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Exploring freshwater fish assemblages and population structure in three Tunisian reservoirs for better fishery management

Abstract

The study of fish populations is essential for sustainable management of the ichthyic resources. This paper aims to assess the state and structure of freshwater fish populations in three Tunisian reservoirs in order to monitor and optimize fishing and stock enhancement for an effective management. The Technical Center of Aquaculture in cooperation with the Higher Institute of Fisheries and Aquaculture of Bizerte has implemented a sampling technique using fish nets inspired by the European standard CEN pr EN 14757. In this study, 3 reservoirs were prospected: Kasseb, Seliana (in March 2016) and Lahjar (in March 2017). The implementation of the sampling protocol allowed the capture of 5 species of freshwater fish. The yields observed are more important in terms of weight than number at the Lahjar reservoir (637.5 in d/1000m^2 and 73008.3 g/1000m^2) average at Seliana (240 in d/1000m^2 and 45191.67 g/1000m^2) and quite low at the Kasseb reservoir (25.49 in d/1000m^2 and 6750 g/1000m^2). The majority of the catches were obtained in the 0-3 and 3-6m strata. An alarming decline of the pike-perch stock was detected in these dams with the absence of carp and eel in all the reservoirs surveyed. It is worth mentioning that overexploitation of fish resources at the level of the explored reservoirs was also observed.

Keywords: Freshwater fish, population assessment, multi-mesh gillnets, reservoirs, management plan, Tunisia

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Tahani Chargui,[1] Manel Fatnassi,[1] Rym Ennouri,[1] Hajer Zarrouk,[2] Houcine Laouar,[3] Naoufel Romdhane,[4] Sami Mili[4]

[1]Exploitation of Aquatic Environments, University of Carthage, Higher Institute of Fisheries and Aquaculture of Bizerte, Tunisia
[2]Technical Center of Aquaculture, Tunisia
[3]Directorate General of Fisheries and Aquaculture, Tunisia
[4]Exploitation of Aquatic Environments, University of Carthage, Higher Institute of Fisheries and Aquaculture of Bizerte, Tunisia

Correspondence: Tahani Chargui, Exploitation of Aquatic Environments, Higher Institute of Fisheries and Aquaculture of Bizerte, University of Carthage, Tunisia, Tel+201672 440 070, Email charguitahani@yahoo.fr

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Abbreviations: NPUE, Number per unit effort; WPUE, Weight per unit effort; (D), Index of margalef; H, Shannon and weaver diversity index; J, Index population distribution of pielou; In d, individual; ISPAB, Higher institute of fisheries and aquaculture of bizerte; TCA, Technical centre of aquaculture; IRESA, Institution of agricultural research and higher education

Introduction

Aquaculture in Tunisia is a very old activity dating back to Roman times as evidenced by some mosaics of the Bardo Museum in Tunis. The first Tunisian experience of fishing in reservoirs initiated in the 1960s by the national fisheries office through the stocking of some dams with fry of various fish species.[1] Currently, 9 governorates are concerned by this fishing activity and the majority of reservoirs are located in the northern part of the country.[2] The fisheries in these reservoirs involve a large number of fishermen's and it was considered as an important economic activity, especially in the disadvantaged region of the country.[1] The most commonly caught species in Tunisian reservoirs are Mullet (*Mugilcephalus* Linnaeus, 1758, Mugiliformes, Mugilidaeand *Liza ramada*Risso, 1827, Mugiliformes, Mugilidae), Pike-perch (*Sander lucioperca,* Linnaeus, 1758, Perciformes, Percidae), Carp (*Cyprinuscarpio*Linnaeus, 1758, Cypriniformes, Cyprinidae), Rudd (*Scardiniuserythrophthalmus* Linnaeus, 1758, Cypriniformes, Cyprinidae), Catfish (*Silurusglanis*Linnaeus, 1758, Siluriformes, Siluridae),Eel(*Anguilla anguillaLinnaeus,* 1758, *Anguilliformes, Anguillidae*), Tilapia (*Oreochromisniloticus*Linnaeus, 1758, Perciformes, Cichlidae), Roach (*Rutilusrutilus*Linnaeus, 1758, Cypriniformes, Cyprinidae) and Barbel (*Barbuscallensis*Linnaeus, 1758, Cypriniformes, Cyprinidae).[1,3,4] Production increased from 843.5 tonnes in 2000 to exceed 1359.821 tonnes in 2017 with a decrease to 919 tonnes in 2011 and 874.407 tonnes in 2019.[5] The decline of 2011 is the result of the unstable political situation of the country and the one, which occurred in 2019, can be explained by the low rate of carp and Mullet stocked for the last years in the Tunisian reservoirs. For 2019, the Carp was the most heavily fished species, with 30.28% of the total production followed by Mullet and Pike-perch with, respectively, 28.19% and 22.45%.[5] This activity can be maintained and developed by monitoring the fish stocks and the status of freshwater population's fishes in the reservoirs. Given the lack of data related to these fisheries and the necessity of management, a research and development project was initiated in collaboration between the Technical Center of Aquaculture in Tunis (CTA) and the Higher Institute of Fisheries and Aquaculture in Bizerte (ISPAB) in order to develop an adequate management plan. The goal of this study was to determinate the specific richness, spatial distribution and abundance of freshwater species. We also seek to provide details on the status of freshwater fish exploited in three reservoirs: Lahjar, Kasseb and Seliana located in different areas in Tunisia.

