo from July to August 2020**

Genus	Species	Gill net	Sambwisa fishing	Nduka fishing	Creel	Fishnet	Sparrow-hawk
<i>Campylomormyrus</i>	<i>Campylomormyrus</i> sp.	+	+	+	-	+	+
	<i>Campylomormyrus tamandua</i> Günther, 1862	+	+	+	-	+	-
	<i>Campylomormyrus elephas</i> Boulenger, 1898	+	+	+	-	+	-
<i>Genyomyrus</i>	<i>Genyomyrus donnyi</i> Boulenger, 1898	+	+	+	+	+	-
<i>Gnathonemus</i>	<i>Gnathonemus petersii</i> Poll, 1958	+	+	+	+	+	+
<i>Hippopotamyrus</i>	<i>Hippopotamyrus</i> sp.	+	+	+	-	+	+
<i>Marcusenius</i>	<i>Marcusenius greshoffii</i> Schilthius, 1891	+	+	+	-	+	+
	<i>Marcusenius fuscus</i> Pellegrin, 1901	+	+	+	-	+	-
	<i>Marcusenius macrolepidotus</i> Boulenger, 1905	+	+	+	+	+	+
	<i>Marcusenius monteiri</i> Günther, 1873	+	+	+	-	-	-
	<i>Marcusenius moorii</i> Günther, 1867	+	+	+	-	+	+
	<i>Marcusenius schilthuisiae</i> , Boulenger, 1899	+	+	+	-	+	+
	<i>Marcusenius stanleyanus</i> Boulenger, 1897	+	+	+	-	+	+
<i>Mormyrops</i>	<i>Mormyrops anguilloides</i> Linnaeus, 1758	+	+	+	+	+	-
	<i>Mormyrops boulengeri</i> Poll M., 1958	-	+	+	-	+	-
	<i>Mormyrops lineolatus</i> Boulenger G.A, 1900	+	+	+	-	+	-
	<i>Mormyrops masuianus</i> Taverne L., 1968	+	+	+	-	+	-
	<i>Mormyrops nigricans</i> Taverne L., 1968	+	+	+	+	+	+
<i>Mormyrus</i>	<i>Mormyrus caballus caballus</i> Thys vanden Audenaede D. 1977	+	+	+	-	+	-
	<i>Mormyrus ovis</i> Thys vanden Audenaede D. 1977	+	+	+	-	+	-
	<i>Mormyrus rume proboxirostri</i> Poll M. 1958	-	+	+	-	+	-
<i>Petrocephalus</i>	<i>Petrocephalus</i> sp.	+	+	+	-	+	+
<i>Pollimyrus</i>	<i>Pollimyrus</i> sp.	-	+	+	-	+	-
<i>Stomatorhinus</i>	<i>Stomatorhinus corneti</i> Boulenger, 1899.	-	+	+	-	+	-

24 species belonging to ten genera of the Mormyridae were identified in the catches of the different fishing gears and cited by the fishermen interviewed.

The Sambwisa and Nduka fishing techniques catch all the species of Mormyridae encountered in the fishing site. They are followed by gillnet fishing (set net, drift net, beach seine). Fishing with creels and hawksbill nets catches fewer Mormyridae.



The dip net is most commonly used on spawning grounds and along the shoreline. It harvests all species of all sizes in these sites, given the very small mesh size. The use of dip nets endangers the recruitment of these fish stocks.

The results of the surveys show that fishermen use several fishing gears depending on the season to maximize their catches. This situation makes it difficult to accurately determine the species caught with each fishing gear.

