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Fishing techniques used for the exploitation of fish in the flooded swamp forest of the Lake Tumba micro-basin on the Mbandaka-Center for Research in Ecology and Forestry (CREF Mabali) road axis in Bikoro in the Equateur Province (R.D Congo)

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Abstrak

Tujuan dari penelitian ini adalah untuk menginventarisasi teknik penangkapan ikan yang berbeda yang digunakan untuk eksploitasi ikan di hutan rawa yang tergenang air di cekungan mikro Danau Tumba di poros jalan Mbandaka-Pusat Penelitian Ekologi dan Kehutanan (CREF Mabali) di Bikoro di Provinsi Equateur, Republik Demokratik Kongo. Survei berbasis pertukaran dilakukan dengan menggunakan formulir survei yang telah ditetapkan sebelumnya untuk bertukar dengan nelayan yang bekerja di lokasi studi yang berbeda untuk mendapatkan data yang diharapkan. Pemanenan ikan dilakukan secara tradisional dengan menggunakan alat tangkap dan teknik penangkapan ikan yang berbeda yang digunakan oleh nelayan di wilayah studi. Hasil yang diperoleh menunjukkan bahwa sebagian besar praktik penangkapan ikan yang diterapkan di daerah ini tidak berkelanjutan. Secara total, sepuluh (10) teknik penangkapan ikan diidentifikasi, di antaranya lima (5) teknik penangkapan ikan yang mudah menghasilkan ikan, yaitu, creel fishing, scooping, penangkapan ikan dengan tanaman ichthyotoxic, longline fishing, dan line fishing, yang paling banyak digunakan oleh nelayan. Empat teknik penangkapan ikan (penangkapan ikan dengan perangkap tradisional, scooping, penangkapan ikan dengan tanaman ichthyotoxic, dan penangkapan ikan dengan cara penyiangan) dianggap tidak selektif dan mampu menciptakan ketidakseimbangan dalam ekosistem perairan yang berbeda yang disurvei. Studi ini berkontribusi pada peningkatan pengetahuan tentang eksploitasi keanekaragaman hayati hewan di Republik Demokratik Kongo, di satu sisi, dan di sisi lain, pengabadian pengetahuan penduduk lokal yang karakternya sudah usang tidak diragukan lagi.

Kata kunci: Alat tangkap; Bikoro; Fauna Ichthyological; RD Kongo; Teknik penangkapan ikan

Abstract

The objective of this study was to inventory the different fishing techniques used for the exploitation of fish in the flooded swamp forest of the Lake Tumba micro-basin on the Mbandaka-Center for Research in Ecology and Forestry (CREF Mabali) road axis in Bikoro in the Equateur Province of the Democratic Republic of Congo. The exchange-based surveys were carried out using a pre-established survey form to exchange with the fishermen working in the different study sites in order to obtain the expected data. The harvesting of fish was done in a traditional manner using the different fishing gears and techniques used by the fishermen in the study area. The results obtained show that the majority of the fishing practices implemented in this area are not sustainable. In total, ten (10) fishing techniques were identified, among which five (5) easily provide fish, namely, creel fishing, scooping, fishing with ichthyotoxic plants, longline fishing and line fishing, which are the most used by the fishermen. Four fishing techniques (fishing with traditional traps, scooping, fishing with ichthyotoxic plants and fishing by weeding the areas) were considered non-selective and capable of creating an imbalance in the different aquatic ecosystems surveyed. This study contributes to the improvement of the knowledge on the exploitation of the animal biodiversity of the Democratic Republic of Congo, on the one hand, and on the other hand, the perpetuation of the knowledge of the local population whose obsolete character is not in doubt.

Keywords: Bikoro; Fishing gear; Fishing techniques; Ichthyological fauna; R.D Congo

1. Introduction

Fishing in Africa is characterized by sustained development in an artisanal manner that contributes strongly to employment (Akonkwa et al., 2017). However, although fishing itself is an important source of employment, previous studies have highlighted that most employment in the fisheries sector is concentrated in post-harvest economic activities, including fish processing and marketing (FAO, 2014, 2017).

Fisheries, including aquaculture, make a fundamental contribution to food, employment, recreation, trade, and economic well-being of people around the world, both present and future generations, and should therefore be conducted in a responsible manner (FAO, 2011). Fishery products remain the only source of animal protein readily available among most poor populations (Masua et al., 2020) and, some developing countries (Lusasi et al., 2019a). Fishing is an essential economic sector for many countries around the world and is also an important source of foreign exchange. It provides employment and economic benefit to those who practice it (Danadu et al., 2017; Lusasi et al., 2019b).

The intensity and constancy of fishing pressure in many regions is a matter of concern for the scientific community, as it results in a progressive reduction in the availability of exploited resources (Lusasi et al., 2022), but also in a set of collateral damages affecting in a more or less irreversible way benthic communities and their habitats, as well as populations of the most vulnerable species (Sacchi, 2006).

Fishing is therefore the human activity that exerts the highest pressure on aquatic ecosystems (Lusasi et al., 2022), and this pressure tends to increase with a more intense and efficient fishing effort due to technological improvements, techniques, and fishing gear used (Akonkwa et al., 2017). The intensification of the exploitation of freshwater and brackish fish populations in Africa by local populations is constantly increasing and, above all, the acceleration of the degradation processes of the natural environment poses a major risk of regression and disappearance of species (Lalèyè et al., 2004). The need to take measures for conservation and rational exploitation becomes a major concern (Lusasi et al., 2022).

