Acta Aquatica Turcica

Home Page: https://dergipark.org.tr/actaquatr
E-ISSN: 2651-5474
21(3): 227-241, 2025
DOI: 10.22392/actaquatr.1610280

Research Article
Araştırma Makalesi

Characterization of Fishing Around Lake Madarounfa (Maradi/Niger) and its Impact on the Ecosystem

Madarounfa Gölü (Marradi/Nijer) Çevresinde Balıkçılığın Karakterizasyonu ve Bunun Ekosistem Üzerindeki Etkisi

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Received: 31.12.2024 **Accepted:** 11.04.2025 **Published:** 01.09.2025

How to Cite: Toudjani, A. A., Youssoufa, I., & Mahamadou, H. I. (2025). Characterization of fishing around Lake Madarounfa (Maradi/Niger) and its impact on the ecosystem. *Acta Aquatica Turcica, 21*(3), 227-241. https://doi.org/10.22392/actaquatr.1610280

Abstract: This study aimed to characterize fishing and its effect on the functioning of Lake Madarounfa. Surveys were conducted to identify the fishing practices, used gears, the fish stock, and the impacts of fishing activities on the ecosystem. The fish fauna was studied through the catches of artisanal fishermen at four stations from June to December 2023. Twenty-two species belonging to twelve families and nineteen genera were identified. The Cichlidae family, with 4 genera and 4 species, was the most prevalent. Of the 5 fishing gear identified, the gillnet was the most used. A total of 35 tons of fresh fish were produced during the present study. This result showed that the greatest catch per unit effort (CPUE) was found with the cast net (9.72 kg/h). The analysis of the size structures showed a dominance of small individuals. More than 73.97% of individuals were smaller than 18.11±9.25 cm, corresponding to the mean total length of all fish individuals measured during this study. This level of fishing pressure on juveniles could affect the normal recruitment of fish stocks and lead to biodiversity erosion. Due to the intensity of uncontrolled fishing all year, agricultural activities and climate change, the functioning of the ecosystem is greatly disrupted. This constitutes a threat to the sustainability of the ecosystemic services provided by the lake. The findings of this work suggests that to ensure a sustainable fishery management of the lake, it is necessary to establish continuous monitoring and strengthen the enforcement of laws concerning ecosystem protection around this water body.

Keywords
- Anthropogenic activities
- Wetland
- Ramsar Site
- Fishing
- Maradi

Özet: Bu çalışma, Madarounfa Gölü balıkçılığını ve ekosisteme etkisini karakterize etmeyi amaçlamıştır. Balıkçılık uygulamalarını, kullanılan av araçlarını belirlemek, balık stoğunu ve balıkçılık faaliyetlerinin ekosistem üzerindeki etkilerini değerlendirmek için anketler yapılmıştır. Balık faunası zanaatkâr balıkçıların 4 istasyondan yakaladıkları av üzerinden Haziran-Aralık 2023 tarihleri arasında incelenmiştir. 12 familya ve 19 cinse ait 22 tür tespit edilmiştir. Cichlidae familyası 4 cins ve 4 tür ile en fazla temsil edilen familyadır. Belirlenen 5 av aracı arasında en çok kullanılanı uzatma ağıydı. Bu çalışma sırasında toplam taze balık üretimi 35 tondur. Bu sonuç, birim çaba başına en büyük avın (CPUE) dökme ağda (9,72 kg/saat) bulunduğunu gösterdi. Boy yapılarının analizi, küçük bireylerin baskınlığını gösterdi. Bireylerin %73,97'sinden fazlasının boyu 18,11±9,25 cm'den küçüktü. Gençler

Anahtar kelimeler
- Antropojenik faaliyetler
- Sulak alan
- Ramsar Alanı
- Balık tutma
- Maradi

üzerindeki bu seviyede balıkçılık baskısı, balık stoklarının normal şekilde kullanılmasını etkileyebilir ve biyolojik çeşitlilik erozyonuna yol açabilir. Madarounfa Gölü'nün küçüklüğü ve yıl boyunca kontrolsüz balıkçılığın yoğunluğu göz önüne alındığında ekosistemin işleyişi büyük ölçüde bozulmaktadır. Bu durum, gölün ekosisteme sağladığı katkıların sürdürülebilirliğine tehdit oluşturmaktadır. Gölde sürdürülebilir bir balıkçılık yönetimi sağlamak için, bu su kütlesinin çevresinde sürekli bir izleme sisteminin kurulması ve ekosistemin korunmasına ilişkin yasaların uygulanmasının güçlendirilmesi gerekmektedir.

1. INTRODUCTION

Fishing is one of the human activities that impacts aquatic ecosystems through uncontrolled fishing and unconventional fishing practices and gears. It is an activity that affects the dynamics of stocks and populations of aquatic living organisms (Lévêque & Paugy, 1999; Albaret et al., 2003; Ouattara et al., 2006). The effects on ecosystems are both direct, through the increase in mortality coefficient of target and non-target species or modifications of the biotope caused by fishing gear (Jennings and Kaiser 1998; Hall et al., 2000). The important role of this activity in the socio-economic development of populations has been confirmed by several studies (Lae, 1997; Ouattara et al., 2006).

Today, fishermen in developing countries no longer talk about the profitability of their activities, but rather about a simple livelihood (Montcho, 2011; Yacouba, 2019). Thus, fishery resources management is becoming more and more of a challenge biologically and economically (Montchowui et al., 2008; Tsikliras et al., 2015; Yacouba, 2019). To deal with this situation, Niger Republic has adopted a fishing development and responsible aquaculture strategy since 2007 for the conservation, management, and development of fishery resources respecting ecosystems and biodiversity, to deal with food insecurity and poverty.

