Growth and reproduction of the Bogue *Boops boops* L. 1758 in the Mediterranean coastal area between Nador and Saïdia (Morocco)

Croissance et reproduction de la Bogue Boops boops L. 1758 dans la zone côtière de la Méditerranée entre Nador et Saidia (Maroc)

Mostafa LAYACHI[1], Moulay Hachem IDRISSI[1], Mohammed RAMDANI[2*], Fatima SAHNOUNI[3] & Roger FLOWER[4]

1. *Centre Régional de l'Institut National de Recherche Halieutique, Nador*
2. *Mohammed V University in Rabat, Institut Scientifique, BP 703 Rabat-Agdal, Maroc *(mramdani@israbat.ac.ma)*
3. *Université de Mascara, Département de Biologie, Mascara, Algérie*
4. *University College of London, Geography. UK*

Abstract. This study is focused on the biological parameters of the Bogue *Boops boops L*., 1758, a commercially important fish of the Moroccan Mediterranean coastal area of Nador-Saïdia. The demographic assemblage structure is characterized by medium-sized individuals. Growth parameters estimated by the Von Bertalanffy equation are: $L\infty$ = 300 mm; K = 0.41; t_0 = -0.30 and Z = 0.848. The period of reproduction occurred during spring and summer. Mean size at the first sexual maturity is 133 mm for males and 143 mm for females.

Keywords : *Boops boops*, Mediterranean coast, reproduction, Morocco

Résumé. Les paramètres biologiques de la Bogue *Boops boops* L., 1758, un poisson d'importance commerciale de la zone côtière de la Méditerranée marocaine entre Nador et Saïdia, sont analysés. La structure démographique du peuplement se caractérise par des individus de taille moyenne. Les paramètres de croissance estimés par l'équation de Von Bertalanffy sont: $L\infty$ = 300 mm; K = 0,41; t0 = -0,30 et Z = 0,848. La période de reproduction se produit au cours du printemps et l'été. La taille moyenne à la première maturité sexuelle est de 133 mm pour les mâles et 143 mm pour les femelles.

Mots-clés : *Boops boops*, côte Méditerranéenne, reproduction, Maroc.

INTRODUCTION

Fishing around the Moroccan Mediterranean coasts has evolved in a major way since the 1980s, mainly due to a marked increase in the number of small-scale coastal fishing units. A multi-specific and multi-gear fishery has been developed by the pelagic and demersal fleets. Demersal fishing plays an important role in the fisheries economy of the Moroccan Mediterranean coast due to the high economic value of marine resources and the wide variety of landed species. These mainly comprise of Sparidae, Carangidae, Clupeidae and Mullidae species (Belhabib *et al*. 2012).

The Bogue (*Boops boops* L. 1758) (Perciformes: Teleostei) is a commercially important sea bream and the most dominant species in the Sparidae; it is landed throughout the whole year at all the fishing ports on the Moroccan Mediterranean coast in large quantities (3.212 in 2013 and 4.843 tons in 2014; 2.609 tons / year in average) (FAO, 2011, ONP 2014). It is considered among the most targeted species by the trawler fishery on Moroccan Mediterranean coasts and fishing effort of trawlers has increased during the last four years (ONP, 2014). The scientific exploration campaigns by bottom trawling show that the Bogue remains abundant on all the Moroccan Mediterranean coasts but especially in the area between the western part of Al Hoceima and Saïdia (Slimani & Hamdi 2004 and internal report of INRH 2011)**.**

The Bogue has a sub-demersal character and lives above the continental shelf, usually down to about 100 m depth but can be found infrequently down to 490 m (Bauchot & Hureau 1990). It is also common in coastal areas from Norway to Angola, in the Azores, the Canary Islands, and in the Mediterranean and Black Seas generally. It can be semi-pelagic and a demersal feeder, living near sand, mud, rocks and seaweed. Omnivorous and planktivorous, it consumes seaweed, small crustaceans (commonly isopods, amphipods and decapods), sponges, and some plankton (Bauchot 1987). It is caught by bottom trawls, purse seines, beach seines and trammels nets, and constituted ~2.5% of the Moroccan Mediterranean catch in the last 4 years (ONP 2014). The Bogue moves in schools that rise to the surface open sea especially at night; it can also be found accidently in estuaries and lagoons (Bauchot & Hureau 1990). Larger fish are usually associated with greater depths as indicated by trawlers catches.