**Table 4: Mormyridae fish identified in catches from four surveyed sites in Pool Malebo from July to August 2020**

Genus	Species	Ngamanzo	Kinkole	Kingabwa	Kinsuka
<i>Campylomormyrus</i>	<i>Campylomormyrus</i> sp.	+	-	-	-
	<i>Campylomormyrus tamandua</i> Günther, 1862	+	+	+	-
	<i>Campylomormyrus elephas</i> Boulenger, 1898	+	-	+	+
<i>Genyomyrus</i>	<i>Genyomyrus donnyi</i> Boulenger, 1898	+	-	+	-
<i>Gnathonemus</i>	<i>Gnathonemus petersii</i> Poll, 1958	+	+	+	-
<i>Hippopotamyrus</i>	<i>Hippopotamyrus</i> sp.	+	-	+	+
<i>Marcusenius</i>	<i>Marcusenius greshoffii</i> Schilthius, 1891	+	+	+	-
	<i>Marcusenius fuscus</i> Pellegrin, 1901	+	+	+	-
	<i>Marcusenius macrolepidotus</i> Boulenger, 1905	+	+	+	-
	<i>Marcusenius monteiri</i> Günther, 1873	+	+	+	-
	<i>Marcusenius moorii</i> Günther, 1867	+	+	+	-
	<i>Marcusenius schilthuisiae</i> , Boulenger, 1899	+	+	+	-
	<i>Marcusenius stanleyanus</i> Boulenger, 1897	+	+	+	+
<i>Mormyrops</i>	<i>Mormyrops anguilloides</i> Linnaeus, 1758	+	+	+	+
	<i>Mormyrops boulengeri</i> Poll M., 1958	-	-	+	-
	<i>Mormyrops lineolatus</i> Boulenger G.A, 1900	+	-	+	-
	<i>Mormyrops masuianus</i> Taverne L., 1968	+	-	+	-
	<i>Mormyrops nigricans</i> Taverne L., 1968	+	+	+	-
<i>Mormyrus</i>	<i>Mormyrus caballus caballus</i> Thys vanden Audenaede D. 1977	+	-	+	-
	<i>Mormyrus ovis</i> Thys vanden Audenaede D. 1977	-	-	+	-
	<i>Mormyrus rume proboxirostri</i> Poll M. 1958	-	-	+	-
<i>Petrocephalus</i>	<i>Petrocephalus</i> sp.	+	-	+	-
<i>Pollimyrus</i>	<i>Pollimyrus</i> sp.	-	+	-	-
<i>Stomatorhinus</i>	<i>Stomatorhinus corneti</i> Boulenger, 1899	-	+	+	-

Ten genera and 24 species of Mormyridae fishes were identified in the catches of fishermen from four survey sites in Pool Malebo. The genus *Marcusenius* predominates with seven species, followed by the genus *Mormyrops* with five species and *Campylomormyrus* with three species. The genera *Gnathonemus*, *Geniomyrus* and *Stomatorhinus* are each represented by one species. The Kinsuka station is poor in Mormyridae, with four species identified. The fishermen of the Kingabwa station fish as far as the vicinity of the Molondo and Mbamu islands. This is the reason why this site is rich in Mormyridae diversity compared to other sites sampled.

### 3.6. Fish marketing

The fish are marketed according to a simple circuit. Each fishing unit sells its production to fishmongers (including traders) who sell to consumers and processors in the markets located at the landing ports or in other municipalities in the city.

The price of fish is fixed without any reference unit among the fishermen. It is set according to the quantity and species of fish (27.1%), the size of the specimen (8.1%), and the size and quantity of fish (64.8%). Among fishmongers, the profits vary between 10-20% (according to 16.2% of respondents); 20-30% (according to 48.6% of respondents); 30-40% (according to 35.1% of respondents). During the week, unsold fish are kept in cold storage to be sold the next day, often at a reduced price, even the purchase price. This situation leads to a loss of profit for the fishmongers.

The predominance of small specimens leads to an increase in the price of large specimens and a lack of interest from consumers. Small specimens are less beneficial and are often bought by low-income consumers from localities bordering fishing ports (56.8%) and also by sellers of Maboke products (a recipe for fish prepared stewed in fresh vegetable leaves) of small fish (32.4%).

The sale of large specimens is beneficial for fishmongers, but requires a significant amount of business. These large specimens of Mormyridae are often bought by sellers of Maboke products and consumers with high incomes who come from the remote localities of Pool Malebo (83.8%). However, given the scarcity of catches, 97.3% of the women fishmongers also sell other large fish such as catfish from upstream of the Malebo Pool (Bandundu and Equateur provinces on the Congo River).

In addition to meeting their social needs, these fishmongers often save their profits in the form of tontines with their colleagues and not in a banking circuit.

### 3.7. Socioeconomic characteristics of fishmongers

The fishmongers interviewed were mostly married (81.8%) with household sizes of 1 to 7 persons (43.4%) and 8 to 14 persons (56.8%). Few single women (8.2%) were identified. Most of them have secondary education (78.6%) and primary education (21.3%). They live in the Kinkole district (56.8%) and Ngamanzo district (13.5%) in the commune of Nsele, the Kingabwa district in the commune of Limete (16.2%) and the commune of Ngaliema (13.5%).

