DOI: 10.2478/cjf-2022-0007

CODEN RIBAEG ISSN 1330-061X (print)
1848-0586 (online)

sciendo

SEX RATIO AND MALE MATURITY FOR SHORTFIN MAKO SHARK IN THE MOROCCAN CENTRAL ATLANTIC COAST

Jihade Alahyene[1*], Brahim Chiahou[1], Hammou El Habouz[2], Abdelbasset Ben-Bani[2]

[1] *Chouaib Doukkali University, Faculty of Sciences, Department of Biology, El Jadida, Morocco*
[2] *National Fisheries Research Institute, Agadir, Morocco*

*Corresponding Author: jihad.20081@hotmail.com

ARTICLE INFO

Received: 10 December 2021
Accepted: 25 March 2022

Keywords:
Sex ratio
Maturity stage
Size at maturity
Morocco

ABSTRACT

The study on the reproductive biology of shortfin mako shark is carried out through the commercial catches from artisanal boats active on the Moroccan Central Atlantic coast and landed in Sidi Ifni Port, for the period between October 2017 and August 2019. A total of 1690 individuals were examined, including 846 females and 844 males. As a result, the overall sex ratio of shortfin mako sharks tends towards equilibrium. The monthly sex ratio in shortfin mako sharks shows that males are more abundant compared to females in winter. In autumn and spring, we encounter more females. For the remainder of the year, the sex ratio tends to be balanced, with a slight predominance of males. Three stages of the maturity scale were found. Juvenile males with a rate of 50% were most frequently encountered during the study, followed by subadults with a rate of 32% and adults with a rate of 18%. The size at first sexual maturity of the male shortfin mako shark was estimated to be between 180 cm and 200 cm in total length, corresponding to an estimated age of 6 years.

How to Cite

Alahyene, J., Chiahou, B., El Habouz, H., Ben-Bani, A. (2022): Sex ratio and male maturity for shortfin mako shark in the Moroccan Central Atlantic coast. Croatian Journal of Fisheries, 80, 67-75. DOI: 10.2478/cjf-2022-0007.

INTRODUCTION

According to Cortés et al. (2010), ecological risk assessments carried out in 2010 and 2012 for pelagic sharks in the Atlantic showed that shortfin mako shark *Isurus oxyrinchus* Rafinesque 1810 is the most vulnerable species due to its very low productivity and high sensitivity, which differs from those of other sharks that occupy the same niche (e.g. *Prionace glauca*) (ICCAT, 2017). Shortfin mako shark, or shortfin, is one of five species belonging to the family Lamnidae. This species is widely distributed throughout the world and is a highly migratory marine shark that preferentially inhabits oceanic areas in almost all oceans. This makes it vulnerable to coastal and oceanic fishing. This species is listed in the CITES Appendix II and in the IUCN Red List as Endangered. A recent stock assessment indicated the North Atlantic shortfin mako was overfished and its overfishing was continuing. A similar situation may occur for stocks in the South Atlantic region (Anon, 2019). Shortfin mako shark populates the temperate and tropical regions of the ocean. It is commonly associated with the Gulf Stream (Compagno, 2001). It prefers epipelagic waters with temperatures ranging from 17 to 22 °C and is found at depths of up to 500 meters (Casey and Kohler, 1992; Poisson, 2007). Also, it is often found in the same waters as other pelagic sharks (blue shark, swordfish, etc.) and tuna (Cortés et al., 2010). In Morocco, shortfin mako shark is captured by the active flotilla along the Moroccan coast. It is caught, incidentally, by longline fleets targeting swordfish (Baibbat et al., 2017). For the rational management of this species, basic scientific data is essential. However, its biological cycle is unknown because no biological data is available in Morocco. This study presents an analysis of the sex ratio and male length at first maturity of shortfin mako sharks obtained through regular biological sampling from commercial catches of artisanal boats that fished off the Moroccan coast of the central Atlantic and landed in the port of Sidi Ifni between October 2017 and August 2019. The objective of this work is to estimate the reproductive biological parameters (sex ratio, maturity stage and sexual maturity) and also to investigate the population dynamics of shortfin mako shark off the Atlantic coast of Morocco. These parameters could be taken into consideration when developing conservation and management measures to improve knowledge of the biological cycle of shortfin mako shark and ensure its sustainability and rational exploitation in Moroccan waters.

MATERIALS AND METHODS

Sampling design and study area

The area covers the Moroccan Central Atlantic coast, and the sampling is done in Sidi Ifni Port (latitude: 29°21'N; longitude: 10°11'W), located about 170 km south of Agadir. The artisanal fishing area was between 10°W and 12°W longitude, and between 29°N and 31°N latitude, and was bound to the north by the coast of Aglou and to the south by a beach commonly known as Plage Blanche (Fig.1).