Various studies have been conducted on this species both on the Atlantic and Mediterranean coasts (Lissia-Frau 1966; Remacle 1971, Sellami & Brusle1975, Zuniga 1967, Mouneime 1981, Mennes 1985, Lamrini 1998, El-Okda 2008). This fish has been recommended as a priority species for assessment studies in the Mediterranean (FAO-GFCM 2002).

The objective of this study is the growth and reproduction of the Bogue (*Boopsboops)* in the eastern part of the Moroccan Mediterranean coastal fishery between Nador and Saïdia, where fish are landed at the ports of Nador and Cap de l'Eau (Fig 1). Trawlers are operating between Melilla and Saïdia from the surface to 200 m depth, some of them approach the coast and do not respect the 3 nautical miles. Results are important for the management of fishery of this species in Morocco.

MATERIAL AND METHODS

Sampling frequency was bimonthly between January 2011 and December 2011. Samples of 60-70 individuals were obtained every 2 weeks from the fish hall at the port of Beni Ensar (Fig. 1). They were kept in a cooler with cold accumulator (+1 - +15°C) during the ca. 4h before the analysis in the laboratory. In total, 1550 individuals were examined.

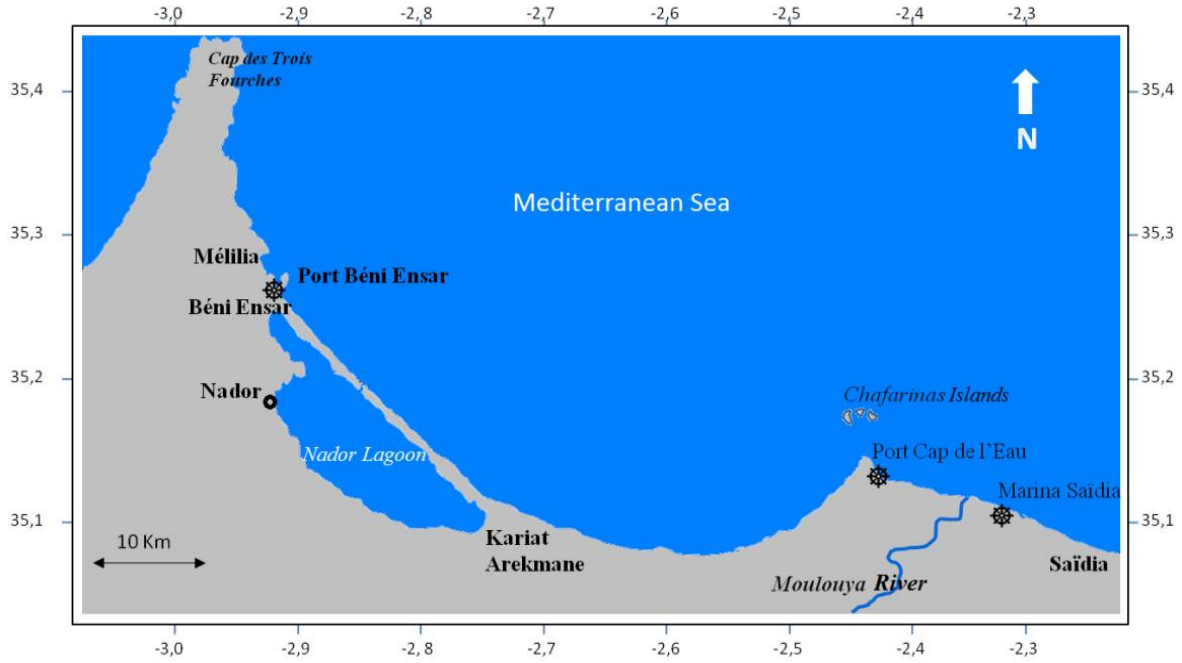

Figure 1. The study area on the Mediterranean east coast of Morocco

For growth estimations, each individual was placed on a graduated dichtyo-meter to measure total length (Lt) and length from the fork (Lf). Precision is 1 mm and the units are in mm. Weights were obtained using a Mettler Toledo balance SB 12001 with an accuracy of 1 g and maximum range of 0-5 kg. Measurements of the total weight (Tw), liver weight (Lw) and gonad weight (Gw) were made.

