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Fishing Activity on Solomougou Dam Lake (Northern Côte d'Ivoire): Synthesis of Recent Data and Additional Information

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Abstract **Review Article**

In Côte d'Ivoire, like other continental waters, many dam lakes in the North are exploited for fishing purposes. This activity provides local communities fish for consumption and income through the economic activities it generates. Therefore, sustainable management of these fisheries is necessary. For this purpose, fishing on the Solomougou Dam Lake was investigated in 2018 in order to analyse the current state of exploited fish resources. The investigation provided data on production factors with reference to fishermen's sociological profiles and the type of fishing gears used, on the ichthyological composition of catches and on stocks exploitation parameters of abundant species caught. This paper is a review of those previous studies. It is completed on the one hand using information on conservation and the vulnerability status of the whole species and on the other hand using stocks exploitation parameters of a second group of species secondarily abundant in catches.

Keywords: Fishing activity, fish stocks, Solomougou Dam Lake, Côte d'Ivoire.

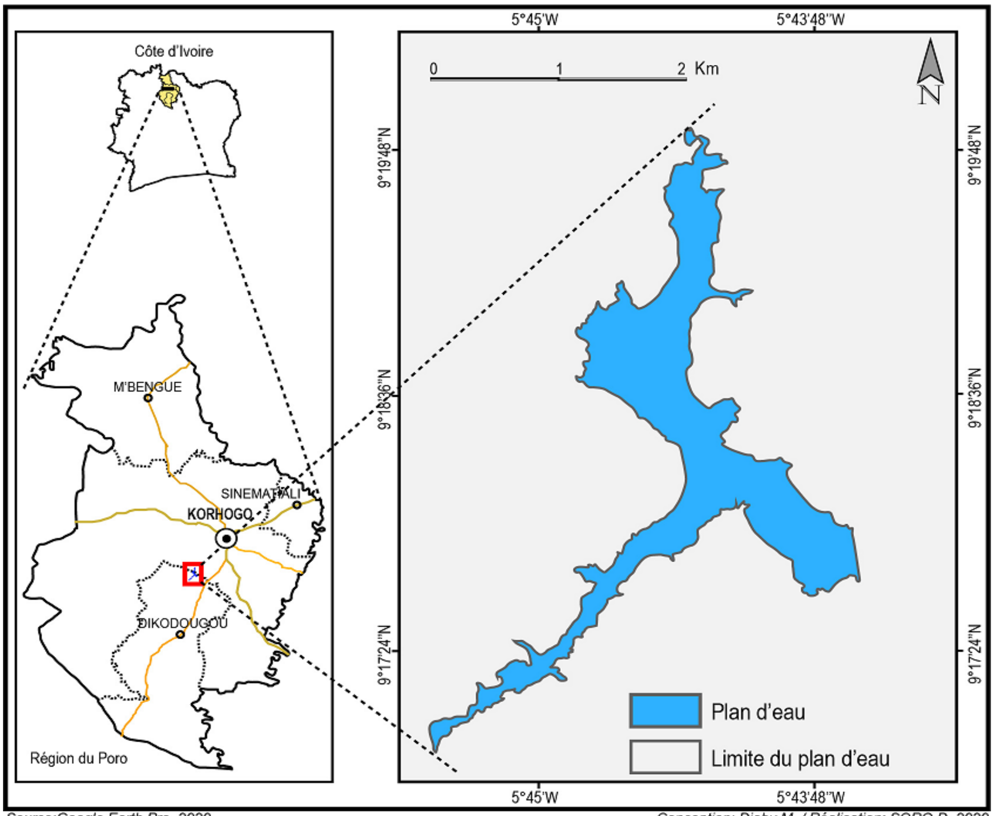
INTRODUCTION

Côte d'Ivoire has various aquatic environments. The Southern part of the country is bordered by the Atlantic Ocean with a continental shelf covering 12,000 km². There are also lagoons with a total area of 1,200 km² (Golé Bi *et al.*, 2005). The country also has four artificial lakes that serve as hydroelectric dams of 1,700 km^2 including rivers (FAO, 2005). In the North, the body of water includes many dam lakes, estimated at 210. They have been created since the 1970s to develop agriculture and livestock breeding (Le Guen, 2002), and some of them are now exploited for fishing.