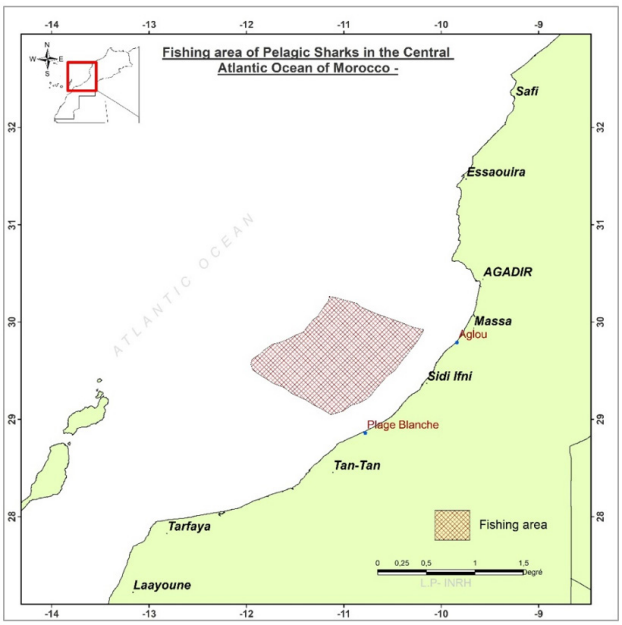


Fig 1. The geographic location of the shortfin mako shark fishing area and sampling zone

This area is subject to a subtropical climate where the surface water temperature varies between 14 °C and 22.1 °C (seasonal acoustic surveys carried out in spring and autumn by the R/V Al Amir Moulay Abdallah during the period 2017–2019). A total of 1690 specimens of shortfin mako shark were sampled monthly during the study period (October 2017–August 2019). The specimens were obtained by longline vessels from the catches of artisanal boats active in Sidi Ifni Port using the simple random sampling technique. At the fish market, all the measurements, sex identification and maturity stage are taken. The monthly number of sampled individuals of shortfin mako shark is presented in the table below (Table 1).

Total length (TL) measurements were taken with a tape measure on each specimen, with the caudal fin in its natural position, and recorded to the nearest centimetre.

Sex ratio

The sex ratio is defined as the proportion of males to females in relation to the total number, and provides information about the balance of the sexes within the population by the month and size. The sex ratio generally reflects the femininity rate of the population (Kartas and Quignard, 1984):

$$SR=(Nf/(Nf+Nm))*100$$

where (Nf) represents the number of females, (Nm) represents the number of males and (SR) represents the sex ratio.

Table 1. The monthly number of shortfin mako shark individuals sampled

Year	Season	Month	Number	
			Female	Male
2017	Autumn	October	41	40
		November	59	39
	Winter	December	13	16
		January	1	3
		February	3	8
	Spring	March	12	7
		April	17	13
		May	35	16
2018	Summer	June	120	97
		July	60	58
		August	14	12
	Autumn	September	137	161
		October	26	23
		November	11	7
	Winter	December	13	16
		January	2	3
		February	3	2
2019	Spring	March	57	72
		April	77	82
		May	64	70
	Summer	June	19	24
		July	34	37
		August	28	38
Total		**1690**	**846**	**844**

Sexual maturity

According to the maturity stage scale of oviparous and viviparous cartilaginous fishes proposed by Stehmann Mathias (2002), the maturity stages of male mako sharks in this study area are determined after a macroscopic examination of their genital organs (Claspers) (Table 2), as shown in Figure (2).

Thus, the length (cm) of the claspers (LC) is measured using a tape measure (Fig. 2). This length extends from the anterior edge of the cloaca to the tip of the posterior