The parameters of the absolute growth model of Von Bertalanffy equation are:

Lt = L∞ [1- exp (-K (t-to)]; where L∞ is the theoretical maximum length, K is the rate at which animal develops L∞ and to is the population recruitment time. These were estimated from the frequency distribution analysis sizes using the LFDA (Length frequency distribution analysis) program. The method used is ELEFAN based on the algorithm described by Pauly (1987), which allows the estimation of L∞, K and to. The mortality rate (Z) is determined by the method of Beverton and Holt (1956).

The weight gain is the relationship between the length and weight of the studied species (Le Cren 1951)**:** $W = aL^b$

Where,

W: weight of fish (g)

L: fish length (mm)

a: constant; b : allometric rate.

The allometric rate b varies from 2 to 4, but it is usually close to 3.

When b = 3, there isometric growth (animal's specific density does not change).

If b> 3 allometry is upper boundary, the fish became bigger faster than it grows.

If b<3 allometry is lower boundary, the fish grows faster than it became bigger. The proportion of female (or male) in the sampled assemblage reflects the rate of masculinity or femininity of the considered population. It is defined as the proportion of male and female individuals compared to the total number and gives an idea about the gender balance within the population.

Proportion = F x 100 / (M+F) and Proportion = M x 100 / (M+F)

With: F = females and M = males.

The size at first maturity is the length at which 50% of individuals are mature (Fontana 1969). To establish curves for the percentages of mature size class females or males, we counted during the laying period the number of females or males that had reached or passed the stage III (early vitellogenesis) compared to the total number of females or males by size class, according to Fontana (1969), Gordo (1995, 1996), Panfili *et al.*(2002), Mendoza Duran (2012), Soykan *et al.* (2015). The presence of several false rings in the otoliths makes them difficult to use for age determinations in growth studies of this species (Panfili *et al.* 2002, Soykan *et al.* 2015). However, using LFDA software, it was possible to estimate the absolute growth parameters of the Von Bertalanffy equation:

The Von Bertalanffy parameters are: L_∞ = 30 cm while K = 0.41; t_0 = -0.3 and Z = 1.12.

Gonad index (GSI) Gonado-Somatic Index:

Determination of the laying phase was performed by calculating the gonad index GSI (Bougis 1952), based on the variation of the mass of the gonads during the sexual cycle.

RGS = weight of the gonad x 100 / weight of live fish

Hepato-somatic Index (HSI). Liver weight changes are influenced by genital conditions that define the timing of spawning fish. Indeed, the development of sexual products is closely related to the physiological activity that occur in the liver (Thiam 1980). The HIS is defined by the relationship:

RHS = liver weight x 100 / somatic weight of fish.

RESULTS

~~Growth relationships~~

Size structure of the sampled Bogue assemblage: The frequency of size (total length) with weight is shown in Figure 2. Analysis of size structure shows that the catch included sizes ranging from 60 mm to 280 mm. Catches usually target medium-sized individuals ranging from 130 mm to 170 mm with a dominance of size classes ranging from the mode 140 mm to 160 mm.

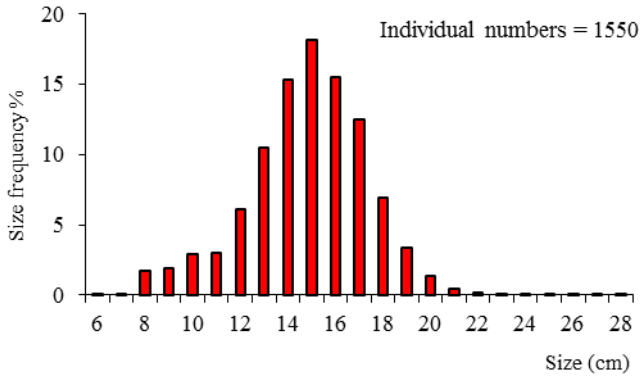

Figure 2. Structure in size of the *Boops boops* from the eastern part of the Moroccan Mediterranean coast during 2011.