Lake Madarounfa with a maximum depth varying between 1.5 and 5 meters according to the seasons and a surface area that varies between 4000 ha during the high-water period and 800 ha during the low-water period, is the largest permanent surface water body in the Maradi region (Niger) (Assane & Issiaka, 2021). This is protected by both national and international legal status. Indeed, the lake has been designated as a wetland of international importance according to the Ramsar Convention in 2021 (Ramsar, 2021). Today, fishing in Lake Madarounfa is an important activity among many other activities that provide several socio-economic benefits to local populations. Previous studies have been conducted on the ichthyological diversity of this lake (Ramsar, 2021, Assane & Issiaka, 2021). This study, the first attempt of its kind in the region, aimed to characterize fishing and its effect on the functioning of the lake Madarounfa.

2. MATERIALS and METHODS

2.1. Working schedule

This study was conducted from June to December 2023.

2.2. Study area

Lake Madarounfa is located in the district of Madarounfa which occupies the southern part of the Maradi region (Niger) between 13° and 15° north latitude and between 6° and 8° east longitude and covers a surface area of 3.500 km^2 which represents 9% of the Region. (Figure1).

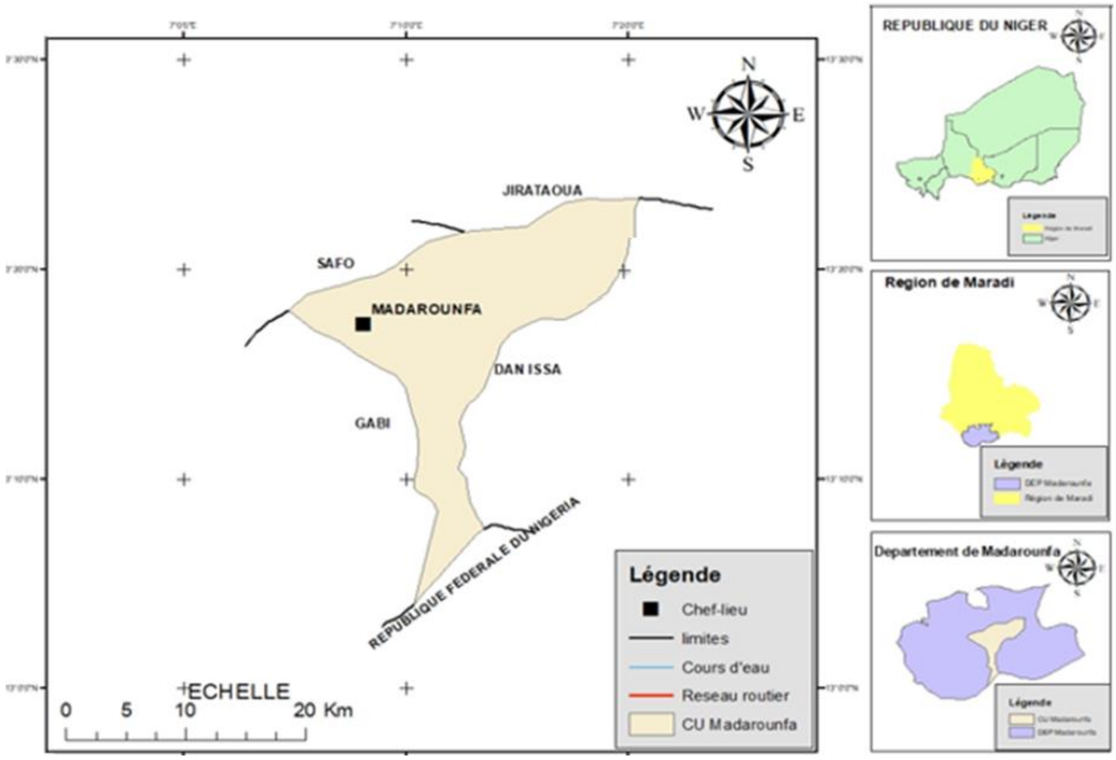

Figure 1. Location of the study area.

2.2. Determination of water physicochemical parameters

During this study, some physicochemical parameters were determined in situ. Measurements were carried out between 7 a.m. and 10 a.m. once a month during six (6) months from June to December 2023. The parameters measured were water temperature (°C), pH, total dissolved solids ((TDS) mg L^{-1}) and conductivity (µS cm^{-1}) using a multiparameter, the water depth (cm), and the water transparency (cm) using a Secchi disc. The data collected were processed and analyzed after testing their normality. The mean and standard deviation of each parameter were calculated and then, the Kruskal Wallis test was used to compare the averages among stations and months.

2.3. Diversity, morphometric characteristics and fish stock

To meet many fishermen, four (4) stations were chosen (Dantoudou, Madarounfa, Gamji, and Saoulaoua). Each station was visited 2 days per month during six months from June to December 2023 between 7 a.m. and 11 a.m. At each station, fish catches from artisanal fishing are sampled to characterize the fish population in the lake.

The fish diversity was studied using Shannon-Wiener Index (H') and the regularity or fairness of Piélou ((Eq) based on equations 1 and respectively.

$$H' = -\sum_{k=0}^{n} \quad (Pi * log2(Pi)) \qquad (1)$$

Pi = ni / N; ni is the number of individuals representing species i and N = total number of individuals.

$$Eq = \frac{H\prime}{log2 * S} \qquad (2)$$

Where S = total number of species. The index varies from 0 to 1.

After identification using the key of Paugy et al. (2003), the morphometric characteristics of fish individuals were measured especially the total length (Lt), the standard length (Ls), and the total weight (Pt) of each individual using an ichthyometer and an electronic scale. Then, a Kruskal-Wallis test was performed to determine the change in species number from one month to another.

