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Unveiling Diversity in Shark Fin Characteristics: A Comparative Study Across Order Carcharhiniforms

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ABSTRACT

An extensive morphometric examination of dorsal fin features for sharks belonging to the order Carcharhiniforms (families Scyliorhinidae, Triakidae, and Carcharhinidae was conducted. We compared the dorsal fin morphometric and diagnostic features of Galeus melastomus, Scyliorhinus stellaris, Galeorhinus galeus, Mustelus asterias, Mustelus mustelus, *Carcharhinus altimus*, *C. brachyurus*, *C. brevipinna*, *C. falciformis*, *C. obscurus*, *C. plumbeus*, and *Prionace glauca* using a mix of direct measurements and ratio-based comparisons. Fin base, height, and other ratio-based metrics provided light on the unique traits of each species, which displayed distinctive fin morphologies, particularly striking for Scyliorhinidae species with distinctive patterns and colors on their relatively big, rectangular dorsal fins. Alternatively, members of the family Triakidae have bigger, triangular fins, with varied tone and clear morphometric ratios. Lastly, the members of the family Carcharhinidae showed a wide range of fin forms and sizes, with different species displaying fin features dependent on ratios. Dorsal fin morphometric cluster analysis uncovered species-specific grouping patterns, emphasized morphological similarities and differences across families, and it was most effective within the family Scyliorhinidae. In addition, ordination methods highlighted the relationship between species and dorsal fin morphometrics by graphically representing the grouping and separation of shark species in three-dimensional areas. The significance of thorough morphometric studies in comprehending the variety and evolutionary connections within the order Carcharhiniforms was highlighted by this research, which offered a thorough foundation for the identification and classification of shark species.

INTRODUCTION

The Mediterranean Sea which lies along Europe is a semi-enclosed marine area with a generally narrow continental shelf. It stretches over 2.5 million square kilometers, has an average depth of 1.5 kilometers, and is 3.7 million cubic kilometers in volume. The sea's coordinates are 6°W and 36°E Long. and Lat. 30° to 46°N **(Poulos & Kotinas, 2021; Al-Khatib *et al.*, 2022)**.

Nearly 1,100 kilometers of the coastline stretch along the Mediterranean Sea in Egypt. It begins in the west at El-Salloum and finishes in the east at El-Arish **(Poulos, 2020)**.

More than 400 of the more than 1100 species in the Chondrichthyes fish family are sharks or closely related batoids or chimaeras **(Cliff & Olbers, 2022)**. Traditional shark fin soup is a cultural treat in China made from the most prized parts of the shark, the fins. Careful dissection of shark fins excludes the meaty underside of the fin. Subsequently, they are dried and packaged for sale **(Clarke *et al.*, 2006; Azab *et al.*, 2019b)**. When it comes to sharks and batoids that resemble sharks, the first dorsal fin is often sold in sets due to its high value **(Martins, 2021)**.

When it comes to taxonomy and identifying sharks, whether they're in the wild or captured by fishermen, the dorsal fin is a crucial trait. When sharks swim close to the water's surface, many wildlife rangers take pictures of their dorsal fins to use for classification purposes. Sharks are commercially important not only for their fins but also for their entire body, while numerous fishermen take the fins off the animals and sell them for profit. This leaves us wondering what kind of sharks are left without fins and if they are an endangered species. Therefore, it is crucial to get further data and information on the dorsal fin of sharks. Consequently, the purpose of this research was to catalogue the dorsal fin dimensions used as taxonomic traits for a number of shark species inhabiting the Mediterranean Sea off the coast of Egypt.

MATERIALS AND METHODS

Samples were taken from the El-Max, Anfushi, Abu-Qir, and Al-Maadia fish markets in Alexandria, Egypt. A new batch of shark specimens were evaluated. Each specimen's total length was obtained to the closest millimeter. To calculate various ratios of dorsal fin morphological characteristics, several pictures were taken for each shark specimen and processed using Image J software V 1.53t. For the subsequent studies, the sharks were brought to the Marine Biology lab at Al-Azhar University in Cairo, Egypt's Faculty of Science, where they were stored in a 10% formalin solution. The laboratory conducted the following experiments after identifying sharks according to the outlines of **FAO (2005)**.

