FISH BIOMASS ESTIMATES IN NON-STRATIFIED TUNISIAN RESERVOIRS: ACOUSTIC AND GILLNET SAMPLING

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ملخص

تقييم الكتلة الحيوية السمكية ببحيرات السدود التونسية بواسطة الذبذبات الصوتيّة والشباك العينية : تم خلال فصل الربيع إجراء مسح بالذبذبات الصوتيّة (SIMRAD EK 60 split beam echosounder, 120 kHz) مع أخذ عينات بالشباك العينية في ثلاثة خزانات سدود ضحلة. حيث أظهرت مصائد الشِباك العينية تواجدا عاليًا لسمك البوري بسدّ سيدي سعد وسمك القاردون في سدّي ملاق وبوهرتمة. وتراوحت أعداد الأسماك بين 45 و431 سمكة لكلّ 1000 متر مربع من الشباك في حين تراوحت كتلة الأسماك بين 3.1 إلى 29.9 كغ / 1000 متر مربع. وتشير النتائج التي تم الحصول عليها في هذه الدراسة إلى أنّ إجمالي الكتلة الحيوية السمكية بسدّ سيدي سعد (458 كغ/ هكتار) كانت أعلى بثلاث مرات منها بسدي بوهرتمة وملاق. وتوزعت الأسماك الكبيرة بشكل رئيسي في طبقة المياه العليا في جميع الخزانات وخاصة بالقرب من السد بعمق أقل من 3 أمتار في سدّ بوهرتمة. كما إرتبطت الكتلة الحيوية للأسماك وكثافتها بالعمق في سدّ سيدي سعد حيث انخفضت من أعلى السد إلى أسفله. ختاما أظهرت الدراسة علاقة خطية بين الكتلة الحيوية / الكثافة السمكية المتحصل عليها بالمسح الصوتي وعدد / كتلة الأسماك المتحصل عليها بالشباك العينية.

الكلمات المفاتيح: مسح بالذبذبات الصوتيّة ، الشِباك العينية، الأسماك ، الارتباطات ، السدود

RESUME

Estimations de la biomasse piscicole dans des retenues des barrages tunisiennes non stratifiées: échantillonnage acoustique et aux filets maillants : Des campagnes d'échantillonnages acoustiques (échosondeur à faisceau partagé SIMRAD EK 60, 120 kHz) et aux filets maillants multimailles ont été menées durant la saison printanière dans trois retenues d'eau peu profonde. Les captures des filets maillants ont montré la forte présence de mulet dans la retenue de Sidi Saad et du gardon dans les retenues de Mellegue et Bouhertma. Le NPUE a varié entre 45 et 431 poissons/1000 m² de panneaux de filets et la BPUE de 3,1 à 29,9 kg/1000 m². Les résultats obtenus au cours de cette étude ont montré que la biomasse totale des poissons à Sidi Saad (458 kg ha-1) était trois fois plus élevée que les biomasses dans les retenues de Bouhertma et Mellegue. De gros poissons ont été détectés dans la couche supérieure de toutes les retenues et plus particulièrement dans le barrage de Bouhertma près de la digue pour une profondeur d'eau inférieure à 3 m. Dans le réservoir de Sidi Saad, la biomasse et la densité des poissons étaient corrélées à la profondeur avec un gradient négatif d'aval en amont. Une corrélation linéaire significative a été mise en évidence entre la biomasse acoustique et la BPUE ainsi qu'entre la densité acoustique et la NPUE.

Mots clés : Hydroacoustique, filets maillants, poisson, corrélations, retenues des barrages

SUMMARY

Hydroacoustic monitoring (SIMRAD EK 60 split beam echosounder, 120 kHz) with gillnet sampling were performed in three shallow water Reservoirs in spring. Gillnets catches showed high presence of mullet in Sidi Saad Reservoir and roach in Mellegue and Bouhertma Reservoirs. NPUE varied between 45 and 431 fish/1000 m² of gillnet panel and BPUE from 3.1 to 29.9 Kg/1000 m². The results obtained in this study indicate that total fish biomass in Sidi Saad (458 kg ha^{-1}) was approximately three times higher than the biomass in Bouhertma and Mellegue Reservoirs. Big fish was detected in the upper layer of all Reservoirs and particularly near the dam for a water depth less than 3 m in Bouhertma Reservoir. Fish biomass and density were related to depth in Sidi Saad Reservoir and decrease from dam to the tributary. A significant linear correlation was showed between acoustic fish biomass/BPUE and acoustic density/NPUE.

Keywords: Hydroacoustic, gillnet, fish, correlations, Reservoirs

INTRODUCTION

Tunisian water network covers an estimated total area of 20,000 ha and retains more than 4.2 billion m^3 of water. This network consists mainly of Reservoirs, hill dams and hill lakes mainly located in northern and central Tunisia (General Department of Water resources, Tunisian Ministry of Agriculture, Hydraulic Resources and Fisheries).
Fishing activity in Tunisian Reservoirs began in the 1960s and is subject to active fish management with annual seeding of fish fry (mullet, Chinese carps and pikeperch) (Mili et *al*., 2013). Production in Reservoirs has increased during the last twenty years from 840 to 1200 t. The commonly caught species are *Liza ramada*, *Mugil cephalus*, *Cyprinus carpio* and *Sander lucioperca* (DGPA, 2016).
Determination of fish densities and assemblage provides useful data for the management of the Tunisian Reservoirs. Recently, Hydroacoustic has been recognized by scientists as an accepted fish sampling method having high reliability for providing fish densities estimates and fish behavior in freshwater system including natural lakes, reservoirs and rivers (Knudsen and Sægrov, 2002;Kubečka et *al*., 2009; Tao et *al*., 2015). Fish densities in surface and deep water can be estimated using horizontal and vertical oriented transducers conjointly. Hydroacoustics are also very efficient in terms of cost and effort, but require some knowledge for processing.
However, Echo sounding must be combined with fishing to obtain information on fish assemblage (Lucas and Baras, 2000) and their age structure. Species composition can only be inferred by secondary sampling gears such as gillnets. Sampling fishes with multi-mesh gillnets have been widely used to sample freshwater fish worldwide (Mehner and Schulz, 2002; Jurvelius et *al*., 2011; Dennerline et *al*., 2012).
In this study, gillnet sampling and acoustic surveys were carried out in three shallow and non-stratified Tunisian Reservoirs in order to (1) determinate the higher acoustic fish biomass detectability according to photoperiod and (2) to inter calibrate the two methods of fish sampling.