A survey was conducted among active fishermen and agents of the Madarounfa departmental environment directorate to determine the fish stock per season. The quantity of fish caught during the period of this study was then deducted and analyzed. Ideally, abundance indices should be derived from scientific studies independent of commercial fishing, such as those carried out by research groups. However, in many cases, due to cost or other logistical issues, fisheries independent surveys are just not feasible and so fisheries dependent, catch-rate data (CPUE) must be used to create an abundance index for stock assessments (Candy, 2004; Ducharme-Barth, 2021). Therefore, determining an abundance index from commercial data is a common procedure in fishing characterization. To analyze fishing catches around the lake, catch per unit of effort (CPUE) in kilogram per hour (kg/h) was calculated from fresh fish quantity recorded during the study period using equation 3.

$$CPUE = \frac{Total\ catch}{Fishing\ time\ x\ number\ of\ fishing\ gears\ x\ number\ of\ fishermen\ per\ fishing\ gear} \quad (3)$$

2.4. Weight-length relationships of abundant species in fish catches

The length-weight equation (Equation 4) was used to estimate the relationship between the weight (g) of the fish and its total length (cm). The length-weight was estimated as (Ricker, 1975):

$$Pt = aLt^b \quad (4)$$

Pt and Lt represent fish individuals' total weight and length, respectively while a and b are characteristic of environmental factors and species respectively.

To determine whether the relationships between selected morphological variables exhibit isometric or allometric change, a linear regression and t-tests were performed using IBM SPSS Statistics 23.

2.5. Condition factor of abundant species

The condition factor k is calculated for abundant species in fish catches using the following equation 5.

$$K = 100 * \left(\frac{Pt}{Lt^b}\right) \quad (5)$$

Pt is the total weight, Lt is the total length of the fish, and b is the allometry coefficient of the weight-length relationship. The condition factor is an important parameter in fisheries biology and is used to assess the fish's corpulence and overweight. Good growth condition of the fish is deduced when $Kn \geq 1$, while the organism is in poor growth condition compared to an average individual with the same length when $Kn < 1$ (Jisr et al., 2018).

2.7. Identification of fishing gears and their selectivity

The different fishing gear types used by fishermen were identified in situ and their selectivity was determined through the number of fish individuals caught by each gear. Then, a canonical correspondence analysis was carried out using the Past 4.03 software to examine the selectivity of fishing gear according to the specific diversity of catches. This permitted the identification of the common species cached by each fishing gear (George and Nédélec, 1991 ; Camille et al., 2016) used by fishermen around Lake Madarounfa.

3. RESULTS

3.1. Physicochemical parameters of the water

The physico-chemical characteristics of the water are presented in Table 1. It appears from the analysis of this table that the conductivity and transparency of water had high standard deviations (15.13 and 4.51, respectively), while the lowest standard deviation (0.11) was observed for TDS. The mean depth of the lake was 0.51±0.11 while the coefficient of variation varied between 0.3 and 0.69 for temperature and TDS respectively. The water temperature ranged from 20.3°C to 22.6°C with an average of 21.50±0.73°C. Statistical analysis showed no significant difference in water temperature between stations (P>0.05). However, there was a significant difference between months ($P < 0.05$).

Table 1. Summary of physicochemical parameters of the water during the study period.

	Temperature	pH	Conductivity (µS/cm)	TDS (ppm)	Transparency (cm)	Depth (m)
Mean	21.50±0.73	6.51±0.40	85.07±15.13	0.15±0.11	25.75±4.51	0.51±0.11
SD	0.73	0.40	15.13	0.11	4.51	0.11
Min	20.3	6.3	69	0.08	20.5	0.37
Max	22.6	7.3	118	0.42	40	0.97
CV	0.33	0.62	0.17	0.69	0.17	0.21

SD: Standard Deviation. Mini: minimum. Max: maximum. CV: coefficient of variation. TDS: total dissolved solids.

3.2. Species abundance

A total of 22 species were identified around the lake (Table 2). The Cichlidae constituted the most represented (44.83%) family with 4 species and 4 genera, followed by the Mormuridae family (14.88%) with 3 species and 3 genera and the Clariidae family (13.73%). The other families are each represented by a single species. The most abundant species in number are Oreochromis niloticus (22.28%), *Sarotherodon galilaeus* (15.33%), and *Bagrus bajad* (7.31%) (Table 2).

Table 2. List of identified fish species.

Families	Genera	Species	% values
Anabantidae	Ctenopoma	*Ctenopoma kingsleyae* (Günther, 1896)	0.67
Bagridae	Bagrus	*Bagrus bajad (Forskål, 1775)*	7.31
Characidae	Alestes	*Alestes macrophthalmus* (Günther, 1867)	0.71
	Brycinus	*Brycinus leuciscus* (Günther, 1867)	2.63
Cichlidae	Hemichromis	*Hemichromis bimaculatus (Gill 1862)*	1.16
	Oreochromis	*Oreochromis niloticus* (Linnaeus, 1758)	22.28
	Sarotherodon	*Sarotherodon galilaeus* (Linnaeus, 1758)	15.33
	Tilapia	*Tilapia zillii* (Gervais, 1848)	6.06
Clariidae	Clarias	*Clarias anguillaris* (Linnaeus,1758)	4.55
		Clarias gariepinus (Burchell, 1822)	5.88
	Heterobranchus	*Heterobranchus bidorsalis* (Geoffroy SaintHilaire, 1809)	3.30
Claroteidae	Chrysichthys	*Chrysichthys auratus* (Geoffroy Saint-Hilaire, 1808)	0.18
Latidae	Lates	*Lates niloticus* (Linnaeus,1758)	4.10
Mochokidae		*Synodontis courteti* (Pellegrin, 1906)	0.18
	Synodontis	*Synodontis schall* (Bloch et Schneider, 1801)	1.07
Mormyridae	Hyperopisus	*Hyperopisus bebe occidentalis* (Lacepède, 1803)	6.69
	Petrocephalus	*Petrocephalus bovei* (Valenciennes,1847)	3.48
	Pollimyrus	*Pollimyrus isidori* (Valenciennes, 1846)	4.72
Polypteridae	Polypterus	*Polypterus senegalus* (Cuvier, 1829)	0.62
Protopteridae	Protopterus	*Protopterus annectens* (Owen, 1839)	0.80
Schilbeidae	Schilbe	*Schilbe intermedius* (Rüppell, 1832)	4.63
		Schilbe mystus (Linnaeus,1758)	4.01

