

Mediterranean Marine Science

Vol 23, No 4 (2022)

VOL 23, No 4 (2022)



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doi: [10.12681/mms.30166](https://doi.org/10.12681/mms.30166)

To cite this article:

ČETKOVIĆ, I., JAMBURA, P. L., PEŠIĆ, A., IKICA, Z., & JOKSIMOVIĆ, A. (2022). Observations of juvenile sandbar sharks *Carcharhinus plumbeus* (Nardo, 1827) around the Bojana River delta (Southern Adriatic Sea). *Mediterranean Marine Science*, 23(4), 748–753. <https://doi.org/10.12681/mms.30166>

Observations of juvenile sandbar sharks *Carcharhinus plumbeus* (Nardo, 1827) around the Bojana River delta (Southern Adriatic Sea)

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Contributing Editor: Branko DRAGICEVIC

Received: 07 April 2022; 12 June 2022; Published online: 02 September 2022

Abstract

The sandbar shark (*Carcharhinus plumbeus*) is considered rare in the Adriatic Sea and the majority of records originate from the northern Adriatic, where a nursery area for this species close to the Po delta system has been repeatedly proposed. This study provides 5 new records and analyses the previously published records of sandbar sharks recorded around the delta of the River Bojana (in Montenegro, in the south-eastern Adriatic). The River Bojana located on the border between Montenegro and Albania, is the second largest river flowing into the Adriatic Sea, where it forms a highly productive ecosystem already known as a local hotspot for smooth-hound sharks (*Mustelus* spp.). New records of sandbar sharks have emerged as a result of citizen science (a social media survey) and direct reports from fishermen. The total length of *C. plumbeus* juveniles ranged from approximately 800 mm to 1100 mm, and most (n=5) were caught by set gillnets. The data presented here show that juveniles are consistently present around the estuary and indicate the importance of this fragile estuarine ecosystem for sandbar sharks. Additionally, this study also provides morphometric data collected from a single individual.

Keywords: elasmobranchs; shark nursery area; estuary; Adriatic Sea; Montenegro.

Introduction

The sandbar shark (*Carcharhinus plumbeus* (Nardo, 1827)) is present across the entire Mediterranean basin but is considered rare in all its sub-regions, including the Adriatic Sea (Serena *et al.*, 2020). This large coastal shark species can grow up to 300 cm, but commonly to 240 cm in total length (Serena, 2005) and, due to its slow growth, late maturation and low fecundity (1-14 pups every second year) it is highly vulnerable to overfishing (Dulvy *et al.*, 2016). According to the IUCN Red List, the sandbar shark is currently declared endangered (EN) in the Mediterranean Sea (Ferretti *et al.*, 2016). Although generally considered rare, temporal aggregations of this species occur in the Mediterranean Sea and have recently been considered a potential tourism attraction (Zemah Shamir *et al.*, 2019; Cattano *et al.*, 2021).

The sandbar shark is the only species of the genus *Carcharhinus* that is known to inhabit the Adriatic Sea (Kovačić *et al.*, 2020). Most of the records of this species in this area were reported from its northern region,

especially around the delta of the River Po (Lipej *et al.*, 2008; Jambura *et al.*, 2021), while it has also been recorded in the middle Adriatic Sea (Dragičević *et al.*, 2010). The high number of neonates and juveniles in this area lead several authors to propose that the Northern Adriatic basin might serve as a nursery area for this species (Costantini & Affronte, 2003; Lipej *et al.*, 2008; Jambura *et al.*, 2021). The presence of this species in the Southern Adriatic Sea has been indicated before, but on the basis of only a few specimens (Jambura *et al.*, 2021). Here, we report additional records of the sandbar shark from the delta of the River Bojana and discuss its potential role as an important habitat for this rare shark species.