Material and methods

Study areas

The study was conducted in three Tunisian reservoirs: Lahjar, Kasseb and Seliana (Figure 1) *Lahjar reservoir: (36°504'18''N, 11°01'14''E): It is located in the northeast of Tunisia[6] near the city of Kelibia with a maximum depth ranging from 13 to 14m and surface area of 254 ha. Lahjar reservoir is used exclusively for irrigation of a large surrounding area.[7] *Kasseb reservoir: (36°45'32"N, 9°0'20"E): It was built in 1968 and it belongs to the north hydrological watershed of Madjerda, situated at some kilometers (20Km) of Beja city. The reservoir has a surface area of 430ha and contains 70Mm^3 of water. It is used mainly for drinking water supply of Tunis city with 40Mm^3/

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year.[7] *Seliana reservoir: (36°09'26''N, 9°20'55''E): It was built in 1978 and it has a surface area of 600ha. It is situated near the North of Seliana city and it belongs to the south hydrological watershed of Medjerda. Seliana reservoir is used for irrigation at the perimeter of Gaafour/Laaroussia city with 23Mm³/year.[7]

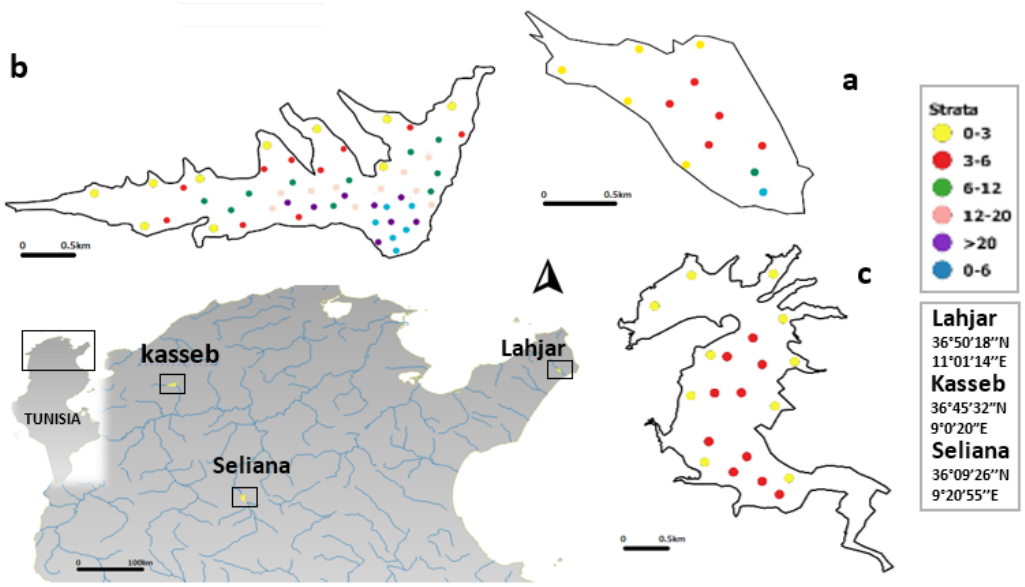

Figure 1 Map of Tunisia indicates the location of the three studied reservoirs ((a) Lahjar Reservoir, (b) Kasseb Reservoir, (b) Seliana Reservoir) with different position of Benthic and Pelagic nets

Data collection and analyses

Fishing operation

Fish sampling operations were carried out with multi-mesh monofilament gillnets inspired from the European standard CEN pr EN 14757.[8] These nets, adapted to Tunisian reservoirs, were used in Tunisia since 2013. There are formed by 8 different meshes (18, 24, 28, 35, 40, 55, 70 and 80 mm, knot-to-knot). Each net has 20 m length and 1.5 m (benthic nets) and 6 m (pelagic nets) depth. A stratified random sampling was used to take into account the irregular spatial distribution of fish in reservoirs. Pelagic nets were put by pairs in the deepest part at depths multiple of 6 (0-6 m and 6-12 m, etc.).[3,9–11] A total of 11, 48 and 20 benthic nets were implemented, respectively, for Lahjar, Kasseb and Seliana reservoirs. Additionally, one and 6 pelagic nets were implemented, respectively, in Lahjar and kasseb reservoir; for Seliana reservoir the low depth (<6m) makes the use of pelagic nets useless (Table 1). Nets were set in late afternoon and left for approximately 12 hours, according to the European Standard and they were removed the following morning. For Kasseb and Seliana reservoirs, sampling was conducted during spring (March 2016) and for Lahjar in April 2017. Captured fishes were identified, referred to the datasheets of kraiem[12] counted by species, measured to the nearest millimeter total lengths and weighted to the nearest gram wet mass. Catches (expressed as Number Per Unit Effort "NPUE") and biomass (Weight Per Unit Effort "WPUE") were calculated for each reservoir. NPUE and WPUE for gill nets were expressed per 1000 m² net.

Table 1 Number of benthic and pelagic nets used in Lahjar, Kasseb and Seliana reservoirs

Reservoirs	Sampling period	Benthic nets per strata					Total Benthic nets	Total Pelagic nets
		0 – 2.9 (m)	3 – 5.9 (m)	6 – 11.9 (m)	12 – 19.9 (m)	19 – 34.9 (m)		
Lahjar	Apr-17	5	5	1	0	0	11	1
Kasseb	Mar-16	10	10	10	10	8	48	6
Seliana	Mar-16	10	10	0	0	0	20	0

Abundance indices

The diversity, of the freshwater fish population in the studied reservoirs, was expressed by specific richness determined by the index of Margalef (d)[13] and calculated according to the formula:

$$d = s - 1 / \ln(N)$$

The Shannon and Weaver diversity index (H')[43] and the index population distribution of Pielou (J') were calculated according to the formulas of Barbault[1]:

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$$H' = -\sum pi \log 2 pi$$

$$J' = \frac{H'}{H' \max} = \frac{H'}{\log_2 S}$$

Results

Specific composition

The implementation of the standardized sampling protocol allowed us to evaluate the species richness. The latter is variable at the level of the studied reservoirs. The most important species richness was recorded in Lahjar and Seliana dams with the presence of 4 different species for each, i.e. 40% of the global richness; followed by the Kasseb reservoir where, only, two species were reported representing 20% of the global specific richness (Figure 2). A total of 5 species were captured in this investigated dams; Mullet (*Liza ramada*), Rudd (*Scardinuserythrophtalmus*), Roach (*Rutilusrubilio*), Pike-perch and Barbel (*Barbuscallensis*) (Table 2). In this study, the Margale index (d) varied from 3.84 at Lahjar to 3.82 at Seliana and to 1.69 at Kasseb reservoir. The Shannon index shows values varying between 1.35 in Seliana, 0.29 in Lahjar and 0.24 in Kasseb dam. The application of the Shannon index to the collected data showed that the fish populations in the different studied reservoirs are not very diversified: H' is often lower than 1.5.