The dominant tribes encountered were the Mongo (29.7%), the Bangala (24.3%), the Lokele (16.2%), the Sakata (8.1%), the Mbunza (5.4%) and the Teke (5.4%). The other tribes encountered were the Basoko, Kongo, Ngombe and Ngwaka, each accounting for 2.7%.

Experience in buying and selling fish: 37.8% are 11 to 15 years old, 24.3% are 16 to 20 years old, 18.9% are 21 years old or more, 13.5% are 6 to 10 years old and 5.4% are 1 to 5 years old.

### 3.8. Category of fishmongers

Two categories of fishmongers were identified in Pool Malebo.

The first is made up of those who buy fish from the fishermen and sell at the market (86.6%).

The second category is made up of traders who, for the most part, pre-finance the activities of fishermen (13.4%) who have experienced difficulties in purchasing or renewing their fishing equipment. The pre-financed fishermen are obliged to sell their production to the financial wholesalers and subtract a percentage each time to recover their credit according to the agreed terms.

The pre-financial fishmonger in turn can either go and sell these fish at the market, or act as an intermediary between the fisherman and the other fishmongers and processors by negotiating the price of the fish. Cases of abuse of trust by fishermen receiving credit who sell their produce either at the camp or to other fishmongers without finishing the repayment of the credit are reported.

### **3.9. Compliance with regulations**

A 34 articles charter on the sustainable management of fishing and aquaculture in the city of Kinshasa was drawn up at the provincial Ministry of Agriculture and Rural Development in Kinshasa in December 2016. This charter identifies the types of fisheries practiced in Pool Malebo, the prohibited fishing techniques (nets with a mesh size of less than 2 cm, use of ichthyotoxic products, use of explosives, use of mosquito netting, weeding of the banks); the composition and role of the local committee responsible for monitoring (control and surveillance of fishing activities, ensuring the application of the principles and rules laid down by the charter).

All the fishermen interviewed (100%) confirmed that these regulations are poorly disseminated, not applied and not followed in the Malebo Pool due to the lack of motivation of the managers and the local monitoring committees. However, 58.6% of the fishermen interviewed were aware of the existence of the charter signed between the provincial government of the city of Kinshasa and the fishermen's associations of Pool Malebo.

In order to comply with these regulations, the fishermen have formulated a number of prerequisites, namely:

- the supervision and sensitization of fishermen by the provincial Ministry of Fisheries (22.9%);
- the creation of alternative activities (35.7%);
- the organization of follow-up between the Provincial Ministry of Fisheries, the local monitoring committees and the fishermen (4.3%);
- the restructuring and functioning of fishermen's organizations and the functioning of local monitoring committees (37.1%).

### **3.10. Fishermen's perception of sustainable exploitation**

57.3% of the fishermen interviewed believe that sustainable exploitation would be a good practice in that it would contribute to the protection of fish, the restoration of stocks and the improvement of catches, which would have a positive influence on the social conditions of all the actors involved in the fishing industry in Pool Malebo.

### **3.11. Proposal for a closed fishing season**

With regard to the respect of the fishing season, 27.4% of the fishermen interviewed believe that it will be beneficial for them, as the fish will grow and reproduce during this period and when the season opens the catches will be improved, the fishing effort will decrease and the revenue will increase. Given the dependence on this resource, fishermen from the Kinsuka site propose that the closure should be partial and not total in the Malebo Pool and that they should be grouped together in the open area to continue fishing.

### **3.12. Difficulties related to fishing activity**

The greatest difficulty in the fishing sector in Pool Malebo is the lack of inputs cited by 77.1% of fishermen. This is followed by the loss of equipment due to bad weather and animal attacks, the lack of rescue equipment and the lack of places to store fish (12.8%). 10.0% of the fishermen acknowledge the lack of means to replace equipment in case of loss.

To overcome these difficulties, 68.6% of the fishermen resort to pre-financing from the fishmongers, 22.9% rent equipment from their colleagues and 8.6% borrow from their colleagues or from the fishmongers.

### **3.13. Conflicts in the fisheries sector**

The causes of conflicts among fishermen are: theft of fishing equipment (15.7%), theft of fish from dormant nets (10.0%), failure to respect the order to arrive at the Ngamanzo net diversion site (15, 7%), dispute over the occupation of the site for the dormant net (40.0%), non-respect of commitments between fishermen and fishmongers (7.9%), non-payment of net and pirogue rental fees (5.0%), sharing of fishing income (5.7%). All these conflicts are resolved either amicably (54.3%), or through the intervention of the wise men (44.2%) or the police office (1.4%).