The species richness of the Congo ichthyo-geographic region is the highest of all African ichthyo-geographic regions described by Roberts (1975), modified by Lévêque (1997); Snoeks et al., (2011) and, is estimated at 1250 species of which 75% are endemic (Snoeks et al., 2011). Globally, it is second only to the Amazon basin (Monsemvula, 2018). In this region, studies have shown that the fishing harvest is significantly higher than its renewal and can produce long-term consequences that can be serious given that the reproduction of fish is conditioned by their sexual maturity (Milandu, 2012; Micha, 2019). The early capture, the intensity of fishing, and the techniques and materials used do not allow the achievement of maximum size or the selection of species in several aquatic ecosystems of the Democratic Republic of Congo (Lusasi et al., 2022).

However, it is important to question the sustainability of fishing in these environments, the persistence of the fish stock, but also the future of the fishermen who work there. It is in this context that this study on the fishing techniques used for the exploitation of fish in the flooded swamp forest of the micro basin of Lake Tumba on the road axis Mbandaka-Center for Research in Ecology and Forestry (CREF Mabali) in Bikoro in the Province of Equateur in the Democratic Republic of the Congo.

2. Materials and Methods

2.1. *Study environment*

This study took place in five sites (Longonye located at 00°30' 23.8'' South latitude and 18°18' 14'' East longitude, Hongo located at 00°41' 43.6'' South latitude and 18°14' 21.2'' East longitude, Ilungu located at 00°43' 30, 7'' South latitude and 18° 12' 45.3'' East longitude, Lotende located at 00° 45' 41.5'' South latitude and 18° 11' 49.5'' East longitude and Membe located at 00° 50' 24.5'' South latitude and 18° 10' 15.9'' East longitude) of sampling (Fig. 1). In this area, there are ponds, swamps, marigots and small streams in relation to Lake Tumba located in the floodplain forest area of the Mbandaka-Mabali road axis in Equateur Province, Democratic Republic of Congo.

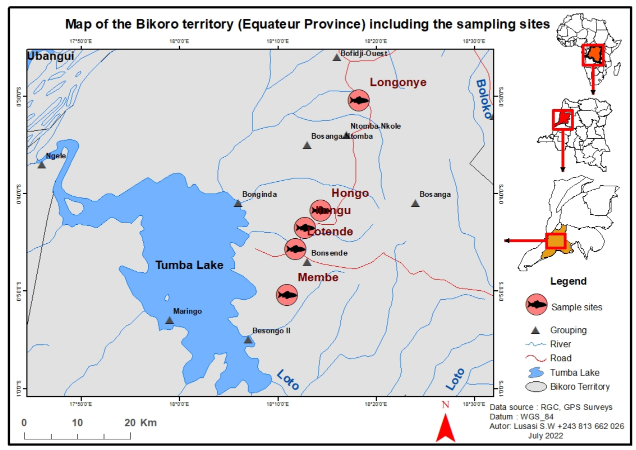

Figure 1. Map of the Lake Tumba region showing the floodplain forest area of the Mbandaka-Mabali road axis in Equateur Province

2.2. *Biological material*

The different species of fish exploited in an artisanal manner by fishermen in the flooded swamp forest of the Lake Tumba micro-basin on the Mbandaka-CREF Mabali road axis in the Democratic Republic of Congo constitute the biological material of this study.

2.3. *Methodology*

2.3.1. *Pre-survey*

This stage served to prospect the sites selected for the surveys in order to certify the presence of fishermen in these sites. We used the interview technique to exchange with the fishermen of the sites concerned to get an idea of their availability to respond to our concerns. It also consisted in determining the category of stakeholders who should be the subject of the exchanges.

The inclusion criteria were based on the age of the reason (± 18 years) and the willingness of the person to provide information was also taken into account. Only fishermen from the sites selected for this study were included. Two exlusion critera were taken into account: inhabitants of villages close to the fishing sites and passengers (travelers).

2.3.2. *Survey itself*

The reasoned choice survey using a convenience sample was used. During the surveys, exchanges were carried out with the fishermen working in the different study sites using a pre-established survey form in order to obtain the expected information. In addition to these exchanges, we also used free

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interviews for several minutes with fishermen who were motivated to tell us more.

The questions first dealt with the socio-demographic characteristics of the fishermen, notably gender, age, length of time in the fishery, as well as their level of education, in order to evaluate their level of knowledge about the phenomenon under study. Secondly, the questions concerned information on the different gears and techniques used by the fishermen. We also used direct observations to establish the manner in which the fishermen carry out their activity, focusing on the materials and methods used and the size of the fish caught by them.

2.3.3. Sampling and conservation of fish

The harvesting of fish was done in an artisanal manner using the different fishing gears and techniques used by the fishermen of the study area. Experimental fishing was carried out at each site after the surveys on fishing techniques. Data collection took place over eight months covering the period from march to october 2018.

After harvesting, the fish specimens were packed in plastic jars according to the harvesting sites and then, fixed in a 10% formalin solution. For the large samples, vernacular names and photos were taken. The samples thus conditioned were sent to the laboratory for systematic identification.