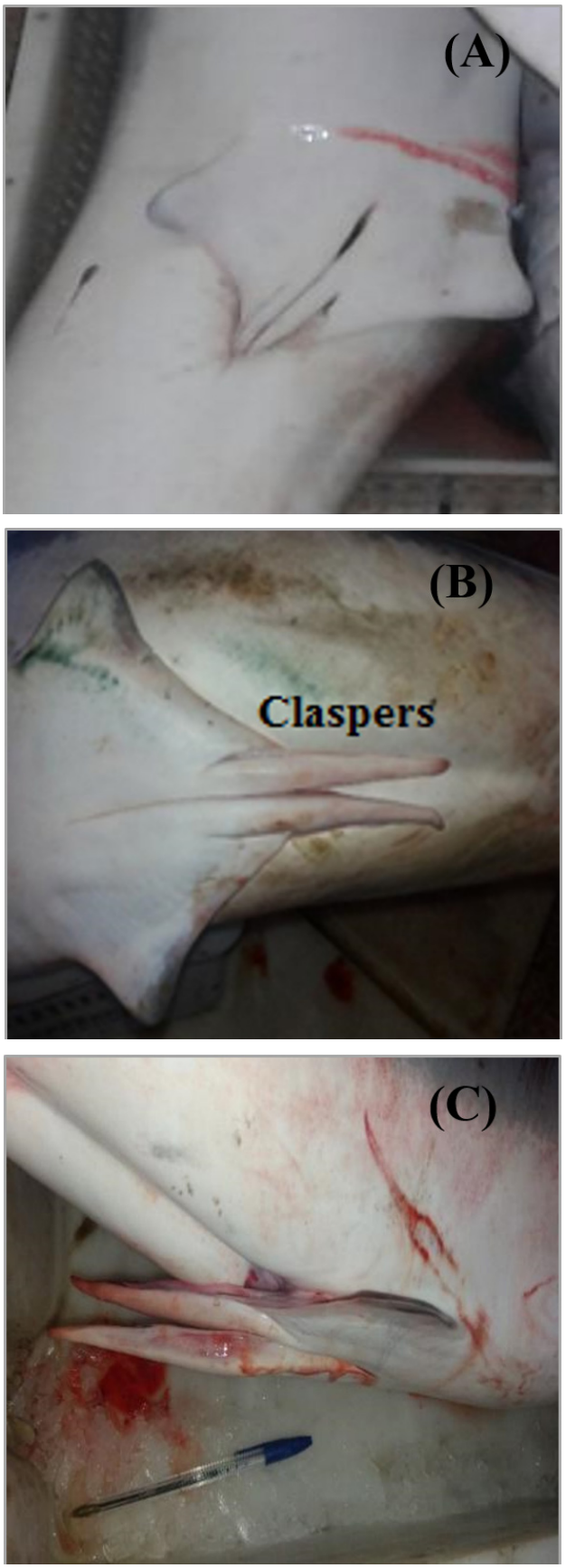


Fig 2. The size of the male genital organ (Claspers) in shortfin mako shark at different stages of maturity: (A) juvenile, (B) subadult and (C) adult

claspers (Branstetter et al., 1986). For the females, the stages of maturity could not be determined because they are not eviscerated and no external clues provide information on their reproductive cycle.

Table 2. Mature stage scales for male placental viviparous sharks

Stage		Characteristics
(A) Juvenile	Immature	Claspers are small, whitish, poorly developed, like small sticks, and flexible, being shorter than the extremities of the posterior pelvic fins
(B) Subadult	Immature	The claspers become prolonged (extended), longer than the posterior pelvic fin lobes, but their skeleton is still soft and flexible
(C) Mature	Adult	The claspers are fully formed and stiff, eventual-ly presenting cartilaginous hooks, claws or spines of glans free and sharp, and the gonads are enlarged, well rounded, filled with flowing sperm, and often reddish in colour

Size and age at first sexual maturity

The estimation of size at first sexual maturity (L_{50}) in males was made by total length. The percentage of mature individuals in each size category was calculated by setting the threshold for maturity at stage 3, which corresponds to the beginning of the maturation phase of the male genital organ. The symmetrical sigmoid model is chosen for the L_{50} graphical representation (Dagnelie P, 1973): (1)

$$\boldsymbol{P = \frac{1}{(1 + e^{-(a+b.L(t))})}}$$

The parameters a and b are obtained by a logarithmic transformation of the expression (1) which allows a linear equation (2), having the formula: (2)

$$\boldsymbol{-Ln\left(\frac{1-p}{p}\right) = a + b * L(t)\ ;\ L_{50} = -\frac{a}{b}}$$

where P is the percentage of mature individuals, L(t) is the total length (cm), a and b are constants; they are the parameters of the fitted line.

The age at sexual maturity (tm) was calculated by inserting the L_{50} maturity size derived from this study into the existing growth of shortfin mako sharks in the Moroccan Central Atlantic coast obtained using the mathematical model of Von Bertalanffy for growth as a function of age (Alahyene et al., 2021) by the following equation:

$$\boldsymbol{L(t) = L\infty(1 - e^{-k(t-t0)})}$$

where *Lt* is the length at age *t*, *L*∞ is the asymptotic length to which the fish grows, *k* is the growth-rate parameter, and t_0 is the nominal age at which the length is zero.

The Von Bertalenffy parameters *L*∞, *k* and t_0 for the growth equation are determined from the size-frequency distribution using the LFDA (Length Frequency Distribution Analysis) software and its subprogram ELEFAN (Electronic Length Frequency Analysis) (Kirkwood et al., 2003). The obtained results are described in Table 3.

Table 3. Von Bertalanffy parameters for the growth equation of shortfin mako sharks in Moroccan Central Atlantic coast, 2017–2019 (Alahyene et al., 2021)

Sex	L∞ (cm)	k (Year^{-1})	t_0	Number
Male	349.40	0.14	-0.34	517

RESULTS

Sex ratio

In a sample of 1690 individuals of sizes between 65 and 317 cm, 846 were females and 844 were males, with rates of 50.1% and 49.9%, respectively. As a result, the overall sex ratio of shortfin mako sharks tends towards an equilibrium 1: 0.9 (M : F), with a slight predominance of males. Found using the X2 test, the contingency table with 51 size classes (n = 51 and ddl = 50) shows there is no significant difference between the sex ratio of females and males (Chi-square test, X2 = 43 < 67.5048 at ddl = 50 and *p* = 0.05). The distribution of the sexes, according to the size classes (cm) of mako shark (Fig. 3), shows that females are generally dominant compared to males in all sizes.