MATERIEL AND METHODS

Study area

Mellegue Reservoir was built in 1956 near the city of Nebeur (Le Kef) (Fig. 1). It belongs to the south hydrological watershed of Medjerda. It has been built in order to: avoid the flooding of the plain of Jendouba, irrigate the lower valley of the Medjerda and produce electricity (Soudoud, 2006). During acoustic surveys, the reservoir covered an area of 315 ha and a volume of 26.8 Mm^3 (Tab I). Fishery statistics evidenced the presence of pikeperch, mullet, barbell, carp, catfish and eel with an annual yield of 42.5 t (DGPA, 2016).
Bouhertma Reservoir, created in 1976, is located on the north hydrological watershed of Medjerda (Fig. 1) and used for irrigation and drinking water supply (Soudoud, 2006). During this study, the volume of this reservoir was 58.5 Mm^3 and the mean depth was 8.4m (Tab. I). Fishery statistics mentions the presence of pikeperch, mullet, barbell (*Luciobarbus callensis*) and carp (*Cyprinus carpio*) with a yield of 6.5 t (DGPA, 2016).
Sidi Saad Reservoir (Fig. 1) was built in 1982 to protect the city of Kairouan against the violent floods of the Zeroud River and it was used for irrigation (Soudoud, 2006). The reservoir contains 33.4 Mm^3 of water and has a surface area of 589 ha (Tab. I). This Reservoir is classified as oligo-mesotrophic with a tendency to be eutrophic (Sellami et *al*., 2012). Fishery statistics show the presence of pikeperch, mullet, barbell, carp, roach (*Scardinius erythrophthalmus*), catfish (*Silurus glanis*) and tilapia (*Oreochromis niloticus*) with a yield of 237 t (DGPA, 2016).

Data acquisition and analysis

Fishing operations

Fish sampling operations were carried out with multi-mesh monofilament gillnets inspired from the European standard CEN prEN 14757 (CEN, 2005). These nets, adapted to Tunisian reservoirs, 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. Forty benthic nets for each reservoir were implemented into four depth layers (0-3 m, 3-6 m, 6-12 m and 12-20 m). 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). Sampling was conducted during spring (May and June 2016). Nets were set in late afternoon and take off the following morning, for approximately 12 hours, according to the European Standard. Captured fish were identified, counted by species, measured to the nearest millimeter total lengths, and weighted to the nearest gram wet mass.
Water temperature and dissolved oxygen content were determined at surface and bottom in the deepest part of each reservoir using a Wissenschaftlich Technische Werkstatten depth probe (Model oxi 197i; Nova Analytics, Weilheim, Germany).

Hydroacoustics

The experimental protocol adopted for acoustic sampling was a zigzag survey with simultaneous

