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MORPHOMETRIC MEASUREMENTS OF THE YOUNG OF THREE CARCHARHINID SPECIES FROM NORTHEASTERN LEVANT (MEDITERRANEAN SEA)

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ABSTRACT

*This study presents the morphometric measurements of young individuals of *Carcharhinus altimus* (Springer, 1950), *C. obscurus* (Lesueur, 1818), and *C. plumbeus* (Nardo, 1827). These data provide valuable information on the morphometry of the populations of the three species in the northeastern Levant.*

Key words: *Carcharhinus*, morphometry, Levantine Sea, Turkey

MISURE MORFOMETRICHE DEI GIOVANI DI TRE SPECIE DI CARCARINIDI DEL LEVANTE NORD-ORIENTALE (MAR MEDITERRANEO)

SINTESI

*Lo studio presenta le misure morfometriche di giovani individui di *Carcharhinus altimus* (Springer, 1950), *C. obscurus* (Lesueur, 1818) e *C. plumbeus* (Nardo, 1827). Questi dati forniscono informazioni preziose sulla morfometria delle popolazioni delle tre specie nel Levante nord-orientale.*

Parole chiave: *Carcharhinus*, morfometria, Mar Levantino, Turchia

INTRODUCTION

Since the genus *Carcharhinus* includes some of the largest species of sharks in the Mediterranean waters, a remarkable research effort has been spent by many authors to provide new data for a better understanding of the species of this genus in the entire region (e.g., Capapé, 1984; Hemida *et al.*, 2002; Lipej *et al.*, 2008; Başusta, 2016; Filiz, 2018; Capapé *et al.*, 2018; Azab *et al.*, 2019). Due to their vital role in describing fish species (Moyle & Cech, Jr., 1988), morphometric measurements have been

reported in most of these studies, and therefore, a remarkable archive of Mediterranean *Carcharhinus* spp. morphometrics is available.

In the present study, the authors report the morphometrics of three species belonging to the genus *Carcharhinus* Blainville, 1816; the bignose shark, *Carcharhinus altimus* (Springer, 1950); the dusky shark, *C. obscurus* (Lesueur, 1818); and the sandbar shark, *C. plumbeus* (Nardo, 1827), which were incidentally captured in the coastal waters of northeastern Levant. The authors also aim to contribute to the available data-set of morphometric measurements



Fig. 1: Map depicting the capture localities of the examined *Carcharhinus altimus* (●), *C. obscurus* (▲) and *C. plumbeus* (■) specimens. Square in the small map indicates the locality in the eastern Levant covered by the present study.

Sl. 1: Zemljevid obravnavanega območja z označenimi lokalitetami, kjer so bili ujeti primerki vrst *Carcharhinus altimus* (●), *C. obscurus* (▲) in *C. plumbeus* (■). Kvadrata na manjšem zemljevidu označuje območje vzhodnega Levanta, obravnavanega v pričujoči raziskavi.

with records of these three Mediterranean carcharhinid species, which may be useful for future research of the same objective.

MATERIAL AND METHODS

Young individuals of *Carcharhinus altimus* (Springer, 1950) (n=6; TL range 54.5–113 cm, mean 73.1 ± 22.3 cm), *C. obscurus* (Lesueur, 1818) (n=1; TL 64.5 cm), and *C. plumbeus* (Nardo, 1827) (n=1; TL 91 cm), were incidentally captured by coastal artisanal long-liners, trammel-netters and gill-netters along the coastline stretching between Dana Island and the mouth of the Göksu River (Fig. 1). *C. plumbeus* is a species protected by the current fisheries law of Turkey and any living sandbar sharks accidentally captured should be immediately released back into the sea. Although not included in the list of protected marine species, based on the researchers' decision, all alive individuals of *C. altimus* and *C. obscurus* in this study were also released due to their conservation status (Data Deficient; Serena *et al.*, 2020). Only dead individuals were retained on board and landed. Before performing any observations and incisions on the sharks, the ethic committee approval was acquired for each shark, which was stored in the freezer.