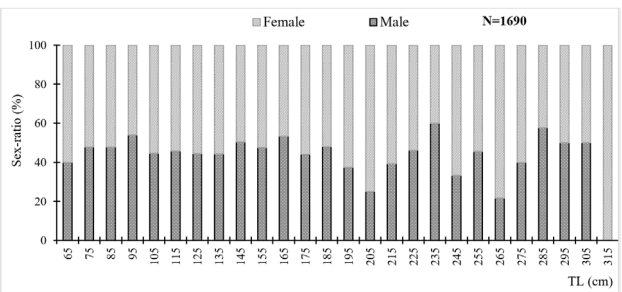


Fig 3. Evolution of the sex ratio of shortfin mako shark by size class (TL in cm)

In the autumn of 2017, females were more abundant than males, with a percentage of 56%. However, males were more abundant than females in the winter of 2018 (68%), while in the spring, autumn and summer of 2018, females that are most frequently found in the catches of artisanal boats were reported (53 to 63%). For the remainder of the year 2019, the sex ratio tends to balance, with a slight predominance of males (Fig. 4). The statistical analysis of the sex ratio using the contingency table with 9 seasons (n = 9 and ddl = 8) shows that there is a significant difference between the sex ratio of females and males (Chi-square test, X2 = 18 > 15.5073 at ddl = 7 and p = 0.05).

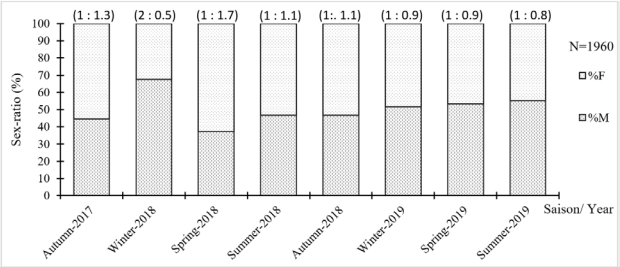


Fig 4. Seasonal variation of sex ratio of shortfin mako shark in 2017, 2018 and 2019

Sexual maturity

A total of 1690 individuals were examined, including 846 females and 844 males. The total length (TL) of both sexes combined ranged from 60 to 317 cm, with an average of 150.83 ± 41.51 cm (mean ± sd). Based on a macroscopic examination of the genital organ (claspers) in males and according to the maturity stage scale of elasmobranchs for placental viviparous sharks by Stehmann Mathias (2002), the three stages of the maturity scale were found. The juvenile individuals with a rate of 50% were dominant in the sample, followed by subadults (32%) and adults (18%). Figure 5 shows monthly changes in the percentage of individuals at different stages of sexual maturity in shortfin mako shark (Fig.5).

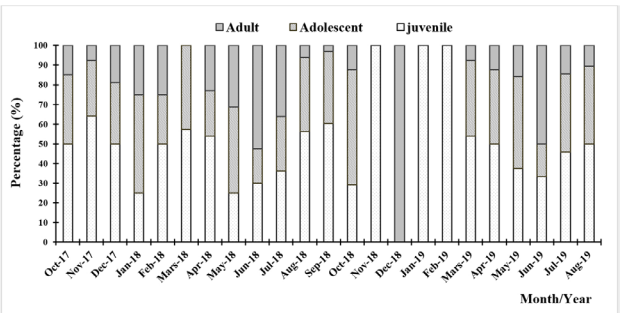


Fig 5. Monthly evolution of the rates of sexual maturity stages in males of shortfin mako sharks

Adult males were more or less absent in the autumn and early 2018 and 2019. However, they were observed in the winter and early summer. The highest proportion (53%) was recorded in June. Subadult and juvenile individuals were observed throughout the year, with a relative abundance in spring, summer and autumn. Their maximum rate was around 64% in November 2017, and 58% in October 2018 for juvenile and subadult individuals, respectively.

Size at maturity

The sizes of the claspers measured in shortfin mako shark males range from 5 to 36 cm, respectively, corresponding to the total lengths of 80 and 305 cm (TL). Male individuals of the mako shark reach maturity at a total length of 180 cm (TL) when their claspers reach a size of more than 25 cm and become calcified and filled with sperm (Fig. 6).

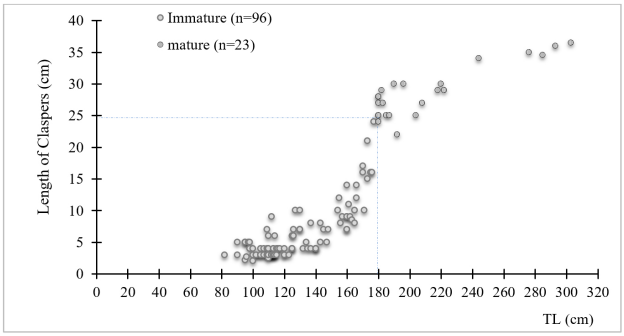


Fig 6. Evolution of the length of claspers as a function of total length in males of shortfin mako shark (N = 119)

To estimate the size at maturity (L_{50}) in the male shortfin mako shark using total length, we have to calculate the constant a and b (Fig.7).