Dorsal fin measurements

To study the morphometric features of the dorsal fin (D.) in sharks, the following measurements (Fig. 1) were recorded for it according to **Marshall and Barone (2016)** and **Azab *et al.* (2019a)**, as follows:

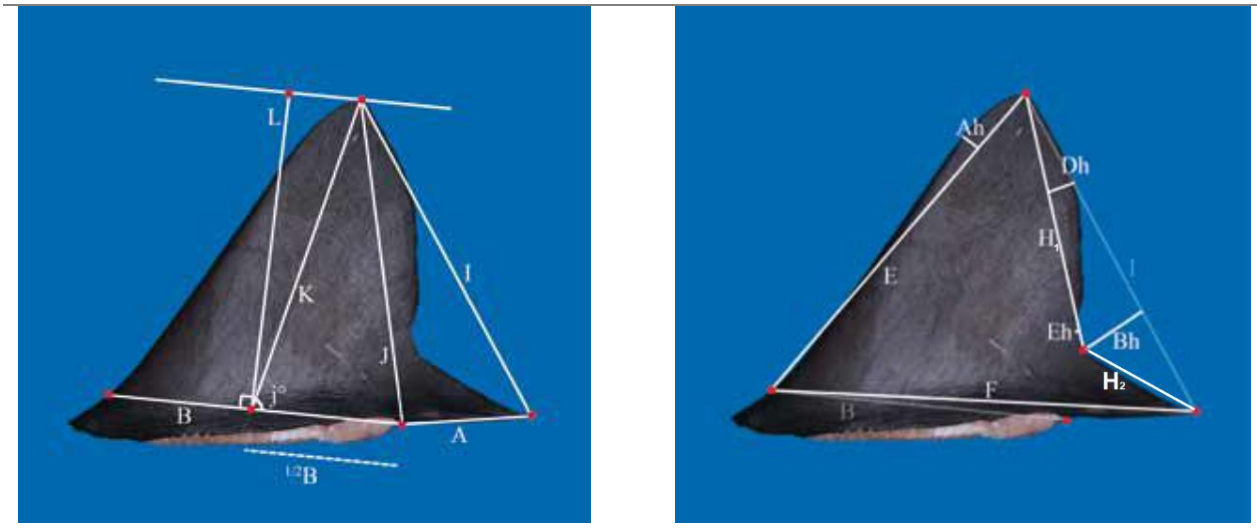

Fig. 1. Diagrammatic representation of morphometric measurements of dorsal fin sharks showing: **Free rear tip (D. A):** The distance between fin insertions to the end of the free rear tip; **Fin base (D. B):** The distance between fin origin to the fin insertion, i.e. the length of the dorsal fin base; **Anterior margin (D. E):** The distance between the dorsal fin origin and the fin tip; **Total fin width (D. F):** The distance between anterior ends of fin base to the end of the free rear tip; **Upper posterior margin (D. H1):** The distance between the tip of the fin and the deepest point of the concave curve of the posterior margin; **Lower posterior margin (D. H2):** The distance between the deepest points of the concave curve of the posterior margin to the end of the free rear tip; **Posterior margin (D. I):** The distance between the fin tip to the posterior tip of the free rear tip; **Fin height (direct) (D. K):** Distance from the mid-fin base (B) to the tip of the fin; **Fin height (absolute) (D. L):** Perpendicular distance from the fin baseline (B) to the tip of the fin; **Anterior margin height (D. Ah)**: The greatest distance (perpendicular) between line E and the anterior margin of the fin, anterior to line E; **Posterior margin depth (D. Bh):** The greatest distance (perpendicular) between line I and the posterior margin of the fin, anterior to line I; **Upper posterior margin convex depth (D. Dh):** The greatest distance (perpendicular) between the line H and the posterior margin of the fin, posterior to line H; and **Upper posterior margin concave depth (D. Eh):** The greatest distance (perpendicular) between the line H and the posterior margin of the fin, anterior to line H.