3.3. Spatial and temporal variations of diversity indices

Species diversity changed from one station to another during the study period. Thus, 21 species were identified at Dantoudou, 18 at Madarounfa, 10 at Gamji, and 14 at Saoulaoua (Table 3). The analysis of this table indicated that the Shannon diversity index changed from

1.96 to 3.88. On another hand, high Piélou fairness (0.8≤ Eq≤1) was observed at Dantoudou, Madarounfa, and Saoulaoua stations. The situation indicated a non-dominance in communities of these three stations contrary to the station of Gamji with low fairness (0≤ Eq ≤ 0.6) which indicated a dominance of one species in the community.

Table 3. Spatial variation of diversity indices.

Stations	Shannon diversity index (H’)	Piélou fairness (Eq)	Species number
Dantoudou	3.88 ±0.18	0.88	21
Gamji	1.96 ±0.19	0.59	10
Madarounfa	3.48 ±0.19	0.83	18
Saoulaoua	3.17 ±0.22	0.83	14

The distribution of fish diversity based on the Shannon diversity index and Piélou fairness during the six months of the study period is represented in Table 4. It appears from the analysis of this table that the diversity index changed according to the months, but indicated a non-dominance of one species contrary to the Piélou fairness which indicated a dominance of one species during the 6 months.

Table 4. Temporal variation of diversity indices.

Months	Shannon diversity index (H’)	Piélou fairness (Eq)	Species number
June	3.43±0.20	0.84	17
July	3.23±0.20	0.80	16
August	3.41±0.17	0.80	19
October	3.13±0.26	0.87	12
November	3.35±0.23	0.87	14
December	2.79±0.27	0.84	10

The result of the Kruskal-Wallis test (p = 0.33) showed that the number of species does not vary from one month to another (Table 5).

Table 5. Summary of the Kruskal-Wallis Test.

Null Hypothesis	Test	Sig.	Decision
The distribution of species is the same across categories of group.	Independent-Samples Kruskal-Wallis Test	0.33	Reject the null hypothesis

Asymptotic significance is displayed. The significance level is 0.05.

3.4. Morphometric variables of species

In total, 1122 fish individuals were measured during the 6 months of the study period. The individual number per species, minimum, average, and maximum values of total length, standard length, and total total weight are presented in Table 6. The total length changed from 5.5 cm (*Pollimyrus isidori*) to 60 cm (*Clarias anguillaris*), while the standard length varied between 5.2 cm (*Tilapia zillii*) to 60 cm (*Clarias anguillaris*). Species weight varied from 2 g (*Brycinus leuciscus*, *Pollimyrus isidori* and *Hemichromis bimaculatus*) to 2600 g (*Clarias anguillaris* and *Lates niloticus*).

The analysis of the extreme sizes in the captured fish by fishing gear showed that the individual with the largest maximum size (60.6 cm) was recorded in the gillnet catches while the creel and the cast net captured individuals having the smallest minimum size (5.5 cm).

Table 6. Morphometric parameters of fish species.

Species	N	Lt (cm)			Ls (cm)			Pt (g)		
		Lt max	Lt mean	Lt min	Ls max	Ls mean	Ls min	Pt max	Pt mean	Pt min
Alestes macrophthalmus	8	24	15.59±5.91	6.7	19	12.65±4.72	5.5	59	34.88±1.62	3
Bagrus bajad	82	49	27.38±9.61	8.7	42	23.30±8.48	7	926	197.01±10.04	3
Brycinus leuciscus	30	13.1	9.20±2	6.1	10.5	7.61±1.51	5	10	5.10±1.55	2
Chrysichthys auratus	2	26	26±0.23	26	24.8	24.80±0.56	24.8	97	97±3.56	9.7
Clarias anguillaris	51	65	25.41±10.18	10.5	60	22.54±9.41	9.3	2600	188.06±8.44	8
Clarias gariepinus	66	52.2	27.03±11.19	11.3	47	23.86±9.90	10	897	183.08±6.74	7
Ctenopoma kingsleyae	3	12.6	12.07±0.76	11.2	11	10.18±0.85	9.3	28	21.67±4.03	16
Hemichromis bimaculatus	13	13.5	8.48±2.15	6	11.5	7.15±1.75	5.3	38	9.54±1.14	2
Heterobranchus bidorsalis	37	54	26.36±9.30	15	48	23.14±8.04	13.7	1196	170.78±6.57	18
Hyperopisus bebe occidentalis	75	51.5	24.68±8.67	7	47	22.70±7.96	6	973	132.13±7.10	3
Lates niloticus	46	60.6	24.13±12.73	7.5	51	21.25±5.52	6.3	2600	323.24±7.06	5
Oreochromis niloticus	250	46	16.93±0.06	6.2	39	14.03±5.25	5.3	735	100.38±5.78	4
Petrocephalus bovei	39	12.2	10.82±1.25	7.2	11	9.33±1.14	6	19	11.72±3.85	3
Pollimyrus isidori	53	12.7	8.93±1.57	5.5	11.1	7.72±1.48	4.5	20	6.83±1.11	2
Polypterus senegalus	7	35	19.06±4.43	9.5	30.5	16.79±3.76	9	139	43.57±7.22	4
Protopterus annectens	9	46	34.72±8.23	20	42	30.59±8.09	19.3	428	197.33±5.31	57
Sarotherodon galilaeus	172	30.9	15.22±5.02	5.5	25.5	12.57±4.26	4.6	504	75.05±8.93	4
Schilbe intermedius	45	11.34	14.09±0.14	8.5	14.5	10.25±1.89	7.5	29	9.80±3.98	3
Schilbe mystus	52	19.2	13.71±3.04	8.5	16.8	12.08±2.68	6.3	51	18.42±4.19	4
synodontis courteti	12	15.6	11.48±2.17	8	12	9.42±1.61	6.5	26	16.58±6.64	7
Synodontis schall	2	21.5	18.45±4.31	15.4	16.3	14.15±3.04	12	96	59.00±4.33	22
Tilapia zillii	68	26.3	12.55±3.65	6.5	20	10.23±2.87	5.2	230	35.68±6.61	5