2.3.4. Systematic identification of fish

The systematic identification of fish was carried out at the Laboratory of Limnology, Hydrobiology and Aquaculture of the Department of Biology of the Faculty of Sciences of the University of Kinshasa. The systematic identification keys of fishes proposed by Lévêque et al. (1990 and 1992); Mbega and Teugels (2003); Stianssny et al. (2007) were used for this purpose. We also used vernacular (in Lotomba and Lingala) and common (in French) names of fish collected from fishermen to establish the systematic position of some fish specimens.

2.3.4. Data processing and statistical analysis

The survey data obtained were grouped according to the different categories of questions and then encoded on the Excel 2013 spreadsheet followed by the calculation of their relative abundance expressed as a percentage for each parameter evaluated. The data on the socio-demographic profile of the fishermen as well as on the fishing gears and techniques were compared by means of analyses of variance with a classification criterion (ANOVA 1) (Scherrer, 1984); the Tukey HSD test (Saville, 1990) was used to identify the smallest significant differences between these data at the 95% confidence interval using Statistix version 10 software. The results obtained are presented in tables and graphs. Origin 6.1 software was used to generate the graphs and the mapping of the study sites was done with ArcGIS 10.8 software using geographic data (longitude and latitude) obtained with a GARMIN Etrex GPS. The Ascending Hierarchical Classification (HHC) analysis of the fishing techniques-numerical abundance matrix of fish specimens was performed with Paleontological Statistics software (version 4.0).

3. Results and Discussion

3.1. Sociodemographic profile of fishers

Table 1 below provides information on the socio-demographic profile of fishermen who harvest fish in the flooded swamp forest of the Lake Tumba micro-basin on the Mbandaka-CREF Mabali road.

Table 1
Socio-demographic profile of fishers operating in the study area

Variables	Study sites					Fr Ab	%
	Longonye	Hongo	Ilungu Genre	Lotende	Membe		
Male	38	28	13	14	34	127	64.80
Female	9	12	11	16	21	69	35.20
Total	47	40	24	30	55	196	100
			Marital status				
Single	16	14	7	7	13	57	29.08
Married	24	20	12	17	30	103	52.55
Divorced	2	4	0	1	4	11	5.61
Widowed	5	2	5	5	8	25	12.76
Total	47	40	24	30	55	196	100
			Age range (years)				
18 – 30	15	12	6	5	12	50	25.51
31 – 40	19	17	12	15	29	92	46.94
41 – 50	7	8	4	7	9	35	17.86
51 years and older	6	3	2	3	5	19	9.69
Total	47	40	24	30	55	196	100
			Level of education				
No schooling	7	4	8	6	13	38	19.39
Primary	11	11	12	14	19	67	34.18
Secondary and humanities	29	24	4	9	23	89	45.41
Higher education and university	0	1	0	1	0	2	1.02
Total	47	40	24	30	55	196	100
			Duration in the fishery (years)				
1 – 5	7	9	3	6	8	33	16.84
6 – 10	8	13	2	5	10	38	19.39
11 – 15	11	12	8	6	12	49	25.00
16 – 20	13	3	6	11	15	48	24.49
21 – 25	6	1	4	1	5	17	8.67
26 – 30	2	2	0	1	4	9	4.59
30 years and older	0	0	1	0	1	2	1.02
Total	47	40	24	30	55	196	100

Legend : FrAb = Absolute frequency

With regard to the results shown in Table 1 above, it should be noted that the study sample is made up of 196 fishermen working in the stations of Longonye (47 fishermen), Hongo (40 fishermen), Ilunga (24 fishermen), Lotende (30 fishermen) and Membe (55 fishermen). With regard to the gender of the fishermen, 64.80% of those surveyed were men, compared to 35.20% of women. The analysis of variance applied to the number of respondents in relation to gender shows a non-significant difference ($F = 4.38$; $p = 0.0696$; Tukey HSD = 12.782) between the number of male and female fishermen. The results of our investigations regarding marital status reveal that a very highly significant difference ($F = 18.6$; $p = 0.0000$) exists in the variation in the number of fishermen in relation to their marital status. The critical value of comparison of the Tukey HSD test (7.6675) shows that the married with 103 fishermen, with 52.55%, followed by the single with 57 respondents, with 29.08%, are in the majority, while the widowed with 25 respondents, with 12.76%, and the divorced with 11 persons, with 5.61%. These results corroborate with those obtained by Makuntim (2015); Mboponga (2018); Lusasi et al. (2022), who revealed the same findings. According to Mboponga (2018), fishing is considered a men's activity in Malebo Pool and, the predominance of married fishermen can be explained in the sense that, married people are called upon to meet the needs of their families so they fish for a living. According to Lusasi et al. (2019b; 2020), fishing is a male preserve; women make up more than half of the workforce among the many people who work in the fisheries and aquaculture sector, such as handling, processing and selling fish.

With regard to the age group, the results of the analysis of variance show a very significant difference (F = 11.8; p = 0.0002) in the distribution of fishermen by age. The critical comparison value of the Tukey HSD test (7.3791) reveals that the fishermen in the 31-40 age group are the most representative with 92 respondents, with 46.94%, followed by those in the 18-30 age group with 19.39 persons, with 19.39%, and those in the 41-50 age group with 35 respondents, with 17.86%. The fishermen in 51 years old and a rare the least represented, with 19 respondents (9.09%). Ntumba (2012); Lusasi et al. (2022) also reported that fishing is predominantly practiced by young people between the ages of 25-35 years in the Malebo Pool. These observations are thought to be due to the fact that young people are motivated to seek the means necessary to survive (Lusasi et al., 2022). These results provide ample evidence that fishing is considered an economic activity that provides a livelihood for many Congolese living along the rivers and lakes of the Democratic Republic of Congo.