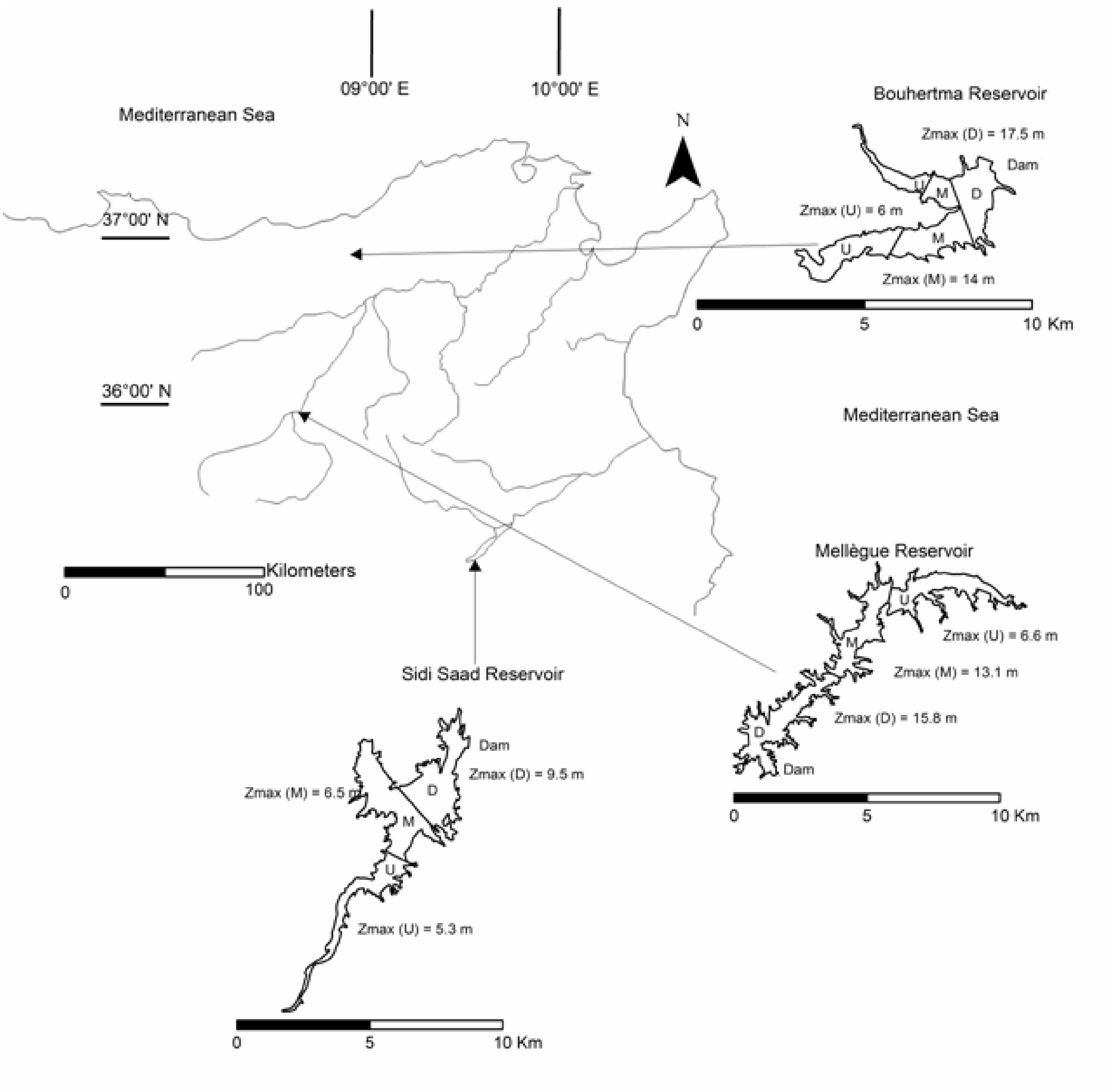

Figure 1: Location of Mellegue, Bouhertma and Sidi Saad Reservoirs showing the three geographic strata (U, upstream; M, middle; D, downstream) and their maximum depths (Zmax).

Table I: Some physical and limnological data of Mellegue, Bouhertma and Sidi Saad Reservoirs during the study

	Mean depth (m)	**Volume (Mm^3)**	**Surface area (ha)**	**Surface/bottom water temperature (°C)**	**Surface/bottom water oxygen concentration ($mg\ L^{-1}$)**
Mellegue	8.5	26,8	315	21.1/20	7.3/6.8
Bouhertma	8.4	58,5	691	19.6/18	8/7.5
Sidi Saad	5.7	33.4	589	25.5/23	7.1/6.9

horizontal and vertical beaming at both day and night into three strata (upstream, center and downstream) with same areas and different depths for each reservoir (Fig. 1). A SIMRAD EK60 split beam echosounder operating with 10 ping s^{-1} and a pulse duration of 0.256 ms was used for detection. This sounder was equipped with a circular transducer (SIMRAD ES-7C) with an opening angle of 7° to -3dB and an elliptical transducer (SIMRAD ES-120), inclined downwards by 2 degree, in horizontal beaming with an angle opening of 4° × 10° at -3dB. Transducers were mounted on a stainless steel support fitted with taps in order to fix them at a depth of 50 cm and connected to the General Purpose Transceiver with a multiplexer. The echosounder was calibrated each year with a copper calibration sphere according to Foote et *al*. (1987).

The Simrad ER 60 (ver.2. 4. 3) and Sonar 5 post-processing software package (Ver. 6.0.4) were used for acoustic acquisition and analyses, respectively. Echo counting method was used for biomass estimation. Target was accepted if it has been detected at least twice with maximum two lost echoes. Vertical distance separating two successive positions of the target must be less than 30 cm.

We applied the TS / Total length relations of Love (1971) in vertical beaming and Frouzová et *al.* (2005) in horizontal beaming. The detection threshold was set at -70 dB. The length/weight relationships ($PT = aLT^b$) were determined from gillnet catches (Tab. II).

Table II: Multispecific parameters of length-weight relationship (a, b) for fish caught in Mellegue, Bouhertma and Sidi Saad Reservoirs

Reservoirs	n	a	b	r^2
Mellegue	823	0.0225	2.6869	0.92
Bouhertma	67	0.0227	2.7387	0.97
Sidi Saad	281	0.0193	2.7337	0.95

The biomass per unit area of the entire water column was the sum of the two (side-looking and down-looking) layers (Kubečka and Wittingerova, 1998).

The average density and biomass obtained for each strata (upstream, center, downstream) corresponds to the weighted average of the transects of each part of the Reservoir according to the following formula (Sokal and Rohlf, 1981):

$$\bar{x}_p = \frac{\sum_{i=1}^{i=n}(B_i * A_{s_i})}{\sum_{i=1}^{i=n} A_{s_i}}$$

Where $\overline{x\ p}$ is weighted average biomass (or density), *n* is the number of ESDUs per zone, B_i is the biomass (or density) along ESDU *i* and As_i is the sampled area of transect *i*.

Statistical analysis

To compare fish size frequency for each Reservoir, by photoperiod and sampling method, Two-sample Kolmogorov-Smirnov (KS) test was used (Sprent, 1992). The differences in acoustic density and biomass between photoperiod, layers and strata were evaluated by multi-way analysis of variance. The comparisons of difference in means of significant effects were made using post hoc Tukey's HSD test. For an approximation to normal distribution and homoscedasticity, the biomass and abundance data were subjected to the Box Cox transformation (Cox, 1972).

To describe the relationship between acoustic biomass and density, with gillnet BPUE and NPUE respectively, we used the major axis regression method (MAR). MAR is usually used for handling the problem of natural variability by minimizing the sums of squares of the perpendicular distance between each point and the regression line. If a linear relationship was observed, we test for common slopes and intercept against the 1:1 fit (slope = 1, intercept = 0) which would indicate a perfect correspondence between the two variables. Data were log10 transformed for an approximation to normal distribution and homoscedasticity.

All statistical analysis was carried out using the R software package version 3.4.3 (R Development Core Team, 2017). Significance levels for all analyses were set at $p < 0.05$.

RESULTS

Fish behavior

Fish occupied the entire water column without any schooling at both day and night whatever the reservoir (Fig. 2). Moreover we do not highlight any thermal stratification in the three reservoirs, and the difference between the temperatures of the surface and the bottom water layers was less than 3°C (Tab. I). Dissolved oxygen was greater than 7 mg/L^{-1} throughout the water column in all reservoirs, without any oxycline (Tab. I).