Materials and Methods

The River Bojana represents the second largest inflow into the Adriatic Sea (Petković & Sekulić, 2019), which has a great influence on the wider area, supplying it with fine sediment and nutrients. The nearby Velika plaža rep-

resents the longest sandy beach in the entire Adriatic basin, with a length of approximately 12 km (Šilc *et al.*, 2016). The beach itself and its hinterland are recognized as important conservation areas for a variety of reasons. Velika plaža is known for its sand dunes and their associated unique vegetation as a highly vulnerable ecosystem (Stešević *et al.*, 2020; Šilc *et al.*, 2020). The beach has been recognized as a natural monument by the national legislation of Montenegro and several NATURA 2000 habitats have been designated in this area and its hinterland (Stešević *et al.*, 2020). The delta of the River Bojana and its surrounding area have been recognized as a local hotspot for coastal sharks of the genus *Mustelus*, which represent a common and traditional catch and which are considered target species by local fishermen (Četković, 2018).

The sandbar shark records described here were either reported by fishermen, or else were obtained through literature research and citizen science (social media surveys). All the individuals were caught as by-catch of local small-scale fisheries using set gillnets or longlines. Only one individual was obtained intact and was examined in the Laboratory for Ichthyology and Marine Fisheries at the Institute of Marine Biology in Kotor, Montenegro. Detailed morphometric measurements were taken to the nearest mm according to Compagno (2001) and expressed as a percentage of total length (TL). For the remaining individuals, photo documentation was obtained, and the total length (TL) and weight (W) were estimated. Each fisherman who caught an individual was asked to measure or estimate its TL and its W. Photos of all the individuals, except one, had other items (e.g., a bucket or other fish) placed next to the shark. The fishermen were asked to estimate the total length and/or weight of the animals, because they handled the individuals directly and were therefore less susceptible to the bias that might be expected from estimating from photographs. Additionally, geographical coordinates were obtained from the fishermen who reported the catches.

The specimens were identified on the basis of photographic material or the specimen itself as described in Serena (2005), with: (1) the 1st dorsal-fin origin over pectoral-fin base, (2) a very tall 1st dorsal fin, and (3) the presence of an interdorsal ridge. One preserved individual was donated to the Natural History Museum of Montenegro in Podgorica and is registered under serial number 15400 (collector number R178).

Results

A total of seven sandbar shark records were obtained from the area of the delta of the River Bojana between 2014 - 2022 (Fig. 1, Table 1). Most of the individuals were juveniles (n=6), ranging from approximately 800 – 1100 mm in TL, while one was considered a subadult due to it having a TL of 1500 mm. Five were caught using set gillnets, one by a bottom longline and one by a drifting longline. They were caught both in warmer and colder months in coastal area (Table 1), without an observable pattern, at depths of up to 100m (Fig. 1). All but one individual were disposed of before the authors were informed of their capture. The single individual caught on 15.02.2022 was examined at the Institute of Marine Biology in Kotor (Montenegro). Its morphometric measurements are provided in Table 2.

Discussion

Previous studies have suggested that the Northern Adriatic basin might serve as a nursery ground for sandbar sharks (Costantini & Affronte, 2003; Lipej *et al.*, 2008). It was proposed that the high concentration of neonates and juveniles in the northern Adriatic Sea is likely directed by the influx of the River Po, which makes this area a highly productive ecosystem (see Jambura *et al.*, 2021 and discussion therein). Estuaries are known to play

