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New records, conservation status and pectoral fin description of eight shark species in the Egyptian Mediterranean waters.

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ABSTRACT
For a taxonomical purpose, the present study described and analyzed the pectoral fin shape and measurements of shark specimens, collected from the Egyptian Mediterranean Sea waters at Alexandria, during the period from May 2017 to June 2018. Morphology and morphometric fin characters were used taxonomically to differentiate between shark species via photo program analysis. After confirming the identification of sharks, a list of shark species in the Egyptian Mediterranean waters was given with emphasize on new record species as well as the conservation status of each species.

Results showed that the collected specimens belong to eight species from different six families belonging to four orders. Species-list of sharks in this study including; *Heptranchias perlo*, *Hexanchus griseus*, *Squalus megalops*, *Centrophorus uyato*, *Oxynotus centrina*, *Squatina squatina*, *Isurus oxyrinchus* and *Isurus paucus*. By comparing the present findings with the previous studies, three shark species out of these eight species were considered as new records in the Egyptian Mediterranean waters. These new records are *Heptranchias perlo*, *Squalus megalops* and *Isurus paucus*. According as the global assessment of the IUCN (2018) red list, *Heptranchias perlo* and *Hexanchus griseus are* reported as near threatened species; while *Oxynotus centrina* considered as vulnerable species. *Isurus oxyrinchus* and *Isurus paucus* mentioned as endangered species. However, *Squatina squatina* is critically endangered. On the other hand, data was insufficient to state the situation of *Squalus megalops* and *Centrophorus uyato*.

The morphological aspects of pectoral fins, for these eight shark species, were greatly varied in shape that proved the potential capability to use this new technique as an important identification and classification tool. The statistical analysis of morphometric ratios also supports this proposition and shows a significant variance between investigated species. Our study attempted to add more update information on shark pectoral fin morphological and dimensional scaling.

INTRODUCTION

The Mediterranean Sea is a semi-enclosed marine area with generally narrow continental shelf. It is the most famous intercontinental sea, mediate the old three continents; Europe, Asia and Africa (about 6°W and 36°E Long. and Lat. 30° to 46°N), and covers an average of approximately 2.5 million square kilometers (UNEP,

1989). The Egyptian Mediterranean Sea coast attained about 1100 km. It extends from El-Salloum in the West to El-Arish in the East (Mehanna *et al*., 2005)

Sharks and their relatives (the batoids and chimaeras) comprise the Chondrichthyes fish, a group of more than 1100 species, of which more than 400 were sharks (Compagno, 2005). Due to their high diversity and their inconvenient identification, shark fins were intensively used by many authors to distinguish between different shark species in many marine locations (Consoli *et al*., 2004; Dragicevic *et al.,* 2009; Dragicevic *et al.,* 2010; Marouani *et al.* 2012; Reynaud & capapé 2014; Yığın *et al.,* 2016; Becerril-García *et al*., 2017).

Recently at the local level, Azab *et al*. (2019) described shark dorsal fin (and analyzed dorsal fin morphometric data) for some shark species in Egyptian Mediterranean waters. They give proof for the potential capability of this method (using the morphological aspects of shark's dorsal fin) in shark species identification, where their statistical analysis of morphometric ratios showed significant variances between investigated species.

Although the shark's pectoral fin considered a key feature in taxonomy, their position to the dorsal fin play important role in the separation and classification between near morphologically identical species (FAO, 2005), it has never been used in Egyptian Mediterranean waters. Moreover, at both local and global levels, the increasing consumption of shark products, along with the shark's fishing vulnerabilities, led to the decrease in certain shark populations (Chuang *et al*., 2016). In addition, IUCN (2018) listed the species in this study as vulnerable, endangered and critically endangered species. There was insufficient data to state the situation of *Squalus megalops* and *Centrophorus uyato* in wild.

The present study aimed to describe the pectoral fin shape and measurements for Egyptian Mediterranean shark species to answer the following question: Does the pectoral fin exhibits enough differences that qualify it to be taxonomic characteristics used in identification and classification of shark species belonging to orders Hexanchiformes, Squaliformes, Squatiniformes and Lamniformes in the given area? By answering that question, it will be easy to update the information about shark species recorded in the Egyptian Mediterranean waters and spot on their conservation status.

MATERIALS AND METHODS

Samples collection

Alexandria is located about 223 Km North of Cairo and lies at 31°12'56.3"N & 29°57'18.97"E. Four Fish land markets (El-Max, Anfushi, Abu-Qir and Al-Maadia) were the main sites for shark specimen collection at the shoreline of Alexandria (Figure 1).

A total of 43 specimens of sharks belong to 8 species (7 of *Heptranchias perlo*, 5 of *Hexanchus griseus*, 10 of *Squalus megalops*, 8 of *Centrophorus uyato*, one of *Oxynotus centrina*, 8 of *Squatina squatina*, 2 of *Isurus oxyrinchus* and 2 of *Isurus paucus*) were seasonally collected from the commercial catch of Mediterranean Sea at land fish markets in Alexandria (Figure 1); during the period from May 2017 to June 2018. Shark specimens were freshly examined. Many photos had been captured using Nikon D3200 Camera Kit with 18.55mm lens for each shark pectoral fins to be processed by Image J V1.46r software to calculate the morphometric measures. Each morphometric feature for the pectoral fins has been measured three times in three separate sessions and the average has been calculated to eliminate the error as could

as possible. Each pectoral fin belonging to one of the investigated species has been fully described with highlighting their diagnostic feature.