For the Bogue sampled in the study area, the length-weight relationship is shown in Figure 3.

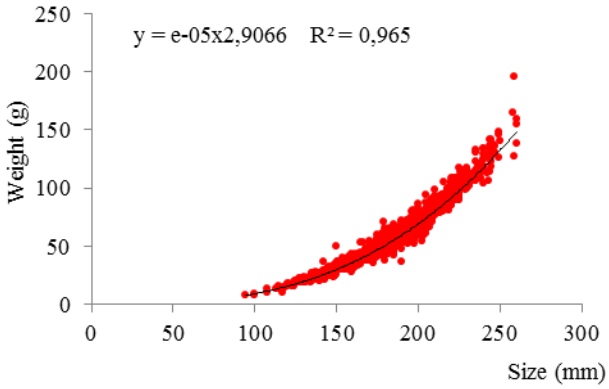

Figure 3. Length-weight relationship of *Boops boops* from the eastern part of the Moroccan Mediterranean coasts

Monthly changes in SGI values: In the Bogue from the Eastern part of the Moroccan Mediterranean coasts, the reproduction period starts in February and ends in August (Fig. 4). The maximum value of the SGI indicates the peak of spawning was during March.

Monthly changes in Hepato Somatic Index (HSI). According to Figure 5, the maximum value of the HIS occurs in March (the breeding season) in *Boops boops* and the minimum value is in September (sexual rest period).

Size at first sexual maturity (Fontana 1969). According to our observations, the examination of sexual maturity concerned the gonads of individuals belonging to the same or higher stages in stage III; those of stage I and II were immature individuals. The size of first maturity observed for males is 133 mm (Fig. 6) whereas for the female, it is reached at 143 mm (Fig. 7).

Temporal variations in the proportion of females. Temporal variations in the proportion of females (Fig. 8) show a predominance of females during the months of February, May, August and October while males predominate during January, March and July.

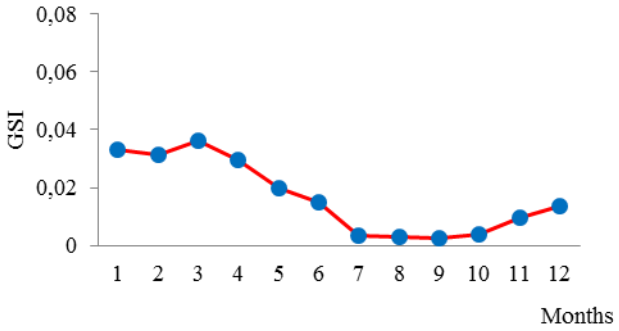

Figure 4. Monthly changes in the gonado-somatic index (GSI) of *Boops boops* from the eastern part of the Moroccan Mediterranean coasts

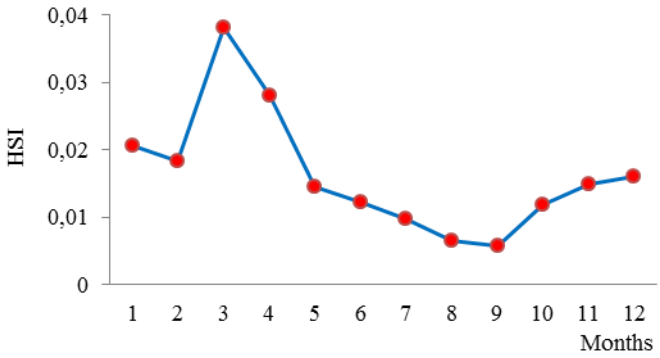

Figure 5. Monthly changes of Hepato Somatic Index (HSI) for *Boops boops* from the Moroccan Mediterranean coasts