Species identification follows Grace (2001) and Serena (2005), and taxonomic nomenclature follows Serena *et al.* (2020). Measurements were recorded on thawed individuals. Total length (TL) is the distance between the tip of the snout and the tip of the upper caudal lobe, where the upper lobe is in stretched position (Ebert & Stehmann, 2013). Twenty-seven morphometric measurements were taken using a measurement tape and recorded to the nearest 0.1 mm, following the procedure outlined in Ebert and Stehmann (2013). Previously published morphometric measurements of the same species were extracted from the relevant references (Devaraj & Gulati, 2004; Lipej *et al.*, 2008; Capapé *et al.*, 2018; Azab *et al.*, 2019; Lee *et al.*, 2019; Ayas *et al.*, 2020; Ergüden *et al.*, 2020; Turan *et al.*, 2020; Froese & Pauly, 2022). All of the measurements were presented as percentages of TL, and for species with multiple individuals, percentages of TL values were computed based on the mean ($\pm$ SD) of each measurement. The captured individuals were recorded in the Museum of Marine Life, Mersin University with catalogue numbers (MEUFC-22-11-135 - MEUFC-22-11-142). Excel worksheets of the three species are available from the corresponding author for inspection on request.

RESULTS AND DISCUSSION

The main morphological characters allowing us to distinguish the three species of *Carcharhinus* were as follows (Ebert & Stehmann, 2013):

Carcharhinus altimus (Springer, 1950)

Anterior nasal flaps usually high and triangular. Distance from nostrils to mouth less than 2.4 times the mouth width. Upper anterolateral teeth very high; upper anterolateral teeth usually in 15 rows. First dorsal fin lower, with height much less than half predorsal space. Interdorsal ridge high.

Carcharhinus obscurus (Lesueur, 1818)

First dorsal fin origin over or anterior to pectoral fin free rear tips. Pectoral fins large and falcate. Seriations of upper anterolateral teeth small and not very coarse. Inner margin of second dorsal fin shorter and generally less than twice fin height (up to 2.1 times). Interdorsal ridge low.

Carcharhinus plumbeus (Nardo, 1827)

Anterior nasal flaps usually low and inconspicuous. Distance from nostrils to mouth more than 2.4 times the mouth width. Upper anterolateral teeth moderately high; upper anterolateral teeth usually in 14 rows. First dorsal fin very high, with height about half predorsal space. Interdorsal ridge low.

In a recent review of the distribution of chondrichthyans in the Mediterranean Sea, Serena *et al.* (2020) described *C. altimus* as a vagrant species for the Mediterranean Sea, and *C. obscurus* and *C. plumbeus* as resident carcharhinids in the region. The occurrence of these three species in Turkish waters has been mostly reported from Mediterranean coasts, while the distribution of *C. plumbeus* in the region also extends to southern Aegean waters (Kabasakal, 2021).

Since all of the individuals examined had prominent interdorsal ridges (Fig. 2), the *C. brachyurus*, *C. brevipinna*, *C. limbatus*, and *C. melanopterus* species were easily excluded as possibilities. Unlike *C. falciformis*, in which the free rear tip of the 2nd dorsal fin is very long (≥ 2 to 3 times in 2nd D fin height), the length of the mentioned body part in the examined individuals was shorter (Tables 1–3); as a result, *C. falciformis*, although also exhibiting an interdorsal ridge, was also excluded as a possibility. Six out of the eight examined sharks coincided with the descriptions of *C. altimus*, and the remaining two individuals were identified as *C. obscurus* and *C. plumbeus*, respectively (Grace, 2001; Serena, 2005).

Despite the slight differences, our measurements generally agree with those given by Compagno (1984) for *Carcharhinus* spp. occurring worldwide, and Ebert & Stehmann (2013) for species occurring in the North Atlantic. The percentage of eye length in TL (EYL-TL) in *C. obscurus* (1.8%) fell within the range given by Compagno (1984) and Ebert & Stehmann (2013), which is reported as 1–2.1%. The EYL-TL ratio of *C. altimus* for the mean and maximum



Fig. 2: Some of the specimens of *Carcharhinus* spp. examined in the present study: (a) ventral view of the head and whole lateral view of *C. altimus*; (b) dorsal view of the head and whole lateral view of *C. obscurus*; and (c) ventral view of the head and whole lateral view of *C. plumbeus*. Scale bar = 10 cm.