Fishing in these dam lakes is of great importance for local communities. It provides them with fish, one of the main animal protein sources in their diet. Indeed, although the Northern region is known as a cattle-breeding area in the country, it has been noted that the price of beef is constantly rising in recent years. Therefore, fishing activities should be monitored for perpetuating fish supply to many economically weaker populations in this region.

The Solomougou Dam Lake is one of the largest fisheries in northern Côte d'Ivoire (Figure 1). Located between 09° 18' 09" N latitude and 05° 37' 36" W longitude, it was created in 1973 for rice cultivation (Cecchi *et al.*, 2007). The water surface is ranked fifth in the country with an area of 500 hectares, Morisson Dam Lake being the largest with its 3,700 hectares (Traoré, 1996). During the last three years, fishing activities in this reservoir have been the subject of several studies. These include the fishermen's sociological profile as well as fishing gears and fishing techniques used (Diaby *et al.*, 2020a), the dynamics of the fishing activity throughout the year (Kouassi *et al.*, 2019), the fish composition of catches (Kouassi *et al.*, 2020a), the biological parameters related to the length-weight relationship of fish species (Kouassi *et al.*, 2020b) or the stocks exploitation parameters of abundantly species caught (Diaby *et al.*, 2020b; Diaby *et al.*, 2020c).

This work is a review of those previous studies. It also provides additional information on the conservation status of the fish species present in this fishery. The latter data have been obtained from the IUCN list (IUCN, 2021) and the Fishbase site (Froese and Pauly, 2021). Species vulnerability levels were retrieved from the Froese and Pauly (2021) database. Brodie (2010) defines vulnerability as sensitivity of organisms to impacts caused by fishing activities or other factors that threaten their existence, such as habitat loss. Additional information also concerns stocks exploitation parameters of a second group of species secondarily abundant in catches. The methods used are identical to those used by Diaby *et al*. (2020b) and Diaby *et al*. (2020c). Indeed, taking these species into account in fisheries management must also be a priority. They are captured for consumption, and they contribute to the biological diversity, and consequently to the proper functioning of these ecosystems.



Source:Google Earth Pro, 2020 Conception: Diaby M. / Réalisation: SORO D. 2020

Fig-1: Geographical location of the Solomougou Dam Lake in Northern Côte d'Ivoire

FISHERMEN'S SOCIOLOGICAL PROFILE

In total, forty-six (46) fishermen have been registered in this fishery from October 2018 to September 2019. Twenty-six (26) of them were working individually and the other twenty (20) organized in seven (7) teams including two (2) teams of two (2) fishermen each, four (4) of three (3) fishermen each and only one (1) of four (4) fishermen. So, this represents a total of thirty-three (33) fishing units, fishing unit representing individual fisherman or fishermen in association operating one fishing gear. Fishermen's sociological profile indicated that 95.65% of them are of Malian origin, while the others are Ivorians. Their ages range from 13 to 61 years old and 95.74% of them have not been to school. Regarding their activities outside fishing, except two (2) fishermen practicing trading and butchering in addition to the fishing, the others do not have alternative livelihoods (Kouassi *et al*., 2019).

