REPRODUCTION OF ATLANTIC BONITO (*SARDA SARDA*) IN SOUTH OF THE MOROCCAN ATLANTIC WATERS

Sid'ahmed Baibbat[1,2], Idrissi Malouli[3], Nourreddine Abid[4], Laurence Kell[5], Flavia Lucena[6] and Bouchra Benazzouz[2]

SUMMARY

The demographic structures of Atlantic bonito, Sarda sarda *(Block, 1793), in the South Atlantic coast of Morocco were studied from the biological sampling data collected from coastal units targeting this species, between 2012 and 2015. In total, 2688 individuals were measured for size frequency analysis and 158 individuals for biological parameters determination. The season of reproduction was determined by analysis of the monthly evolution of the gonado-somatic index and the percentage of sexual maturity. The demographic structure of the Atlantic bonito landings is dominated by sizes between 45 and 52 cm. The analysis of the monthly evolution of the gonado-somatic index showed that this species reproduces between May and July.*

RÉSUMÉ

*Les structures démographiques de la bonite à dos rayé (*Sarda sarda*) (Block, 1793) le long des côtes de l'Atlantique Sud du Maroc ont été étudiées à partir de données d'échantillonnage biologique recueillies par des unités côtières ciblant cette espèce entre 2012 et 2015. Au total, 2.688 spécimens ont été mesurés à des fins d'analyse de fréquence des tailles et 158 spécimens à des fins de détermination de paramètres biologiques. La saison de reproduction a été déterminée en analysant l'évolution mensuelle de l'indice gonado-somatique et du pourcentage de maturité sexuelle. La structure démographique des débarquements de bonite à dos rayé est dominée par des tailles oscillant entre 45 et 52 cm. L'analyse de l'évolution mensuelle de l'indice gonado-somatique montrait que cette espèce se reproduit entre mai et juillet.*

RESUMEN

Se estudiaron las estructuras demográficas de bonito del Atlántico, Sarda sarda (Block, 1793) en la costa del Atlántico sur de Marruecos a partir de los datos de muestreo biológico recopilados en las unidades costeras que se dirigieron a esta especie entre 2012 y 2015. En total, se midieron 2.688 ejemplares para analizar las frecuencias de tallas y 158 ejemplares para la determinación de los parámetros biológicos. La temporada de reproducción fue determinada por el análisis de la evolución mensual del índice gonado-somático y el porcentaje de madurez sexual. La estructura demográfica fr los desembarques de bonito del Atlántico estuvo dominada por tallas entre 45 y 52 cm. El análisis de la evoluación mensual del índice gonado-somático mostraba que esta especie se reproduce entre mayo y julio.

KEYWORDS

Size frequency, reproduction, gonado-somatic index, sexual maturity, sex-ratio

Introduction

Atlantic bonito (*Sarda sarda* (Bloch, 1793)) which is a member of Scombridae is distributed in both sides of the tropical and subtropical Atlantic Ocean, in the Gulf of Mexico, and in the Mediterranean and Black Seas. In the Eastern Atlantic it is distributed from Oslo (Norway) to Port Elizabeth (South Africa), including the Mediterranean and Black Sea. In the western Atlantic off the east coast of the United States and Canada its usual northern limit is Cape Ann but also has been recorded along Nova Scotia (ICCAT Manuel, 2010 edition). Atlantic bonito is a small tuna species that feeds on small fishes, especially clupeoids such as anchovy, sardine, and sprat, and also on crustaceans (Campo *et al.*, 2006). Maximum length in the Atlantic is 91.4 cm fork length (FL) and 5.4 kg and in the Black Sea is 85 cm and 5 kg weight (Collete & Nauen 1983). Common size is 50 cm fork length and about 2 kg. Maximum published weight is 11.0 kg (IGFA 2001).

In Morocco, this species is distributed along the Atlantic Coast, especially in the southern part of the Atlantic coast (INRH 2015). Coastal fishing units, using various artisanal gears, exploit the Atlantic bonito. However, this species is also caught as by catch mainly by trawlers.

The fisheries targeting Atlantic bonito in Morocco are particularly important in terms of catches, but the information about the stock is not available. So, the study of biological parameters of this species is very important as the first step to a rational management of the stock.

This document presents results of some biological aspects of the Atlantic bonito, given that the knowledge regarding biology of this species is very limited in the Atlantic Ocean.

Material and Methods

Study area. Samples were collected between 2012 and 2015 at the ports of Laayoune and Dakhla. The geographical coordinates are respectively 27°05'43.66 N, 13°25'45.79 W and 23°39'33'' N, 15°56'47'' W (**Figure 1**).

This region of the Kingdom of Morocco is among the most important fishing areas in the world, due to the phenomenon of upwelling, which is almost permanent (Makaoui *et al* 2000). In the area north of Cap Boujdour, the surface temperature is between 18.4 and 20°C. In south of Cap Boujdour, temperatures between 18.4 °C and 21.6°C are recorded. The distribution of surface salinity corresponds to the temperature distribution, with 36.2-36.4 Ppm in Upwelling zone and 36.5-36.8 Ppm in deeper waters (**Figure 2**). The Atlantic bonito can adapt to temperatures ranging from 12 °C to 27°C and at salinities from 14 to 39 Ppm (Bianchi *et al* 1999).

Biological sampling and data sources. All biological sampling data of Atlantic bonito were collected by the fishery resources laboratories teams based in Laayoune and Dakhla.

For each biological sampling operation, four boxes (2 per category, small and Large) were taken randomly from the commercial catches of artisanal longliners to determine their size composition and estimate the biological parameters of Atlantic bonito.

Table 1 shows the number of individuals sampled annually per port. All individuals were measured at the nearest 1 cm (fork length). The biological parameters data were taken from 158 individuals during 2015 and the collected parameters for each fish were size (mm), weight (g), sex, sexual maturity stage, gonads weight (g) and liver weight (g).