Concerning the level of education, the comparison of the data by the one-factor variance shows a very significant difference (F = 8.24; p = 0.0015) between the fishermen. With a critical comparison value of 10.615, the Tukey HSD test shows that the majority of fishermen have gone to school. The fishermen with secondary and humanitarian education present 45.41% or 89 respondents followed by those with primary knowledge with 34.18% or 67 fishermen. Fishermen who have not attended school represent 19.39%, with 38 respondents, and fishermen with university level and above are less numerous with 2 respondents, with 1.02%. With regard to the duration of fishing, it should be noted that most of the fishermen have been practicing this activity for several years. The results of the one-way analysis of variance show that there is a highly significant difference (F = 7.82; p = 0.0001) between the fishermen with regard to the duration of fishing. The critical value of the Tukey HSD test (6.0382) reveals that the fishermen who have totaled between 11 and 15 years are more numerous with 49 respondents, with 25%, followed by those who have totaled between 16 and 20 years with 48 fishermen, with 24.49%, then those who have totaled between 6 and 10 years of fishing represent 19.39%, with 38 respondents, and the fishermen who have fished between 1 and 5 years represent 16.84%. The fishermen least represented in terms of the duration of this activity are those who have been fishing for 30 years or more. These observations are sufficient proof that the fishermen who exploit the fish in the streams, ponds, and swamps of the flooded swamp forest of the Lake Tumba micro-basin on the Mbandaka-CREF Mabali road have acquired considerable experience in fishing activities.

3.2. Analysis of fishing activity in the flooded swamp forest

3.2.1. Fishing equipment used

The different materials used by fishermen to collect fish in the streams, ponds and swamps of the flooded swamp forest of the Lake Tumba micro-basin on the Mbandaka-CREF Mabali road are shown in Table 2.

Table 2
Different fishing gear used for fish collection

Materials	Study sites									
	Longonye		Hongo		Ilungu		Lotende		Membe	
	Ef	%	Ef	%	Ef	%	Ef	%	Ef	%
Mosquito net	16	15.38	21	19.27	11	25.58	9	15	26	21.14
Dormant nets	6	5.77	12	11.01	2	4.65	4	6.67	9	7.32
Hawk nets	5	4.81	2	2	1	2.33	2	3.33	7	5.69
Hooks	24	23.08	19	17.43	8	18.6	13	21.67	18	14.63
Traditional creels	31	29.81	26	23.85	14	32.56	17	28.33	34	27.64
Harpoons	8	7.69	8	7.34	2	4.65	6	10	8	6.5
Ichthyotoxic plants	14	13.46	21	19.27	5	11.63	9	15	21	17.07
Total	104	100	109	100	43	100	60	100	123	100

Legend : Ef = Effectif

In total, seven (7) types of fishing equipment are identified among fishermen who exploit fish in the flooded swamp forest of the Lake Tumba micro-basin on the Mbandaka-CREF Mabali road axis. In general, the one-factor analysis of variance applied to these data shows a highly significant difference (F = 7.98; p = 0.0000) between the frequency of use of fishing equipment; the Tukey HSD test reveals that traditional traps with 27.64% of citations, nets made of insecticide-impregnated mosquito netting with 21.14%, ichthyotoxic plants with 17.07% and hooks with 14.63% are the fishing materials most used by these fishermen (Fig. 2); still nets, sparrow nets and harpoons are used to a small extent. In terms of fishing sites, traditional traps with 31 quotes or 29.81% followed by hooks with 24 quotes or 23.03%, nets made of mosquito netting impregnated with insecticide with 16 quotes or 15.38% and ichthyotoxic plants with 14 quotes or 13.46% are frequently used in the Longonye site. In the Hongo site, traditional traps with 26 quotes or 23.85%, fish-eating plants and nets impregnated with insecticide with 21 quotes or 19.27% respectively and hooks are the most used in fishing. In the Ilungu site, the materials most used are traditional traps (32.56%), followed by nets impregnated with insecticide (25.58%), hooks (18.60%) and ichthyotoxic plants (11.63%). In Lotende, traditional traps with 17 quotes (28.33%) followed by hooks with 13 quotes (21.67%), fish nets and nets made of insecticide-impregnated mosquito netting with 9 quotes (15%) are the materials frequently used by fishermen. In the Membe site, traditional traps (27.64%), landing nets impregnated with insecticide (21.14%), ichthyotoxic plants (17.07%) and hooks (14.63%) are the materials most frequently used by the fishermen. These observations are similar to those made by Akonkwa et al. (2017); Matita (2020); Lusasi et al. (2022). In their studies, the latter noted the use of dip nets, nets of all kinds, hooks, traditional traps, harpoons, chemical products and ichthyotoxic plants by fishermen who exploit fish in the Congo River in the Malebo Pool and Lake Kivu in the Democratic Republic of Congo.