Statistical data analysis

The data was coded and inputted using SPSS V.22. For the purpose of ensuring that the data satisfied the requirements of parametric testing, we used the Shapiro-Wilk and Kolmogorov-Smirnov tests to determine if the continuous variables were normally distributed. The data were normalized for probability and percentile using arcsine square root. We displayed the data as mean ± standard deviation. Moreover, we used MiniTab V 14 to conduct the analysis of variance (ANOVA) on the recorded morphometric measures. Additionally, we used three replicates for each measure to ensure accuracy, and we examined the fins' features three times for each specimen to rule out measurement error. As of version 5.0, Pc-Ord is compatible with Windows applications and offers two-way cluster analysis and ordination.

RESULTS

1. Order: Carcharhiniforms

1.1. Family: Scyliorhinidae

Galeus melastomus was characterized by a moderately sized, rectangular dorsal fin; this species displayed a unique light coloration. The dorsal fin base averaged 2.05± 0.26cm, while the fin height was around 2.3± 0.35cm. Notably, the fin height as a percentage of various fin dimensions (total fin width, anterior margin, and direct fin height) ranged from 46.52 to 69.26%. Other ratios, such as the posterior height to posterior margin and the free rear tip to fin base also exhibited specific ranges, underscoring distinct morphological traits (Table 1 & Plate 1I).

Scyliorhinus canicular featured a dorsal fin with a moderate size and rectangular shape, marked by black dots. Its dorsal fin base and height measurements averaged 2.12± 0.19 and 2.08± 0.35cm, respectively. The fin height as a percentage of various dimensions revealed a higher range (52.69 to 88.43%) compared to *G. melastomus*. The distinct ratios in posterior height and margin depth further differentiate this species (Table 1 & Plate 1J). On the other hand, *S. stellaris* is similar in coloration to *S. canicula*; this species has a dorsal fin base averaging 4.32± 1.97cm and a height of 4.88± 1.65cm. The fin height percentages exhibited a range of 50.6 to 68.33%, slightly different from the previous two species. In addition, unique ratios in posterior heights and margins were observed (Table 1 & Plate 1k).

1.2. Family: Triakidae

Galeorhinus galeus was distinguished by a large, triangular dorsal fin with a dark tone. The dorsal fin base averaged 13.33± 2.58cm, significantly larger than the Scyliorhinidae species. The fin height percentage ranged from 61.73 to 108.98%, and other ratios such as the posterior height and margin depth offered a distinct profile compared to Scyliorhinidae sharks (Table 1 & Plate 1L).

Mustelus asterias featured a large, light-toned, triangular dorsal fin; this species showed a dorsal fin base averaging 6.2± 2.42cm. The ratios of fin height to other dimensions (64.23 to 99.65%) and posterior height to margin percentages presented a unique morphological signature (Table 1 & Plate 1M). While, *M. mustelus* exhibited a dorsal fin similar to *M. asterias*; this species has a dorsal fin base averaging 6.6± 2.82cm. The percentage ranges for fin height relative to other dimensions (59.51% to 99.49%), and distinct ratios in posterior heights and margins further distinguished it (Table 1 & Plate 1N).

Table 1. Measurements (cm, %) of dorsal fin shark species in families Scyliorhinidae and Triakidae, collected from Alexandria during the study period