Reproduction. Two approaches were used to determine the spawning period of the Atlantic bonito: a qualitative approach based on monitoring the monthly variation of percentage of different stages of gonad development, and a quantitative approach based on monthly monitoring of changes in gonad somatic index (GSI) (Lahaye 1980) and condition factor K (Do Chi 1978):

GSI = (GW/TW) x 100
where: GW is the gonads weight (g) and TW is individual total weight (g).

K= (TW*100)/L3
where: TW is individual total weight (g) and L is fork length (cm).

The sex ratio is defined as the proportion of each sex in the population, determined by macroscopic observation of gonads. The X^2 test was used in order to compare sex proportions. It consists of comparing the observed values and theorical values equality of the workforce.

$X^2_{obs}=\sum (N_{obs}-N_{the})^2/N_{the}$

where: N_{obs} is observed effective of sex in samples; N_{the} is the theoretical effective calculated of sex samples.

Principal hypothesis supposes that we have equal proportions of sexes. The alternative hypothesis proposes that we have a significant difference in proportions between the two sexes:

If $\chi_{obs} < \chi\ \mu; 0.05$, principal hypothesis is accepted.
If $\chi_{obs} > \chi\ \mu; 0.05$, principal hypothesis is rejected.

Results

Demographic structures. The size frequency analysis of Atlantic bonito catch by coastal longliners showed that the size of fish ranged between 31 cm and 74 cm. The size classes (45-55 cm) are the most dominant in catches. Concerning the port of Laayoune, the analysis of demographic structures in 2012, showed a predominance of sizes between 44 and 66cm, with two modal classes, 48-49 cm (26%) and 50-51 cm (21%). While in 2013, the demographic structure covers sizes between 41 and 72 cm, with two modal classes, 49-50 cm (17%) and 51-53 cm (27%).

For Dakhla port, the analysis of the annual size frequency distribution of catches showed a wide range of sizes, with a dominance of sizes between 45 and 55 cm. By comparing the two ports, there is the appearance of sizes less than 40 cm at Dakhla, which is not the case in Laayoune where the minimum size is 40 cm FL.

In 2012 and 2013, the analysis of the monthly distribution of sizes showed generally the dominance of sizes between 48 and 58 cm, with the appearance of large sizes in June, July, August, November and December.

The monthly size structure of Atlantic bonito at the port of Dakhla showed the presence of large sizes in June, July and August (**Figures 3 and 4**).

Reproduction. The analysis of the monthly evolution of GSI showed that the reproduction period of Atlantic bonito is between May and July (**Figure 5**). The smallest mature female in our samples measures 42 cm (45 cm, Dardignac 1962), while the smallest mature male measures 41 cm (40 cm, Dardignac 1962). These results are confirmed by the monthly monitoring of the percentage of mature individuals. The highest proportion of mature individuals was recorded in May (80%), June (72.7%) and July (77.7%) (**Figure 6**).

Condition factor (K). The condition factor (K) varies in the opposite direction of the GSI. Indeed, the maximum value of this index was recorded during the biological recovery of the species (**Figure 7**).

Sex-ratio. One hundred eighty five individuals of Atlantic bonito were sampled in 2015 for biological studies. Of which 75 females and 83 males. The difference in proportion of the two sexes is significant according to the seasons of the year (**Table 2**). The proportions of males and females sampled during 2015 are shown in **Figure 8**.

Discussion

The sizes frequency analysis of Atlantic bonito at ports of Laayoune and Dakhla shows a dominance of mature individuals, whose size is larger than 40 cm. However, we observe small percentage of sizes smaller than 40 cm only at the port of Dakhla. Knowledge of the early life stages in tunas is very scarce, during the first life stages bonitos are not caught and juvenile life history is unknown (Zengin *et al.* 2005).

Unpublished studies on selectivity conducted in the southern Atlantic coast of Morocco (Baibbat *et al.* 2015), suggest that Atlantic bonito is fully accessible to fishing only from the age of 4 years (FL > 40 cm).

As seen in **Table 3**, the length range of sampled specimens in this study was similar to those found in other studies: Gibraltar Strait: 40.0–55.0 cm (Rodriguez-Roda, 1966) and 33.0– 70.5 cm FL (Rey *et al*., 1984); the Spanish Mediterranean coasts: 41.0–48.0 cm (Macias *et al*., 2005) and 40.0–61.0 cm (Valeiras *et al*., 2008); Tiran and Sicily coasts of Italy, respectively: 35.0–82.0 cm and 35.0–67.0 cm (Di Natale *et al*., 2006); Adriatic Sea coasts: 33.0–67.0 cm (Franičević *et al.* 2005); the Turkish coasts of the Black Sea, the Sea of Marmara, and the Mediterranean Sea: 29-37 cm (Yankova *et al* 2013), 14.0–90.0 cm (Kara, 1979), 23.0–66.0 cm (Oray *et al*., 2004), 23.5–71.0 cm (Ateş *et al*., 2008), 23.8–72.0 cm (Cengiz, 2013).

All the species of genus are heterosexual and without any dimorphism, however some fishermen are able to recognize male from female by the rigidity of the ventral skin in proximity of the anus (Dardignac 1962; Demir 1963).

Atlantic bonito inhabits neritic and offshore waters, but spawning generally occurs in more coastal area. In the Western Mediterranean, there are several spawning grounds: the Algerian coast, Sicily and Balearic Island, the Tyrrhenian, the Ligurian and the Catalan Sea. On the Atlantic coast of Morocco, spawning areas were previously identified near Agadir and Casablanca-Fedala (Dardignac 1962; Rodriguez-Roda & Dicenta 1980).

The monthly analysis of the GSI and the stages of sexual maturity showed that Atlantic bonito reproduction period is between May and July. The maximum values of GSI as well as the maximum of gonads activity were recorded during this period of the year.