FISHING GEARS TYPES

The fishermen used six fishing gear types including sparrow hawk, longline, trap, bamboo trap, seine net and gillnet. Sparrow hawks, constituted in monofilament, have bar length of 20 to 60 millimetres and opening diameters from 3 to 5 meters. The main line of longlines is 300 to 500 meters long, on which are attached at least 3,000 hooks spaced generally 10 centimetres apart. The traps are of an artisanal model made by weaving liana with average height of 1 meter and an opening in the upper part. As for Bamboo traps, they are made up of 1-meter-long hollowed china bamboo pieces mounted on a 500 meters long rope. Seine nets had nets with bar length of 16 millimetres, their total lengths ranging from 500 to 800 meters. Gillnets have bar length from 14 to 40 millimetres. Most of them used 30 millimetres ones (31.94%) followed by 20 millimetres (22.93%). Those with bar length smaller than 20 millimetres represent only 22.91% against 32.64% which have meshes between 20 and 30 millimetres. In addition, the lengths of these gears vary between 50 and 200 meters and the depth is from 1 to 2 meters. However, the most used have lengths from 100 to 150 meters (40.28%) and height between 1.10 and 1.50 meters (67.36%) (Diaby *et al*., 2020a).

RELATIVE ABUNDANCES OF FISHING GEAR TYPES

Among the 321 fishing gears enumerated during the study period, traps (47.35%) and gillnets (44.86%) were the dominant ones, representing over 90% of fishing gears deployed. The least used are bamboo traps (0.31%) and seine nets (1.25%), while longlines and sparrow hawks have respective proportions of 2.80% and 3.43%. Relatively to the thirty-three (33) fishing units, 15.15% of them use more than one fishing gear type, including the association gillnet and longline (3.03%), sparrow hawk and gillnet (6.06%) and trap and sparrow hawk (6.06%). As for the others operating with only one fishing gear type, they use mostly gillnets (45.45%) and seine nets (12.12%), sparrow hawks and traps 9.09% each, longline (6.06%) and bamboo trap (3.03%) (Diaby *et al*., 2020a).

FISHING GEARS PERIODS OF USE

Two fishing gear types were used throughout the year regardless of the change in water depth. These were gillnets and sparrow hawks. However, the first were less used from August to October during the flood period of the reservoir and the second ones from April to September. The other fishing gears were characterized by their periods of use limited to a few months. Traps were not used from April to June in the period of low water, contrary to seine nets exclusively used during this period. As for longlines and bamboo traps, used respectively during 7 and 5 months, their periods of use were disparate and do not seem to be related to variations in water depth (Kouassi *et al*., 2019).

TEMPORAL VARIATION OF FISHING ACTIVITY

As a reminder, forty-six (46) fishermen grouped into thirty-three (33) fishing units have been identified. Fishing is practiced throughout the year. However, the site remains less frequented from August to October with only four (4) to seven (7) fishing units. From November, its colonization gradually increases to reach the peak in March with 21 units corresponding to 33 fishermen in total. Outside this period, the number of fishing units varies between eleven (11) and seventeen (17).

The length of stay of fishermen on the site varies between one (01) and twelve (12) months. Anyway, most of the fishermen stayed for less than 6 months. In fact, 24.24% stayed for only one month while 30.30% stayed there for four months. A second group of fishermen, fewer in number, stayed longer on the site for a period of 8 months for most of them. In any case, only two fishermen remained on the site for most of the year, 11 months for one and 12 months for the other (Kouassi *et al*., 2019).

FISHERY EXPLOITATION LEVEL

The total number of fishing units (33) and the area of the fishery (500 hectares or 5 km^2) corresponds to a density of 6.6 fishing units per km^2. As some fishing units use more than one fishing gear type, those using longlines, bamboo traps and seine nets are at a density lower than 1 per km^2 each. The others using traps, sparrow hawks and gillnets are respectively at 1, 1.4 and 3.6 per km^2. In terms of the number of fishing gear types, bamboo traps (0.2 per km^2), seine nets (0.8 per km^2), longlines (1.8 per km^2) and sparrow hawks (2.2 per km^2) can be deployed in more places. The most numerous are gillnets (28.8 per km^2) and traps (30.4 per km^2) (Kouassi *et al*., 2019).