Sp.	N	D.B	D.K	D.L/ D.F	D.L/ D.E	D.L/D.K	D.J/D.I	D.A/ D.B	D.Bh/ D.I	D.Dh/ D.H1	D.Eh/ D.H1	D.Ah/D. E	D.H2/ D.H1
G. melastomus	12	1.63-2.56	1.81-2.93	46.52-55.49	47.13-54.38	57.99-69.26	189.89-208.85	57.1-66.8	7.59-10.83	8.57-12.15	--	3.65-6.36	73.27-91.28
		2.05±0.26	2.3±0.35	51.52±2.65	50.73±2.01	64.17±3.14	200.76±6.42	62.5±3.04	9.66±1.06	10.76±1.09	--	5.03±0.79	85.15±5.29
S. canicula	4	1.85-2.43	1.4-2.7	52.69-63.66	53.56-62.94	78.68-88.43	96.9-108.07	40.3-48.22	4.54-6.07	9-16.41	--	1.81-6.1	53.08-59.94
		2.12±0.19	2.08±0.35	57.72±3.63	58.43±3.06	83.33±3.11	103.39±3.13	44.15±2.45	5.21±0.51	13.19±2.3	--	4.36±1.31	57.93±2.08
S. stellaris	3	2.04-5.57	2.97-5.86	50.6-56.94	47.15-53.25	64.43-68.33	125.23-128.4	40.88-47.41	5.09-5.31	24.29-26.65	--	5.86-6.41	63.18-66.47
		4.32±1.97	4.88±1.65	53.35±3.24	50.79±3.21	66.67±2.01	127.09±1.65	44.53±3.33	5.22±0.11	25.58±1.19	--	6.15±0.27	64.87±1.64
G. galeus	4	10.14-16.37	8.9-12.91	61.73-66.24	80.06-84.14	100.7-108.9	86.36-88.89	39.82-43.66	19.62-21.47	4.55-5.7	6.98-7.37	4.02-4.57	52.66-56.97
		13.33±2.58	11±1.64	64.32±2.19	81.37±1.86	105.54±3.54	87.23±1.13	41.17±1.69	20.39±0.83	5.3±0.53	7.13±0.16	4.32±0.23	55.26±1.83
M. asterias	4	2.93-8.78	3.68-9.14	64.23-66.13	83.63-85.75	92.83-99.65	84.17-88.93	62.76-65.82	14.59-16.27	5-5.61	2.77-3.76	5.56-7.09	39.66-41.34
		6.2±2.42	6.63±2.25	64.97±0.85	84.9±0.89	97.72±3.26	86.57±2.42	63.99±1.3	15.47±0.71	5.31±0.33	3.29±0.4	6.25±0.69	40.36±0.7
M. mustelus	9	3.97-13.23	4.1-10.32	59.51-68.13	72.57-78.92	89.63-99.49	83.37-98.65	50.09-57.23	17.15-22.3	4.98-8.17	8.09-10.71	5.25-6.09	50.5-56.84
		6.6±2.82	6.37±2	63.79±2.73	75.28±1.95	95.11±2.95	88.66±4.49	53.77±2.74	19.23±1.86	5.9±0.94	9.55±0.78	5.57±0.27	54.02±2.11

1.3. Family: Carcharhinidae

We compared the dorsal fin characteristics of seven Carcharhinidae family sharks, *Carcharhinus altimus, C. brachyurus, C. brevipinna, C. falciformis, C. obscurus, C. plumbeus,* and *Prionace glauca*. This comparison revealed distinct morphological features and measurement ratios, contributing to the nuanced understanding of shark taxonomy (Table 2 & Plate 1O).

Carcharhinus altimus is notable for its fairly tall, sickle-shaped dorsal fin with darker tips and a small free rear tip. The fin base averaged 13.42± 3.84cm, with a height of 12.69± 4.77cm. The fin ratios including fin height to total fin width and anterior margin ranged from 60.64 to 99.7%, indicating a unique fin profile (Table 2 & Plate 1P). Whereas, *C. brachyurus* featured a tall dorsal fin with a concave trailing margin and a small free rear tip. The single specimen measured showed a dorsal fin base of 25.79cm and a height of 22.35cm. The ratios of fin height to fin width and other dimensions presented a distinct pattern, different from *C. altimus* (Table 2 & Plate 1Q). On the other hand, *Carcharhinus brevipinna* was characterized by a tall, falcate dorsal fin with a round apex. The fin base ranged from 5.87- 17.45cm (average 11.57± 4.11cm), and the height from 6.12- 23.89cm (average 12.16± 6.28cm). The fin ratios here were slightly different from the previous species, especially in the height to the total fin width and anterior margin (Table 2 & Plate 1R).