These results are in agreement with those by Dardignac (1962), however, other authors reported different period in different area (**Table 4**). The observed difference in the spawning season could be due to several factors such as variability in environmental conditions (e.g., temperature and salinity), season habitat, fishing area, depth, sampling methodology, selectivity of fishing gear, sex and gonad maturity (Ricker 1969; Baganel & Tesch 1978; Potts *et al* 1998; Basilone *et al* 2006; Froese 2006; Soykan *et al* 2010).

The analysis of the monthly evolution of the condition factor (K) showed that both male and female have a similar strategy in using intake energy during the gonads maturity. The maximum values of K correspond to the months that precede the beginning of the reproduction. This implies an accumulation of reserves by the species for the reproduction process, then a transfer of energy for gamete production.

Sex ratio in Atlantic bonito was previously studied in Mediterranean (Rodriguez-Roda 1966). In this paper, a significant difference was observed between the two sexes during the 4 seasons (**Table 5**). Other studies in the Ionian Sea in the period 1992-1994 (AAVV 1995) found a parity of sex ratio.

Conclusion

The Atlantic bonito stock status remains unknown, due to the lack of statistical and biological data as well as the population structure information. In addition, continued fishing pressure on this species without any regulation could ultimately reduce the spawning stock below levels sufficient to remain the population. Therefore, it is expected that this results would contribute to assess the stocks of species and provide management measures for this species within ICCAT.

References

AAVV.1995. Characterization of large pelagic stocks *(Thunnus thynnus* L., *Thunnus alalunga* Bonn, *Sarda sarda* Bloch, *Xiphias gladius* L.) in the Mediterranean. Final report EC N°XIV MED/91/012.

Ateş C, Deval MC, Bok T (2008). Age and growth of Atlantic bonito (*Sarda sarda* Bloch, 1793) in the Sea of Marmara and Black Sea, Turkey. J Appl Ichthyol 24: 546–550.

Atlantida, 2007 acoustic survey monitoring of pelagic ecosystem by Atlantida ship in Moroccan waters in the area between Cape Cantin and Cape Blan.

Baganel TB, Tesch FW (1978). Age and growth. In: Baganel TB, editor. Methods for Assessment of Fish production in Fresh Waters. Oxford, UK: Blackwell Scientific Publications, pp. 101–136.

Baibbat Sid'Ahmed, Noureddine Abid, Carlos Palma and Laurence Kell. 2015. A lengthbased assessment for Atlantic bonito (*Sarda sarda*). Collect. Vol. Sci. Pap. ICCAT, 72(8): 2208-2220.

Basilone G, Guisande C, Patti B, Mazzola S, Cuttitta A, Bonanno A, Vergara AR, Maneiro I (2006). Effect of habitat conditions on reproduction of the European anchovy (*Engraulis encrasicolus*) in the Strait of Sicily. Fish Oceanogr 15: 271–280.

Bianchi, G., K. E. Carpenter, J.-P. Roux, F.J. Molloy, D.Boyer and H.J. Boyer, 1999- Field guide to the living marine resources of Namibia. FAO species identification guide for fishery purposes. Rome, FAO. 265 p., 11 o colour plates.

Bigelow, H. B. and W.C. Schroeder. 1953. Fishes of the Gulf of Maine. U.S. Fish. Wildl. Serv. Fish. Bull. 53: 577pp.

Campo D, Mostarda E, Castriota L, Scarabello, MP, Andaloro F (2006). Feeding habits of the Atlantic bonito, *Sarda sarda* (Bloch, 1793) in the southern Tyrrhenian Sea. Fish Res 81: 169–175

Cengiz Ö (2013). Some biological characteristics of Atlantic bonito (*Sarda sarda* Bloch, 1793) from Gallipoli Peninsula and Dardanelles (northeastern Mediterranean, Turkey). Turk J Zool 37: 73–83.

Collette, B. B. and C. E. Nauen., 1983 FAO species catalogue. Vol. 2. Scombrids of the world. An annotated and illustrated catalogue of tunas, mackerels, bonitos and related species known to date. FAO Fish. Synop. 125(2). 137 pp.

Dardignac, J. 1962. La bonite du Maroc Atlantique (*Sarda sarda* Bloch). Rev. Trav. Inst. Pêches Marit., 26(4): 399-406.

Demir, M. 1963. Synopsis of biologycal data on bonito *Sarda sarda (*Bloch) 1793. FAO Fish Rep. 6(2):101-129.

Di Natale A, Mangano A, Celona A, Navarra E, Valastro M (2006). Atlantic bonito (*Sarda sarda*) catch composition in the Tyrrhenian Sea and in the Strait of Sicily in 2004. Coll Vol Sci Pap ICCAT 59: 564–570.

Dieuzeide, R., M. Novella, J. Roland. 1954. Catalogue des poissons des côtes Algériennes. Stat. Acq. Peches Castiglione 6: 384 pp.

Do Chi T. 1978. Modèles cinétiques et structuraux en dynamique des populations exploitées. Application aux squilles Squilla mantis L (Crustacés Stomatopodes) du golfe de Lion. Thèse Doct. Etat es Sciences U. S. T. L. Montpellier, 272 p.

Fournestin, J., J. Dardignac, C. Maurin, A. Vincent, R. Coupè, H. Boutiere. 1958. Données nouvelles sur les poissons du Maroc Atlantique. Rev. Tra. Inst. Peches Marit. 22: 379 – 493.

Frade, F. and E. Postel. 1955. Contribution à l'étude de la reproduction des scombridés et thonidés de l'Atlantique tropical. Rapp. P. - V Reun. CIESM 137: 33 – 35.

Franičević M, Sinovčić G, Čikeš Keč V, Zorica B (2005). Biometry analysis of the Atlantic bonito, *Sarda sarda* (Bloch, 1793), in the Adriatic Sea. Acta Adriat 46: 213–222.

Froese R (2006). Cube law, condition factor and weight–length relationships: history, meta-analysis, and recommendations. J Appl Ichthyol 22: 241–253.