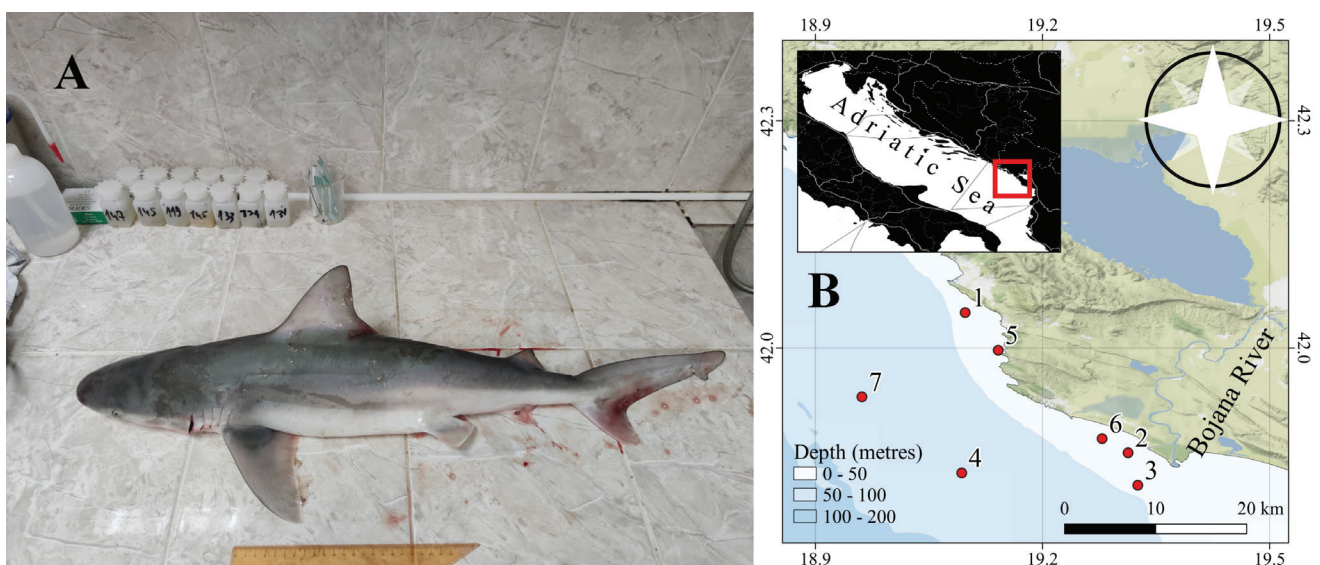


Fig. 1: The individual measured at the Institute of Marine Biology in Kotor (A) and the locations of sandbar shark catches in the area of the delta of the River Bojana (B).

Table 1. Records of sandbar sharks from the area around the delta of the River Bojana.

Ind. no.	Date	Total length (TL/mm)*	Weight (W/kg)*	Life stage	Fishing gear	Source
1	2014	800*	2*	Juvenile	Gillnet	Citizen science
2	2016	-	4*	Juvenile	Gillnet	Citizen science
3	14.05.2017.	1100*	2,8	Juvenile	Gillnet	Jambura <i>et al.</i> (2021)
4	29.08.2020.	1500*	35	Subadult	Drifting longline	Jambura <i>et al.</i> (2021)
5	23.02.2021.	800*	2,5*	Juvenile	Gillnet	Fisherman's report
6	12.03.2021.	1100*	3,5*	Juvenile	Gillnet	Fisherman's report
7	15.02.2022.	870	2,95	Juvenile	Bottom longline	Fisherman's report

*The measurement is estimated

Table 2. Morphometric measurements of the sandbar shark recorded on 15.02.2022.