## 4. Discussion

### 4.1. Fishermen's perception of the evolution of the fish resource

In the Malebo Pool, fish are harvested without taking into account the renewal of existing stocks. 15.7% of the fishermen interviewed believe that the fish resource is still reproducing and that there will be fish for future generations. However, the use of non-selective gear and habitat-destroying techniques is a permanent threat to the reproduction of Mormyridae fish and influences stock levels. The FAO (1999) considers that the main threat to the sustainability of inland fisheries resources is not so much their overexploitation as the deterioration of the environment.

In this respect, fishermen believe that the implementation of certain strategies such as: the use of selective techniques (80.0%), respecting spawning grounds (8.6%), respecting fishing periods (5.7%) could help conserve the resource.

### 4.2. Degradation of Mormyridae stocks in Pool Malebo

In Pool Malebo, the use of mosquito nets, beach seines with a mesh size of less than 1.5 cm, Sambwisa fishing, and dip-net fishing in spawning grounds and nurseries leads to the destruction of fish stocks by capturing larvae and fry. The exploitation of juveniles and small immature specimens jeopardises the renewal of fish stocks and thus promotes their degradation.

These inappropriate nets and fishing techniques that affect the relative abundance of species are harmful and particularly dangerous because they scrape the bottom, turning over the substrate, thus obstructing food sources and fish nests (Ormerod, 2003; and Watling and Norse, 1998). This is a major threat to biodiversity and the maintenance of exploited stocks (Codjo et al., 2020).

For Ouattara et al. (2006), overfishing leads to a decrease in the size of individuals in the catch, abundance, yield and profitability of fishing operations. The fishermen interviewed in Pool Malebo stated that they put in a lot of fishing effort to obtain low catches and low incomes.

### 4.3. Causes of the decrease in catches

The increase in the number of fishermen, the use of non-selective and habitat-destroying fishing techniques and tools, the lack of monitoring of fishing regulations and the high demand for fish by consumers have been identified as the main causes of the decrease in catches in the Malebo Pool.

Already in 2011, Mbadu reported that the decline in catches, which contain fewer and fewer large specimens, was due to the lack of enforcement and the high pressure of continuous fishing throughout the year (without biological rest periods).

These results corroborate those of Balole-Bwami et al. (2018) and Kasigwa et al. (2020), in Lake Edward and Micha et al. (2021) at Lake Mai Ndombe where the decline in catch per unit of fishing effort was attributed to the emergence of poor fishing gear and techniques (the use of purse seines and beach seines), the increase in fishing effort on the lake the non-respect of fishing regulations, the absence of monitoring and control of net mesh and fishing sites, the destruction of habitats, the fishing of immature fish and illegal fishing, particularly with mosquito nets (Micha, 2019a).

On the other hand, Mukabo Okito et al. (2017) observed in Lake Tanganyika a reduction in the number of active fishing units due to a lack of fish as a result of the decrease in catches per unit of fishing effort, with much impact on their profitability and income.

This pressure on the resource contributes to the elimination of species of all sizes and destroys the source habitats of their prey. This situation has also been observed in Kenya where several restrictions have been observed in traditional fishing to conserve and restore fish stocks. But the maintenance of high numbers of fishermen in the sites and the use of beach seining techniques have kept the pressure on the resource (McClanahan et al., 1997)

The resolution of these problems at the root of the decline in catches must involve the eradication of bad fishing gear and techniques, the effective involvement of the provincial Ministry of fisheries, local committees, and the participation of fishermen.

These causes of the decrease in catches can also be eradicated by reducing the fishing effort to appropriate levels, implementing fishing regulations incorporating a strong form of the precautionary principle with limits on exploitable areas, including spawning grounds (Pauly *et al.*, 2002).

#### **4.4. Complementary activities of fishermen**

To supplement their income, which is affected by low catches, 42.9% of the fishermen interviewed in the Malebo Pool turn to complementary activities. But these activities are secondary and less profitable than fishing. This result is in line with that of Vanga (2011) in the Ayamé dam lake, where the continuous and uncontrolled exploitation of fishery resources has led to a gradual drop in production and a decline in the income of fishery stakeholders. They also agree with those of Kien *et al.* (2018), according to whom the decline in fishermen's incomes in the lower Bandama River in Côte d'Ivoire has forced them to turn to other activities that have become their mainstay, while fishing has become a secondary activity.