Numerical and weighted yields

The highest yields were recorded in Lahjar dam with 637.5 ind/1000m^2 and 73008 g/1000m^2, representing a population of 612 in d and a biomass of 70088g, followed by Seliana dam which showed an average yields: 45191g/1000m^2 and 240 in d/1000m^2. The lowest numerical and weight yields were recorded at Kasseb dam with 25.49 in d/1000m^2 and 6750 g/1000m^2 (Table 3).

Table 2 Captured species in the investigated reservoirs

Reservoirs	Roach	Pike-perch	Mullet	Rudd	Barbel
	Rutilusrubilio	*Sander lucioperca*	*Liza ramada*	*Scardinuserythrophtalmus*	*Barbuscallensis*
Lahjar	×	×	×	×	
Kasseb			×		×
Seliana		×	×	×	×

Table 3 Numerical and weighted abundances of ichthyic species in Lahjar, Kasseb and Seliana reservoirs

Reservoirs	Species	Captures				Yields	
		Numerical (ind)	Numerical (%)	Biomass (g)	Biomass (%)	Numerical (ind/1000m^2)	Weighted (g/1000m^2)
Lahjar	Roach	588	96.08	57735	82.38	612. 50	60140.62
	Mullet	16	2.61	9084	12.96	16.67	9462.5
	Rudd	3	0.49	349	0.5	3.13	363.54
	Pike-perch	5	0.82	2920	4.17	5.21	3041.66
	Total	612	100	70088	100	637.5	73008.3
Kasseb	Barbel	25	96.15	6660	96.73	24.51	6529.41
	Mullet	1	3.85	225	3.27	0.98	220.59
	Total	26	100	6885	100	25.49	6750
Seliana	Mullet	85	59.03	20165	74.37	141.67	33608.33
	Barbel	2	1.39	100	0.37	3.33	166.67
	Rudd	45	31.25	4775	17.61	75	7958.33
	Pike-perch	12	8.33	2075	7.65	20	3458.33
	Total	144	100	27115	100	240	45191.67

In Lahjar Dam, 612 individuals belonging to 4 different species, were captured in 11 benthic nets (total area 720m^2) and one in the pelagic net (area 240m^2). The species captured are dominated by the Roachwith 505 specimens sampled in the benthic nets, against 83 for the pelagic net. This species shows a numerical percentage of 96.08% followed by Mullets with 2.61% (16 individuals). The numerical yields are respectively 612.5 in d/1000m^2 for Roach and 16.67 in d/1000m^2 for Mullet. Pike-perch and Rudd show very low numbers of individuals respectively (5 and 3 individuals) with respective percentages of 0.82% and 0.49%. Their numerical yields are as follows: 6.94ind/1000m^2 for Pike-perch and 4.17ind/1000m^2 for Rudd (Table 3). Regarding the weighted yields, the lowest values are observed

for Rudd (0.48kg/1000m^2) and Pike-perch (4.06 kg/1000m^2). Mullet and Roach have higher yields: they are respectively around 12.62 kg/1000m^2 and 69.04 kg/1000m^2 In Kasseb reservoir the catch yields vary between 0.98ind/1000m^2 for Mullet and 24.51 in d/1000m^2 for Barbel. The weight yields recorded for Mullet and Barbel are about 220.59 g/1000m^2 and 6529.41g/1000m^2 for a biomass of 6660g and 225g, respectively (Table 3). In Seliana reservoir, a total of 144 specimens were captured which is corresponding to a numerical yield of 240 in d/1000m^2 and a weight yield of 45191.67kg/1000m^2. The weight and number catches were dominated by Mullet followed by a forage fish (Rudd). The yields recorded are 33608.33g/1000m^2, 141.67 in d/1000m^2 for Mullet and 7958.33g/1000m^2; 75 in d/1000m^2 for Rudd. Barbel and Pike-perch showed low numbers, respectively 2 and 12 individuals. Their numerical yields oscillate respectively, between 3.33 in d/1000m^2 and 20 in d/1000m^2 and their weight yields were 166.67g/1000m^2 for Barbel against 3458.33g/1000m^2 for Pike-perch(Table 3).

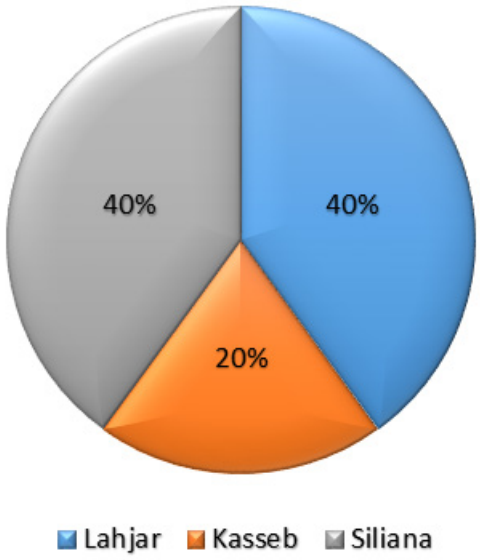

Figure 2 Variation in specific richness in Lahjar, Kasseb and Seliana reservoirs.

Spatial distribution of catches

The majority of the catches, collected in Lahjar reservoir, were obtained at the level of the 0-3m strata. These catches represent 69.4% of the total number of fish caught, followed by the stratum 3-6m (30.6%). In this reservoir, Roach dominate in all depth strata. Pike-perch and Rudd are found only in the 3-6m stratum. Mullet occupy the 0-3m stratum. Pelagic nets caught only Roach in the 6-12 m stratum (Figure 3). In Kasseb reservoir, Barbel was captured by benthic nets, as well as by pelagic nets and in all strata, mainly that of 0-3m. The only Mullet specimen was caught in the 0-3m stratum (Figure 4). The species populating Seliana reservoir colonize the two sampled strata (0-3m and 3-6m) with a quantitative predominance in the superficial stratum (0-3m). Rudd and Mullet are present in the whole reservoir, while the Pike-perch and the specimens of the Barbel are present only in the 0-3m stratum (Figure 5).

Population structure Roach

The size of fish caught only in Lahjar reservoir ranged between 15 and 27cm for Roach. Besides the size frequencies histogram shows the presence of two age classes (Figure 6).

Mullet

The size classes of the captured specimens of Mullet in Lahjar reservoir is ranged from 35 to 42cm, the length frequency distribution show the presence of two age classes. For Seliana reservoir, the size structures of the catches of Mullet are mainly composed by three age classes. The average size is about 28.98±1.84cm with an average weight of 237.24±33.54g. The Kasseb reservoir shows a deficit of Mullet (Figure 7).