ICCAT. 2010. ICCAT Manual. International Commission for the Conservation of Atlantic Tuna. In: ICCAT Publications [on-line]. Updated 2013

IGFA, 2001 Database of IGFA angling records until 2001. IGFA, Fort Lauderdale, USA.

INRH. 2015. Abid N, Baibbat.S, Benchoucha.S, Al Arraf.S, El Fanichi.C, Oumarous.M, Idrissi.MH, Hamdi.H. National Report on large pelagic 2015.

Kahraman Abdullah Ekrem, Didem Göktürk, Taner Yildiz, Uğur uzer, 2014, Age, growth, and reproductive biology of Atlantic bonito (*Sarda sarda* Bloch, 1793) from the Turkish coasts of the Black Sea and the Sea of Marmara Turkish Journal of Zoology (2014) 38:614-621.

Kara F (1979). Observations on growth and relationship between length and weight of *Sarda sarda* (Bloch). Inv Pesq 43: 95–105.

Lahaye J. 1980. Les cycles sexuels chez les poissons marins. Oceanis, 6, 7, 637-654.

Macias D, Gomez-Vives MJ, Garcia S, Ortiz de Urbina JM (2005). Reproductive characteristics of Atlantic bonito (*Sarda sarda*) from the south-western Spanish Mediterranean. Col Vol Sci Pap ICCAT 58: 470–483

Makaoui.A, J. Larissi, A.Orbi, K.Hilmi, S.Zizah. (2000). Evolution des principales caractéristiques océanographiques de la côte Atlantique marocaine de 1994 à 1998. In Rapp. INRH.

Oray IK, Karakulak FS, Zengin M (2004). Report on the Turkish bonito (*Sarda sarda*) fishery in 2000/2001. Coll Vol. Sci. Pap., ICCAT 56: 784–788.

Postel, E. 1955. Contributions à l'étude de la biologie de quelques Scombridae de l'Atlantique tropicooriental. Ann. Stn. Oceanogr. Salammbò 10: 167 pp.

Potts J, Manooch CS, Vaughan DS (1998). Age and growth of vermilion snapper from the southeastern United States. Trans Amer Fish Soc 127: 787–795.

Rey, J. C., Alot, E. and Ramos, A., 1984. Synopsis of biological nice, Sarda Sarda (Bloch) in the Mediterranean and Eastern Atlantic. Collect. Vol. Sci. Pap. ICCAT, 20(2): 469-502.

Ricker WE (1969). Effects of size-selective mortality and sampling bias on estimates of growth, mortality, production and yield. J Fish Res Board Can 26: 479–541.

Rodriguez-Roda J (1966). Study tunny , Euthynnus alleteratus (Raf.) Beautiful, Sarda Sarda (Bloch) and frigate tuna , Auxis thazard (Lac.) , Captured by the Spanish almadrabas. Inv Pesq 30: 247–292 (in Spanish).

Rodriguez-Roda, J. 1980. Area sunset tuna , frigate tuna and bonito in the coasts of Spain and Morocco. Col. Doc. ICCAT 15 (2). Madrid

Sabatés, A. and L. Recasens. 2001. Seasonal distribution and spawning of small tunas (*Auxis rochei* and *Sarda sarda*) in the northwestern Mediterranean. Sci. Mar. 65 (2): 95-100.

Sanzo, L. 1932. Eggs and early larval stages of Sardinian Pelamys Cuvier and valenc. Mem. Com. Talass. Ital. 188: 3- 9 + 1 Plate.

Sette, O.E. 1943. Biology of the Atlantic mackerel (Scomber scombrus) of North America, Part 1: Early life history, including the growth, drift, and mortality of the egg and larval populations. U. S. Fish Wildl. Serv. Fish. Bull. 50: 149 – 237.

Soykan O, İlkyaz AT, Metin G, Kınacıgil HT (2010). Growth and reproduction of blotched picarel (Spicara maena Linnaeus, 1758) in the central Aegean Sea, Turkey. Turk J Zool 34: 453–459.

Valeiras X, Macias D, Gomez MJ, Lema L, Alot E, Ortiz de Urbina JM, de la Serna JM (2008). Age and growth of Atlantic bonito (*Sarda sarda*) in western Mediterranean Sea. Collect Vol Sci Pap ICCAT 62: 1649–1658.

Yankova M, Pavlov D, Mihneva V (2013). Length–weight relationships of eight fish species from the Bulgarian Black Sea waters. In: Gupta VK, Verma AK, editors. Animal Diversity, Natural History and Conservation, Vol 3. New Delhi, India: Daya Publishing House, pp. 189–195.

Zengin, M., F. S. Karakulak and I.K. Oray, 2005. Investigations on bonitos (*Sarda sarda*, Bloch 1793) on the southern Black Sea coast of Turkey. Collect. Vol. Sci. Pap. ICCAT, 58(2): 510-516.

Table 1. Number of Atlantic bonito individuals sampled per year and per port.

Year	*Number*	*Port*
2012	498	Laayoune
2013	875	Laayoune
2014	530	Dakhla
2015	785	Dakhla

Table 2. Variations of proportions of males and females with seasons (SS= significant).

	Winter	*Spring*	*Summer*	*Autumn*
Male	*32*	11	15	25
Female	21	18	13	23
Total	53	29	28	48
%Male	39.62	62.07	46.43	47.92
%Female	60.38	37.93	53.57	52.08
X^2cal	5.36	7.42	0.98	0.71
P	0.25	0.12	0.91	0.95
Rules decisions	SS	SS	SS	SS

Table 3. The length range of specimens for Atlantic bonito in different area.