Sl. 2: Nekaj preiskanih primerkov iz rodu *Carcharhinus* iz te raziskave: a) pogled na glavo vrste *C. altimus* s trebušne strani in pogled z boka; (b) pogled na glavo vrste *C. obscurus* s hrbtne strani in pogled z boka; in (c) pogled na glavo vrste *C. plumbeus* s trebušne strani in pogled z boka. Merilo = 10 cm.

values of the examined specimens (1.5% and 1.7%, respectively), were in agreement with those reported by Compagno (1984) and Ebert & Stehmann (2013), which is 1.4–2.3%; however, the percentage of eye length in TL in the smallest examined specimen (1.2%) was lower than the reported range. In the examined specimen of *C. plumbeus*, the percentage of eye length in TL (1.2%) was also lower than the reported range (1.7–2.9%; Compagno, 1984; Ebert & Stehmann, 2013).

Compagno (1984) and Ebert & Stehmann (2013) reported the percentages of 2nd dorsal fin height in TL (D2H-TL) and pectoral anterior margin length in

TL (PAL-TL) in *Carcharhinus altimus* as 2.8–3.4% and 20–22%, respectively. Mean and maximum values of D2H-TL and PAL-TL ratios of the examined specimens of *C. altimus* (2.9% and 3.1% for mean and max. D2H-TL, and 17.7% and 17.8% for mean and max. PAL-TL, respectively), coincided with the reported percentages. On the other hand, the same percentages of the smallest examined specimen (2.6% for D2H-TL and 16.5% for PAL-TL) are lower than the above-published percentage ranges. D2H-TL percentages for examined specimens of *C. obscurus* and *C. plumbeus* (2.3% and 3.3%, respectively), are agreed with those reported by Compagno (1984) and Ebert & Stehmann (2013),

Tab. 1: Morphometric measurements of *Carcharhinus altimus* examined in the present study. In bold the percentages mentioned in Compagno (1984) and Ebert & Stehmann (2013).**Tab. 1: Morfometrične meritve na primerkih vrste *Carcharhinus altimus*, preiskanih v pričujoči raziskavi. V mastnem tisku so deleži, ki jih omenjajo Compagno (1984) in Ebert & Stehmann (2013).**

Measurements	Present Study (TL range 54.5-113 cm)					Turan <i>et al.</i> (2020)		Ayas <i>et al.</i> (2020)		Azab <i>et al.</i> (2019)		Froese & Pauly (2022) (74 cm TL)
	Mean	SD	% of mean TL	% of min TL	% of max TL	TL	% of TL	TL	% of TL	TL	% of TL	% of TL
Total length (TL)	73.1	22.3				68		65.2		54.6		
Fork length (FL)	58.4	18.0	79.9	79.8	80.5			53.0	81.3		78.7	82.5
Standard length	53.3	16.5	72.9	72.5	73.5	59.0	86.8	48.5	74.4		70.7	79.6
Head length	18.1	4.8	24.7	26.4	23.9	11.1	16.3	15.8	24.2		17.5	
Mouth length	7.0	2.1	9.6	10.1	9.3			5.6	8.6			
Eye length	1.1	0.2	1.5	1.7	1.2	0.8	1.2	0.9	1.4			
Eye height	1.1	0.2	1.4	1.7	1.2							
Internarial distance	4.5	1.1	6.1	7.3	5.7							
Pre-branchial length	14.8	4.1	20.3	20.2	19.5	9.0	13.2	13.5	20.7			23.5
Pre-orbital length	6.8	1.9	9.3	8.8	8.8			5.8	8.9			
Pre-D1 fin length	22.8	6.8	31.1	31.2	31.0			21.0	32.2			29.9
Pre-D2 fin length	46.9	14.3	64.1	62.4	63.7							
Pre-pectoral fin length	17.8	4.4	24.4	24.8	22.1			13.5	20.7			24
D1 fin length	11.6	4.1	15.8	15.4	16.8			9.6	14.7			
D1 fin height	7.9	2.9	10.8	9.2	11.1			6.4	9.8			
D1 fin base	8.3	2.8	11.4	11.0	11.9			7.0	10.7			
D2 fin length	5.1	1.2	6.9	7.0	4.9			4.5	6.9			
D2 fin height	2.2	0.9	2.9	2.6	3.1	2.0	2.9					
D2 fin base	2.9	1.1	3.9	4.4	4.0			2.1	3.2			
Pectoral fin length	13.0	4.3	17.7	16.5	17.8	10.5	15.4	13.5	20.7			
Pectoral fin base	5.3	2.4	7.3	6.4	8.8			2.8	4.3			
Pelvic fin length	5.8	2.0	8.0	7.3	8.0							
Pelvic fin base	2.6	0.9	3.6	3.3	3.5			2.8	4.3			
Anal fin length	5.8	2.0	7.9	8.3	8.0							
Anal fin base	3.4	1.2	4.6	4.6	4.9			2.4	3.7			
Caudal upper lobe length	19.4	6.2	26.6	26.6	27.0			16.0	24.5			
Caudal lower lobe length	8.1	2.6	11.1	12.8	11.1			6.2	9.5			