Gillnetting

Five species from 3 families (Percidae, Mugilidae and Cyprinidae) were caught. Two species (*Liza ramada* and *Luciobarbus callensis*) are endemic to Tunisian water, while three species (*Sander lucioperca*, *Rutilus rubilio* and *Cyprinus carpio*) were introduced (Tab. III).

Scientific fishing at Mellegue Reservoir showed a high number and biomass yields of roach with 408 fish/1000m² of gillnet panel and 12.93 kg/1000m² followed by mullet with 15 fish/1000m² and 2.83 kg/1000m² (Tab. 3). The roach was present at the entire water column except the 6-12 m pelagic layer, and its presence decrease with depth (Fig. 3). The

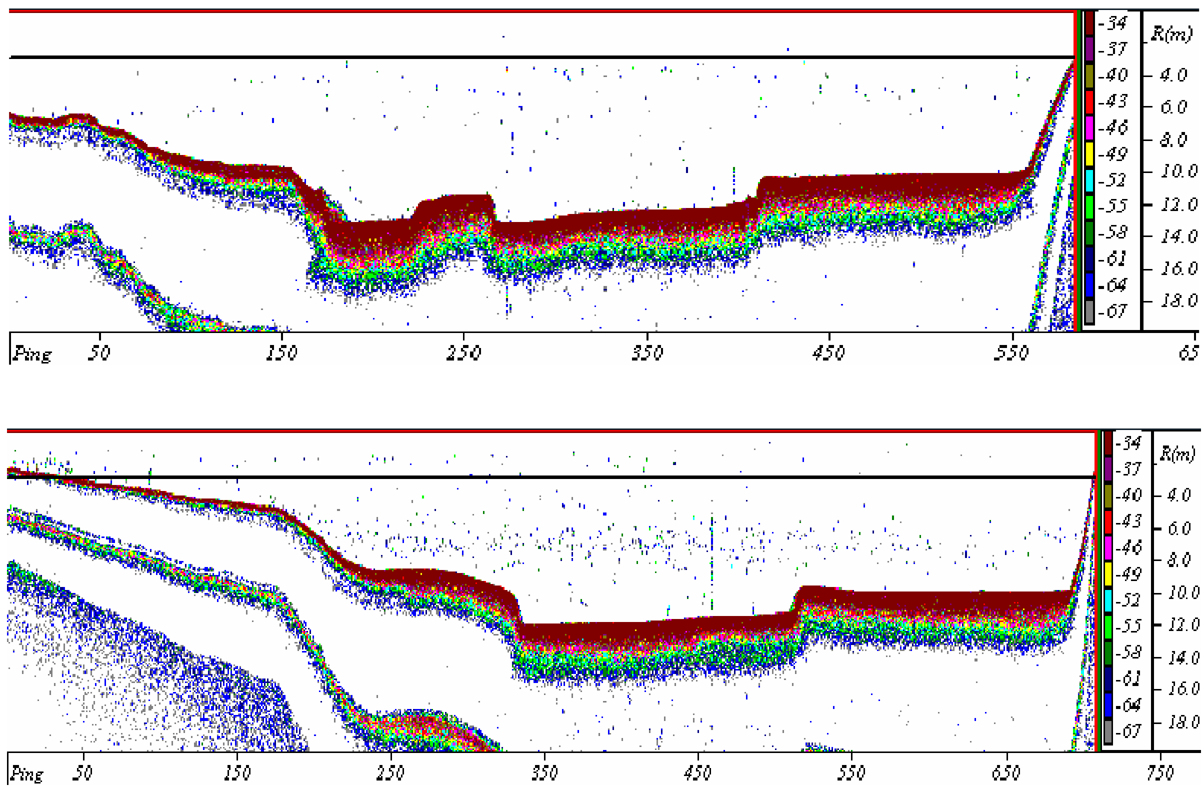

Figure 2: Echograms of one transect example recorded in Bouhertma Reservoir during (a) the day and (b) the following night. Dark brown coloring indicates the Reservoir bottom; scatter points provide visual representations of echoes from individual fish.

Table III: Catch per unit effort values by number (NPUE, fish/1000 m2) and biomass (BPUE, g/1000m2) in gillnet samples of Mellegue, Bouhertma and Sidi Saad Reservoirs.

Gillnet	Species	Mellegue		Bouhertma		Sidi Saad	
		NPUE (fish/1000m^2)	BPUE (g/1000m^2)	NPUE (fish/1000m^2)	BPUE (g/1000m^2)	NPUE (fish/1000m^2)	BPUE (g/1000m^2)
Benthic	*Sander lucioperca*	6	446	2	773		
	Liza ramada	21	4144	3	1001	266	39901
	Rutilus rubilio	623	19769	53	2286		
	Luciobarbus callensis	6	413	2	367	2	197
	Cyprinus carpio	1	493			3	366
	Total	655	25301	60	4426	271	40464
Pelagic	*Sander lucioperca*						
	Liza ramada	6	636			58	8450
	Rutilus rubilio	50	1553	13	340		
	Luciobarbus callensis						
	Cyprinus carpio					2	325
	Total	56	2189	13	340	60	8775
Total	*Sander lucioperca*	4	301	1	525		
	Liza ramada	15	2829	2	681	197	29417
	Rutilus rubilio	408	12938	40	1663		
	Luciobarbus callensis	4	258	1	249	1	131
	Cyprinus carpio	1	308			3	352
	Total	**431**	**16634**	**45**	**3119**	**201**	**29901**