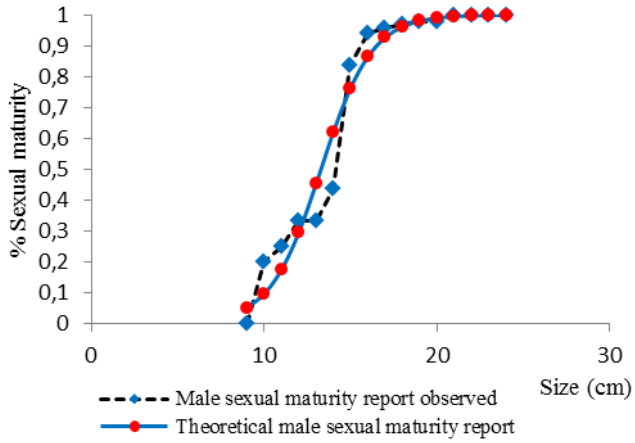

Figure 6. Relationship of percentage sexual maturity with size in males of *Boops boops* during the period January 2011 - December 2011.

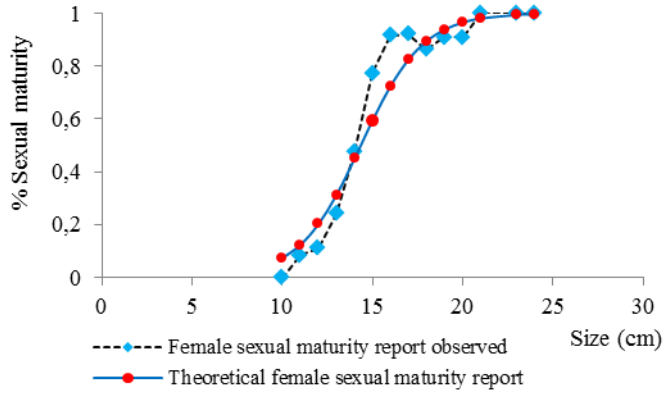

Figure 7. Relationship of percentage sexual maturity with size in female *Boops boops* the period from January 2011 to December 2011.

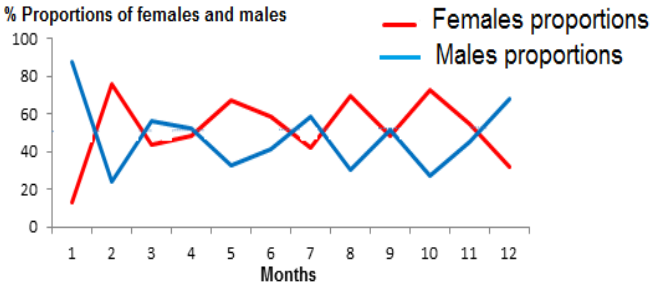

Figure 8. Monthly changes in proportion of females and males of *Boops boops* during the period January 2011 - December 2011.

DISCUSSION

The demographic structure obtained for the Bogue characterized the population as consisting mainly of medium-sized individuals. These results are consistent with those of Khemiri *et al.* (2005) who reported that the structure sizes of *B. boops* from Tunisian coasts is mostly represented by medium-sized individuals (140 mm-160 mm). Similar results were demonstrated by Lamrini (1998), Gordo (1995), and El Agamy *et al.* (2004).

Estimated L_∞ in this study was lower than the value recorded by Bauchot & Hureau (1986) for the Mediterranean studied sites (36 cm). Although the difference in aging methods used by some authors, it is possible to achieve some agreement on growth patterns of *B. boops* from different areas of the Mediterranean Sea (Tab. 1). Several parameters may cause variability in growth including biotic factors related to the genotype or physiological condition of the fish (Khemiri *et al.* 2005).The estimated index of growth performance (Φ') for *B. boops* is 2.54. This value compared well to those obtained for the same species from different areas in the Mediterranean Sea was given in table 1.