Tab. 2: Morphometric measurements of *Carcharhinus obscurus* examined in the present study. In bold the percentages mentioned in Compagno (1984) and Ebert & Stehmann (2013). TL of respective specimens examined by Devaraj & Gulati (2004), Azab *et al.* (2019) and Lee *et al.* (2019) are given in parentheses under the authors' names.

Tab. 2: Morfometrične meritve na primerku vrste *Carcharhinus obscurus*, preiskanem v pričujoči raziskavi. V mastnem tisku so deleži, ki jih omenjajo Compagno (1984) in Ebert & Stehmann (2013). Dolžine telesa primerkov, ki jih navajajo Devaraj & Gulati (2004), Azab *et al.* (2019) in Lee *et al.* (2019) so podane v oklepajih pod avtorjevimi imeni.

Measurements	Present Study		Devaraj & Gulati (2004) (99.5 cm TL)	Azab <i>et al.</i> (2019) (58.08 cm TL)	Lee <i>et al.</i> (2019) (83.9 cm TL)
	cm	% of TL	% of TL	% of TL	% of TL
Total length (TL)	64.5				
Fork length (FL)	51	79.1			78.6
Standard length	47.5	73.6	73.2	73.8	71.2
Head length	16.5	25.6	18.5		18.8
Mouth length	6.5	10.1	7.8		
Eye length	1.15	1.8	1.7	1.7	
Eye height	1.05	1.6			
Internarial distance	3.9	6.0			
Pre-branchial length	13	20.2	18.5	5.4	
Pre-orbital length	6	9.3	8.1		
Pre-D1 fin length	19	29.5	31.0	34.2	
Pre-D2 fin length	41	63.6	62.1	63.9	
Pre-pectoral fin length	16	24.8	21.2	22.6	
D1 fin length	10	15.5			
D1 fin height	6.5	10.1	8.1	11.2	
D1 fin base	8	12.4	8.6	82.4	
D2 fin length	4.5	7.0		3.0	
D2 fin height	1.5	2.3	2.0		
D2 fin base	2.5	3.9	2.8	2.2	
Pectoral fin length	10	15.5	11.5	16.1	
Pectoral fin base	5	7.8	5.2	5.9	
Pelvic fin length	5	7.8		4.0	
Pelvic fin base	2	3.1	4.2		
Anal fin length	4.9	7.6		4.7	
Anal fin base	2.5	3.9	3.6	2.8	
Caudal upper lobe length	17	26.4	25.5	27.1	
Caudal lower lobe length	7	10.9	10.6	11.8	