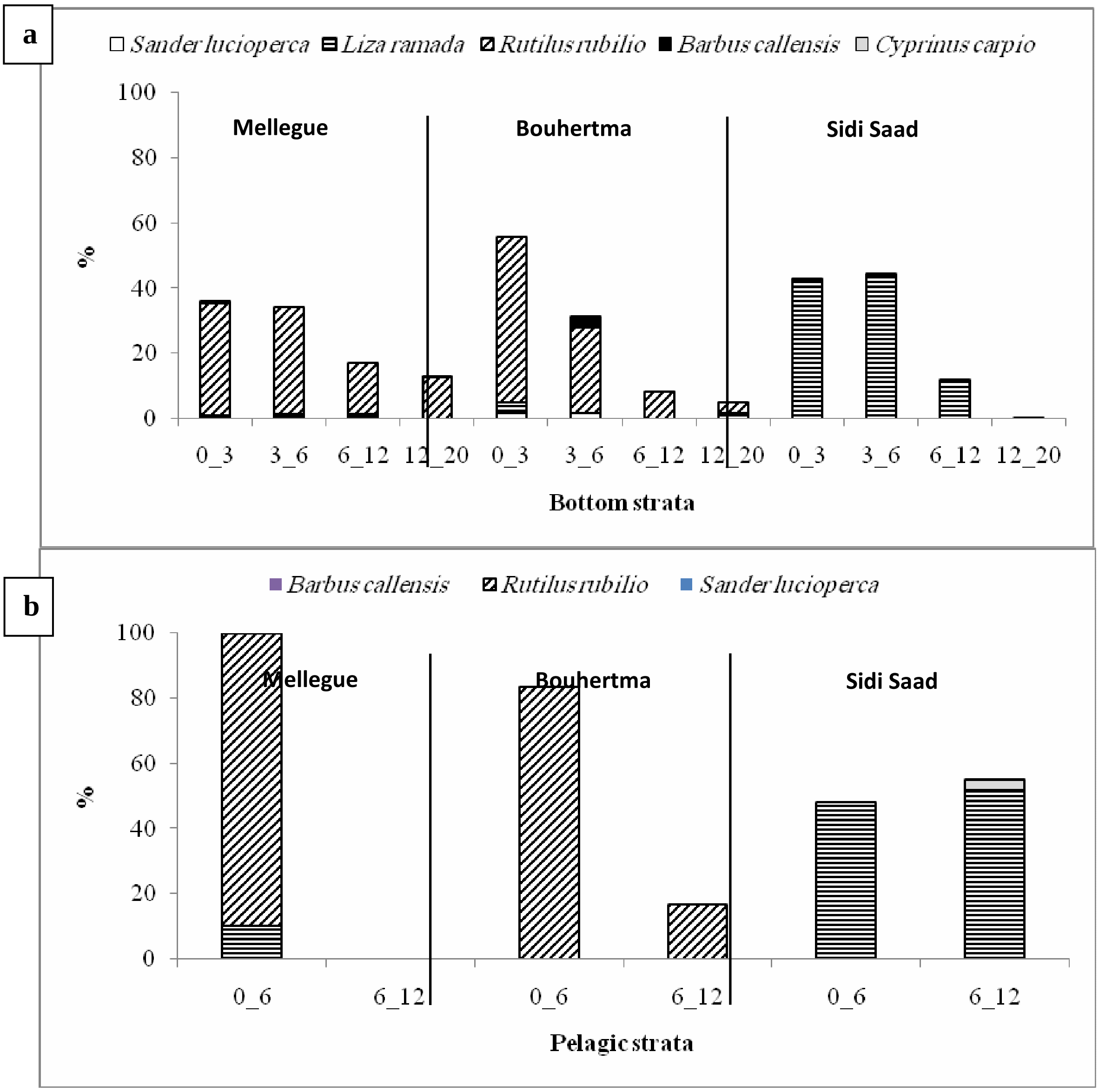

Figure 3: Spatial distribution catches of benthic (a) and pelagic (b) gillnet in Mellegue, Bouhertma and Sidi Saad Reservoirs

mullet occupied bottom less than 12 m and pelagic area less than 6m. The barbell occupied the stratum 0-3 m whereas the common carp was only present at depths greater than 12m (Fig. 3). Fish were rarely captured in the pelagic layer of the water column (7.6 % in number and biomass yields) (Tab. III).

Fish sampling carried out in Bouhertma Reservoir showed the predominance of roach which represents 90% of the NPUE (Tab. III). The roach's proportion of BPUE was also the highest with 53% followed by mullet and pikeperch which represent 22% and 17% of BPUE, respectively (Tab. III). Pelagic gillnet sampled 21.6 % in number and 7.6 % in biomass of captured fish. Spatial distribution of roach covered the entire water column. Pikeperch occupied the benthic areas less than 6 m whereas barbell was only present in the layer 3-6 m (Fig. 3).

Sidi Saad Reservoir was populated essentially by mullet which represents more than 97% of CPUE (Tab. III). Benthic fish catches in the 3-6m depth represent 45% of the catches, followed by the 0-3m and 6-12m depth layers with a percentage of 43% and 12% respectively (Fig. 3). Mullet was present in all sampled layers except the depth layer 12-20 m and more than 20% of fish was captured by pelagic gillnet (Tab. III).

Fish size frequencies

Size range of fish in gillnet catch was 11-65 cm, 12-44 cm and 14-37 cm in Mellegue, Bouhertma and Sidi Saad Reservoirs, respectively (Fig. 4). Most fish caught were between 12 and 15 cm in Mellegue (79%) and Bouhertma (71%) Reservoirs and between 20 and 29 cm in Sidi Saad Reservoir reservoir (86%) (Fig. 4).