The size at first sexual maturity *Boops boops* was 13.3 cm in female and 14.3 cm in males. These values are compared with other data obtained from different areas in the Mediterranean Sea (Tab. 2). The maximum value of 17.2 cm was observed for the Algerian coast (Kherraz 2011) and the minimum value of 10 cm was indicated for the Gulf of Lion (Girardin 1981).

The rate of allometry "b" for *B. boops* is roughly equal to 3 according the literature. This is consistent with results obtained in other sites from the Mediterranean coasts (Gaamour *et al.* 2003, Gordo 1995, El Agamy *et al.* 2004, Khemiri *et al.* 2005). The correlation between the length and the weight is highly significant ($R^2 = 0.97$)(see Fig. 3).

The breeding season began in March and lasted until June (spring-early summer), according to this study. The peak spawning is in March. Khemiri *et al.* (2005) showed that reproduction of the Bogue along the Tunisian coast, took place from January to May. According to Lamrini (1998), spawning takes place between April and July. Gordo (1995) states the breeding season extends from February to June. El Agamy *et al.* (2004) showed the breeding season lasts from January to May and the peak of the reproduction is in February. According to Gaamour *et al.* (2003), the Bogue reproduced from February to May (Tab. 2). All these results for Mediterranean surveys are very close to those obtained in this study. Also, compared to other species of Sparidae (Soykan *et al.* 2015), sexual maturity of *Boops boops* is quite early and spawning is relatively short, for example in the Straits of Gibraltar this occurs during three spring months (Lamrini 1998). At other areas of the Mediterranean Sea, spawning is shorter, about two months, starting on Lebanese shores in February (Mouneime 1981). Shortening of the breeding period in the Moroccan study area could be explained by the relatively high temperatures in spring and summer and food availability in the spring.

Changes in Hepato Somatic Index (HSI)

The HSI and GSI show similar patterns and we can conclude the reliability for the former to be used as a parameter of reproduction in *Boops boops*.

Size at first maturity

Sexual maturity in males is earlier than females in our analyzed sample. These results confirm those reported for the same species in the Mediterranean. According to Lamrini (1998), size at first maturity is 15,4 cm (both sexes), which corresponds to an age of one year and, according to the same author, females cannot lay below 12 cm in length and the percentage of mature females increases with the size peaking at 20 cm. Khemiri *et al* .(2005) showed that the size at first maturity is between 14 cm and 16 cm (both sexes). According to El Agamy *et al.* (2004), size at first maturity is 12 cm in males and 13 cm in females. Gordo (1995) reports that on Portuguese coasts, the size at first maturity varies from 13 cm to 15 cm (both sexes). Gaamour *et al.* (2003) observed that in Tunisian Mediterranean waters, size at first maturity is reached at 13 cm (both sexes).

Temporal variations in the sex ratio

During the winter, males proportion (51%) slightly predominate over females (49%), while during the spring the opposite occurs and it is the females (51%) slightly predominante male (49%). However, during the summer and fall, females (60%) become dominant. This dominance coincides with the sexual resting phase. According to Lamrini (1998), the Bogue has a proportion of females/males slightly in favor of females (39%) compared to males (37%), the rest are hermaphrodite (24%). This sex imbalance in our study could be due to sampling, error however.

Table 1. Growth parameters, growth performance and aging methods for *Boops boops* from different areas in the Mediterranean Sea and the Atlantic Moroccan coasts