Measurement	mm	% of TL	Measurement	mm	% of TL
Total length (TL)	870	100	Second dorsal-fin inner margin (D2I)	28	3.22
Fork length (FL)	670	77.01	Second dorsal-fin posterior margin (D2P)	40	4.6
Precaudal-fin length (PCL)	600	68.97	Pelvic-fin length (P2L)	70	8.05
Pre-second dorsal-fin length (PD2)	515	59.2	Pelvic-fin anterior margin (P2A)	43	4.94
Pre-first dorsal-fin length (PD1)	243	27.93	Pelvic-fin base (P2B)	44	5.06
Head length (HDL)	208	23.91	Pelvic-fin height (P2H)	38	4.37
Prebranchial length (PG1)	155	17.82	Pelvic-fin inner margin length (P2I)	29	3.33
Preorbital length (POB)	63	7.24	Pelvic-fin posterior margin length (P2P)	54	6.21
Prepectoral-fin length (PP1)	202	23.22	Anal-fin length (ANL)	65	7.47
Prepelvic-fin length (PP2)	398	45.75	Anal-fin anterior margin (ANA)	53	6.09
Snout-vent length (SVL)	425	48.85	Anal-fin base (ANB)	41	4.71
Preanal-fin length (PAL)	505	58.05	Anal-fin height (ANH)	33	3.79
Interdorsal space (IDS)	183	21.03	Anal-fin inner margin (ANI)	29	3.33
Dorsal caudal-fin space (DCS)	54	6.21	Anal-fin posterior margin (ANP)	35	4.02
Pectoral-fin pelvic-fin space (PPS)	199	22.87	Dorsal caudal-fin margin (CDM)	218	25.06
Pelvic-fin anal-fin space (PAS)	69	7.93	Preventral caudal-fin margin (CPV)	83	9.54
Anal-fin caudal-fin space (ACS)	61	7.01	Upper postventral caudal-fin margin (CPU)	122	14.02
Pelvic-fin caudal-fin space (PCA)	163	18.74	Lower postventral caudal-fin margin (CPL)	46	5.29
Vent caudal-fin length (VCL)	307	35.29	Caudal-fin fork width (CFW)	59	6.78
Prenarial length (PRN)	40	4.6	Caudal-fin fork length (CFL)	68	7.82
Preoral length (POR)	63	7.24	Subterminal caudal-fin margin (CST)	19	2.18
Eye length (EYL)	11	1.26	Subterminal caudal-fin width (CSW)	25	2.87
Eye height (EYH)	11	1.26	Terminal caudal-fin margin (CTR)	50	5.75
Subocular pocket depth (SOD)	2	0.23	Terminal caudal-fin lobe (CTL)	55	6.32
Intergill length (ING)	47	5.4	Head height (HDH)	95	10.92
First gill slit height (GS1)	25	2.87	Trunk height (TRH)	110	12.64
Second gill slit height (GS2)	26	2.99	Abdomen height (ABH)	108	12.41

Continued

Table 2 continued

Measurement	mm	% of TL	Measurement	mm	% of TL
Third gill slit height (GS3)	27	3.1	Tail length (TAH)	79	9.08
Fourth gill slit height (GS4)	24	2.76	Caudal-fin peduncle height (CPH)	35	4.02
Fifth gill slit height (GS5)	20	2.3	Head width (HDW)	111	12.76
Pectoral-fin length (P1L)	93	10.69	Trunk width (TRW)	115	13.22
Pectoral-fin anterior margin (P1A)	140	16.09	Abdomen width (ABW)	95	10.92
Pectoral-fin radial length (P1R)	115	13.22	Tail width (TAW)	70	8.05
Pectoral-fin base (P1B)	61	7.01	Caudal-fin peduncle width (CPW)	30	3.45
Pectoral-fin inner margin (P1I)	42	4.83	Second dorsal-fin insertion anal-fin insertion (DAI)	0	0
Pectoral-fin posterior margin (PIP)	119	13.68	Second dorsal-fin origin anal-fin origin (DAO)	0	0
Pectoral-fin height (P1H)	125	14.37	First dorsal-fin midpoint pectoral-fin insertion (DPI)	72	8.28
First dorsal-fin length (D1L)	127	14.6	First dorsal-fin midpoint pelvic-fin origin (DPO)	125	14.37
First dorsal-fin anterior margin (D1A)	110	12.64	Pelvic-fin midpoint first dorsal-fin insertion (PDI)	103	11.84
First dorsal-fin base (D1B)	94	10.8	Pelvic-fin midpoint second dorsal-fin origin (PDO)	82	9.43
First dorsal-fin height (D1H)	81	9.31	Mouth length (MOL)	40	4.6
First dorsal-fin inner margin (D1I)	35	4.02	Mouth width (MOW)	73	8.39
First dorsal-fin posterior margin (D1P)	103	11.84	Nostril width (NOW)	14	1.61
Second dorsal-fin length (D2L)	63	7.24	Internarial space (INW)	48	5.52
Second dorsal-fin anterior margin (D2A)	39	4.48	Anterior nasal-flap length (ANF)	5	0.57
Second dorsal-fin base (D2B)	33	3.79	Interorbital space (INO)	88	10.11
Second dorsal-fin height (D2H)	24	2.76	Weight (W)	2.95 kg	

a significant role in the life cycle of sandbar sharks and serve as important habitats for juveniles (Collatos *et al.*, 2020).