Rudd

The three specimens of Rudd captured in Lahjar reservoir show an average size of 21.33cm with an average weight of 116,33g; but for the Kasseb reservoir, the average length of the catches is about 20.6±2.2cm for an average weight equal to 106.1±21g. The majority of the catches in Lahjar and Kasseb reservoirs belong to adult sizes. The fry and juvenile stages are not included in our catches because the minimum mesh length used for fishing is 18mm (Figure 8).

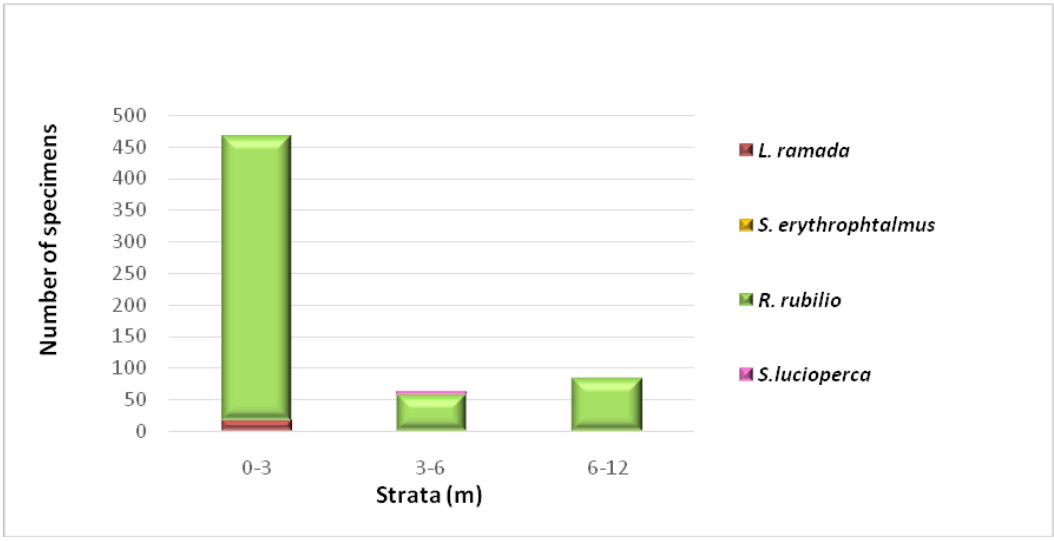

Figure 3 Spatial distribution of the freshwater fishes caught in Lahjar reservoir.

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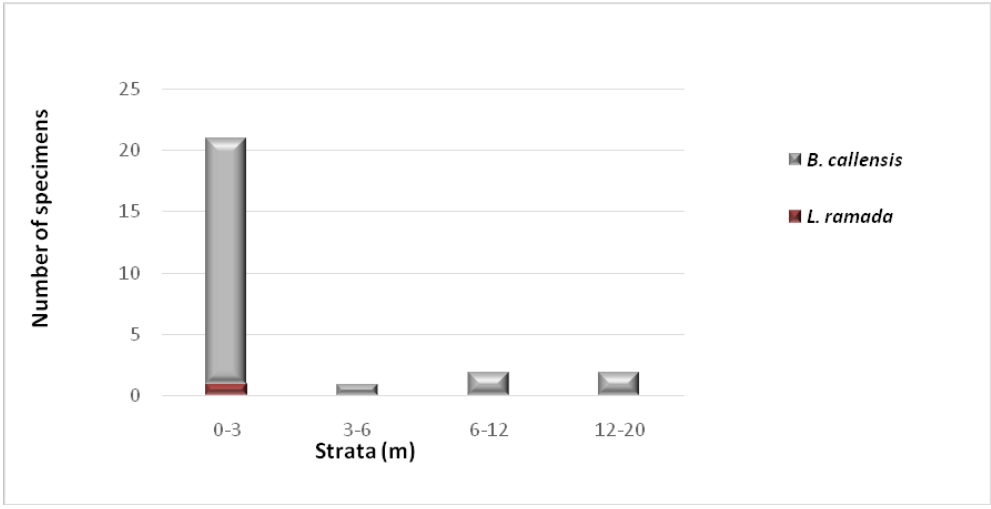

Figure 4 Spatial distribution of the freshwater fishes caught in Kasseb reservoir.

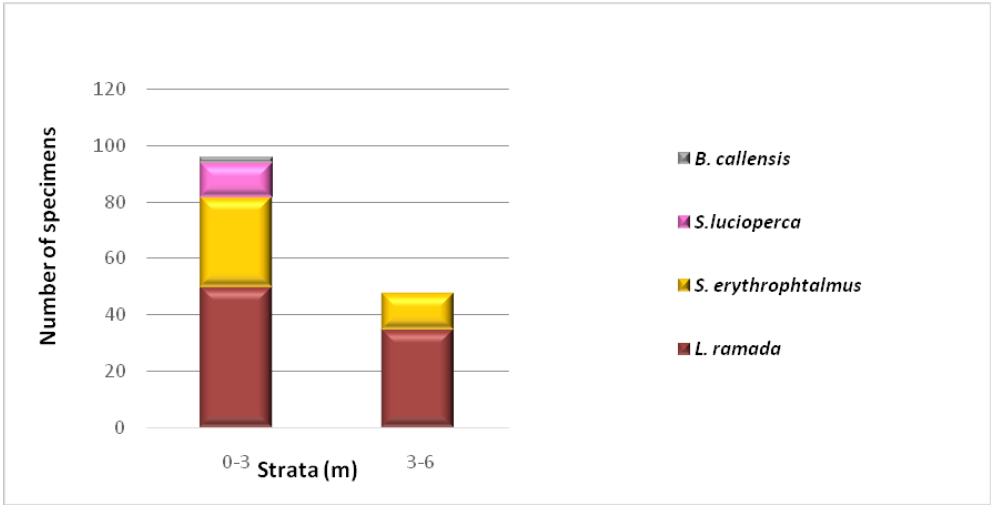

Figure 5 Spatial distribution of the freshwater fishes caught in Seliana reservoir.