Country	Growth parameters				Aging method	Authors
	L_∞	K	t_0	Φ'		
Algeria	25.40	0.29	-	2.27	-	Chali Chabane, 1988
Algeria	24.04	0.4	-1.23	-	FISAT IIELEFANI	Kherraz, 2011
	22.31	1	-0.39	-	LFDAELEFAN I	
France	30.20	0.18	-	2.22	-	Campillo, 1992
Morocco (S. Atlantic)	32.00	0.29	-	2.47	Length-frequency	Mennes, 1985
Adriatic	33.20	0.168	-1.481	2.28	Otolith	Hernandez, 1989
Adriatic	33.90	0.155	-1.460	2.20	Bhattacharya	Hernandez, 1990
Greece	36.00	0.40	-	2.71	Length-frequency	Tsangridis & Filippousis, 1991
Tunisia	32.27	0.11	-1.688	-	Otolith	Ktari and Anato, 1983
North Tunis	28.70	0.20	-1.410	2.22	Otolith	Khemiri *et al*., 2005
Gulf of Tunis	24.30	0.23	-1.650	2.13	Otolith	Khemiri *et al*., 2005
East Tunisia	26.70	0.22	-1.430	2.20	Otolith	Khemiri *et al*., 2005
South Tunisia	23.50	0.21	-1.980	2.06		Khemiri *et al*., 2005
Cyprus	24.00	0.53	-0.450	-	Scales	Livadas, 1989
Egypt	29.80	0.18	-1.330	2.20	Scales	Hassan, 1990
Egypt	31.90	0.15	-1.530	2.18	Scales	El Haweet *et al.*, 2005
Egypt	29.90	0.25	-0.700	2.34	Bhattacharya	El Haweet *et al*., 2005
Egypt	30.11	0.15	-1.508	2.14	Otolith	El-Okda, 2008
Morocco (Mediterranean)	30.00	0.41	-0.300	2.54	Length-frequency	This study

Table 2.The size at first sexual maturity of *Boops boops* in different areas of Mediterranean Sea.

Authors	Areas	Size at first sexual maturity (cm)
Ktari & Anato, 1983	Tunisia	14 to 18
Matta, 1958	Toscan Archipelago	13 (♀) and 11.6 (♂)
Mouneime, 1981	Lebanon	13
El Agamy *et al*., 2004	Egypt	12 (♀) and 13 (♂)
Hassan, 1990	Egypt	10 to 13
Gordo, 1995	Portugal	15 (♀) and 14 (♂)
Kherraz, 2011	Algeria	17.2
Chali Chabane, 1988	Bou Ismail coast (Algeria)	13.5
Meguedad & Mahious, 1989	Oran coast (Algeria)	13.2
Kherraz, 2011	Oran coast (Algeria)	17.1
Present study	Mediterranean coast (Morocco)	14.3 (♀) and 13.3 (♂)

Table 3.Breeding periods of *Boops boops* in different areas of the Mediterranean Sea. (GSI: Gonado Somatic Index: breeding).

	J	F	M	A	M	J	J	A	S	O	N	D	Method	Authors
Tunisian coasts	■	■	■	■	■								GSI	Khemiri *et al*. (2005)
Gibraltar - Morocco				■	■	■							GSI	Lamrini (1998)
Portuguese coasts			■	■	■	■							GSI	Gordo (1995)
Turkish coasts	■	■	■	■	■								GSI	Soykan *et al*. (2015)
Egyptian coasts	■	■	■	■	■								GSI	El Agamy *et al* (2004)
Tunisian coasts		■	■	■	■								GSI	Gaamour *et al.* (2003)
Lebanon coasts		■											GSI	Mouneime (1981)
Nador-Saïdia (Morocco)			■	■	■								GSI	Present study

CONCLUSION

The Bogue population assemblage in the eastern part of the Moroccan Mediterranean coast, as sampled at the fish market of Nador, showed that fish with an average size ranging from 130 mm to 170 mm are the most targeted. However, large quantities of immature individuals (80 – 130 mm) are also caught contributing to overfishing of the specie in this area. The study of the biology of *Boops boops*, (growth and reproduction), indicates that inshore fishing is applying considerable pressure to the brood stock. The increase in fishing effort of trawlers only aggravates the situation for this fishery resource. To reduce pressure on the stocks, fisheries management needs to be introduced so that fishing effort in the inshore zone is reduced through partial transfer of fishing activity to offshore zones, beyond 3 nautical miles. This is recommended to prevent collapse of the stock of the Bogue fishery in the region of the eastern Moroccan Mediterranean coasts. There are many examples where over-fishing inshore fisheries has caused the collapse of coastal fisheries (e.g. Wroblewski *et al.* 2005). Moving the Bogue fishery offshore, through changes in management policy, will undoubtedly help conserve this fishery for future generations.

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