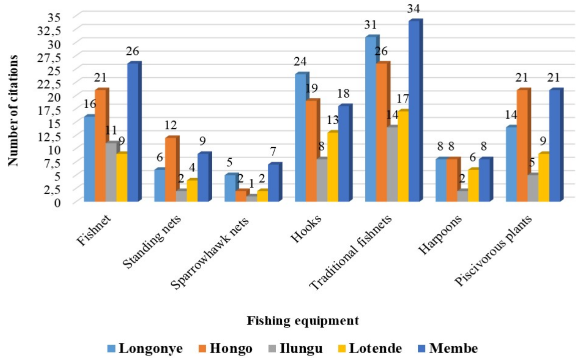

Figure 2. Frequency of use of fishing equipment in the exploitation of fish in the flooded swamp forest of the Lake Tumba micro-basin on the Mbandaka-CREF Mabali road axis

3.2.2. Different fishing techniques used

The different fishing techniques used by fishermen exploiting the rivers, ponds and swamps of the flooded swamp forest of the Lake Tumba micro-basin on the Mbandaka-CREF Mabali road axis are recorded in Table 3.

Table 3
Different fishing techniques used to catch fish (FrAb = Absolute frequency)

Techniques	Study sites						%
	Longonye	Hongo	Ilungu	Lotende	Membe	FrAb	
Weed control in fishing areas	6	8	7	9	11	41	9.62
Fishing with hawk nets	4	4	2	5	6	21	4.93
Fishing with passive nets	4	6	4	3	5	22	5.16
Active gillnet fishing	5	3	6	4	3	21	4.93
Angling	8	6	8	6	11	39	9.15
Fishing with creels	24	18	11	14	17	84	19.72
Scooping	12	9	12	15	18	66	15.49
Longline fishing	11	8	10	12	10	51	11.97
Harpoon fishing	7	4	2	3	5	21	4.93
Fishing with ichtyotoxic plants	13	11	9	11	16	60	14.08
10	94	76	71	82	102	426	100

The information in Table 3 above shows that ten fishing techniques are used by fishermen who exploit the fish in the rivers, ponds and swamps of the flooded swamp forest of the Lake Tumba micro-basin on the Mbandaka-CREF Mabali road axis. Of all these techniques, creel fishing with 84 quotations (19.72%), scooping with 66 quotations (15.49%), fishing with ichthyotoxic plants with 60 quotations (14.08%) and longline fishing with 51 quotations (11.97%) are the fishing techniques most frequently used by the fishermen. Fishing with harpoon, gillnets and weeding of the areas with 21 quotations or 4.93% are used to a small extent. Poor fishing practices constitute a problem for the renewal of organisms (Luhusu and Micha, 2013) because overexploitation associated with destructive gears and techniques leaves no chance for aquatic animal species to reproduce and develop well (Lusasi et al., 2022). In several studies conducted in Lake Mai-Ndombe in the Democratic Republic of Congo, Luhusu and Micha (2013); Micha (2019) note that mosquito nets with a mesh size of 2 mm no longer allow for the natural recruitment of species classically captured as adults with gillnets in this aquatic ecosystem.

3.2.3. Fishing techniques that provide easy access to fish

The results visualized in Figure 3 below inform us that five (5) fishing techniques provide fish easily. Of all these techniques, creel fishing (24.4%), scooping (22%), and fishing with ichthyotoxic plants (19.9%) are the most solicited by the fishermen who exploit the fish in the rivers, ponds, and swamps of the flooded swampy forest of the Lake Tumba micro-basin on the Mbandaka-CREF Mabali road axis. They are followed by longline fishing (17.7%) and line fishing (16.4%). The frequency of use of the traditional creel in the study area is due to the fact that this gear is easy to obtain; it is designed by the fishermen themselves by pulling the creel's spawning inputs from the forest, but also to the fishing tradition in this area, which has used the creel for years to collect fish. The pyrethroid insecticides (such as deltamethrin and permethrin) used for impregnating nets (Equiterre, 2019) are safe for humans but very harmful to aquatic invertebrates. The use of landing nets made with insecticide-impregnated mosquito netting is related to the types of habitats (ponds and swamps) that are generally shallow where these fishermen harvest fish. Boika et al. (2022) showed in their research that the depth of the water column is shallow across the different ponds, swamps, and rivers in the flooded swamp forest; it varies from 84.5±38.5 cm (Membe) to 113.75±46.25 cm (Longonye); these shallow depths are a major asset in the use of landing nets.

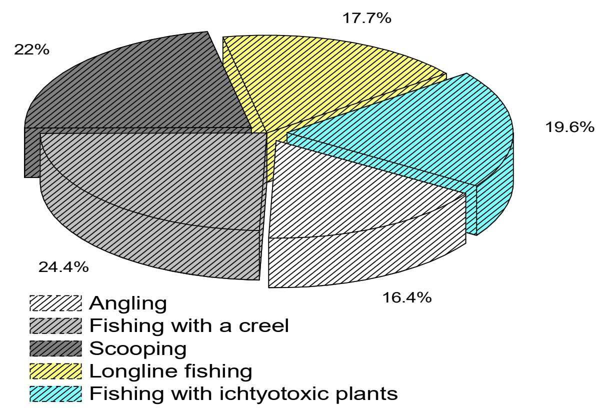

Figure 3. Fishing techniques that provide easy access to fish in the rivers, ponds, and swamps of the flooded swamp forest of the Lake Tumba micro-basin

3.2.4. Reasons for the choice of fishing techniques used

The reasons given by the fishermen to justify the choice of fishing techniques used to exploit the fish in the study area are listed in Table 4.