C. falciformis exhibited a moderately sized dorsal fin with a slightly convex anterior margin. The fin base averaged 7.81± 1.21cm and a height of 7.91± 2.31cm. The fin height ratios, particularly to the total fin width, are lower compared to other species (Table 2 & Plate 1S). At the same manner, *C. obscurus,* this species has a moderately sized, somewhat falcate dorsal fin with a pointed apex. Its dorsal fin base averaged 12.55± 4.35cm with a height of 12.65± 3.86cm. The fin ratios, including height to total width and anterior margin, showed unique variations (Table 2 & Plate 1T). At the same time, *C. plumbeus* was known for its fairly tall, sickle-shaped dorsal fin with a blunt apex. The fin base averaged 10.33± 0.17cm with a height of 10.87± 0.38cm. The fin ratios here, especially the height to total width and anterior margin, differed slightly from other species (Table 2 & Plate 1U). Lastly, *Prionace glauca* featured a fairly tall, triangular dorsal fin with a pointed apex. The fin base was 24.2cm, and its height was 27.52cm. The ratios of fin height to total width and anterior margin were distinct, especially compared to other species (Table 2 & Plate 1V).

Table 2. Measurements (cm, %) of dorsal fin shark species in family Carcharhinidae, collected from Alexandria during the study period

Species	N	D.B	D.K	D.L/ D.F	D.L/ D.E	D.L/ D.K	D.J/D.I	D.A/ D.B	D.Bh/ D.I	D.Dh/ $D.H_1$	D.Eh/ $D.H_1$	D.Ah/ D.E	$D.H_2$/ $D.H_1$
C. altimus	14	5.93-19.63	4.93-19.01	60.64-69.37	75.63-88.16	87.66-99.7	90.84-104.77	36.13-42.02	17.5-21.67	5.06-8.42	3.86-5.77	6.06-7.38	40.39-56.41
		13.42±3.84	12.69±4.77	65.75±2.57	80.79±3.66	95.33±3.71	96.57±4.77	38.86±1.92	19.35±1.45	7.04±0.91	4.57±0.58	6.84±0.36	45.3±4.45
C. brachyurus	1	--	--	--	--	--	--	--	--	--	--	--	--
		25.79	22.35	71.41	74.98	96.26	97.67	16.98	19.13	7.06	5.84	8.16	45.04
C. brevipinna	7	5.87-17.45	6.12-23.89	71.06-75.6	72.55-76.2	91.73-96.83	85.92-93.83	31.91-36.1	17.34-20.48	8.54-11.33	5.92-9.3	5.93-8.44	41.61-47.3
		11.57±4.11	12.16±6.28	72.84±1.6	74.45±1.5	94.24±1.79	89.41±3.11	34.54±1.28	19.03±1.33	9.74±1.12	6.99±1.12	7.01±0.99	44.25±2.23
C. falciformis	2	6.95-8.67	6.28-9.54	54.68-54.87	63.97-65.1	78.26-88.07	90.69-90.84	45.23-46.3	19.4-22.12	11.27-11.4	8.23-9.9	7.62-10.7	48.68-53.06
		7.81±1.21	7.91±2.31	54.78±0.13	64.57±0.85	83.17±6.93	90.76±0.1	45.79±0.79	20.76±1.92	11.33±0.09	9.06±1.17	9.16±2.17	50.87±3.09
C. obscurus	8	6.64-19.92	5.91-19.05	69.44-73.38	69.98-79.4	89.64-97.42	89.34-97.63	41.03-45.4	19.51-24.75	5.7-6.8	4.95-5.95	7.73-9.47	43.87-49.73
		12.55±4.35	12.65±3.86	70.95±1.23	74.69±3.49	93.95±2.98	93.43±2.55	43.19±1.38	21.45±2.01	6.25±0.47	5.41±0.34	8.76±0.66	47.45±1.96
C. plumbeus	3	10.14-10.4	10.56-11.3	67.06-69.05	71.32-75.3	90.89-93.92	94.04-96.89	39.95-47.3	14.74-16.07	3.5-9.98	2.88-3.28	6.17-7.21	39.54-40.82
		10.33±0.17	10.87±0.38	67.89±1.03	73.41±2.03	92.87±1.71	95.47±1.42	43.47±3.73	15.33±0.67	6.71±3.23	3.08±0.2	6.63±0.53	40.09±0.66
P. glauca	1	--	--	--	--	--	--	--	--	--	--	--	--
		24.2	27.52	76.11	81.95	96.63	110.65	50.73	18.5	7.27	2.5	1.56	36.82