Tab. 3: Morphometric measurements of *Carcharhinus plumbeus* examined in the present study. In bold the percentages mentioned in Compagno (1984) and Ebert & Stehmann (2013).**Tab. 3: Morfometrične meritve na primerku vrste *Carcharhinus plumbeus*, opravljene v pričujoči raziskavi. V mastnem tisku so deleži, ki jih omenjajo Compagno (1984) in Ebert & Stehmann (2013).**

Measurements	Present Study		Lipej <i>et al.</i> (2008)			Capapé <i>et al.</i> (2018)		Ergüden <i>et al.</i> (2020)	
	cm	% of TL	Mean	SD	% of mean TL	cm	% of TL	cm	% of TL
Total length (TL)	91		74.3	6.2		89		68	
Fork length (FL)	72.5	79.7	59.8	5.4	80.5				
Standard length	65	71.4	54.7	5.1	73.6				
Head length	22.5	24.7	19.1	1.9	25.7	17	19.1	16.7	24.6
Mouth length	8	8.8	7.2	0.5	9.6	8	9.0		
Eye length	1.1	1.2	1.0	0.2	1.4	1.1	1.2	0.9	1.3
Eye height	0.9	1.0	1.1	0.1	1.4	1.2	1.3		
Internarial distance	5.3	5.8	4.5	0.3	6.0	5	5.6		
Pre-branchial length	19	20.9	14.8	1.6	19.9	16.5	18.5		
Pre-orbital length	8.5	9.3	6.5	1.0	8.7				
Pre-D1 fin length	28.5	31.3	21.5	1.7	28.9				
Pre-D2 fin length	59	64.8	46.7	3.8	62.8				
Pre-pectoral fin length	23	25.3	17.2	2.0	23.1				
D1 fin length	14.5	15.9	10.4	0.3	14.0	12	13.5	12	17.6
D1 fin height	10.5	11.5	7.2	1.0	9.6				
D1 fin base	10	11.0	9.0	0.3	12.1	10	11.2		
D2 fin length	7	7.7	3.1	0.3	4.2	4	4.5	5.4	7.9
D2 fin height	3	3.3	2.3	0.5	3.1				
D2 fin base	3.5	3.8	2.9		3.9	4	4.5		
Pectoral fin length	15.5	17	12.5	0.7	16.9	14	15.7	9.2	13.5
Pectoral fin base	7	7.7	4.9	0.6	6.6	5.5	6.2		
Pelvic fin length	7	7.7	6.0	0.6	8.0	4	4.5	5.8	8.5
Pelvic fin base	3.5	3.8	3.1	0.3	4.1	4	4.5		
Anal fin length	7	7.7	5.6	0.3	7.6	5	5.6	5.3	7.8
Anal fin base	4	4.4	3.1	0.3	4.2	3.5	3.9		
Caudal upper lobe length	25	27.5	10.6	1.1	14.3	22	24.7		
Caudal lower lobe length	9	9.9	5.2	0.5	7.0	8	9.0	6	8.8

of which as 1.5–2.3% for *C. obscurus* and 2.1–3.5% for *C. plumbeus*. Similarly, PAL-TL percentages of *C. obscurus* and *C. plumbeus* (1.5% and 17%, respectively) were within the ranges reported for *C. obscurus* (17–22%) and *C. plumbeus* (17–22%) by Compagno (1984) and Ebert & Stehmann (2013).

The slight variations between our measurements and those given by Compagno (1984) and Ebert & Stehmann (2013) suggest incongruity with the published descriptive ratios; however, similar variations have been observed in young individuals of the present *Carcharhinus* spp. before. When comparing our results to those reported for young individuals of *C. altimus*, *C. obscurus* and *C. plumbeus* from several regions of the Mediterranean Sea and elsewhere in the world (Devaraj & Gulati, 2004; Lipej *et al.*, 2008; Capapé *et al.*, 2018; Azab *et al.*, 2019; Lee *et al.*, 2019; Ayas *et al.*, 2020; Ergüden *et al.*, 2020; Turan *et al.*, 2020; Froese & Pauly, 2022; Tables 1–3) it is clear that the results concerning the three examined carcharhinid species from our study coincide better with the percentages reported by the above authors for young specimens (bold numbers in the relevant tables) than they do with those reported by Compagno (1984) and Ebert & Stehmann (2013) for adult individuals.