Table 4
Reasons for the choice of fishing techniques used by the fishermen (FrAb = Absolute frequency)

Reasons	Study sites					FrAb	%
	Longonye	Hongo	Ilungu	Lotende	Membe		
Requires less effort	23	14	6	9	16	68	18.33
Cost effective in terms of fish quantity	19	17	10	13	31	90	24.26
Cost effective in terms of fish quality	6	8	4	8	11	37	9.97
Access to all sizes of fish	21	20	8	11	27	87	23.45
Less expensive materials	20	19	9	12	29	89	23.99
Total	89	78	37	53	114	371	100

The fishermen justify the choice of fishing techniques implemented in the study area by five (5) reasons. Among these reasons, profitability in relation to the quantity of fish caught (24.26%), the cost of acquiring equipment (23.99%), the possibility of catching all sizes of fish (23.45%) and the low demand for fishing effort (18.33%) are the reasons given by the respondents to justify the choice of a fishing technique. The use of ichthyotoxic plants in the study area is justified according to the fishermen by the ease of collecting and obtaining fish in large quantities with less fishing effort, but also most often by women. According to Kimpouni et al. (2011), women most often use empirical techniques ranging from scooping to the use of ichthyotoxic plants. The use of ichthyotoxic plant extracts is a sampling technique well known to scientists (Lévêque and Paugy, 2006). This illegal fishing with ichthyotoxic plants, which is practiced in the lakes and rivers of the Congo Basin, has indeed become widespread over the past several years (Kimpouni et al. 2011). These plants are ineffective in large bodies of water or in running water; generally they are used in marshes with an area of no more than forty ares (Kimpouni et al. 2011). The use of ichthyotoxics is mostly effective, quantitatively, in closed-type environments such as ponds,... etc; in open water, or in fast currents, the use of ichthyotoxics gives much more random results due to the escape of the poison (Leveque and Paugy, 2006). Without direct harmful influence on humans, the plant substances used in this type of fishing are toxic to fish, amphibians, and freshwater invertebrates and, inhibit the filtration capacity of bivalve mollusks (Micha, 2019).

3.2.5. *Time spent fishing*

The results shown in figure 4 below indicate that the majority of respondents (36.6%) fish for 12 hours, followed by those who fish for 6 hours (29.6%), 24 hours (19%), and less than 6 hours (14.8%).

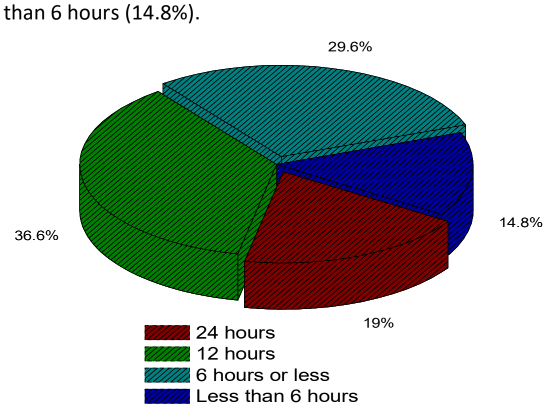

Figure 4. Variation in time spent fishing

3.3. *Fish species exploited in the surveyed sites*

The different species of fish caught with the different fishing techniques used by the fishermen who exploit the rivers, ponds, and swamps of the flooded swamp forest of the Lake Tumba micro-basin on the Mbandaka-CREF Mabali road axis are recorded in Table 5.

Table 5
Fish species exploited through fishing techniques implemented in the flooded swamp forest of the Lake Tumba micro-basin on the Mbandaka-CREF Mabali road axis

Orders	Families	Genus	Species	Vernacular names (Lotomba)
Cyprinodontiformes	*Aplocheilidae*	*Aphyosemion*	*A. elegans* Boulenger, 1899	Moningo
Cypriniformes	*Hepsetidae*	*Hepsetus*	*H. odoe* Bloch, 1794	Mwenge
Channiformes	*Channidae*	*Parachanna*	*P. obscura* Günther, 1861	Mongusu
Gonorhynchiformes	*Phractolaemidae*	*Phractolaemus*	*P. ansorgii* Boulenger, 1901	Mobili
Lepidosireniformes	*Protopteridae*	*Protopterus*	*P. dolloi* Boulenger, 1900	Nsembe
Mormyriformes	*Mormyridae*	*Mormyrus*	*M. rume* Valenciennes, 1847	Mbese
		Petrocephalus	*P. microphtalmus* Pellegrin, 1908	Mbeyi
			P. pellegrini Poll, 1941	Ntoku
Osteoglossiformes	*Notopteridae*	*Xenomystus*	*X. nigri* Günther, 1868	Ilembe
	Pantodontidae	*Pantodon*	*P. buccholzi* Peters, 1877	Ihanzoli
	Anabantidae	*Ctenopoma*	*C. ansorgii* Boulenger, 1912	Lokaka
Perciformes			*C. kingsleyae* Günther, 1896	Molombe
			C. lineatum Nichols, 1923	Lokaka
			C. nanum Günther, 1923	Lokaka
			C. pellegrini Boulenger, 1902	Mwende
	Cichlidae	*Hemichromis*	*H. fasciatus* Peters, 1852	Ebindi
			H. elongatus Guichenot, 1861	Ebindi
		Oreochromis	*O. niloticus* Linné, 1758	Mokeke
Polypteriformes	*Polypteridae*	*Polypterus*	*P. ansorgii* Boulenger, 1910	Monkonga
Siluriformes	*Clariidae*	*Clarias*	*C. anguillaris* Linné, 1758	Ngolo
			C. sp	Ngolo
		Clariallabes	*C. brevibarbis* Pellegrin, 1913	Lokamba
		Channallabes	*C. apus* Gunther, 1873	Mohombi
	Claroteidae	*Auchenoglanis*	*A. biscutatus* Saint-Hilaire, 1809	Mpoka
	Malapteruridae	*Malapterurus*	*M. electricus* Gmelin, 1789	Nina
	Mochokidae	*Synodontis*	*S. pleurops* Boulenger, 1897	Likoko
10	15	19	26	