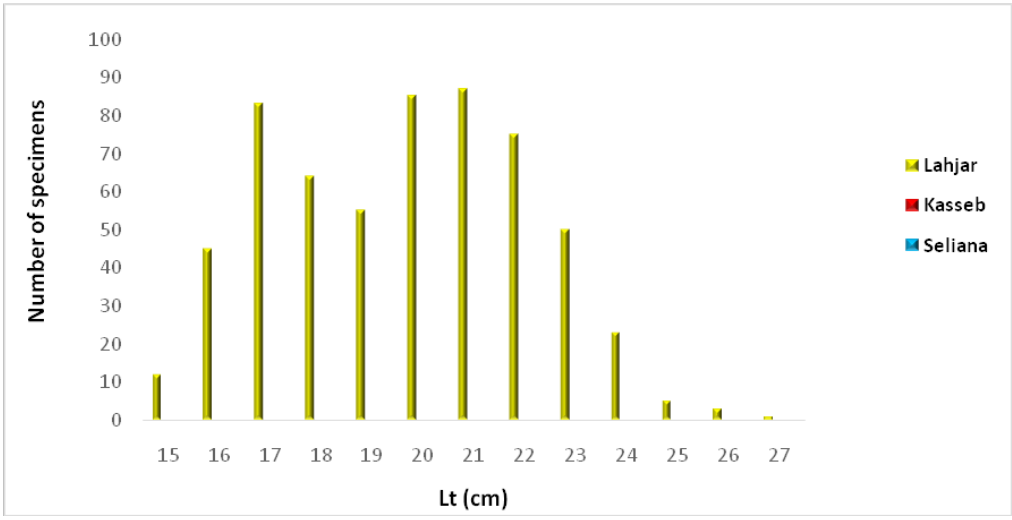

Figure 6 Length frequency distribution of Roach in the three reservoirs studied.

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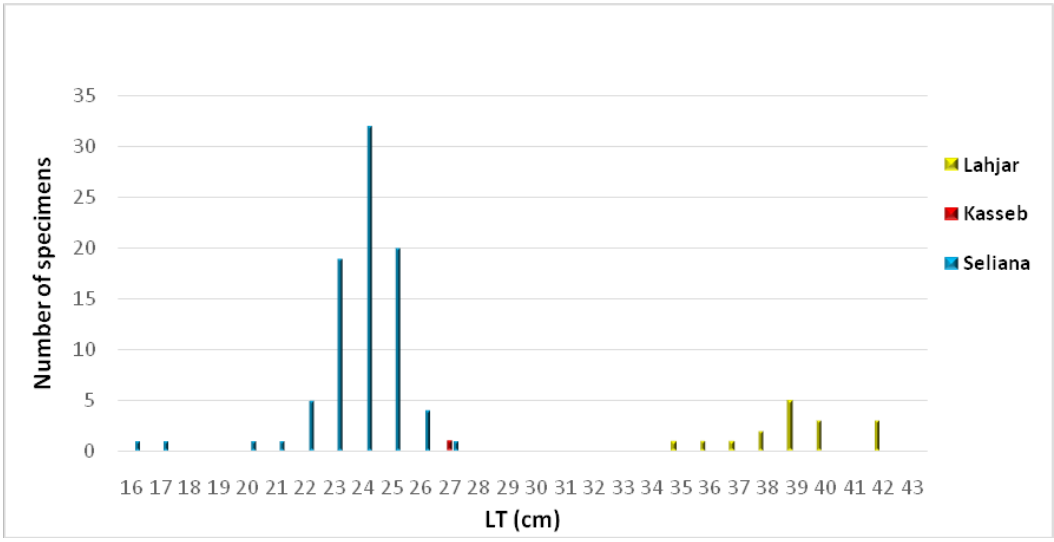

Figure 7 Length frequency distribution of Mullet in the three reservoirs studied.

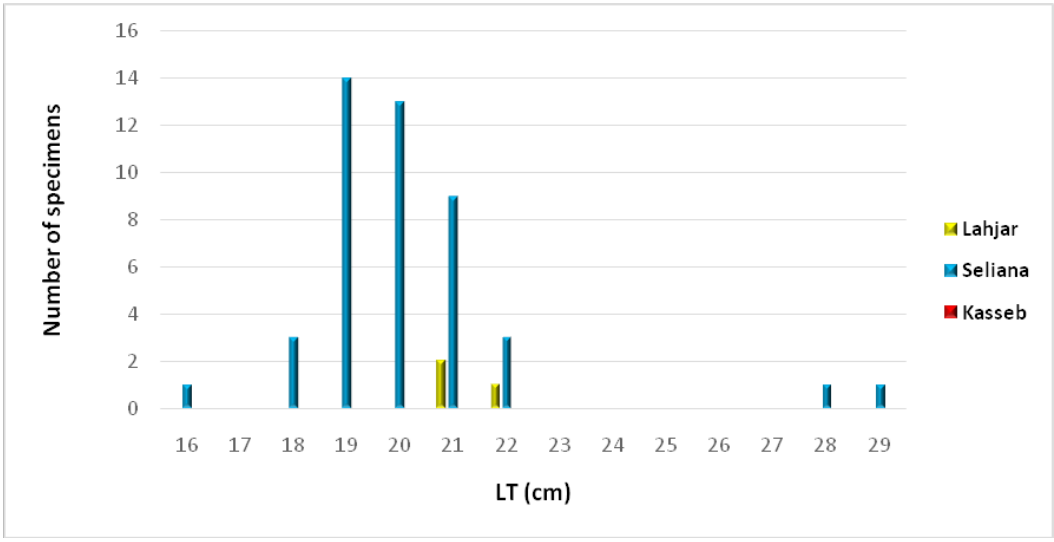

Figure 8 Length frequency distribution of Rudd in the three reservoirs studied.

Pike-perch

The size classes of the catches of pike-perch in Lahjar reservoir is ranged between 39.7 and 43.8cm. In Kasseb reservoir, the size classes of this latter are ranged from 18 to 22cm with an average length of 23.5±9.67cm and a weight of 172.92±364g. Two age classes were caught in the two reservoirs (Figure 9).

Barbel

Barbel is an endemic species, which is quite widespread in Kasseb reservoir. This species presents class sizes varying between 26 and 33.5cm. We identify two age classes at the level of the captured individuals (Figure 10).