The percentage of EYL-TL of the examined specimens of *Carcharhinus altimus* was in agreement with those reported by Ayas *et al.* (2020) and Turan *et al.* (2020) (Table 1). The percentage range of D2H-TL of the examined specimens of *C. altimus* was also within the range reported by Turan *et al.* (2020); however, the percentage of PAL-TL of the examined specimens exceeded the percentage range reported by Ayas *et al.* (2020), and was higher than the ratio reported by Turan *et al.* (2020) (Table 1). Specimens of *C. altimus* reported by Ayas *et al.* (2020) and Turan *et al.* (2020) were also incidentally captured in the vicinity of the present sampling localities.

The EYL-TL percentages in the present specimen of *Carcharhinus obscurus* and in the Indian Ocean specimen reported by Devaraj & Gulati (2004) are in agreement with the percentage range reported for dusky sharks from Korean waters (Lee *et al.*, 2019) (Table 2), and the percentage of D2H-TL for the present specimen fits within the range reported by Lee *et al.* (2019), as well (Table 2). The PAL-TL percentages reported for the present specimen (15.5%) and for the Indian Ocean specimen (16.1%; Devaraj & Gulati, 2004) both exceed the range recorded in Korean dusky sharks (11.5–13.9%; Lee *et al.*, 2019).

For *Carcharhinus plumbeus*, the EYL-TL, D2H-TL, and PAL-TL percentages recorded in the present speci-

men differ from those recorded in specimens reported by Lipej *et al.* (2008), Capapé *et al.* (2018) and Ergüden *et al.* (2020), standing at 1.2 vs. 1.4%, 3.1 vs. 3.3% and 13.5 vs. 17%, respectively (Table 3).

CONCLUSIONS

Due to similar body shapes, colours and overlapping distributions, the Carcharhinidae genera can generally be difficult to identify, particularly *Carcharhinus* spp. (Grace, 2001). Since the existing literature addressing worldwide distribution (e.g., Compagno, 1984) or covering wide marine regions (e.g., Serena, 2005; Ebert & Stehmann, 2013) may not be applicable to carcharhinids occurring in Turkish waters, a set of multiple descriptions including a broad range of ratios and characters may be needed for their identification, as was the case in the present study. Identification of *Carcharhinus* spp. is facilitated by division into two groups based on the presence or absence of an interdorsal ridge. The origin of the first dorsal fin in relation to the pectoral fin and also the snout shape are useful for further subdivision of each group and, ultimately, species identification. This conventional order of division of characteristics follows the accepted identification keys (e.g., Compagno, 1984; Grace, 2001; Serena, 2005; Ebert & Stehmann, 2013), so what could be the underlying reasons for the differences in morphometric percentages?

Geographically distant (allopatric) populations of the same fish species tend to exhibit morphometric characters at the opposite margins of the value ranges (Cailliet *et al.*, 1986). The morphometric differences seen in the present study can thus be considered admissible based on the above-mentioned situation. Although the morphometric data reported for *Carcharhinus altimus*, *C. obscurus* and *C. plumbeus* in the present study provide valuable information on the morphometry of their populations in the northeastern Levant, it is clear that morphometric analysis of more specimens of each *Carcharhinus* species are required to obtain statistically significant results.

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MORFOMETRIČNE MERITVE MLADIČEV TREH VRST MORSKIH PSOV IZ DRUŽINE CARCHARHINIDAE IZ SEVERNOVZHODNEGA LEVANTA (SREDOZEMSKO MORJE)

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POVZETEK

Avtorji poročajo o morfometričnih meritvah na mladih primerkih vrst Carcharhinus altimus (Springer, 1950), C. obscurus (Lesueur, 1818) in C. plumbeus (Nardo, 1827). Te meritve nudijo pomembne podatke o morfometriji populacij treh vrst v severovzhodnem Levantu.

Ključne besede: *Carcharhinus*, morfometrija, Levantsko morje, Turčija

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