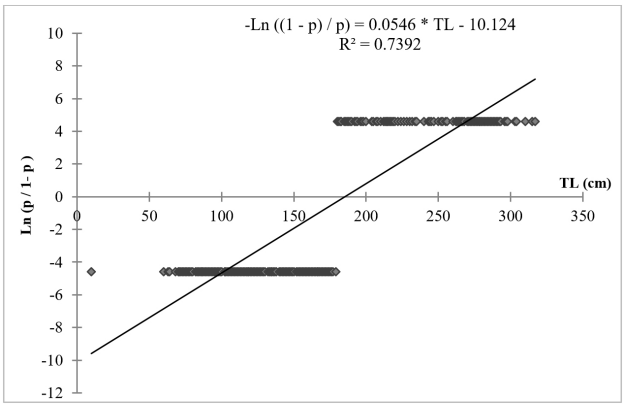


Fig 7. The parameters a and b are obtained by a linear equation, having the following formula: a + b * TL = - Ln ((1 - p) / p)

The size at maturity in male shortfin mako sharks was 187.5 cm in total length (Fig. 8). This result is similar to the result described above, which estimates maturity from the size of 180 cm TL, based on the characteristics of the claspers.

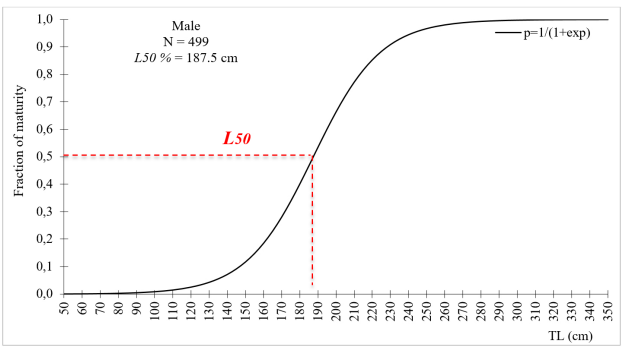
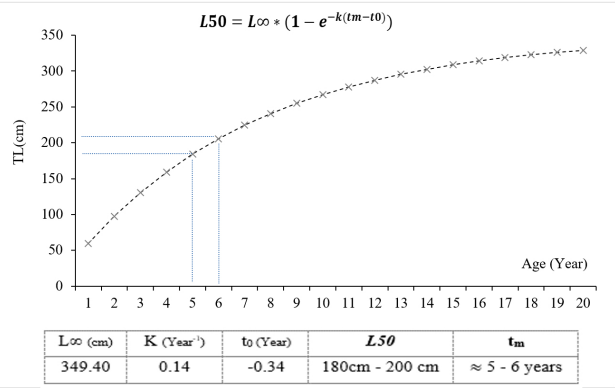


Fig 8. First sexual maturity size (L_{50}) based on the total length of male shortfin mako shark individuals

Age at maturity

Age of sexual maturity (tm) for males of *I. oxyrinchus* is reached at 5 or 6 years. This age corresponds to a length

that varies between 180 cm and 200 cm. The figure below shows the size and age corresponding to the maturity of shortfin mako shark based on the Von Bertalanffy equation used to study the growth of shortfin mako sharks as a function of age on the Moroccan Central Atlantic coast. The size distribution was used to determine the *L*, *k* and t_0 parameters of the growth equation (Alahyene et al., 2021) (Fig. 4).



L∞ (cm)	K (Year⁻¹)	t0 (Year)	*L50*	t_m
349.40	0.14	-0.34	180cm - 200 cm	≈ 5 - 6 years

Fig 9. Methods for estimating size and age at first maturity (t_m) in shortfin mako sharks

In short, the relationship between the evolution of the stages of maturity of male shortfin mako sharks as a function of size and age in the present study is determined in the diagram below (Fig. 8). The size at first sexual maturity, which corresponds to the size at which 50% of individuals of the male shortfin mako shark are mature, was estimated at more than 180 cm TL. At this size, males are almost six years old, which corresponds to the passage from the subadult stage to the adult stage based on the characteristics of the claspers (Fig. 9).

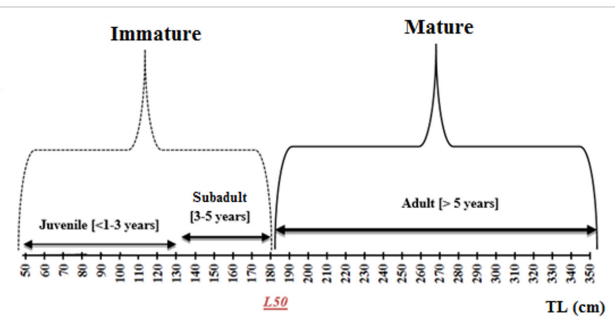


Fig 10. Diagram illustrating the evolution of the stages of maturity of the male shortfin mako shark as a function of size and age

DISCUSSION

All the individuals of *I. oxyrinchus* sampled during the study period show an overall balanced sex ratio of 1 : 0.9 (M : F) between males and females, with a slight predominance of males. Males are abundant in winter, while females are most common in spring. Reversely, in the western Mediterranean, the sex ratio is close to 0.9 : 1, with a slight predominance of females (De la Serna et al., 2002). Also, on the southwest Portuguese coast, by Maia et al. (2007), in the eastern North Atlantic, the overall sex ratio was 1.18 :1, biased toward males, although it varied through the sampling months. And, according to the data provided by Mejuto and Garcés (1984) for the North East Atlantic, in the area between Spain and the Azores, the sex ratio for shortfin mako sharks indicates a higher proportion of males in sizes over 200 cm FL (sex ratio of 1: 0.4). ICCAT (2010) data from tagging studies in the Northwest Atlantic obtained a sex ratio of 1 : 1. These results differ from those obtained by Coelho et al. (2018) in the Northwest and Southwest Atlantic regions, where 45% of the subjects were females and the remaining 55% were males, with more males in the NW and SW regions and more females in the tropical NE. Likewise, the sex ratio of sharks caught off the beach of KwaZulu-Natal, South Africa, varies from month to month, with ratios of two sexes ranging from 0.6 : 1 to 2.5 : 1, where males are more abundant than females for most of the year (Castro et al., 1999). The sex ratio seasonality with the greater availability of males could be indicative of reproduction-driven migrations or be due to prey preference, habitat occupation or other behavioral traits. Also, this difference would be due to the influence of the physical and chemical properties of the environment on shark reproduction.