Authors	*Area*	*N*	L_{min}-L_{max} *(cm)*
Rodriguez-Roda (1966)	Strait of Gibraltar, Spain	165	40-55
Rey *et al* (1984)	Strait of Gibraltar, Spain	878	19-72
Macias *et al* (2005)	Spanish coast of the Mediterranean Sea	183	41-48
Valeiras *et al* (2008)	Spanish coast of the Mediterranean Sea	136	40-61
Di Natale *et al* (2006)	Tyrrhenian coast, Italy	240	35-82
Di Natale *et al* (2006)	Sicilian coast, Italy	109	35-67
Franičević *et al* (2005)	Coast of the Adriatic Sea	665	33-67
Kara (1979)	Turkish coasts of the Black Sea and the Sea of Marmara	1608	14-90
Oray *et al* (2004)	Turkish coasts of the Black Sea and the Sea of Marmara	1168	23-66
Ateş *et al* (2008)	Turkish coasts of the Black Sea and the Sea of Marmara	694	23-71
Cengiz (2013)	Northern Aegean Sea (Gallipoli Peninsula and Dardanelles)	238	23-72
Yankova *et al* (2013)	Black Sea, Bulgaria	411	29-37
Kahraman *et al* (2014)	Turkish coasts of the Black Sea and the Sea of Marmara	212	17-63
Present study (2016)	Moroccan Atlantic coast	2688	31-74

Table 4. Spawning periods and grounds of Atlantic bonito (from Rey *et al* (1984) with addition).

Authors	*Area*	*Period*
Sanzo (1932)	Sicily	May 20 - June 30
Dieuzeide *et al* (1954)	Algerian coast	March-May
Rodriguez-Roda (1966)	Gibraltar	May-July
Fournestin (1958)	Atlantic Morocco	June-July
Frade & Postel (1955)	Tropical East Atlantic	February-March
Postel (1955)	Dakar	December-June
Bigelow & Schroeder (1953)	Western Atlantic-USA	June
Sette (1943)	Western Atlantic	July
Sabates & Recasens (2001)	Catalan coast	July
Present study	Southern Atlantic Morocco	May-July

Table 5. Sex ratio of Atlantic bonito in the Ionian Sea.

Year	*Sex*	*Samples*	*Sex ratio*
1992	Males	130	1.24
	Females	105	
1993	Males	33	0.73
	Females	44	
1994	Males	24	0.77
	Females	31	
Total	Males	187	1.04
	Females	180	

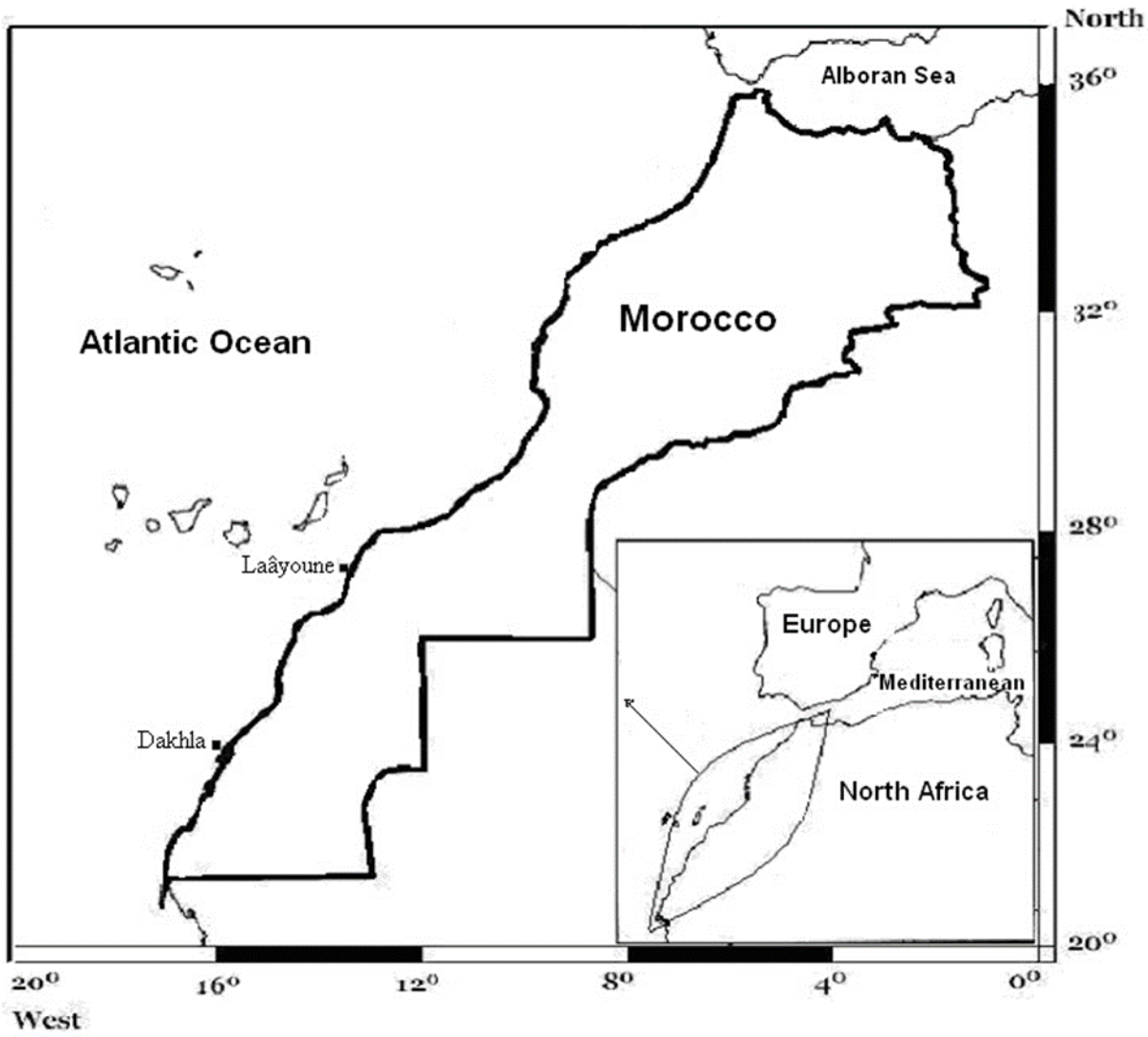

Figure 1. Location of the study area.