#### **3.5. Monitoring of regulations**

The existing regulations on fishing at provincial government level are not popularized or followed in the Malebo Pool. The local committees responsible for controlling and monitoring fishing activities and the service responsible for ensuring the application of the principles and rules set out in the charter are not operational due to the lack of financial and material resources allocated to the fishing sector. This lack of compliance with regulations was also observed in Lake Edouard (Balole-Bwami Lubala *et al.*, 2018), Lake Mai Ndombe (Micha *et al.*, 2021), Lake Albert (Kasigwa *et al.*, 2020). This observation is also made in Ivory Coast by Kien *et al.* (2018), and results in resource exploitation that is close to a critical state.

This non-compliance with regulations is also due to the lack of involvement of stakeholders directly involved in the exploitation and management of the resource (fishermen and local committees) and the failure to take into account their concerns and needs. There is a need for management involving all stakeholders (Pita *et al.*, 2010), as the representation and participation of all relevant actors is now considered a prerequisite for sustainable management (Mikalsen and Jentoft, 2001).

#### **4.6. Proposal for a fishing closure**

In order to restore the stock of Mormyridae fish in the Malebo Pool, it is necessary to proceed in consultation with the fishermen to close the fishery during the reproduction period between September and November, when the water level rises. This closure will allow the fish to grow and reproduce before being caught. During this period the majority of Mormyridae fish are in the process of maximum gonad development (Ntumba *et al.*, 2022b). According to Lévêque *et al.* (2006), most freshwater fish species in the intertropical zone mature and spawn when the water level rises following the start of the rainy season.

The suspension of fishing activities during the period corresponding to both the peak of gonadal maturation of fish and the maximum fishing activity in Lake Ayamé was also proposed by Ouatarara *et al.* (2006).

Garcia and Cochrane (2005) proposed that sustainable management of the fishery must include changes in fishing gear and practices, and spatial and temporal closures to protect spawning areas, critical habitats, biodiversity and life stages.

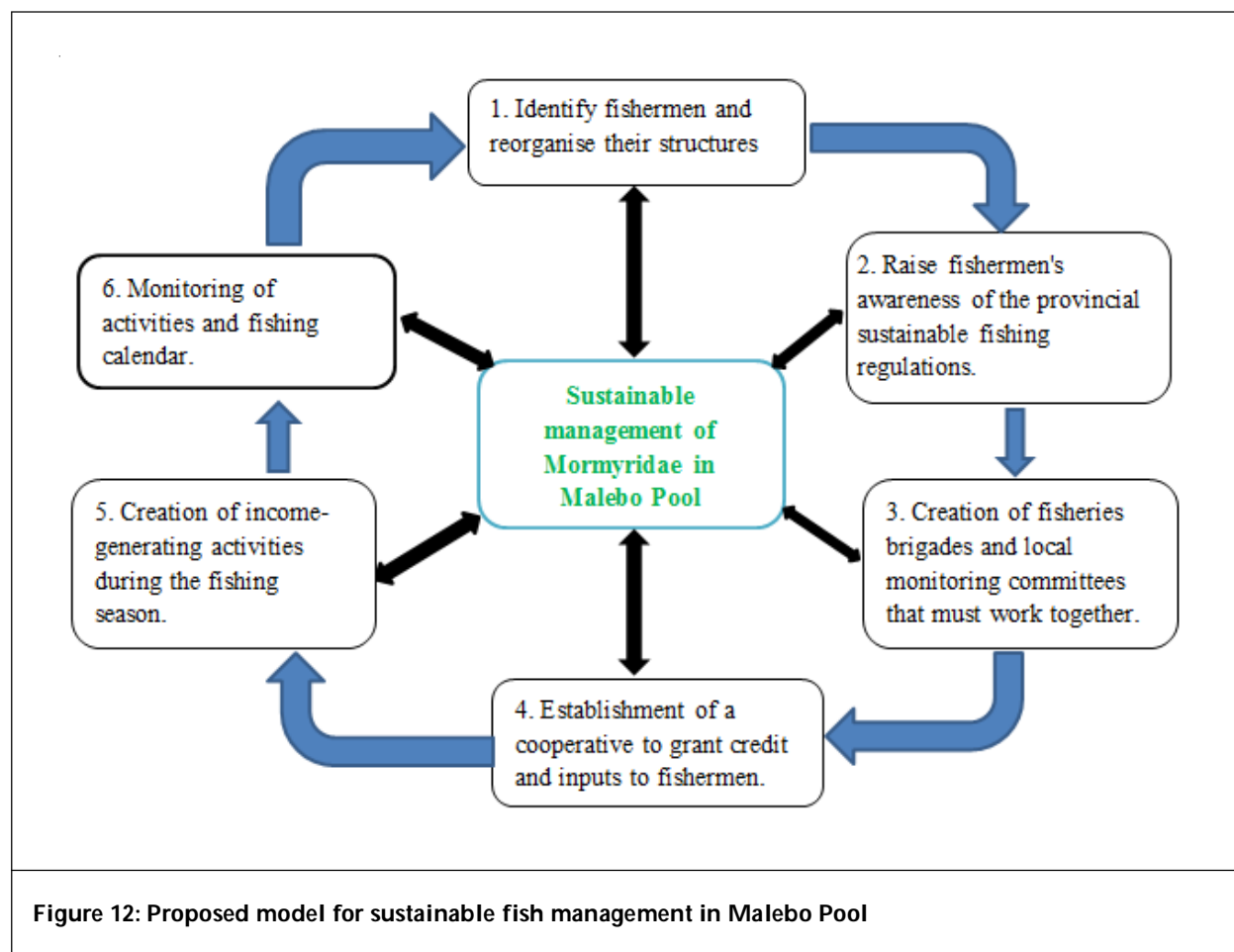
#### **4.7. Proposal for a sustainable fish fishery in Malebo Pool**