FISH COMPOSITION, RELATIVE ABUNDANCES AND TEMPORAL DISTRIBUTION OF SPECIES

In total, fourteen (14) families, twenty-five (25) genera and thirty-seven (37) species were recorded. As for families, the most diverse are Cichlidae, Mormyridae and Cyprinidae with ten, six and five species respectively. On the other hand, the most abundant are the Cichlidae (41.87%), followed by the Alestidae (14.47%) and the Mochokidae (12.84%). At the species level, the three most representative species in proportions varying between 10% and 15% are *Brycinus imberi* (14.41%), *Synodontis schall* (12.76%) and *Oreochromis niloticus* (11.62%) (Table I).

The different species were grouped into fourteen (14) accidental, one (01) incidental and twenty-two (22) constant species. The former was encountered between one (01) and three (3) months during the year, as opposed to four (4) for the latter. As for the so-called constant species, they appeared during the year between seven (7) and twelve (12) months (Kouassi *et al*., 2020a).

Table-I: Composition, relative abundances and temporal distribution of species: Accid., accidental; Acces., accessory and Const., constant. (Kouassi *et al*., 2020a)

Families	Species	Number	Relatives Abundances (%)	
			Per species	Per family
	Brycinus imberi ***(Const.)***	1,866	14.41	
Alestidae	*Brycinus nurse* ***(Accid.)***	8	0.06	14.47
Anabantidae	*Ctenopoma patherici* ***(Const.)***	27	0.21	0.21
	Chromidotilapia guntheri ***(Const.)***	248	1.92	
	Hemichromis bimaculatus ***(Accid.)***	6	0.05	
	Hemichromis fasciatus ***(Const.)***	906	7.00	
	Oreochromis niloticus ***(Const.)***	1,505	11.62	

Cichlidae	*Sarotherodon galilaeus* ***(Const.)***	1,160	8.96	41.87
	Sarotherodon melanotheron ***(Accid.)***	18	0.14	
	Tilapia busumana ***(Accid.)***	2	0.02	
	Tilapia guineensis ***(Accid.)***	21	0.16	
	Tilapia mariae ***(Const.)***	1,115	8.61	
	Tilapia zillii ***(Const.)***	441	3.41	
	Clarias gariepinus ***(Const.)***	1,036	8.00	
Clariidae	*Heterobranchus longifilis* ***(Const.)***	129	1.00	9.00
	Chrysichthys maurus ***(Const.)***	252	1.95	
Claroteidae	*Chrisychthys nigrodigitatus* ***(Const.)***	529	4.08	6.03
	Barbus sacratus ***(Accid.)***	8	0.06	
	Barbus wurtzi ***(Accid.)***	7	0.05	
Cyprinidae	*Labeo coubie* ***(Const.)***	213	1.64	2.97
	Labeo parvus ***(Const.)***	138	1.07	
	Raiamas senegalensis ***(Const.)***	18	0.14	
Malapteruridae	*Malopterurus electricus* ***(Accid.)***	4	0.03	0.03
	Synodontis nigrita ***(Accid.)***	10	0.08	
Mochokidae	*Synodontis schall* ***(Const.)***	1,653	12.76	12.84
	Marcusenius furcidens ***(Const.)***	322	2.49	
	Marcusenius senegalensis ***(Accid.)***	1	0.01	
Mormyridae	*Marcusenlus ussheri* ***(Const.)***	253	1.95	8.78
	Mormyrus rume ***(Const.)***	314	2.42	
	Petrocephalus Bovei ***(Const.)***	245	1.89	
	Pollimyrus isidori ***(Accid.)***	2	0.02	
Notopteridae	*Papyrocranus afer* ***(Accid.)***	7	0.05	0.05
Osteoglossidae	*Heterotis niloticus* ***(Const.)***	29	0.22	0.22
Polypteridae	*Polypterus endlicheri* ***(Accid.)***	5	0.04	0.04
Protopteridae	*Protopterus annectens* ***(Accid.)***	5	0.04	0.04
	Schilbe intermedius ***(Const.)***	439	3.39	
Schilbeidae	*Schilbe mystus* ***(Acces.)***	8	0.06	3.45
	Total	**12,950**	**100.00**	**100.00**