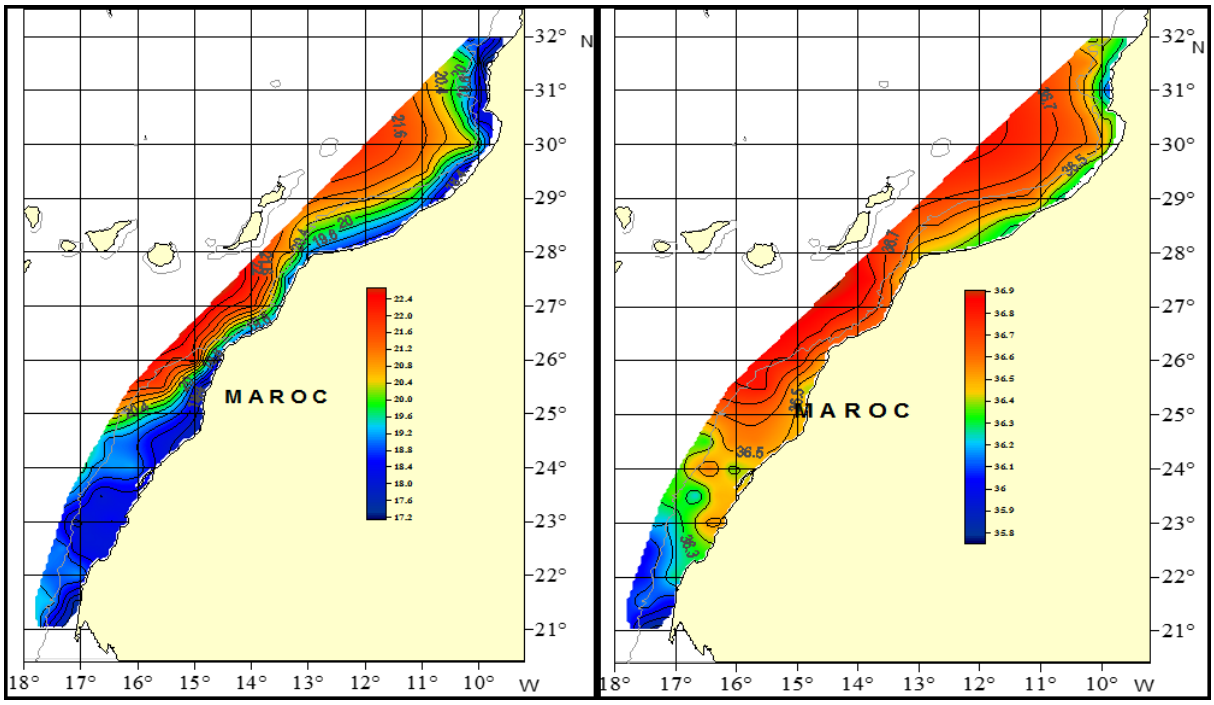

Figure 2. Distribution of the surface temperature in °C (left) and salinity in Ppm right) (Source: Atlantida 2007).

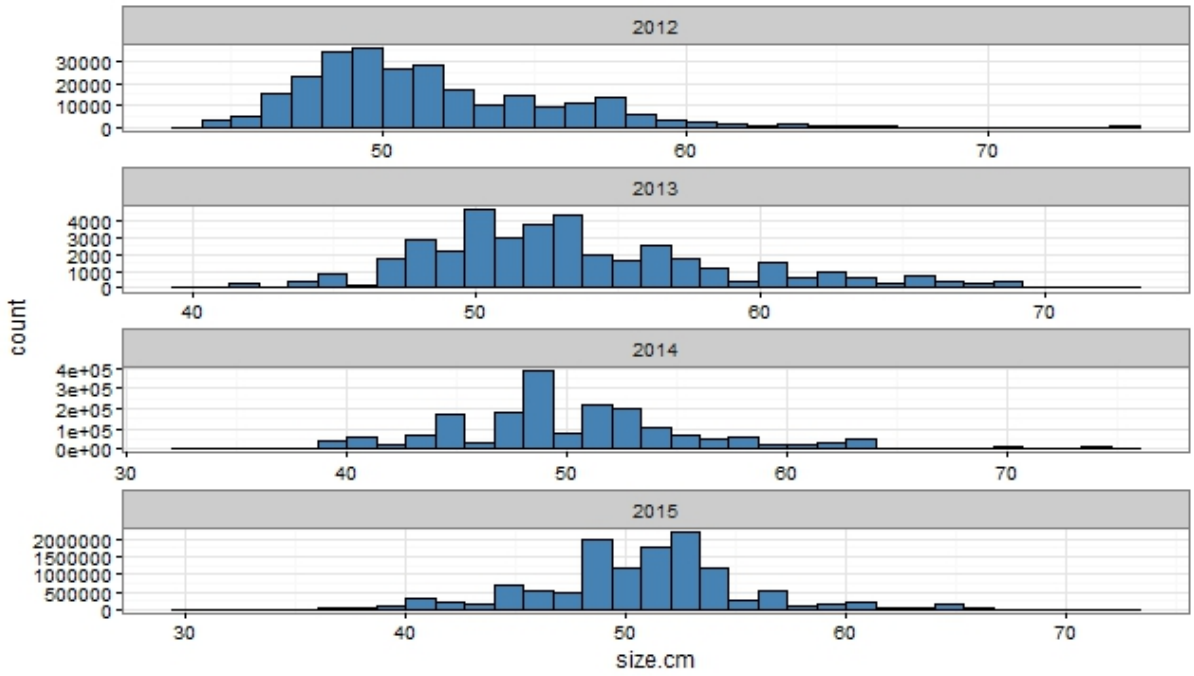

Figure 3. Annual size structure distribution of Atlantic bonito sampled at the port of Laayoune (2012 and 2013) and Dakhla (2014 and 2015).