All stages of sexual maturity in males were found during this study. It can be seen that the Central Moroccan Atlantic coast seems to be a nursery where immature individuals of shortfin mako shark are most dominant. This result coincides with that of Coelho et al. (2018) in the temperate zone of the North and Central Atlantic, in particular in the areas closer to continental and insular shelf waters. Similarly, in the North East Atlantic, it is presumed that the Strait of Gibraltar might be a nursery ground (Buencuerpo et al., 1998; Tudela et al., 2005). In the South Atlantic, large proportions of juveniles have also been noted. The capture of the smallest individuals in the late autumn to mid-spring suggests the parturition period. Our results agree with Mollet et al. (2000) who, after reviewing worldwide shortfin mako data, concluded that late winter to mid-spring was the parturition period in both hemispheres. However, this disagrees with Bigelow and Schroeder (1948), Gilmore (1993), Costa et al. (2002) and Maia et al. (2007) who showed the parturition season happens in the summer months. It appears that in some areas of the Atlantic, there is variability according to the season and the parameters of the ocean. Muñoz-Chàpulli (1985) states that there is a segregation of sexes by the

parturition period, with the females moving to warmer waters and the males to colder waters, suggesting that it is to protect the neonates and young-of-the-year shortfin mako sharks against predation by adults. Also, the lack of sampled large shortfin mako sharks might be explained by overfishing. So, in 2022, the Ministry of Maritime Fisheries in Morocco took a decision to ban shortfin mako shark fishing for a period of five years.

Assessing the level of development of the reproductive system is the best way to determine the state of sexual maturity. Maturity in females could not be determined because they are not eviscerated and no external clues could provide information on their maturity status or their reproductive cycle. According to Pratt and Casey (1983), female shortfin mako sharks become sexually mature at a size of 270–300 cm TL, while males reach maturity at 200–220 cm TL. Developing embryos have no placental connection during development (ovoviviparous) and feed on unfertilized eggs in the uterus during the gestation period, which lasts from 15 to 18 months. The 4 to 25 young survivors were born as free-swimming sharks in late winter and early spring at a size of around 70 cm TL (Pratt and Casey, 1983). According to Mollet et al. (2000), females can rest for 18 months after birth and before fertilization of the next batch of eggs. In the present study, the size at first sexual maturity, which corresponds to the size at which 50% of individuals of the male shortfin mako shark are mature, was estimated at 187.5 cm TL. At this size, males are almost six years old. This value is close to the size of 180 cm, which corresponds to the passage from the subadult stage to the adult stage based on the characteristics of the claspers. Our results are similar to those of the USA Pacific study by Caillet and Bedford (1983). Conde-Moreno et al. (2006) reported a similar size on the south-western coast in Baja California, Mexico, where male shortfin mako sharks were mature at around 180 cm TL, implying that subadult sizes were between 158 and 182 cm TL. Likewise, the sizes of our subadult shortfin mako sharks vary between 140 and 180 cm TL, similar to those mentioned by Compagno (2001), which varied between 140-199 cm TL, but he reported a bigger size at maturity, about 203-215 cm TL. According to Stevens (1983), males reach maturity at 195 cm total length in the Atlantic, while in the Pacific Northwest, males of shortfin mako shark reach their maturity at a size ranging between 184 and 213 cm total length. Joung and Hsu (2005) estimated the size at maturity to occur at 210 cm TL for north-western Pacific shortfin mako sharks, and Campana et al. (2005) found that all males between the ages of 8 and 15 (FL > 199 cm) were mature. We may conclude that Moroccan Atlantic male shortfin mako sharks mature at a smaller size than those in other areas, especially on the Atlantic coast. Coelho et al. (2018) described the size distribution of shortfin mako shark based on a large database from several fleets (including Morocco) in the Atlantic Ocean. They concluded that juveniles were more abundant in the higher latitudes, while the larger individuals were more in the tropical waters.