N= species number, Lt= total length, Ls= standard length, Pt= total weight, max= maximum, min = minimum

3.5. Weight-length relationship for dominant species and their condition factor

The analysis of the weight-length relationship of *Oreochromis niloticus*, *Sarotherodon galilaeus*, *Bagrus bajad*, and *Hyperopisus bebe occidentalis* which were dominant species in terms of numerical abundance during this study is shown in Table 7 and Figure 2. It appears from this analysis that the value of b is around 3 for *Sarotherodon galilaeus* showing an isometric growth (I, t-test, $P < 0.05$) which is statistically significant, b > 3 for *Bagrus bajad* which indicating a positive allometry (A+, t-test, $P > 0.05$) and a negative allometry (A-, t-test, $P > 0.05$) with b < 3 for *Oreochromis niloticus* and *Hyperopisus bebe occidentalis* indicating an insignificant variation. Also, there was a variation in the K factor values from one species to another with higher values for *Oreochromis niloticus* and lower for *Hyperopisus bebe occidentalis*. The high regression coefficients (R^2) obtained indicated that for all the species, the weight of the fish was highly correlated with the total length.

Table 7. Result of the morphometric variables analysis. The values given are from the equation $Pt = aLt^b$ and t-tests.

Species	a	b	R^2	K	Growth Type	P
Oreochromis niloticus	0.0184	2.9174	0.9308	2.73±0.010	A-	0.306
Sarotherodon galilaeus	0.0133	3.0351	0.9394	1.89±0.011	I	0.002
Bagrus bajad	0.0043	3.1292	0.9613	0.38±0.004	A+	0.726
Hyperopisus bebe occidentalis	0.0062	2.973	0.9429	0.3±0.004	A-	0.590

a is intercept and b is slope value of regression ; R^2 is the regression coefficient; I, A- and A+ indicating isometric, negative and positive allometric growth type, respectively. P is the t-tests P-values.