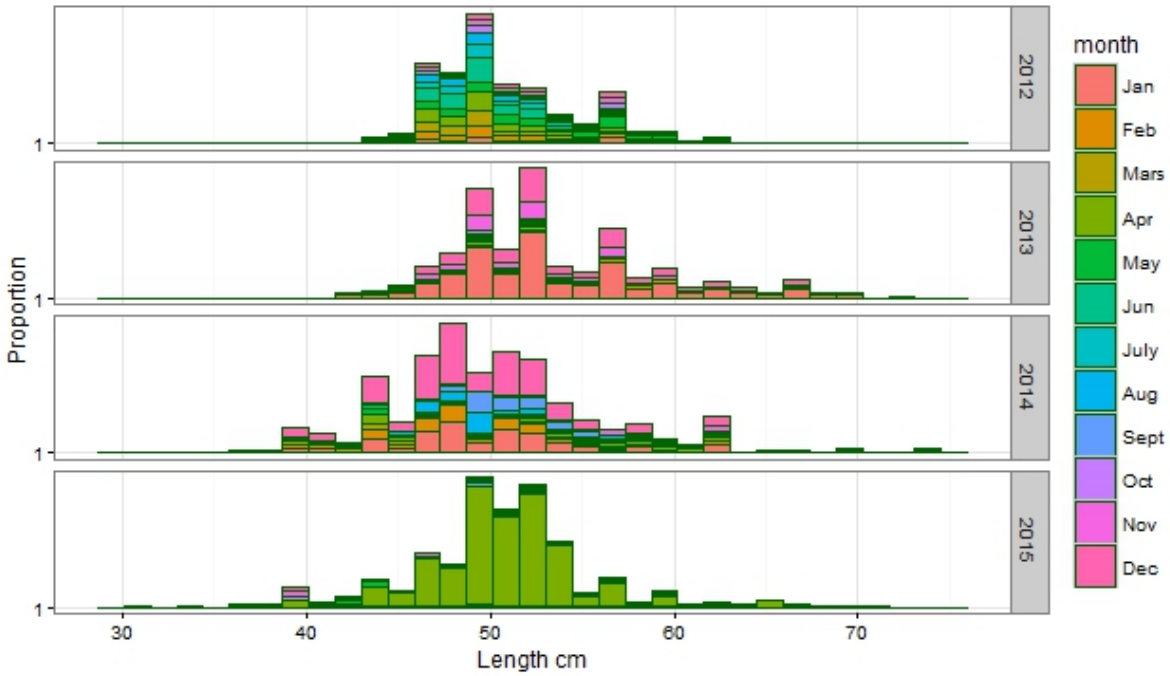

Figure 4. Annual, monthly size distribution of Atlantic Bonito sampled in ports of Laayoune (2012 and 2013) and Dakhla (2014 and 2015).

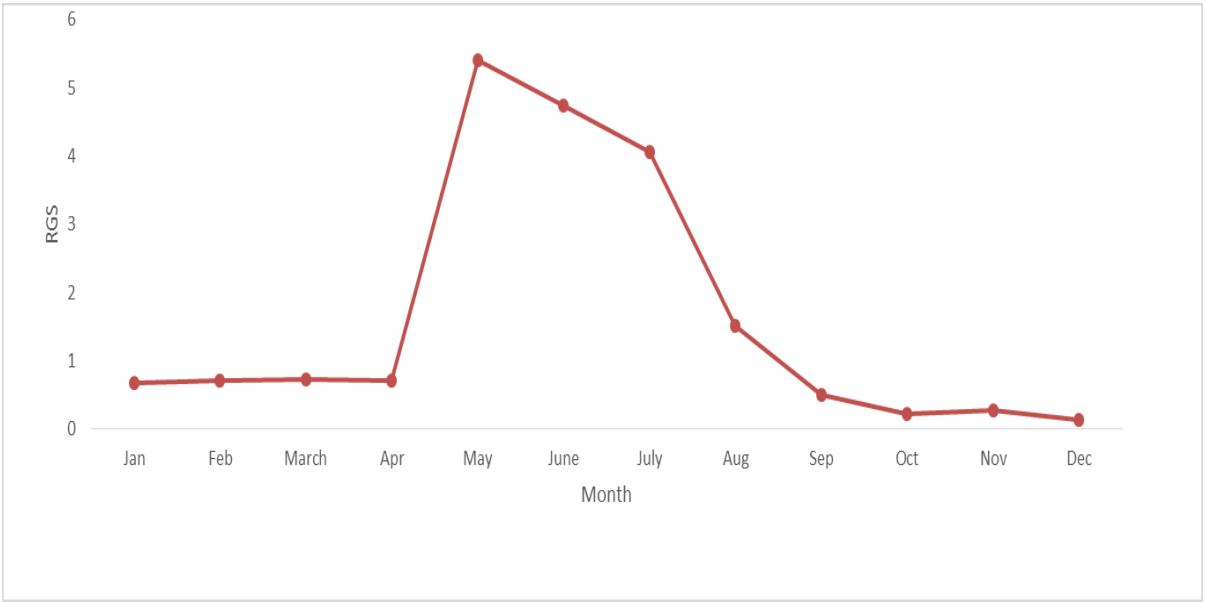

Figure 5. Monthly variations of gonado-somatic index of Atlantic bonito.