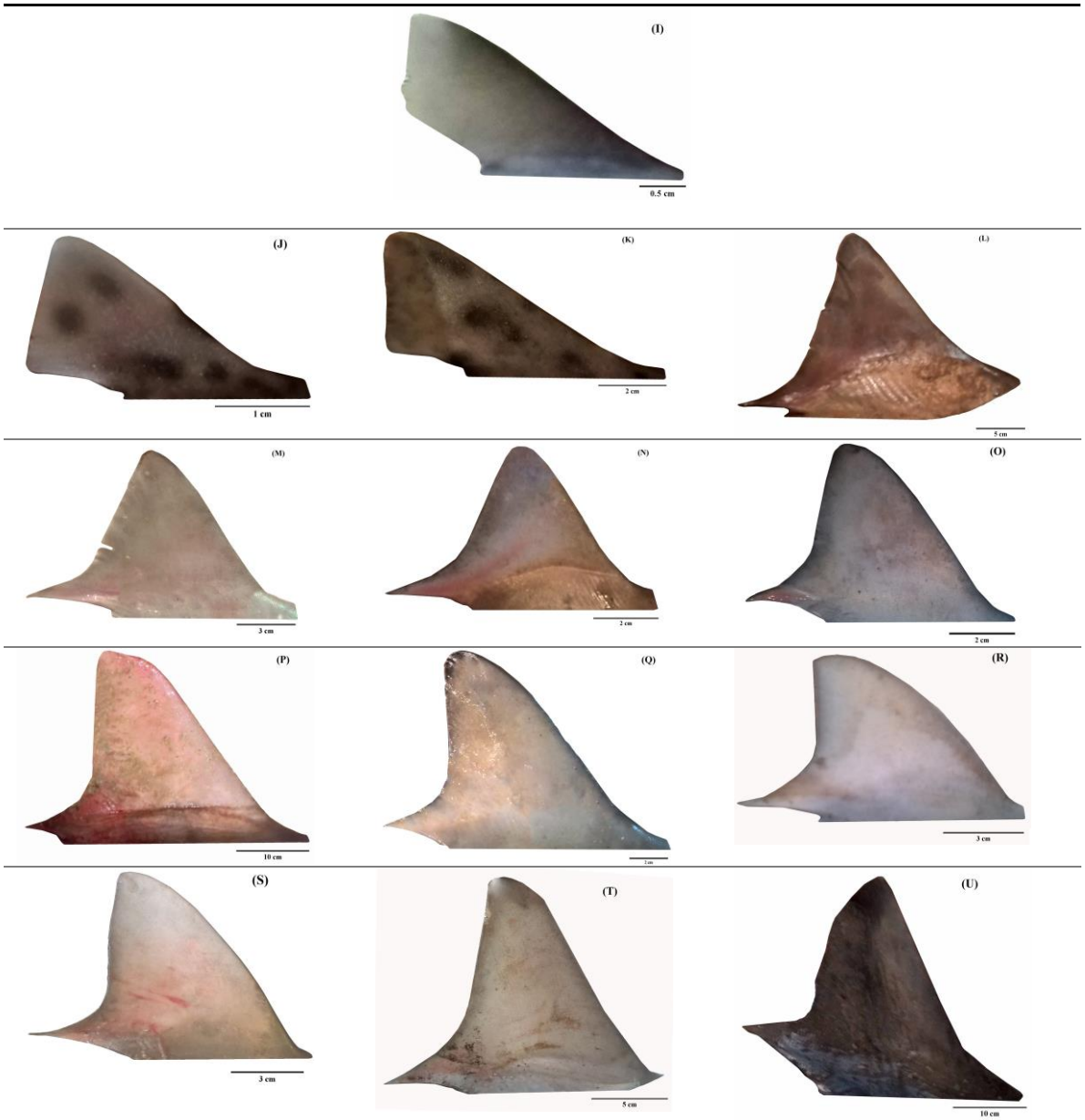

Plate 1. Photographs of dorsal fin showing: **(I)** *Galeus melastomus*, **(J)** *Scyliorhinus canicula*, **(K)** *Scyliorhinus stellaris*, **(L)** *Galeorhinus galeus*, **(M)** *Mustelus asterias*, **(N)** *Mustelus mustelus*, **(O)** *Carcharhinus altimus*, **(P)** *Carcharhinus brachyurus*, **(Q)** *Carcharhinus brevipinna*, **(R)** *Carcharhinus falciformis*, **(S)** *Carcharhinus obscures*, **(T)** *Carcharhinus plumbeus*, and **(U)** *Prionace glauca*

As shown in Fig. (2), dorsal fin morphometric ratios result in the clustering of Scyliorhinidae species into separate, closely related clades. While, Triakidae family species were clustered closely, but *G. galeus* were located in separate clade. This result shows the similarity of close ratios of dorsal fin morphometric between different Carcharhiniforms families. Moreover, as