Discussion

In this study, species richness and fishing yields are low, as is the case for most of the reservoirs in Tunisia due to the recent introduction of species and the annual seeding of Mullet fry. In addition, the spatial distribution and survival of fish seems to be strongly influenced by oxygen content and temperature. A similar study was carried out by Holubová[14] at the Rímovdam (Czech Republic) and showed a positive correlation between temperature and the density of freshwater fish present in the epipelagic stratum. These authors noted that the increase in temperature in late spring increases the rate of encounters with predators, which leads to the probability of group constitution. Other research, such as Society[15] and Weetman,[16] confirm that high temperature stimulates fish activity. Similarly, the small changes in temperature can lead to changes in distribution.[17] Furthermore, in Lake Balaton in Hungary, György[18] showed that the variability of catch per unit effort is mainly related to the degree of water transparency which can influence the efficiency of the nets. On the other hand, Macy[19] and Figuerd.[20] noted that fish activity increases with light intensity, are very elevated in high light but low in darkness as well as with water transparency, the fish is more likely to be entangled in the net in turbid water than in clear water. Previous studies showed that prey

species escape periods of high light and seek protection in deep layers or shaded objects.[21–23] In contrary, Kerry and Bellwood[24] showed that this behavior is related to light avoidance phenomenon more than predators. According to the literature, the percentage of piscivorous fish is considered as an indicator of water quality.[25] Therefore, the potential piscivorous biomass, including all size classes, shows a total imbalance in all sampled reservoirs. In our study the fish communities are composed mainly by cyprinids, (588 Roach) in Lahjar reservoir with a percentage of 75% of the total catches within the 3 dams, as is the case for most lakes in France[6]. In Tunisia, Sidi Salem reservoir proves this statement; this water reservoir is characterized by a high abundance of Roach and Rudd. These two species, with a phytophilic character, seem to have a good reproductive success in Tunisian reservoirs.[10]

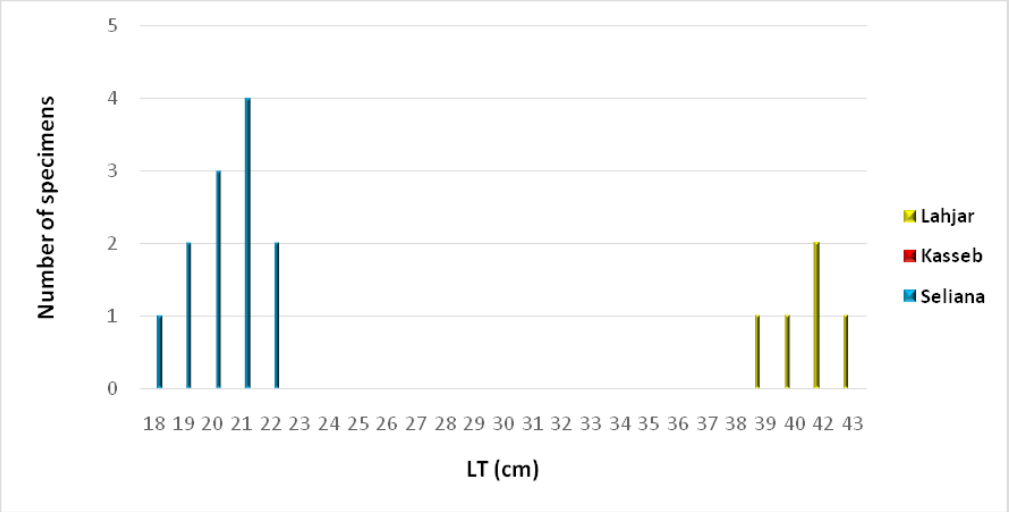

Figure 9 Length frequency distribution of Pik-perch in the three reservoirs studied.

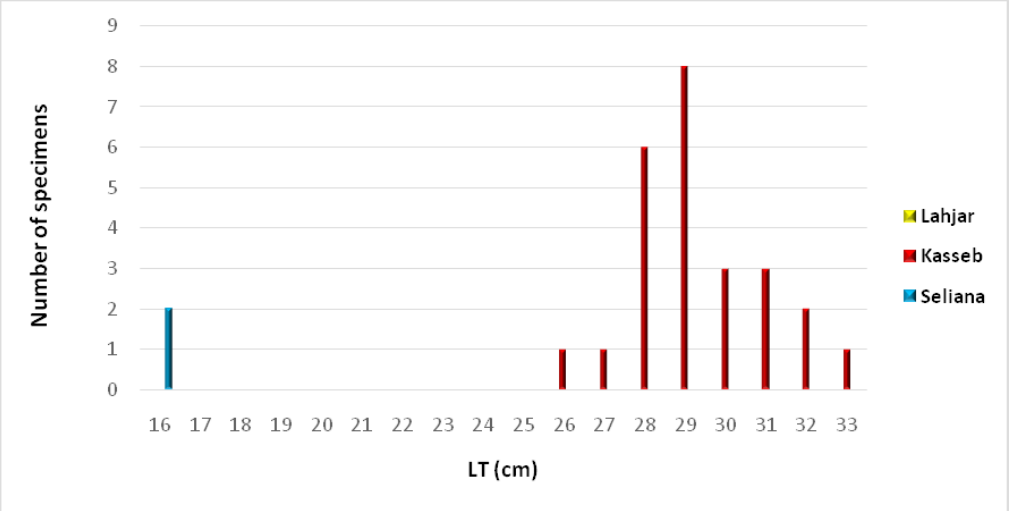

Figure 10 Length frequency distribution of Barbel in the three reservoirs studied.