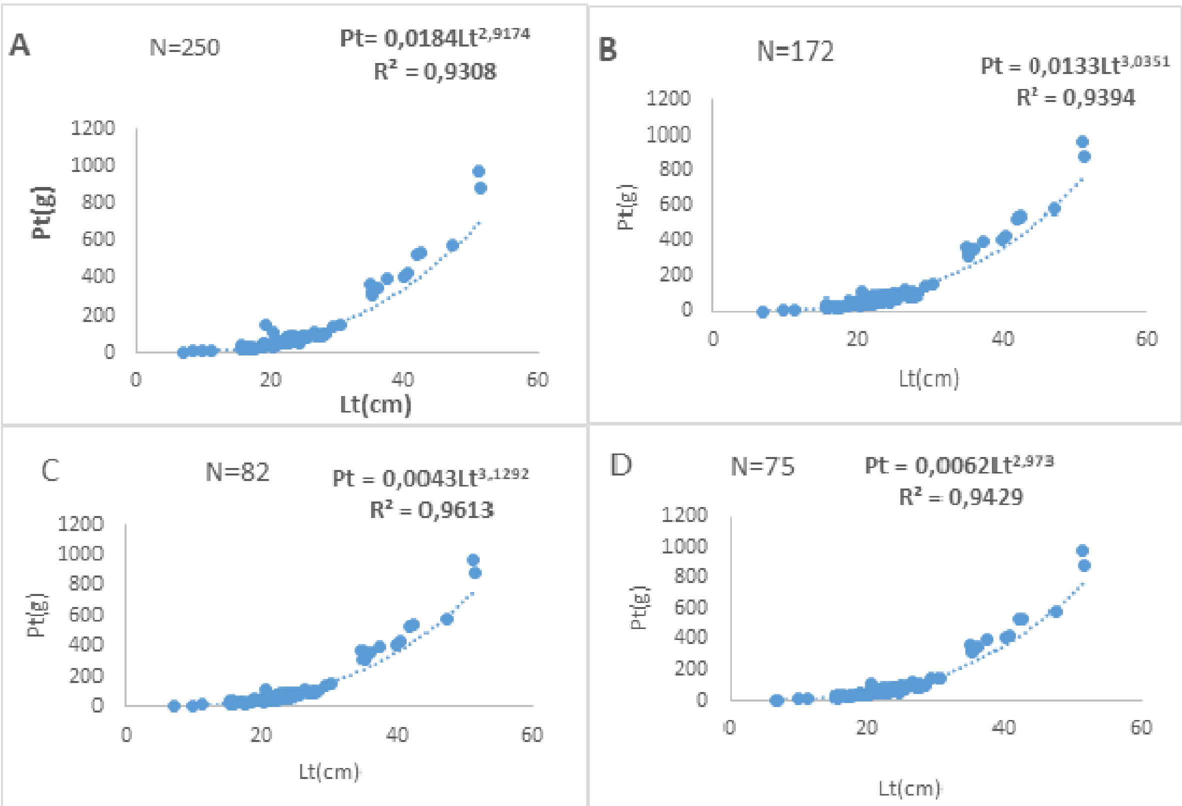

Figure 2. Weight-length relationship for dominant species : Lt= total length, Pt= total weight, A= *Oreochromis niloticus* ; B= *Sarotherodon galilaeus* ; C= *Bagrus bajad* ; D= *Hyperopisus bebe occidentalis*.

3.6. Typology of fishing gear and their selectivities

Madarounfa fishermen mainly used traditional equipment and most of the techniques used were widely used in artisanal fisheries in West Africa (Figure 4). The most widely used gear was the gillnet, which is a long, rectangular, single-walled net anchored to the seabed. It catches fish when they come into contact with it. This was used by 30% of fishermen. Traps were also widely used. These are stationary structures of many shapes and sizes into which fish are guided or pushed by the current. They can also be drawn into the gear by bait or other attractants. Cast nets are constructed from a series of tailored netting sections joined together to produce a cone-shaped net with weights and a drawstring attached to the perimeter, and are cast by fishermen to catch fish. Set longlines are longline gears that are anchored or otherwise fixed to the seabed at either end of the mainline. Butterfly nets are not specified. These are butterfly-shaped gillnets. The net, stretched over its supports, is held by a fisherman who moves through the water. As a result of this movement, the fish become entangled in the net.

Figure 3. Used fishing gears : a) Traps, b) Cast net, c) set gillnet, d) set longline, e) butterfly net.

The analysis of numerical abundance by fishing gear showed that the set gillnet was the most selective gear (45.01%) followed by the traps (35.65%), the set longline (13.57%), the cast net (3.39%) and then the butterfly net (2.67%). On the other hand, the selectivity of the gear according to weight abundance showed that 42.83% of the biomass was recorded for set longline followed by the set gillnet (39.62%), the traps (15.84%), the cast net (1.01%) and then the butterfly net (0.70%). To understand the selectivity of fishing gears related to the specific diversity in the catches around Lake Madarounfa, a canonical correspondence analysis (CCA), a multivariate analysis was carried out. From this analysis, it appears that the first two axes (1 and 2) concentrated 98.41% of the information (Table 8). Thus, *Bagrus bajad*, *Clarias gariepinus*, *Lates niloticus*, *Hyperopisus bebe occidentalis*, *Heterobranchus bidorsalis* and *Chrysichthys auratus* were the most captured by longlines, while *Oreochromis niloticus*, *Sarotherodon galilaeus*, *Polypterus senegalus* and *Protopterus annectens* were best represented in the catches of butterfly net. The trap catches contained more individuals of *Pollimyrus isidori*, *Ctenopoma kingsleyae,* and *Tilapia zillii* while those of the cast net contained more representatives of *Synodontis schall* and *Petrocephalus bovei*. The gillnet captured more individuals of *Protopterus annectens*, *Schilbe mystus*, and *Alestes macrophthalmus* (Figure 5).

Table 8. Summary of canonical correspondence analysis (CCA) of fishing gears and species selectivity.

Axis	Eigenvalue	%
Axis 1	0.25551	58.42
Axis 2	0.17489	39.99
Axis 3	0.0065013	1.487
Axis 4	0.0043215	009882