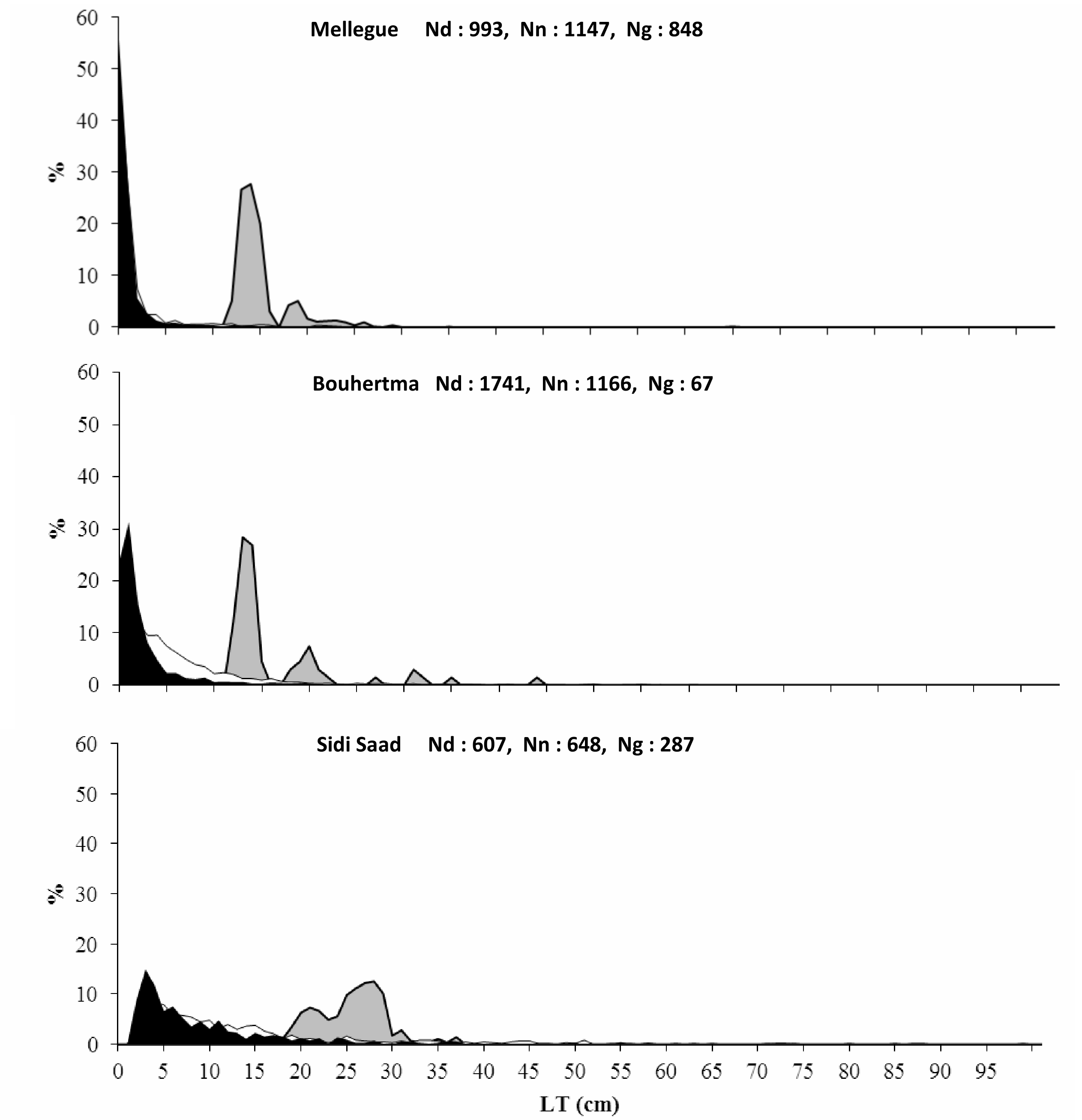

Figure 4: Frequency distributions of fish tracked by hydroacoustic and collected by gillnet in Mellegue, Bouhertma and Sidi Saad Reservoirs. White, black and grey bars represent day, night and gillnet data, respectively (Nd, Nn and Ng represent the number of tracked fish detected during day and night surveys and the number of fish caught with gillnet respectively).

Acoustic fish size showed a high number of small fish size in the three reservoirs which was not sampled by gillnets. Large fish were also only detected by acoustical surveys (Fig. 4). Gillnetting and acoustics provided different fish size distribution (KS, $p < 0.05$).

The Kolmogorov-Smirnov non parametric statistical test showed no differences between day and night fish size distributions tracked by horizontal and vertical beaming in Mellegue ($D = 0.02$; $p = 0.99$), Bouhertma ($D = 0.2$; $p = 0.10$) and Sidi Saad ($D = 0.08$; $p = 0.90$) Reservoirs.

Acoustic Density and biomass

Density was significantly different between the two layers in Mellegue Reservoir (Tab. IV).

Table IV: Multi-way analysis of variance (ANOVA) of fish density (fish ha^{-1}) and biomass (kg ha^{-1}) after Box-Cox transformation in Mellegue ($\lambda_{density}$ = 0.26, $\lambda_{biomass}$= 0.21), Bouhertma ($\lambda_{density}$ = 0.3, $\lambda_{biomass}$= 0.21) and Sidi Saad ($\lambda_{density}$ = 0.32, $\lambda_{biomass}$= 0.19) Reservoirs. Independent variables include photoperiod, layer and strata.

	Mellegue				**Bouhertma**				**Sidi Saad**			
	Density		**Biomass**		**Density**		**Biomass**		**Density**		**Biomass**	
Source	**F**	**P**	**F**	**P**	**F**	**P**	**F**	**P**	**F**	**P**	**F**	**P**
Photoperiod	3.31	0.087	1.24	0.282	5.27	**0.03**	0.01	0.912	0.31	0.583	2.14	0.156
Layer	24.65	**<0.001**	2.03	0.173	23.98	**<0.001**	2.09	0.160	20.38	**<0.001**	7.65	**0.010**
Stratum	1.13	0.347	0.24	0.786	1.96	0.160	0.73	0.490	6.01	**0.007**	5.44	**0.011**
Photoperiod *layer	0.17	0.682	0.42	0.527	5.04	**0.033**	0.01	0.924	0.01	0.923	0.07	0.795
Photoperiod *stratum	1.41	<0.271	0.2	0.822	1.33	0.282	0.25	0.782	1.29	0.293	0.83	0.449
Layer*stratum	2.89	0.084	1.29	0.301	3.97	**0.031**	0.91	0.416	1.83	0.181	1.38	0.270

Significative p values are in bold.