CONCLUSION

In the light of this work, biological parameters relating to the reproductive biology of the male shortfin mako shark were studied on the Moroccan Central Atlantic coast. The reproduction study showed that the overall sex ratio in shortfin mako shark tends towards the equilibrium 0.9 : 1 for both sexes. The males are abundant in winter, while females are most common in spring. The monthly rate of evolution of the different stages of maturity in males shows the dominance of immature individuals throughout the year. Therefore, the Moroccan Central Atlantic coast could be a nursery for the species *I. oxyrinchus*. The size at first sexual maturity has been estimated to be from 180 cm to 200 cm in males. These sizes correspond to the age of 6. It is important to note that the results of this study could be used to elaborate a management plan for shortfin mako shark fishery off the Moroccan Central Atlantic coast. However, concerning the reproductive traits of females, parturition grounds and migration patterns, further research should be carried out. It is also important to locate the nursery areas that can be protected in order to avoid fishing for young individuals and establish a commercial size that should be greater than the size at first sexual maturity in order to give young adults the chance to reproduce before they are caught;

ACKNOWLEDGEMENTS

The authors of this article are very grateful to everyone who contributed to this valuable study. We would like to pay particular tribute to Mr Bouaddi and all the fishing crews working at the small-scale fishing at Sidi Ifni Port on the Moroccan Central Atlantic coast. We also wish to thank the National Fisheries Office of the Port of Sidi-Ifni for sharing the data and helping in several ways. Thanks to their great efforts we were able to obtain information based on real facts and real discoveries. We would also like to thank anonymous reviewers and editors for their outstanding and helpful comments. This study was supported by the National Fisheries Research Agadir, Morocco.

ODNOS SPOLOVA I ZRELOSTI MUŽJAKA MORSKOG PSA KUČKA NA MAROKANSKOJ SREDNJOJ ATLANTSKOJ OBALI

SAŽETAK

Studija reproduktivne biologije morskog psa kučka provodila se putem komercijalnih ulova ribarskih brodova aktivnih na marokanskoj srednjoatlantskoj obali i iskrcaja u luci Sidi Ifni, u razdoblju od listopada 2017. do kolovoza

2019. godine. Pregledano je 1690 jedinki, uključujući 846 ženki i 844 mužjaka. Kao rezultat toga, utvrđeno je da je ukupni omjer spolova morskog psa kučka u ravnoteži. Mjesečni omjer spolova morskog psa kučka pokazuje da su mužjaci brojniji u odnosu na ženke tijekom zime. U jesen i proljeće utvrđeno je više ženki. U ostatku godine omjer spolova je uravnotežen, uz blagu prevlast mužjaka. Pronađena su tri stupnja ljestvice zrelosti. Tijekom istraživanja najčešće su se susreli mladi mužjaci sa stopom od 50%, zatim podadultni sa stopom od 32% i adultni sa stopom od 18%. Veličina mužjaka morskog psa kučka pri prvoj spolnoj zrelosti procijenjena je na između 180 cm i 200 cm ukupne duljine, što odgovara procijenjenoj dobi od 6 godina.

Ključne riječi: omjer spolova, faza zrelosti, veličina u zrelosti, Maroko

REFERENCES

Alahyene, J., Chiahou, B., El Habouz, H., Mekyassi, B., Ben-bani, A. (2021): The Growth Parameters of the Mako Shark *Isurus oxyrinchus* Rafinesque, 1810 in the Moroccan Central Atlantic Coast. Egyptian Journal of Aquatic Biology Fisheries. Vol. 25(3): 119-136.

Anon (2019): Report of the 2019 shortfin Mako shark stock assessment update meeting. ICCAT shortfin Mako shark stock assessment intersessional meeting. Madrid, Spain 20-24 May 2019, 41 pp.

Baibbat, S.A., Abid, N., Malouli, M.I. (2017): Catch rate and size frequency of the shortfin Mako (*Isurus oxyrinchus*) caught as by-catch by the swordfish longline fishery south of the Moroccan Atlantic coast. Collect Vol Sci Pap ICCAT 74:1867–1872.

Bigelow, H.B., Schroeder, W.C. (1948) Sharks. In: Fishes of the Western North Atlantic, vol. 1, part 1. Memoir 1. H. B. Bigelow, C. M. Breder, D. M. Cohen, G. W. Mead, D. Merriman, Y. H. Olsen, W. C. Schroeder, L. P. Schultz and J. Tee-Van (Eds): Sears Foundation for Marine Research, New Haven, pp. 59–576.

Branstetter, S., McEachran, J.D. (1986): Age and growth of four carcharhinid sharks common to the Gulf of Mexico: a summary paper. In T Uyeno, R Arai, T Taniuchi, K Matsuura, eds. Indo-Pacific fish biology: Proceedings of the Second International Conference on Indo-Pacific. Tokyo: Ichthyology Society of Japan, pp. 361-371.

Buencuerpo, V., Rios, S., Moron, J. (1998): Pelagic sharks associated with the swordfish *Xiphias gladius* fishery in the eastern North Atlantic Ocean and the Strait of Gibraltar. Fishery Bulletin, 96: 667-685.

Cailliet, G.M., Bedford, D.W. (1983): The biology of three pelagic sharks from California waters, and their emerging fisheries: a review. CalCOFI Rep, 24, 57-69.

Campana, S.E., Marks, L., Joyce, W. (2005): The biology and fishery of shortfin Mako sharks (*Isurus oxyrinchus*) in Atlantic Canadian waters. Fisheries Research, 73(3), 341-352.

Casey, J.G., Kohler, N.E. (1992): Tagging studies on the shortfin Mako shark (*Isurus oxyrinchus*) in the western North Atlantic. Marine and Freshwater Research 43(1): 45-60.