CONSERVATION STATUS AND VULNERABILITY OF SPECIES

In the Solomougou Dam Lake, fish species are mainly benthopelagic (43.24%) and demersal (48.65%), and secondarily pelagic (8.11%). According to the classification of the International Union for Conservation of Nature (IUCN), 97% of the lake's fish population belong to the category of Least Concern (LC). Only one species, *Marcusenius furcidens*, is Near Threatened (NT). In addition, the different species belong to seven (7) levels of vulnerability. Those with "low" and "low to moderate" vulnerability levels are the most represented, respectively 27.03% and 29.73% of the species, followed by "moderate" (18.92%) and "moderate to high" (10.81%) vulnerabilities. Species with "high" (5.41%), "high to very high" (5.41%) and "very high" (2.70%) vulnerabilities are less abundant (Table II).

EXPLOITATION PARAMETERS OF SPECIES STOCKS

In Solomougou Dam Lake, stocks exploitation parameters of the nineteen (19) fish species studied are variable. The longest asymptotic lengths (L_∞) are noted for *Clarias gariepinus* (47.78 cm) and *Mormyrus rume* (43.58 cm) and secondarily for *Heterobranchus longifilis, Labeo coubie, Marcusenius furcidens, Marcusenlus ussheri and Schilbe intermedius* with values between 30 cm and 40 cm. In contrast, growth rates (K) are higher for *Mormyrus rume*, *Petrocephalus Bovei*, *Schilbe intermedius*, *Hemichromis fasciatus*, *Sarotherodon galilaeus* and *Synodontis schall* (K between 7 and 10). These growth parameters provide longevities greater than five years for nine species, with those of *Chromidotilapia guntheri, Heterobranchus longifilis*, *Labeo parvus* and *Marcusenlus ussheri* being the maximum, ranging from nine to ten years.

Mortality parameters were used to obtain exploitation rates. Three species were overexploited. These were *Chromidotilapia guntheri* (E=0.54), *Chrysichthys maurus* (E=0.78) and *Schilbe intermedius* (E=0.60). These exploitation rates, higher than reference points E_{10}, E_{50} or E_{max}, confirm this level of exploitation. Four other species, represented by *Marcusenius furcidens*, *Marcusenlus ussheri*, *Mormyrus rume* and *Tilapia zillii* are close to their optimal exploitation level. Indeed, with their exploitation rates close to E=0.5 and above E_{50}, their stocks have therefore reached critical level. The stocks of the remaining twelve species are underexploited (Table III).

Table-II: Conservation status, vulnerability and habitat of fish species encountered in the period January-December 2019 in the Solomougou Dam Lake (Northern Côte d'Ivoire) (IUCN, 2021; Froese and Pauly).