shown in Figs. (3, 4), ordination visually represents the separation and close grouping of the shark species in the 2D and 3D dimension, with a clear reference to the correlation between shark species and dorsal fin

morphometric ratios. It is evident that D.Dh/ D.H and D.A/ D.B have the highest correlation value among other contributed ratios, while the lowest correlation value was observed for D.Ah/ D.E.

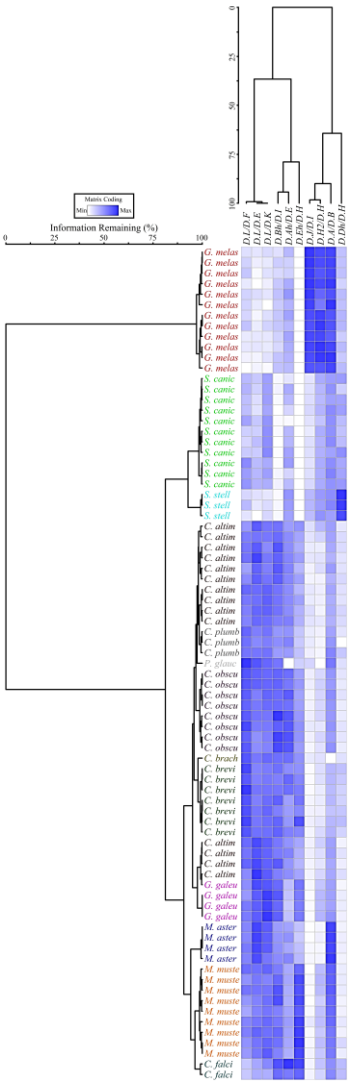

Fig. 2. Dendrogram showing two-way cluster analysis (Heat map) for dorsal fins morphometric ratios using Euclidean distance measure with Ward's group linkage method of sharks, collected from Alexandria during the study period

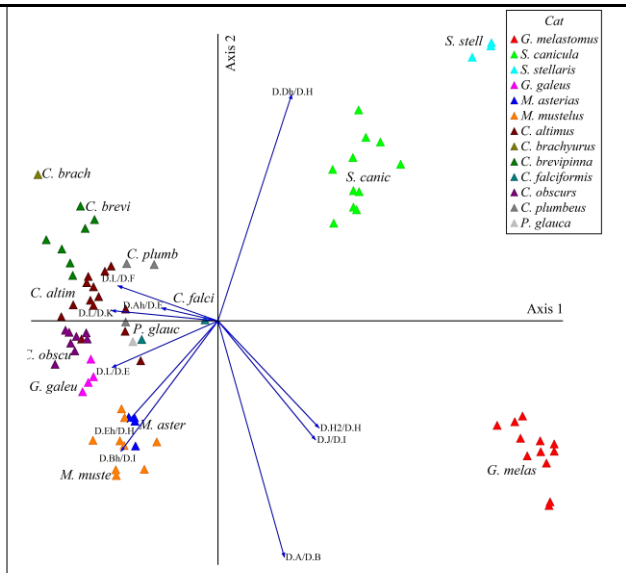

Fig. 3. Dendrogram showing 2D principal component analysis (PCA) for dorsal fin morphometric ratios of sharks, collected from Alexandria during the study period