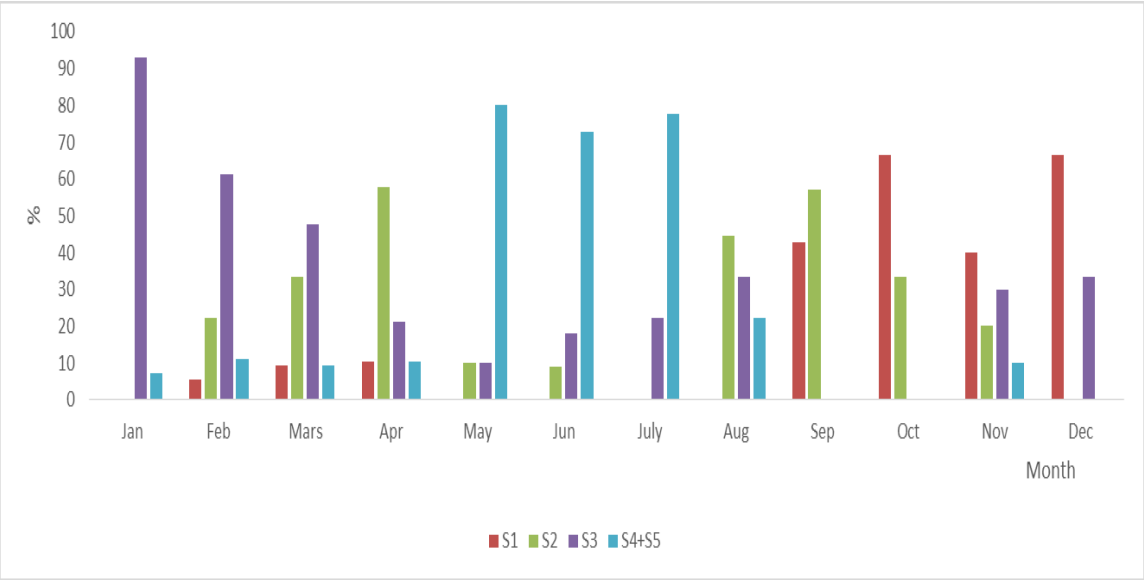

Figure 6. Sexual maturity stages of Atlantic bonito (S1, S2…S5, are the maturity stage).

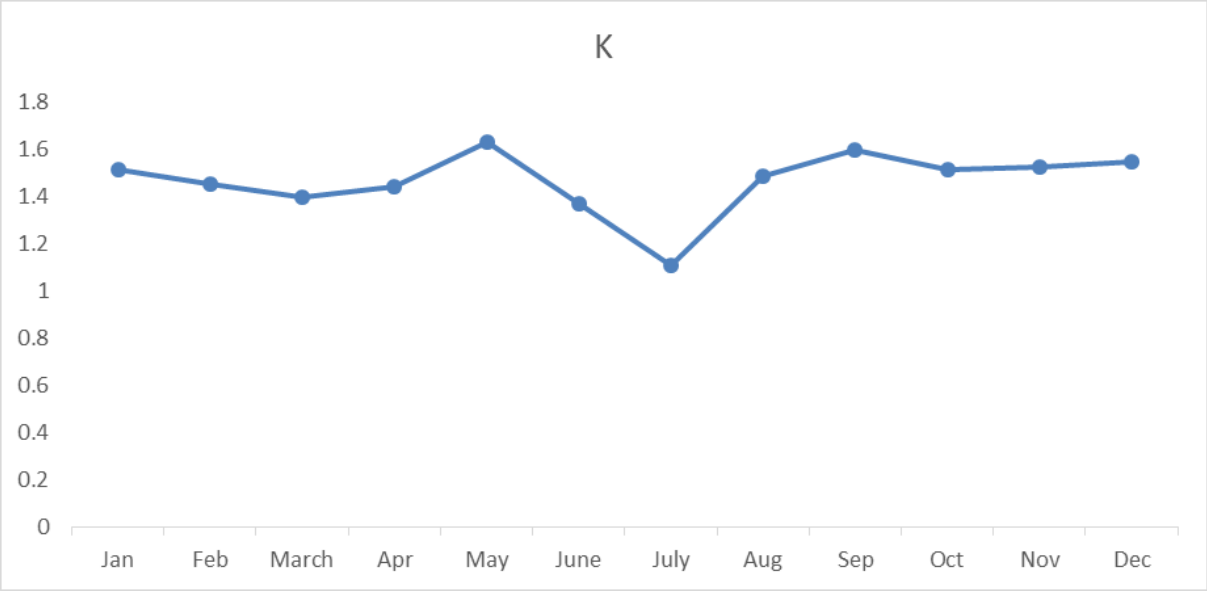

Figure 7. Condition factor of Atlantic bonito.

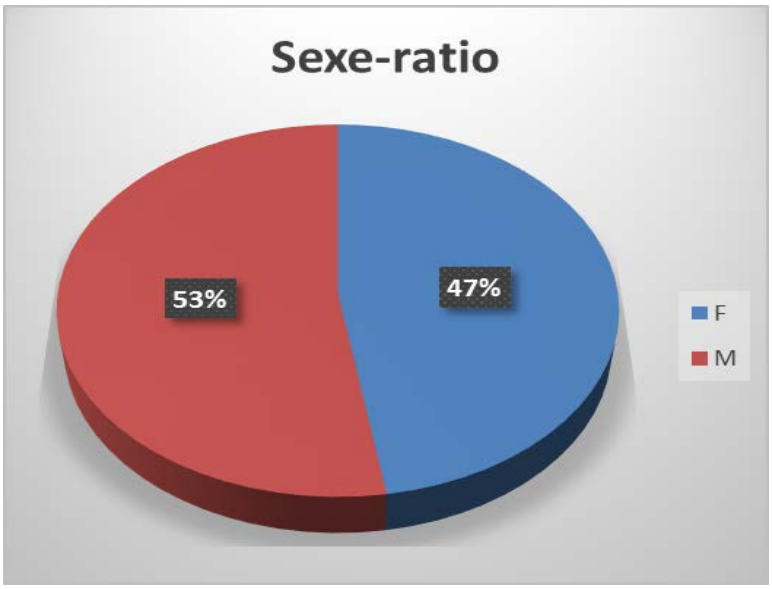

Figure 8. Proportions of males and females in Atlantic bonito.