Castro, J.I., Woodley, C.M., Brudek, R.L. (1999): A Preliminary Evaluation of the Status of Shark Species. Food & Agriculture Org. Fisheries Technical Paper No. 380. ISBN 92-5-104299-3. 78 pp.

Coelho, R., Domingo, A., Courtney, D., Cortés, E., Arocha, F., Liu, K.M., Lino, P. (2018): An updated revision of shortfin mako size distributions in the Atlantic. Collective Volume of Scientific Papers-International Commission for the Conservation of Atlantic Tunas, 75, 476-492.

Compagno, L. J.V. (2001): Sharks of the world. An annotated and illustrated catalogue of shark species known to date. Volume 2. FAO Species Catalogue for Fishery Purposes. No. 1, Vol. 2. Rome, FAO. 2001. 269p.

Conde-Moreno, M., Galván-Magaña, F. (2006): Reproductive biology of the mako shark *Isurus oxyrinchus* on the south-western coast of Baja California, Mexico. Cybium, 30(4), 75-83.

Cortés, E., Arocha, F., Beerkircher, L., Carvalho, F., Domingo, A., Heupel, M., Simpfendorfer, C. (2010): Ecological risk assessment of pelagic sharks caught in Atlantic pelagic longline fisheries. Aquatic Living Resources 23(1): 25-34.

Costa, F.E.S., Braga, F.M.S., Arfelli, C.A., Amorim, A.F. (2002): Aspects of the reproductive biology of the shortfin mako, *Isurus oxyrinchus* (Elasmobranchii Lamnidae), in the southeastern region of Brazil. Braz. J. Biol. 62, 239–248.

Dagnelie, P. (1973): Théorie et méthodes statistiques. press.Agron.de Gembloux 1. 378p.

De la Serna, J.M., Valeiras, J., Ortiz, J.M., Macias, D. (2002): Large Pelagic sharks as by-catch in the Mediterranean Swordfish Longline Fishery: some biological aspects. NAFO SCR Doc, 2, 137.

Gilmore, R.G. (1993): Reproductive biology of Lamnoid sharks. Environ. Biol. Fishes 38, 95-114.

ICCAT. (2010): Valeiras, J., Abad, E. (2010): MANUEL ICCAT, 1ère édition (janvier 2010) chapitre 2.2.1.2 : *Isurus oxyrinchus*, Rafinesque, 1810. International Commission for the Conservation of Atlantic Tunas, Madrid. 273-283.

ICCAT. (2017): DE Bruyn, P. (2017): Report of the 2017 ICCAT Shortfin mako assessment meeting. International Commission for the Conservation of Atlantic Tunas, Madrid. 64p.

Kartas, F., Quignard, J.P. (1984): The fecundity of teleost fishes. Coll. Biol. Marine environments. Ed. Masson Paris: 121p.

Maia, A., Queiroz, N., Cabral, H.N., Santos, A.M., Correia, J.P. (2007): Reproductive biology and population dynamics of the shortfin mako, *Isurus oxyrinchus* Rafinesque, 1810, off the southwest Portuguese coast, eastern North Atlantic. J. Appl. Ichthyol. 23: 246–251.

Mejuto, J., Garces, A.G. (1984): Shortfin Mako, *Isurus oxyrinchus*, and porbeagle, Lamna nasus, associated with longline swordfish fishery in NW and N Spain. ICES, C.M. 1984/G: 72.

Mollet, H.F., Cliff, G., Partt, Jr H.L., Stevens, J.D. (2000): Reproductive biology of the female shortfin Mako, *Isurus oxyrinchus*, with comments on the embryonic development of lamnoids. Fish. Bull. 98: 299-318.

Muñoz-Chàpulli, R. (1985): Analisis de las capturas de escualos demersales en el Atlantico NE (27°N 37°N) y mar de Alboron (Mediterrâneo occidental): Investig. Pesquera 49, 121–136.

Poisson, F. (2007): Compilation of information on blue shark (*Prionace glauca*), silky shark (*Carcharhinus falciformis*), oceanic whitetip shark (*Carcharhinus longimanus*), scalloped hammerhead (Sphyrna lewini) and shortfin mako (*Isurus oxyrinchus*) in the Indian Ocean. 3rd Session of the IOTC Working Party on Ecosystems and Bycatch, July 11-13 2007, Victoria, Seychelles.18 p.

Pratt, Jr.H.L., Casey, J.G. (1983): Age and growth of the shortfin Mako *Isurus oxyrinchus*, using four methodes. Can. J. Fish. Aquat. Sci. 40:1944-1957.

Stehmann, M.F. (2002): Proposal of a maturity stages scale for oviparous and viviparous cartilaginous fishes (Pisces, Chondrichthyes). Archive of Fishery and Marine Research. 50(1): 23-48.

Stevens, J.D. (1983): Observations on reproduction in the shortfin Mako *Isurus oxyrinchus*. Copeia (1983): 126-130.

Tudela, S., Kai, A., Maynou, F., El Andalossi, M., Guglielmi, P. (2005): Driftnet fishing and biodiversity conservation: the case study of the large-scale Moroccan driftnet fleet operating in the Alboran Sea (SW Mediterranean). Biological Conservation, 121: 65-78.