Recent studies revealed that fish populations are influenced mainly by the depth of the dam as well as the amount of chlorophyll "a" it contains.[26,27] The majority of cyprinids (Freshwater bream, Roach and bleak) colonize the epipelagic part of the reservoir which represents a rich feeding habitat especially for the forage species.[28] This result is in agreement with our results: the majority of Roach as well as Rudd captured, respectively, at Lahjar and Seliana reservoirs were recorded at the upper strata 0-3m and 3-6m. The same result was mentioned by Mili[10] following a study in Ghezela dam. Barbel occupies mainly the stratum 0-3m in Kasseb, but it is also foundin deeper strata (6-12m and 12-20m). These results are comparable to those of Vašek[29] who found that the majority of fishes are located in the superficial layers. The work of Djemali[30] and Mili[10] indicate that going from the dike to upstream, the distribution of fish biomass is influenced by water depth. These authors state that the highest concentrations were recorded at the surface layers of the deepest areas of the reservoir. Hydro acoustic studies conducted in Tunisian dams showed that fish densities vary considerably between the surface and the bottom due to the mobility of ichthyic resources and the lack of predictable behavior in these animals.[30,31] The study of Vašek[31] which focused on the analysis of fish yields and distribution in European reservoirs, showed that pike-perch harbor the lower epilimnion and upper metalimnion with nyctimeral migrations from the pelagic layer to the coastal areas.

Inter-organism interactions are major factors affecting the composition and location of fishes at the trophic level, particularly predator-prey interactions, that can alter the spatial distribution of fishes.[26,33–35] This is concordance with the results found by Mili[36] stating that the decline of Barbel stocks in Tunisian reservoirs is due to the introduction of carnivorous predatory species. The present study shows that the presence of Pike-perchis linked to that of Roach for Lahjar and Rudd for Seliana reservoirs. The low numbers sampled during the month of March within these two reservoirs, is probably related to the behavior of this species during the breeding season. This lack of Pike-perchand Mulletin Lahjar and Kasseb reservoirs can be explained by the fact that these species are strongly targeted by fishermen in these dams. The study conducted by Mili[10] in Sidi Salem reservoir (Tunisia) showed that the Mullets seem to be overexploited in this dam. Furthermore, referring to the study of Winfield,[37] the analysis of size structures of fish caught by multi-mesh nets showed that these gears catch more medium-sized individuals compared to other sampling methods. In similar studies, larger individuals were caught near the dam, but smaller individuals and juveniles were concentrated near the shore. These areas have better trophic conditions but may shelter carnivores come to lay eggs.[38,29] Additionally, Carol[35] found that freshwater ecosystem productivity and nutrient concentrations increase from the dam to the river.

In this study, all Pike-perch captured were adults since sexual maturity of this species is reached at the age of one year for a size of 24 cm and a weight of 90g.[39] Roach caught in Lahjar have sizes varying between 15 and 27cm and belonging to adult specimens. Indeed, the sexual maturity of this species is reached at the age of one year, which corresponds to a size between 11.92cm for males and 12.04cm for females.[29] The majority of specimens of Rudd caught are adult given that the size at first sexual maturity for males is about 11.99cm and around 12.48cm for females.[40] Barbel size frequencies in Kasseb reservoir, illustrates the presence of adult individuals. Sexual maturity of this species is reached for males at 19.6cm and for females at 27.7cm.[41] Deceliere-Vergès and Guillard[42] indicate that the abundance of species in the pelagic stratum would be better assessed by hydro acoustic surveys than nets because sampling biases can be due to the passive nature of the multi-mesh nets and the escapement of small individuals.

Conclusion

Reservoirs are essential for the sustainable management of aquatic resources and for fisheries production in areas far from the coast in Tunisia.[43] In our study, the application of a sampling by multi-mesh nets inspired by the European standard CEN14575 and adapted to Tunisian dams has allowed the capture of 5 species of fish with important values of numerical and weight yield at Lahjar reservoir against average values recorded in Seliana demand very low ones at Kasseb. Therefore, a rapid intervention is necessary for the preservation of the specific richness of the ichthyofauna by a reinforcement of the Pike-perch and Mullet population through seeding the dams with fry.

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Conflicts of interest

The author declares no conflict of interest.

References

1. Mili S, Ennouri R, Laouar H, et al. Fisheries in the Tunisians dams: diagnosis of the current situation and development opportunities. *FAO Fish and Aqua Proceedings*. 2015;39:95–106.
2. DGPA Direction Generale de la peche et de l'aquaculture. Annulaire des Statistiques des peches et aquaculture en Tunisie, Ministere de l'agriculture. 2013.
3. Mili S, Ennouri R, Ghanem R, et al. Additional and unusual records of blue crabs *Portunussegnis* and *Callinectessapidus* from the northeastern Tunisian waters (Central Mediterranean sea). *Journal of New Sciences*. 2020;14(2):303–311.
4. Mtimet N. Socioeconomic analysis of the continental fish farming sector in the North–West of Tunisia. Project Safeguarding and socio–economic development of environmental resources in the north–western region of Tunisia. *COSPE / GIPP*. 2010:150.
5. DGPA Direction Generale de la peche et de l'aquaculture. Annulaire des Statistiques des pêches et aquaculture en Tunisie, Ministère de l'agriculture. 2019.
6. Barbault C. Ecology of populations and stands. Ed Masson. Paris. 1981;200.
7. Soudoud. Specific database of large dams in Tunisia. General Directorate of Dams and Major Hydraulic Works. *Ministry of Agriculture and Water Resources*. Tunisia. 2006.
8. CEN. Water quality–sampling of fish with multi–mesh gillnets EN 14757. 2005.
9. Mili S, Ennouri R, Dhib A, et al. Characterization of fish assemblages and population structure of freshwater fish in two Tunisian Reservoirs. Implications for fishery management. *Environmental Monitoring and Assessment*. 2016a;188(6):364.
10. Mili S, Ennouri R, Laouar H, et al. Etude des peuplements piscicoles de la retenue du barrage de Sidi Salem. *Journal of new sciences, Agriculture and Biotechnology*. 2016b;27(1):1454–1465.
11. Mili S, Ennouri R, Laouar H, et al. Etude des peuplements piscicoles de la retenue de barrage de Sidi Barrak. *Bull Inst Natn Scien Tech Mer de Salambo*. 2016c;43:55–69.
12. Kraiem MM. Freshwater fish from Tunisia. Commented inventory and geographical distribution. *Bulletin of the National Institute of Science and Technology of the Sea*. 1983; 10: 107–124.
13. Margalef R. Perspective in Ecological Theory. Chicago: University of Chicago Press, 1968;3:313–315.
14. Holubová M, Blabolil P, Čech M, et al. Species–specific schooling behaviour of fish in the freshwater pelagic habitat: an observational study. *Journal of Fish Biology*. 2020;97(1):64–74.
15. Society BE, EcologyA, Persson L. Temperature–induced shift in foraging ability in two fish species, Roach (*Rutilusrutilus*) and Perch (*Percafluviatilis*): Implications for coexistence between poikilotherms. *Journal of Animal Ecology*. 1986;55:829–839.
16. Weetman D, Atkinson D, Chubb JC. Effects of temperature on anti–predator behaviour in the guppy, Poeciliareticulata. Animal Behaviour. 1998;55:1361–1372.