Almost all the sandbar shark records from Montenegrin waters were located around the delta of the River Bojana, suggesting that this confined area might be another important locality for this endangered coastal shark in the Adriatic Sea. This estuarine ecosystem is highly productive and rich in different food sources, which makes it favorable for numerous species. The records presented here span a nine-year period and show the continued presence of this coastal shark in the target area. However, the reported abundance of this species was rather low, which might be the result of the small number of fishing vessels operating along the Montenegrin coast (Pešić *et al.*, 2021).

Previously, the presence of even a few neonate and juvenile sharks was often considered to be an indicator for a potential nursery area (Costantini & Affronte, 2003; Bašusta *et al.*, 2021). An overview of the main areas where juvenile and neonate sandbar sharks are found in the Mediterranean Sea is given in Figure 2 (Bašusta *et al.*, 2021 and references therein). Even though several young juveniles were recorded around the Bojana estuary, the

absence of neonate and pregnant sandbar sharks do not qualify it to be a primary nursery area (an area where young sharks are born; Bass, 1978). Nonetheless, the River Bojana seems to be an important habitat for older juvenile sandbar sharks, and thus could potentially serve as a secondary nursery area (an area where slightly older juveniles remain for an extended period as they grow to maturity; Bass, 1978). Heupel *et al.* (2007) defined shark nurseries based on three criteria: (1) juvenile sharks are more common in this area than in other areas; (2) they remain or return for extended periods; (3) the area is utilized repeatedly over several years. Because of the rarity of sandbar sharks in the entire Adriatic Sea and across the Mediterranean basin more generally, areas proposed as nursery grounds often fail to comply with these criteria and it is doubtful whether all of them are in fact true nursery grounds. To prove the presence of nursery areas, significant efforts, i.e. scientific surveys, are needed to make such conclusions. Nonetheless, as our understanding of the biology and ecology of sharks and rays in the Mediterranean Sea is still mostly limited by a lack of available data, studies such as the current one can shed light on the distribution of specific species and thus provide the first

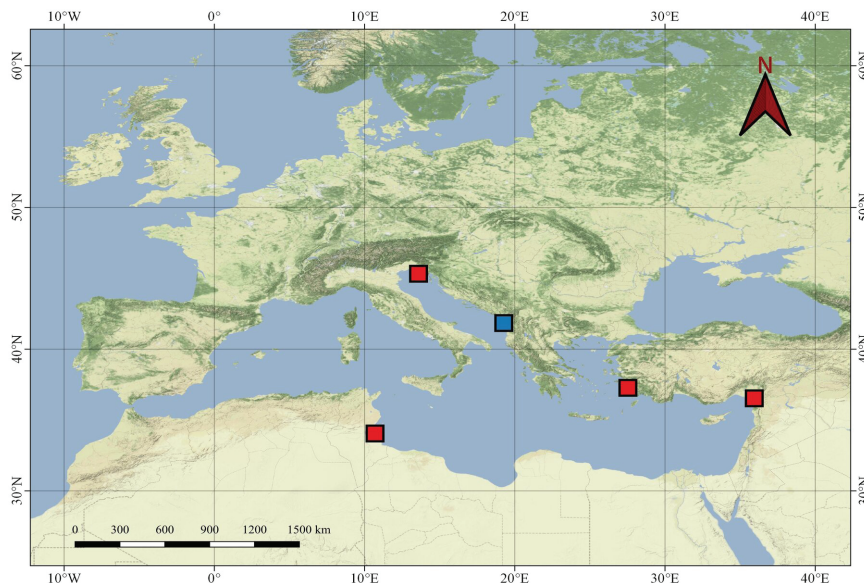


Fig. 2: The main areas where *C. plumbeus* juvenile forms occur in the Mediterranean Sea (red) and the location of delta of the River Bojana (blue).

results on which future studies and surveys can build.

Acknowledgements

The authors are grateful to Vaso Kostić, Milan Milić, Srećko Deković, Boris Mihailović and Ivo Knežević who kindly provided data on their catches. This research was funded in part by the Rufford Foundation and the Austrian Science Fund (FWF) P 33820.

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