Species	Conservation status	Vulnerability	Habitat
Brycinus imberi	Least Concern (LC)	Low vulnerability (10%)	Demersal
Brycinus nurse	Least Concern (LC)	Low to moderate vulnerability (29%)	Pelagic
Barbus sacratus	Least Concern (LC)	Moderate vulnerability (42%)	Benthopelagic
Barbus wurtzi	Least Concern (LC)	Moderate vulnerability (40%)	Benthopelagic
Labeo coubie	Least Concern (LC)	Moderate vulnerability (39%)	Benthopelagic
Labeo parvus	Least Concern (LC)	Moderate to high vulnerability (51%)	Benthopelagic
Raiamas senegalensis	Least Concern (LC)	Low to moderate vulnerability (32%)	Benthopelagic
Protopterus annectens	Least Concern (LC)	Moderate vulnerability (42%)	Demersal
Heterotis niloticus	Least Concern (LC)	Moderate to high vulnerability (55%)	Pelagic
Marcusenius furcidens	Near Threatened (NT)	Moderate vulnerability (35%)	Demersal
Marcusenius senegalensis	Least Concern (LC)	Moderate vulnerability (35%)	Demersal
Marcusenius ussheri	Least Concern (LC)	Low to moderate vulnerability (35%)	Demersal
Mormyrus rume	Least Concern (LC)	High vulnerability (63%)	Demersal
Petrocephalus bovei	Least Concern (LC)	Low vulnerability (13%)	Demersal
Pollimyrus isidori	Least Concern (LC)	Low vulnerability (11%)	Demersal
Papyrocranus afer	Least Concern (LC)	Moderate vulnerability (38%)	Demersal
Ctenopoma petherici	Least Concern (LC)	Low to moderate vulnerability (31%)	Benthopelagic
Chromidotilapia guntheri	Least Concern (LC)	Low vulnerability (25%)	Benthopelagic
Hemichromis bimaculatus	Least Concern (LC)	Low vulnerability (19%)	Benthopelagic
Hemichromis fasciatus	Least Concern (LC)	Low vulnerability (14%)	Benthopelagic
Oreochromis niloticus	Least Concern (LC)	Low to moderate vulnerability (30%)	Benthopelagic
Sarotherodon galilaeus	Least Concern (LC)	Low to moderate vulnerability (35%)	Demersal
Sarotherodon melanotheron	Least Concern (LC)	Low vulnerability (16%)	Demersal
Tilapia busumana	Least Concern (LC)	Low vulnerability (25%)	Demersal
Tilapia guineensis	Least Concern (LC)	Low vulnerability (19%)	Benthopelagic
Tilapia mariae	Least Concern (LC)	Low to moderate vulnerability (28%)	Demersal
Tilapia zillii	Least Concern (LC)	Low to moderate vulnerability (27%)	Benthopelagic
Polypterus endlicheri	Least Concern (LC)	Moderate to high vulnerability (49%)	Demersal
Clarias gariepinus	Least Concern (LC)	Very high vulnerability (79%)	Benthopelagic
Heterobranchus longifilis	Least Concern (LC)	High to very high vulnerability (69%)	Demersal
Chrysichthys maurus	Least Concern (LC)	Moderate to high vulnerability (46%)	Demersal
Chrysichthys nigrodigitatus	Least Concern (LC)	High vulnerability (60%)	Demersal
Malapterurus electricus	Least Concern (LC)	High to very high vulnerability (74%)	Benthopelagic
Schilbe intermedius	Least Concern (LC)	Low to moderate vulnerability (29%)	Pelagic
Schilbe mystus	Least Concern (LC)	Low to moderate vulnerability (33%)	Demersal
Synodontis nigrita	Least Concern (LC)	Low to moderate vulnerability (29%)	Benthopelagic
Synodontis schall	Least Concern (LC)	Low vulnerability (21%)	benthopelagic

Table-III: Stocks exploitation parameters of species. L∞, asymptotic length; K, growth rate; to, age at zero length; Ø' growth index in length; tmax, longevity; Z, total mortality; M, natural mortality; F, fishing mortality; E, exploitation rate; L_{25}, L_{50} and L_{75}, lengths at which 25%, 50% and 75% of specimens are captured; E_{50}, exploitation rate reducing virgin biomass by half; E_{max}, exploitation rate at maximum relative yield per recruit; E_{10}, exploitation rate at which the marginal increase in relative yield per recruit is 10% of its value at E = 0; Y'/R, relative yield per recruit; B'/R, relative biomass per recruit. Highlighted parameters are from Diaby *et al*. (2020b) and Diaby *et al*. (2020c).