17. Biro PA, Beckmann C, Stamps JA. Small within–day increases in temperature affects boldness and alters personality in coral reef fish. *Proceedings of the Royal Society B Biological Sciences.*2010;277:71–77.

18. György ÁI, Tátrai I, Specziár A. Relationship between horizontal hydro acoustic stock estimates and gillnet catches of surface oriented fish in shallow Lake Balaton (Hungary). *Knowledge and Management of Aquatic Ecosystems*. 2012;06:1–17.

19. Macy WK, Sutherland SJ, Durbin EG. Effects of zooplankton size and concentration and light intensity on the feeding behavior of atlantic mackerel Scomberscombrus. *Marine Ecology Progress Series*. 1998;172:89–100.

20. Figueiredo BRS, Mormul RP, Chapman BB, et al. Turbidity amplifies the non–lethal effects of predation and affects the foraging success of characid fish shoals. *Freshwater Biology*. 2016;61:293–300.

21. Jones FRH. The behaviour of minnows in relation to light intensity. *Journal of Experimental Biology*. 1956;33:271–281.

22. Järvalt A, Krause T, Palm A. Diel migration and spatial distribution of fish in a small stratified lake. *Hydro biologia*. 2005;547:197–203.

23. Sajdlová Z, Frouzová J, Draštík V, et al. Are diel vertical migrations of European Perch (*PercafluviatilisL.*) Early Juveniles under direct control of light intensity? Evidence from a large field experiment. *Freshwater Biology*. 2018;63(5):473–482.

24. Kerry JT, Bellwood DR. The functional role of tabular structures for large reef fishes: Avoiding predators or solar irradiance? *CoralReefs*. 2015;34:693–702.

25. Søndergaard M, Jensen JP, Jeppesen E. Seasonal response of nutrients to reduced phosphorus loading in 12 Danish lakes. *Freshwater Biology*. 2005;50:1605–1615.

26. Mehner T, Holmgren K, Lauridsen TL, et al. Lake depth and geographical positionmodify lake fish assemblages of the European 'central plains' ecoregion. *Freshwater Biology*. 2005;52:2285–2297.

27. Ríha M, Ricard D, Vašek M, et al. Patterns in diel habitat use of fish covering the littoral and pelagic zones in a reservoir. *Hydrobiologia.* 2015;747:111–131.

28. Vašek M, Kubecka J. In situ diel patterns of zooplankton consumption by subadult/adult roach *Rutilusrutilus*, bream *Abramisbrama*, and bleak *Alburnusalburnus*. *Folia Zoologica*. 2004;53:203–214.

29. Vašek M, Kubečka J, Čech M, et al. Diel variation in gillnet catches and vertical distribution of pelagic fishes in a stratified European reservoir. *Fisheries Research*. 2009;96:64–69.

30. Djemali I, Laouar H, Toujani R. Distribution patterns of fish biomass by acoustic survey in three Tunisian manmade lakes. *Journal of Applied Ichthyology*. 2010;26:390–396.

31. Djemali I, Toujani R, Guillard J. Hydro acoustic fish biomass assessment in man–made lakes in Tunisia: horizontal beaming importance and diel effect. *Aquatic Ecology*. 2009;43:1121–1131.

32. Vašek M, Kubečka J, Matěna J, et al. Distribution and diet of 0+ fish within a canyon–shaped European reservoir in latesummer. *International Review of Hydrobiology*. 2006;91:178–194.

33. Magurran AE. The adaptive significance of schooling as an anti predator defense in fish. *Annales Zoologici Fennici*. 1990;27:51–66.

34. Morgan MJ, Godin JGJ. Antipredator benefits of schooling behaviour in a cyprinodontid fish, the banded killifish (*Fundulusdiaphanus*). *Zeitschrift fürTierpsychologie*. 1985;70:236–246.

35. Carol J, Benejam L, Alcaraz C, et al. The effects of limno logical features on fish assemblages in fourteen Spanish reservoirs. *Ecology of Freshwater Fish*, 2006;15:66–77.

36. Mili S, Ennouri R, Houcine L. Saving freshwater fishes and habitats: An update on the status of autochthonous freshwater fishes in Tunisian reservoirs. Newsletter of the IUCN SSC/WI Freshwater Fish Specialist Group. 2017a;3:19–22.

37. Winfield IJ, Fletcher JM, Ben James J. et al. Assessment of fish populations in still waters using hydroacoustics and survey gill netting: Experiences with Arctic charr (*Salvelinusalpinus*) in the UK. *Fisheries Research*. 2009;96:30–38.

38. Hladık M, Kubecka J. Fish migration between a temperate reservoir and its main tributary. *Hydro biologia.* 2003;504:251–266.

39. Toujani R, Missaoui H, Romdhane MS. Cycle sexuel des femelles de sandre (*Stizostedionlucioperca*) dans la retenue du barrage de Sidi Salem. *Bulletin institut National Sciences Technologies Mer*. 2000;27:85–96.

40. Mili S, Ennouri R, Laouar H, et al. Optimization of fishing for stock enhancement of *Rutilisrutilus* and *Scardiniuserythropththalmus* in forage fish–deficient Tunisian reservoirs. *Environmental Monitoring and Assessment*. 2017b;189:12.

41. Chaouachi B, Ben Hassine OK. Le barbeau Barbus callensis Valenciennes 1842 (Poisson, Teleosteen) de la lagune de l'ichkeul. *Archs Inst Pasteur Tunis*. 1998;75(3/4):211–218

42. Deceliere–Verges C, Guillard J. Assessment of the pelagic fish populations using CEN multi–mesh gill nets: consequences for the characterization of the fish communities. *Knowledge and Management of Aquatic Ecosystems*. 2008;389:1–16.

43. Shannon C, Weaver E. The Mathematical Theory of Communication. Urbana: University of Illinois Press, 1963.