The results in Table 5 above show that twenty-six (26) species of fish grouped in ten (10) orders, fifteen (15) families and twenty (20) genera are identified in the flooded swamp forest of the Lake Tumba micro-basin on the Mbandaka-CREF Mabali road. These results are close to those obtained by Mathes (1964); Boika et al., (2021); Boika et al., (2022). In contrast, Boika et al., (2022) noted the presence of twenty-two (22) species of fish divided into 15 genera, 13 families and 10 orders. Mathes (1964) reports the presence of thirty-one (31) species inventoried during his study in the same area of Lake Tumba. According to Boika et al., (2022), the difference in catches could be explained by the fishing techniques used, the area exploited and the duration and period of sampling.

3.3.1. Relative abundance of the orders of fish identified

Of the ten orders of fish identified, fish of the orders *Siluriformes* with four families or 26.7%, Osteoglossiformes and Perciformes with two families or 13.3% respectively are the most numerous (Fig. 5). The remains of the orders are less represented with one family or 6.67% respectively.

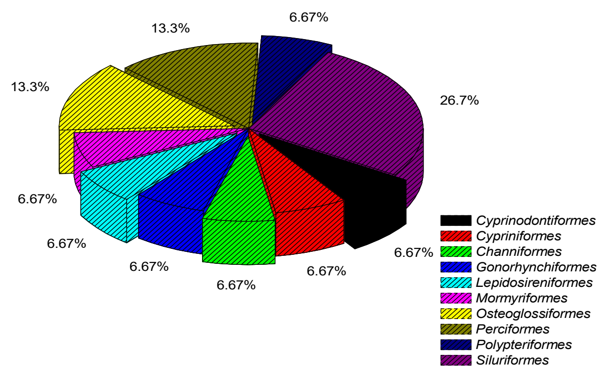

Figure 5. Relative abundance (%) of the orders of fishes surveyed

3.3.2. Relative abundance of the families of fishes surveyed

It appears from the results shown in figure 6 below that in terms of genera, the family *Clariidae* is the most representative with three genera or 15.8% followed by the families *Cichlidae* and *Mormyridae* with two genera each or 10.5%. The rest of the families are represented by only one genus or 5.26%.

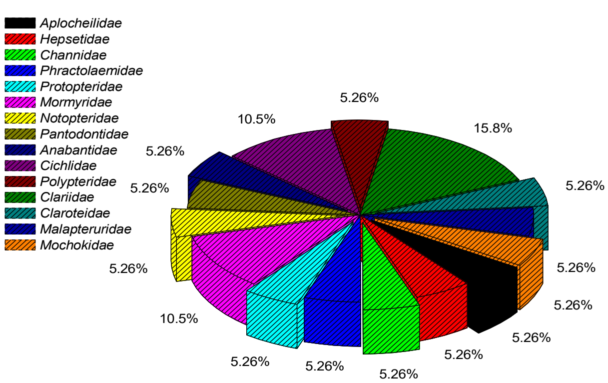

Figure 6. Relative abundance (%) of fish families surveyed

3.3.3. Relative abundance of fish genera surveyed

The information shown in figure 7 below reveals that the fish grouped in the genus *Ctenopoma* (19%), *Clarias* (8%) and *Hemichromis* (8%) are more numerous than those of the other genera, which represent 4% for each of the genera

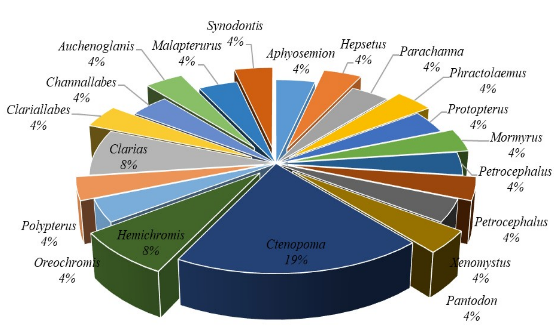

Figure 7. Relative abundance (%) of the genera of the fishes surveyed

3.3.4. Selectivity of fishing techniques and numerical abundance of fish in the catches

The selectivity of the different fishing techniques used and the numerical abundance of fish in the catches with the same techniques are shown in Table 6.