	Growth parameters			Ø'	Tmax	Mortality parameters			E	Lengths probabilities at of capture			Reference points for Y'/R and B'/R		
	L_∞ (cm)	K/an	$t_{0\ (an)}$			Z	M	F		L_{25}	L_{50}	L_{75}	E_{10}	E_{50}	E_{max}
Brycinus imberi	18.38	1.10	-0.16	2.570	2.73	3.25	2.12	1.13	0.35	9.34	9.91	10.40	0.720	0.375	0.832
Chromidotilapia guntheri	20.4	0.310	-0.60	2.111	9.68	1.97	0.91	1.06	0.54	9.84	10.41	10.97	0.650	0.370	0.749
Chrysichthys maurus	25.73	0.390	-0.44	2.412	7.69	4.61	0.99	3.62	0.78	10.04	10.62	11.19	0.560	0.339	0.699
Clarias gariepinus	47.78	0.390	-0.37	2.950	7.69	1.04	0.84	0.20	0.20	15.42	16.34	17.26	0.466	0.285	0.581
Heterobranchus longifilis	38.33	0.30	-0.52	2.644	10.00	0.96	0.75	0.21	0.22	15.05	16.35	17.65	0.567	0.343	0.699
Labeo coubie	33.08	0.390	-0.41	2.630	7.69	1.05	0.93	0.12	0.12	16.51	17.87	19.23	0.655	0.376	0.799
Labeo parvus	29.93	0.30	-0.56	2.429	10.00	1.05	0.80	0.25	0.24	11.92	12.62	13.31	0.569	0.339	0.699
Marcusenius furcidens	32.03	0.520	-0.31	2.727	5.77	1.91	1.13	0.78	0.41	12.69	13.30	13.91	0.550	0.327	0.688
Marcusenlus ussheri	33.08	0.31	-0.52	2.530	9.68	1.53	0.80	0.73	0.48	13.05	13.60	14.16	0.555	0.328	0.699

Mormyrus rume	43.58	0.760	-0.19	3.159	3.95	2.22	1.33	0.89	0.40	17.61	19.84	22.07	0.570	0.348	0.682
Petrocephalus Bovei	13.13	0.850	-0.24	2.166	3.53	3.22	2.00	1.22	0.36	10.02	10.64	11.27	0.650	0.397	0.799
Schilbe intermedius	32.03	0.730	-0.22	2.874	4.11	3.55	1.41	2.14	0.60	11.12	11.33	11.55	0.453	0.313	0.579
Tilapia zillii	27.83	0.640	-0.26	2.695	4.69	2.53	1.34	1.19	0.47	8.94	10.48	12.01	0.500	0.268	0.613
Hemichromis fasciatus	19.95	0.96	-0.02	2.582	3.13	2.69	1.92	0.77	0.29	9.91	10.36	10.82			
Oreochromis niloticus	24.15	0.42	-0.01	2.389	7.14	1.26	1.06	0.20	0.16	15.95	17.77	19.6			
Sarotherodon galilaeus	25.2	0.84	-0.01	2.727	3.57	1.94	1.65	0.29	0.15	8.43	8.59	8.75			
Tilapia mariae	18.9	0.64	-0.01	2.359	4.69	1.73	1.50	0.23	0.13	8.89	9.12	9.35			
Chrysichthys nigrodigitatus	24.15	0.60	-0.01	2.544	5.00	1.66	1.34	0.32	0.19	11.8	12.05	12.3	0.601	0.329	0.699
Synodontis schall	22.05	0.73	-0.01	2.550	4.11	2.11	1.56	0.55	0.26	10.67	11.17	11.67	0.553	0.359	0.699

CONCLUSION

This study is an overview of fishermen, fishing gear types, fish species and levels of exploitation of their stocks in the Solomougou Dam Lake. It provides information to decision-makers for better control of fishing activity on this reservoir.

Some illegal fishing gears are used, resulting in overexploitation of three species, four others being close to their optimal exploitation level. However, the exploitation regime of this fishery, characterised by its low frequentation over a good period of the year, preserves the stocks of many species. Thus, the use of regulatory fishing gears could be accompanied by an increase in fishing effort to increase yields.

In any case, regular assessment of fishing gears on fish stocks should be done to ensure sustainable fishing activity in this fishery

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