Fish are a public resource and should be managed through institutional arrangements that take into account the public interest in a stakeholder-based approach to fisheries management (Mikalsen and Jentoft, 2001). In order to shift the overfishing of fish in the Malebo Pool to sustainable exploitation, collaborative management between all actors in the exploitation would build trust between the different stakeholders. This concerted management concerns the provincial Ministry of Fisheries and the local committees for monitoring fishing activities involving fishermen and fishmongers. According to Kien *et al.* (2018) concerted monitoring of fishing activities would help safeguard the fish resource.

According to Bongeaba and Micha (2013) concerted management should involve fishermen with an emphasis on training in conservation and sustainable exploitation based on a series of biological and socio-economic indicators (yield and income) accepted by all stakeholders. Thus, to improve productivity and consequently fishermen's incomes, the current fishing practice raises the need for good governance in order to regulate fishing effort and encourage fishermen to comply with the regulations (Balole-Bwami *et al.*, 2018).



Thus, based on the results of the fishermen's surveys and personal reflection, here is a proposed conceptual model in six activities for sustainable management of Mormyridae in Malebo Pool.



From this model presented in Figure 12, the identification of fishermen and the revitalization of their associations, awareness raising, the strengthening of management bodies (control and monitoring), the granting of fishing inputs, as well as the diversification of sources of income could lead to the respect of the regulations for sustainable fishing.

The constraints linked to the implementation of sustainable fishing in the Malebo Pool are the lack of funding for the fishing sector, the lack of inputs, the difficulty of renewing equipment, the lack of credit and other income generating activities. These constraints demotivate 67.1% of the fishermen to join or remain in associations where they find no interest. Yet, these fishermen's associations would constitute a good channel for supervision and monitoring for sustainable fishing.

According to Micha (2019b), in order to reduce overfishing to sustainable exploitation, adequate measures must be applied, setting biological, economic and social indicators accepted by all stakeholders. In addition, the operational capacities of co-management bodies need to be strengthened and fishermen's livelihoods diversified through the promotion of alternative income-generating activities. This bottom-up participatory strategy should better integrate these field actors in a sustainable exploitation and aim at better strengthening the maintenance of the resource for present and future generations.

## 5. Conclusion

In the Malebo Pool, the overfishing of Mormyridae fishes results in a reduction in catches and a drop in the income of fishermen, fishmongers, traders and processors. The scarcity of large specimens leads to an increase in the price of fish and a lack of interest from consumers. In order to restore fish stocks and ensure sustainable fishing, compliance with the regulations in force, the closure of fishing during the reproduction period, concerted management of the sector with all the actors concerned, the restoration of the fishing brigade, the motivation of

the local committees for monitoring and controlling fishing and the diversification of the means of survival of fishermen will be able to build confidence among the various partners and lead to sustainable management.

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