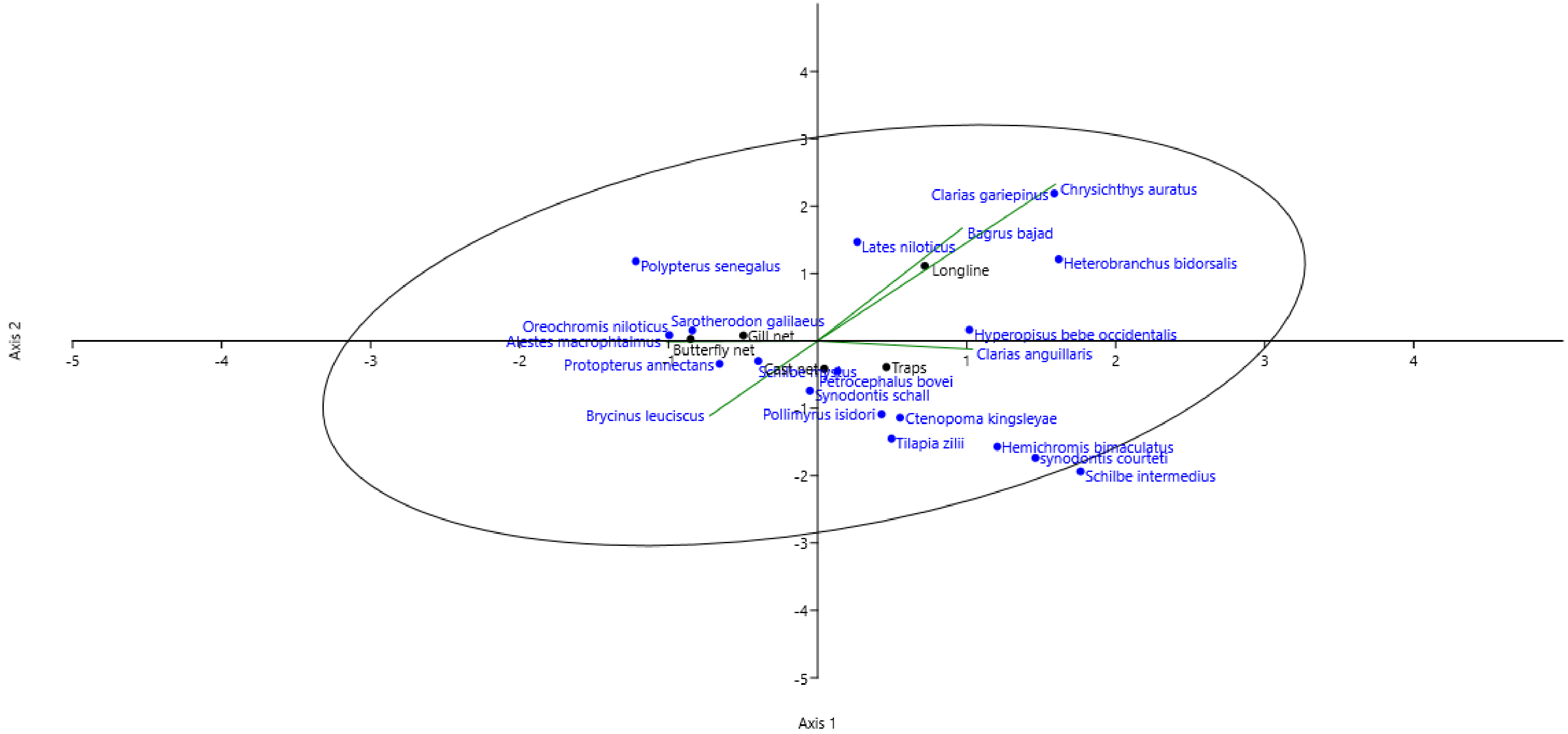

Figure. 4. Canonical correspondence analysis (CCA) plot of fishing gears and species selectivity.

3.7. Fish stock and catch per unit effort (CPUE)

The production of fresh fish recorded by the environmental services for the six months corresponding to the data collection period for this study was estimated at 35 tonnes. From this production, the catches per unit of effort (CPUE) by type of fishing gear were calculated in kilograms per hour (kg/h). Thus, the CPUE for gillnets, creels, longlines, butterfly nets, and cast nets were respectively 1.94 kg/h, 2.43 kg/h, 2.43 kg/h, 4.86 kg/h, and 9.72 kg/h. From this result, it appears that the greatest catch was made with the cast net (9.72 kg/h) while few fish were captured with gill net (1.94 kg/h) over the same fishing time interval.

3.8. Impacts of fishing on the lake

From the characterization of fishing activities around the lake, it appears that gillnet and creel were fishing gears that captured all size classes with a high proportion (>50%) of small individuals. Also, more than 73.97% of the catches had smaller lengths than the average size (18.11±9.25 cm). Moreover, high catch per unit of effort (CPUE) relative to the small size of the lake indicates pressure on fishery resources. This situation could lead to a reduction in abundance and a change in population dynamics.

Fishermen around Lake Madarounfa most often use unconventional methods and some have more than one fishing campaign per day. These practices are a threat to the lake ecosystem and could be a disturbance that could lead to the death of certain aquatic organisms, thus disrupting the natural balance of the environment. Indeed, it has been reported in the survey and observed in the field the destruction of spawning areas during the crossing of fishing boats and the trampling of fishermen.

4. DISCUSSION

The water temperatures measured during this study were different from those of the lake Marounfa reported by Ramsar (2021) and Ibrahim (2020), who reported a temperature variation between 29.6˚C and 30.3˚C. This could be due to the influence of the rain and cold seasons which coincided with our data collection period. The pH values obtained during this study were between 6,5 and 8,5 and differ slightly from those (5.5-7.4) reported by Ramsar (2021). The low conductivity could be due to low mineralization. The low transparency values observed during this study could be due to runoff which carries suspended matter and throws it into the lake. These high concentrations of suspended matter affect the transparency of water in the rainy season, which becomes low (Akpan, 2004).

The ichthyological fauna during the study was constituted of 22 species belonging to 21 genera and 12 families dominated by the Cichlidae. This result was different from that obtained by Assane and Issiaka (2021) who reported 40 species belonging to 30 genera and 14 families from 2013 to 2019 in the same lake. This difference could be explained by the duration of data collection and the disappearance of some species from the lake during the data collection period. The number of species identified is also lower than that (95 species) obtained by Yarombé et al. (2019) in Lake Séligué in Mali. This could probably be due to the small size of Lake Madarounfa comparatively to Lake Séligué, but also to the intensity of artisanal fishing activities all the year around Lake Madarounfa. Indeed, Montcho (2011) reported that increasing fishing efforts by multiplying the number of fishing campaigns in time and/or space increases the probability of catching more species.

The spatial and temporal distribution in terms of number and biomass showed a dominance of Oreochromis niloticus for 4 months. Indeed, this species is naturally distributed in several African watersheds such as the Nile and Congo basins, and several Ethiopian lakes. In West Africa, its natural distribution covers the Senegal, Gambia, Volta, Niger, and Chad basins (Assane & Issiaka, 2021). But its numerical and weight abundances changed according to months, habitats, and fishing techniques, Yacouba (2019).