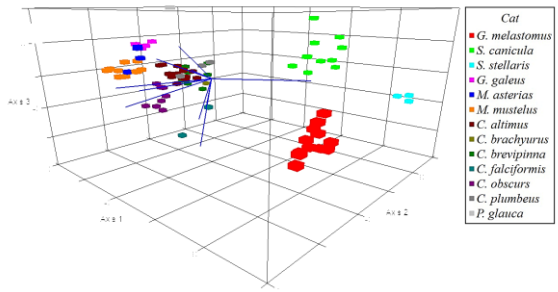

Fig. 2. Dendrogram showing 3D principal component analysis (PCA) for dorsal fin morphometric ratios of sharks, collected from Alexandria during the study period

DISCUSSION

The dorsal, pectoral, and caudal fins of sharks are particularly important for taxonomy and the identification of sharks, both in the wild and when caught by fishermen

(FAO, 2005). Taking pictures of sharks' dorsal fins as they swim close to the water's surface allows many wildlife rangers to classify the shark species. In addition to the high monetary worth of shark fins, many fishermen have a penchant for removing them and selling them on the market. This leaves us wondering what kind of sharks are left and if they are endangered or not. More research on the dorsal fin of sharks is, therefore, urgently required **(Shaban & El-Tabakh, 2019)**.

The morphological aspects of dorsal fin of species studied proved the potential capability for shark species identification. Where in the present study, the dorsal fin of *H. perlo* is small in size, anterior and posterior margins are concave in shape with rounded tip and dark tone of color with pinkish concave back margin. The average of dorsal fin base (D.B) and fin height (D.K) was 5.53± 0.84 and 3.94± 0.44cm, respectively. This result is nearly similar to the result recorded for the female of the same species while higher than that recorded for the male from the Northern Tunisian Coast and the Central Mediterranean Sea **(Reynaud & Capape, 2014; Azab *et al*., 2022b)**. In the present study, the dorsal fin of *H. griseus* is small in size and triangular in shape with a dark color. The shape and average of dorsal fin measurements match with the result recorded for the same species from Baja California Sur, Mexico **(Becerril-García *et al*., 2017)**.

In the present study, the average posterior margin depth (D.Bh) in the dorsal fin of *Scyliorhinus canicula* is lower than that recorded for the same species from the Mediterranean Sea **(Barrull *et al.*, 2002)**. On the other hand, the average of the anterior margin (D.E), posterior margin (D.I) and posterior margin depth (D.Bh) in the dorsal fin of *Mustelus mustelus* is higher than that recorded for the same species from the Black Sea **(Eryılmaz *et al*., 2011; Azab *et al.*, 2022a)**.

In the current study, the dorsal fin measurements of *Carcharhinus plumbeus* are higher than the results recorded for the same species from the Southern Tyrrhenian Sea **(Consoli *et al*., 2004)** and the Middle Adriatic Sea **(Dragičević *et al*., 2010)**. In the present study, the average of the dorsal fin height (D.K) and posterior margin depth (D.Bh) of *Prionace glauca* is higher than that recorded from the Canadian Atlantic waters **(McKBwzln & Tibbo, 1964)**. The differences in dorsal fin measurements may be due to differences in sizes.

CONCLUSION

It was found that, although these species have certain commonalities in dorsal fin morphology, there are significant and quantifiable variations in fin ratios and size. The accurate taxonomic categorization and comprehension of the morphological variety within the order Carcharhiniforms depend on these distinctions. Eminently, observing the diverse dorsal fin traits among sharks of the order Carcharhiniformes provides valuable insights into the importance of these traits for taxonomy and identification purposes.

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