Concerning Bouhertma Reservoir, fish density differed significantly between photoperiod and layer. There was also a significant photoperiod*layer and layer*strata interaction (Tab. IV) which showed greater vertical movement in the water layer (Fig. 2). The highest density was observed at night in deep layer with an average of 11700 fish ha^{-1}. The lowest density was observed near the dam for a water depth less than 3m (Fig. 5).

For these two reservoirs, biomasses were uniform between photoperiod, layers and strata (Tab. IV) and were estimated at 146 kg ha^{-1} and 131 kg ha^{-1} which corresponded to a biomass of 52 t and 90 t in Mellegue and Bouhertma Reservoirs, respectively (Fig. 5).

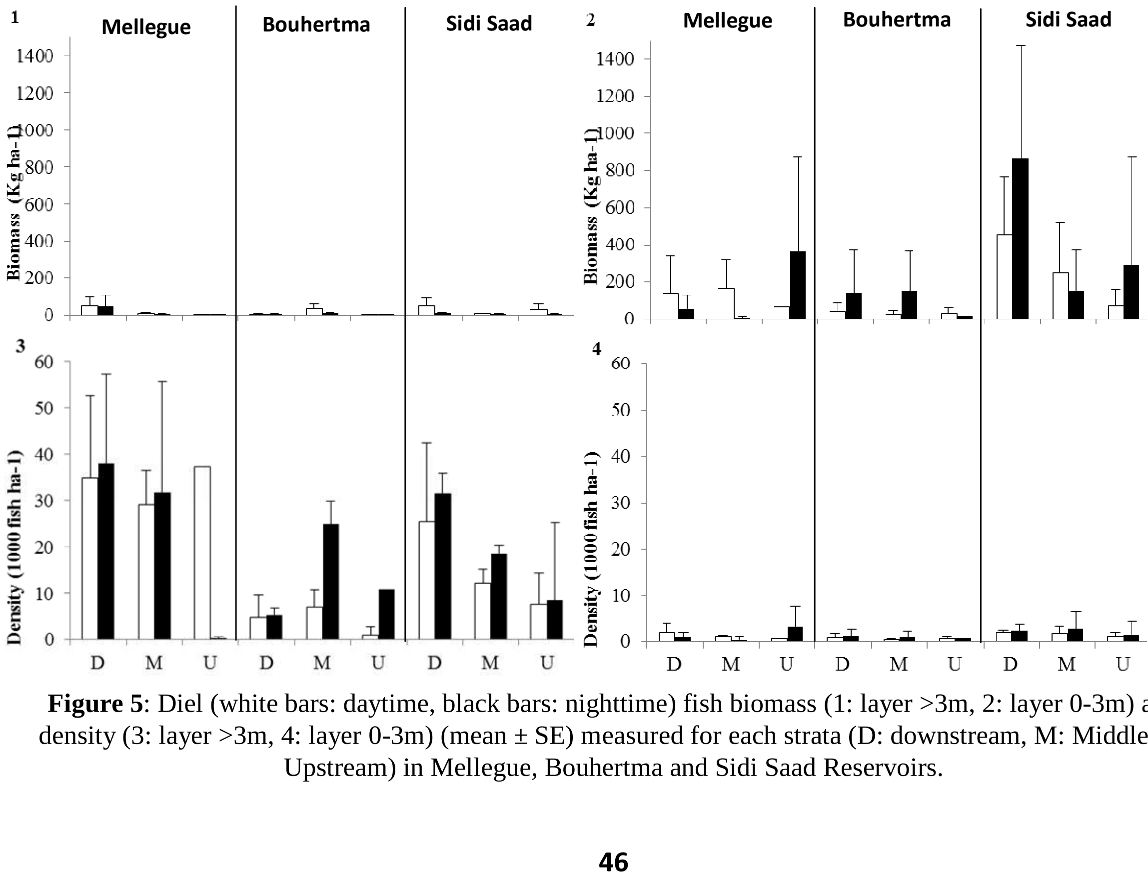

Figure 5: Diel (white bars: daytime, black bars: nighttime) fish biomass (1: layer >3m, 2: layer 0-3m) and density (3: layer >3m, 4: layer 0-3m) (mean ± SE) measured for each strata (D: downstream, M: Middle, U: Upstream) in Mellegue, Bouhertma and Sidi Saad Reservoirs.

Densities seemed highest in downstream than in upstream at Sidi Saad Reservoir (Fig. 5). The results of the multi-way analysis of variance showed no significant differences for the average fish density and biomass between day and night (Tab. IV). Fish biomass assessment in this Reservoir was 458 kg ha^{-1} corresponded to a biomass of 270.3 t.

Comparison between gillnetting and hydroacoustics

We found a linear correlation between acoustic biomass and gillnet BPUE for all acoustic size as well as the acoustic size class higher than 4 cm (Tab. V). No significant difference was observed when comparing the fitted line of all acoustic fish size from the 1:1 fit (Tab. V). A linear correlation was also found between acoustic density and gillnets NPUE for all acoustic size in which slope not significantly different from 1 (Tab. V).

Table V: MAR between $\log_{10}$ transformed areal fish biomass/density, for all acoustic size (thresholds = -70/-70 dB) as well as the acoustic size class lower than 4 cm (thresholds = -64/-52 dB) and multi-mesh gillnet catches (BPUE/NPUE) with tests for common slopes and intercept against the 1:1 fit (slope = 1, intercept = 0).