Among the parameters used in fisheries biology, the study of weight-length relationships and the condition factor plays a very important role (Moutopoulos & Stergiou, 2002; Lederoun et al., 2016, 2022; Brahim et al., 2023). Weight-length relationships make it possible to determine the weight of fish by knowing their length, or vice versa, and to evaluate the overweight of fish to assess their growth, and the fishing pressure in the environment (Lalèyè, 2006; Lederoun et al., 2022; Brahim et al., 2023). The weight-length relationship of dominant species showed positive allometry for Sarotherodon galilaeus and Bagrus bajad indicating more individuals growing in weight than in length during this study. This is probably due to the high water period during which food is abundant for the fish and coincided with the reproduction period where the majority of mature females carry eggs increasing their weight to increase further while their growth in length becomes stable. According to Brahim et al. (2023), weight-length relationships can be used in fisheries management, to monitor the growth of organisms (overweight) and, consequently, to formulate recommendations for responsible exploitation of the stock. The condition factor (K) during the study for Oreochromus niloticus and Sarotherodon galilaeus showed that these species lived in better nutritional conditions. However, the K factor indicated an unfavorable ecological condition for Bagrus bajad and Hyperopisus bebe occidentalis which could be due to excessive use of some fishing gear and techniques which result in permanent stress for several species. According to Lévêque and Paugy (2006), the condition factor is an indicator of not only fish evolution state but also a better tool for comparing the overall physiological state of populations between basins presenting different ecological conditions. Moreover, it has been reported that the condition factor makes it possible to assess the health status or well-being of the fish (Froese, 2006, Lederoun et al., 2016), but also to evaluate the ecological status of the ecosystem in which the fish live (Anene, 2005; Lederoun et al., 2022).

Relatively to the size of the lake, fish production over the study period can be considered high. This situation resulted in high CPUEs indicating more pressure on fishery resources. However, according to Justin (2007), the CPUE is an excellent exploitation indicator whose value is inversely proportional to that of the fishing pressure.

It appears from this study that the gillnet and the creel were fishing gears that caught all size classes with a high proportion (>50%) of small individuals. This result is similar to the finding of Lévèque and Paugy (2006) who reported that among fixed gears, the most frequently used by scientists as well as by fishermen are gillnets because of their advantage of being easy to use. Fishing is one of the human activities that affects aquatic ecosystems through uncontrolled fishing efforts, and widespread use of non-regulatory fishing practices and gears (Adélie, 2018). There are several effects of fishing on ecosystems which range from direct effects, such as reduction in abundance and modification of size spectra, to indirect effects on trophic levels (Albaret & Laë 2003; Balirwa et al., 2003; Chapman et al., 2003; Laurans et al., 2004).

The analysis of the size classes around Lake Madarounfa showed a predominance of small individuals. This fishing pressure on juveniles could affect the normal recruitment of fish stock in the lake and lead to biodiversity erosion. Jeppe et al. (2017) reported that the pressure of overly selective fishing in certain arid areas of sub-Saharan Africa has reduced the stock of large fish species which have been replaced by small species.

Overexploitation can lead to biodiversity reduction, or in some cases, the extinction of species or groups of species. This situation occurs when the biological capacities of some species no longer allow them to cope with intense fishing pressure and ensure population renewal. In this case, only a small number of species manage to adapt to fishing pressure and end up dominating the population (Greenstreet et al., 1999). Also, the degradation level of the lake can increase due to the large number of boats, combined with the effect of trampling by fishermen which could lead to mortality and disturbance of fish life cycle.

Given the small size of Lake Madarounfa and the intensity of uncontrolled fishing all year round, has greatly disrupted the functioning of the ecosystem and threatens the sustainability of the ecosystemic services provided by the lake. This worrying situation, the consequences of which could be dramatic, should be analyzed to detect its impacts on the functioning of the lake ecosystem and on the dynamics of fish populations and species. This diagnosis is an essential requirement for the preservation and sustainable management of the lake. For sustainable exploitation of the lake fishery resources, respecting seasonal fishing closure periods is necessary as recommended by Ouattara et al. (2006). Indeed, fishing activities modify the substrate of exploited ecosystems and directly associated populations, in particular the benthos. The majority of mobile fishing gears scrapes the surface, or digs into the substrate of aquatic ecosystems could result in diversity reduction, especially in populations of fish that use these structures as habitat (Hall-Spencer & Moore, 2000; Piet et al., 2000; Kaiser et al., 2002; Justin, 2007). These fishing gears could also directly affect the physical properties of the substrate (Kaiser et al., 2002).

5. CONCLUSION

Lakes are wetlands that host significant biodiversity and are sources of numerous ecosystem services. These lake environments ensure food needs through the services provided and contribute to the development of local communities socio-economic activities. Lake Madarounfa is subject to several anthropogenic pressures including agricultural activities, fishing and domestic use. However, uncontrolled fishing activities constitute a threat to the sustainability of the ecosystem services provided by the lake. This worrying situation whose consequences could be dramatic, should be analyzed to detect its impacts on the functioning of the lake ecosystem and on the dynamic of fish populations and species. The main direct effect of fishing is the reduction in species abundance. It primarily affects large species which are becoming rare in fisherman catches and the functioning of the lake.

To ensure the sustainable management of the lake, continuous monitoring and the enforcement of ecosystem protection laws around the water body must be strengthened. The findings of this study showed that Lake Madarounfa is an excellent site for biodiversity conservation in general and fish resources in particular.

ACKNOWLEDGEMENT

Authors would like to thank Dan Dicko Dankoulodo University of Maradi and University of Diffa for providing technical support.

FUNDING

No financial support was received for the present study.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

AUTHOR CONTRIBUTIONS

Fiction: AAT, IY; Literature: AAT; Methodology: AAT, IY; Data collection: HIM, AAT; Data analysis and manuscript writing: AAT, HIM; Supervision: IY.

ETHICAL STATEMENTS

Local Ethics Committee Approval was not obtained because experimental animals were not used in this study.

DATA AVAILABILITY STATEMENT

Data supporting the findings of the present study are available from the corresponding author upon reasonable request.

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