Table 6
Occurrence and numerical abundance of fish species surveyed according to fishing techniques

Species	Fishing techniques										Total
	DZP	PFE	PFD	PFM	PLi	PNa	Eco	Ppa	PHa	PPI	
A elegans	11	0	0	2	0	16	24	0	0	21	74
H odoe	9	2	6	0	0	18	16	8	0	17	76
P obscura	21	0	8	5	0	15	25	19	6	14	113
P ansorgii	24	0	11	4	6	21	19	6	0	26	117
P dolloi	29	4	2	0	0	12	19	8	2	15	91
M rume	4	0	3	2	2	7	13	6	3	11	51
P microphtalmus	9	3	6	0	0	12	2	8	0	16	56
P. pellegrini	6	0	3	2	0	6	4	1	0	14	36
X nigri	6	0	6	0	0	9	12	6	0	11	50
P buccholzi	9	8	11	12	0	21	11	0	0	7	79
C ansorgii	15	2	13	8	0	19	6	4	0	4	71
C. kingsleyae	13	0	10	14	2	28	8	9	0	11	95
C. lineatum	8	0	4	9	0	14	5	3	0	5	48
C. nanum	2	0	3	4	0	7	8	6	0	8	38
C. pellegrini	4	0	6	0	0	8	4	2	0	4	28
H fasciatus	5	2	4	3	2	9	8	0	0	8	41
H. elongatus	2	6	7	6	2	11	9	1	0	3	47
O niloticus	6	2	0	3	0	8	4	0	0	8	31
P ansorgii	3	0	0	5	7	4	8	0	0	12	39
C anguillaris	2	0	0	0	0	32	6	6	0	26	72
C. sp	6	0	0	0	0	21	12	8	0	15	62
C brevibarbis	9	0	0	0	0	18	14	6	0	11	58
C. apus	4	0	0	0	0	36	29	16	0	23	108
A biscutatus	11	0	6	0	0	14	18	12	0	6	67
M electricus	9	0	7	0	0	6	11	8	0	6	47
S pleurop	3	0	0	0	0	16	13	5	0	4	41
A frequency	230	29	116	79	21	388	308	148	11	306	1636
Occurrence (%)	14.05	1.77	7.09	4.83	1.28	23.7	18.81	9.04	0.67	18.69	99.93

Legend: DZP = Weeding of fishing area; PFE = Hawk net fishing; PFD = Dormant net fishing; PFM = Active gillnet fishing; PLi = Line fishing; PNa = Pole and line fishing; Eco = Ecopage; Ppa = Longline fishing; PHa = Harpoon fishing and PPI = Pichthyotoxic plant fishing

A total of 1,636 fish specimens were recorded during this study. Of all the fishing techniques used during the sampling, traditional creel fishing with 388 fish specimens captured, i.e. 23.70% of occurrence, scooping with 308 fish specimens captured, with 18.81% of occurrence, ichthyotoxic plant fishing with 306 fish specimens captured, with 18.69% of occurrence, and site weeding fishing with 230 fish specimens, with 14.05% of occurrence, are the ones that facilitate the capture of the fish in the study area. The remaining fishing techniques were found to be selective by their low percentage of occurrence. The dendrogram of similarity established between the fishing techniques and the numerical abundance of fish species according to these techniques shows two large groups that are significantly different (correlation coefficient = 0.8654) (Fig. 8). The first group is composed of four fishing techniques (traditional trap fishing, scooping, fishing with ichthyotoxic plants and fishing by weeding the areas) considered non-selective. The second group is made up of the remains of the fishing techniques.

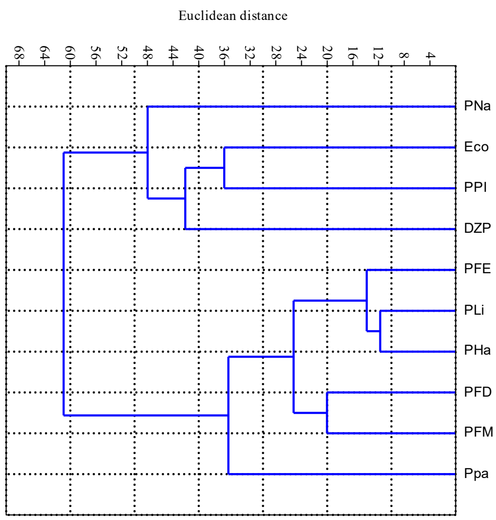

Figure 8. Hierarchical Ascending Classification Dendrogram of fishing techniques according to the numerical abundance of specimens of different fish species caught

4. Conclusion

The overall objective of this study was to identify the different fishing techniques used in the exploitation of fish in the flooded swamp forest of the Lake Tumba micro-basin on the Mbandaka-Center for Research in Ecology and Forestry (CREF Mabali) road axis in Bikoro in the Equateur Province of the Democratic Republic of Congo. The results obtained showed that the majority of the fishing practices implemented in this area are not sustainable. In total, ten (10) fishing techniques were identified, among which five (5) easily provide fish, namely creel fishing, scooping, fishing with ichthyotoxic plants, longline fishing and line fishing, which are the most used by the fishermen. Four fishing techniques (fishing with traditional traps, scooping, fishing with ichthyotoxic plants and fishing by weeding the areas) were considered non-selective and capable of creating an imbalance in the different aquatic ecosystems surveyed. Changes in fishing practices are strongly desired to avoid increasing food insecurity by reducing, through overexploitation, the access of populations to this precious and excellent halieutic resource.

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