Variables	TS thresholds (dB) (Vertical/Horizontal beaming)	MAR		Slope (95% confidence interval)	H0 : Slope not different from 1		Intercept (95% confidence interval)	H0 : Intercept not different from 0	
		R^2	p		r	p		t	P
BPUE/acoustic fish biomass (n=6)	-70/-70	0.72	**0.03**	0.71 (0.2 – 1.69)	-0.48	**0.32**	2.33 (-1.64 – 4.39)	2.59	**0.06**
	-52/-64	0.88	**0.005**	0.83 (0.48 – 1.38)	-0.45	**0.36**	1.78 (-0.42 – 3.22)	2.19	0.04
NPUE/acoustic fish density (n=6)	-70/-70	0.8	**0.01**	0.62 (0.25 – 1.16)	-0.71	**0.11**	2.87 (1.67 – 3.67)	8.55	0.001
	-52/-64	0.47	0.12	0.34 (-0.13 – 1.3)	-	-	2.32 (0.82 – 3.37)	-	-

Significative p values are in bold.

DISCUSSION

Acoustic and gillnet sampling performed in three Tunisian shallow water Reservoirs allowed us to estimate the CPUE and densities of fish assemblage.

Gillnets catches showed high presence of mullet in Sidi Saad Reservoir and roach in Mellègue and Bouhertma Reservoirs. NPUE in these reservoirs varied between 45 and 431 fish/1000 m² of gillnet panel and BPUE from 3.1 to 29.9 kg/1000 m². These CPUE were similar than CPUE of Lahjar and Ghezala Reservoirs (Mili et *al*., 2016). The absence of *Anguilla Anguilla* and *Siluris glanis* from sampling despite their presence in statistic fishery data can be explained by their low catchability and density associated to the fact that they are not easy to catch using gill nets because of their morphology, behavior, or their preferred habitat in lakes (Mili et *al*., 2016). The high number of small targets (LT: 1 – 5 cm) observed in Reservoirs is linked with the recruitment of juvenile fish after spawning which happened in spring for the majority of species; March and April for roach (Djemali, 2005) and pikeperch (M'Hetli *et al.* 2011), between April and June for barbell (Ould Rouis *et al.*, 2012) and between March and July for common carp (Hajlaoui et *al.*, 2016).

Fishing data in our study given different fish size frequency comparatively to acoustic detections. Gillnets used during this study catch only fish greater than 11 cm meaning that species composition of fish is bias because of small length (assuming equal inter and intra-species probability of gillnet capture). Our gillnets did not include small mesh sizes panels but even with small mesh sizes, Nordic gillnets have relatively low elasticity and this might be the reason for its poor catchability of small sized fish (Kurkilahti et *al*., 1998). Large fish are also suspected to be poorly represented in standard netting surveys which occupies deep water (Pope et *al*., 2005; Emmrich et *al*., 2012).

The results obtained in this study indicate that total fish biomass in Sidi Saad was approximately three times higher than the biomass in Bouhertma and Mellegue Reservoirs. The high biomass detected in Sidi Saad is comparable to biomass estimated in Bir Mcherga Reservoir (Tunisia) which is reported by Djemali et *al*. (2016) and in Malta Reservoir (Poland) (Godlewska et *al*., 2012). This fact can be related to the intensive operation of seeding mullet fry which occurred regularly in Tunisian Reservoirs. The first experience of mullet nursery (100 000 fry of *Mugil cephalus*) was performed in 1964 in Mellegue Reservoir. The fry are collected each year in water with salinity between 7 and 37 g/l and discharged in Reservoirs after acclimatization, by replacing gradually fresh water during transport (Mili et *al*., 2013). Sidi Saad Reservoir was stocked with an average of 285 fry ha^{-1} $year^{-1}$ during the last years against 200 fry ha^{-1} $year^{-1}$ and 245 fry ha^{-1} $year^{-1}$ in Bouhertma and Mellegue Reservoirs, respectively (unpublished data).

Big fish was detected in the upper layer of all Reservoirs and particularly near the dam for a water depth less than 3m in Bouhertma Reservoir. Our results are in concordance with other studies (Djemali et *al*., 2010). These authors obtained similar distribution in Lakhmess Reservoir when bottom layer (> 3m) was denser than the surface one and fish biomass was significantly higher in layer < 3m. Big fish occupying surface water of downstream, was also reported by Laouar and Djemali (2018) in Kasseb Reservoir (Tunisia).

Fish biomass and density was related to depth in Sidi Saad Reservoir and decrease from dam to the tributary. Many studies in Tunisian Reservoirs (Djemali et *al*., 2009, 2010) showed that fish biomass distribution was governed by the depth and was the most abundant in areas with deep waters. Fish escapement to deep water (i.e downstream) was apparently due to stability of the wide Reservoir body and also the anthropogenic disturbance around the Reservoir.

For similar studies, gillnet used simultaneously with hydroacoustic highlighted a strong correlation between BPUE and hydroacoustic biomass estimates (Boswell et *al*., 2011; Emmrich et *al*., 2012) despite of different sampling strategies. Overall, gillnet catch was a poor predictor of acoustic-derived abundance (Dennerline et *al*, 2012). In the present study, despite of the linear significant relationships between acoustic biomass/BPUE and acoustic density/NPUE for all acoustic data (thresholds = -70 dB), it will be more interesting to increase the number of sampled Reservoirs in order to have powerful statistical correlation. Furthermore, with echocounting method, applying thresholds to select specific acoustic sizes had several limitations; some targets with few detections can be eliminated altogether with the selected tracking parameters used (Djemali et *al*., 2009), and biomass may be underestimated by rising TS mean of targets.

CONCLUSION

The surveys conducted in three Tunisian non stratified shallow Reservoirs showed low spatial and temporal variations in fish abundance and biomass across photoperiod. This study demonstrated that on a diel basis and on the whole of each reservoir, there is no difference in fish acoustic detectability highlighted the possibility to sample the reservoirs only by day or by night. On the other hand, a significant linear correlation was observed between acoustic biomass/BPUE and acoustic density/NPUE: the perfect correlation with the 1:1 fit was showed only between acoustic biomass and BPUE. A significant linear correlation was showed between acoustic density/NPUE and acoustic biomass/BPUE but no perfect correlation with the 1:1 fit was showed because the intercept was different from 0. During this study acoustic method was pair with passives gillnets but in order to have complementary information it will be interesting to use active gear in order to fish small size as the acoustic sampling.

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