Some sharks were preserved in 10% formalin solution and transported to laboratory of Marine Biology, Zoology Department, Faculty of Science, Al-Azhar University, Cairo, Egypt for latter examinations. In the laboratory, sharks were identified according to FAO (2005) and the following studies were carried out.

Fig. 1: A map showing Alexandria coast of Egyptian Mediterranean Sea

Pectoral fin measurements:

To study morphometric features of the pectoral fin in sharks, the following measurements (Figure 2) were recorded for it according to Marshall & Barone (2016):

1. Free rear tip (P. A): The distance between fin insertions to the end of the free rear tip.
2. Fin base (P. B): The distance between fin origin to the fin insertion; i.e. the length of the pectoral fin base.
3. Anterior margin (P. E): The distance between the pectoral fin origin and the fin tip.
4. Total fin width (P. F): The distance between anterior ends of fin base to the end of the free rear tip.
5. Upper posterior margin (P. H_1): The distance between the tip of the fin and the deepest point of the concave curve of the posterior margin.
6. Lower posterior margin (P. H_2): The distance between the deepest points of the concave curve of the posterior margin to the end of the free rear tip.
7. Posterior margin (P. I): The distance between the fin tip to the posterior tip of the free rear tip.
8. Fin angle (P. J^o): The angle between the direct fin height (K) and the he mid-fin base (1⁄2 B).
9. Fin height (direct) (P. K): Distance from the mid-fin base (B) to the tip of the fin.
10. Fin height (absolute) (P. L): Perpendicular distance from the fin baseline (B) to the tip of the fin.
11. Anterior margin height (P. Ah): The greatest distance (perpendicular) between line E and the anterior margin of the fin, anterior to line E.
12. Posterior margin depth (P. Bh): The greatest distance (perpendicular) between line I and the posterior margin of the fin, anterior to line I.

13. Upper posterior margin convex depth (P. Dh): The greatest distance (perpendicular) between the line H and the posterior margin of the fin, posterior to line H.
14. Upper posterior margin concave depth (P. Eh): The greatest distance (perpendicular) between the line H and the posterior margin of the fin, anterior to line H.

Data analysis

Analysis of variance (ANOVA) using Fisher LSD method to refuse the null hypnosis and confirm the presence of significant variance between different pectoral fins morphometric measurements. The analysis become available using SigmaPlot V12.5 and MiniTab V18.1 software.

Tow way cluster (Heat map) constructed using Euclidean (Pythagorean) distance measure with Ward's group linkage method, the analysis applied using Pc-Ord V5.0 software.

Principal components analysis (PCA) become available using correlation cross-products matrix. While, the score of the ratios calculated using distance-based biplot in Pc-Ord V5.0 software.

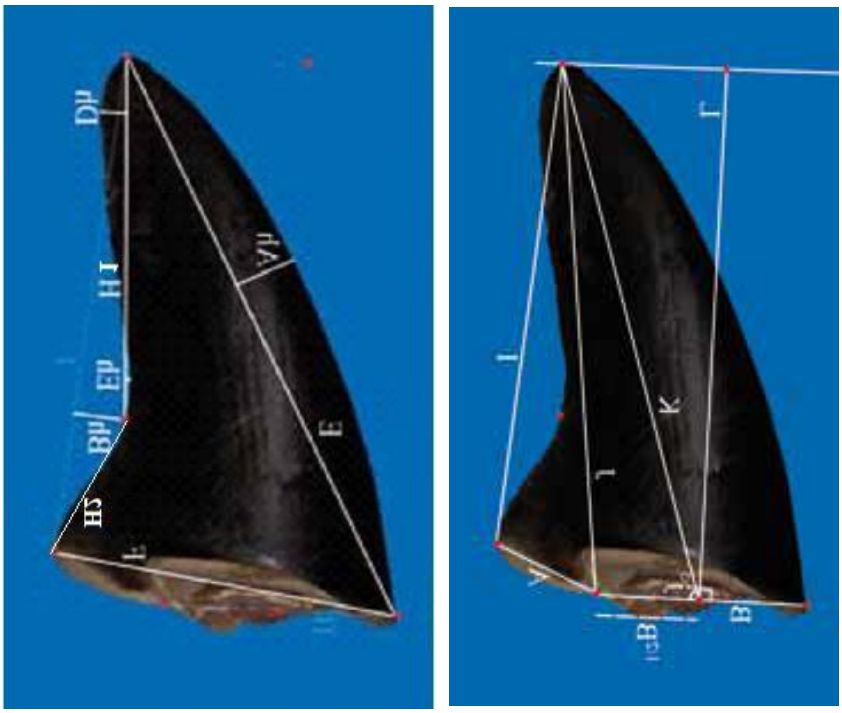

Fig. 2: Diagrammatic representation of morphometric measurements of pectoral fins of sharks

RESULTS

Classification and conservation status:

Results of Table (1) showed that the shark specimens collected from the Egyptian Mediterranean waters at Alexandria belong to eight species from different six families belonging to four orders. Order Hexanchiformes represents by 2 species; *Heptranchias perlo* (Bonnaterre, 1788) and *Hexanchus griseus* (Bonnaterre, 1788) belongs to family: Hexanchidae. Order Squaliformes comprises 3 species; *Squalus megalops* (Macleay, 1881) belongs to family: Squalidae; *Centrophorus uyato* (Rafinesque, 1810) belongs to family: Centrophoridae and *Oxynotus centrina* (Linnaeus, 1758) belongs to family: Oxynotidae. Order Squatiniformes, represents by

one species; *Squatina squatina* (Linnaeus, 1758) belongs to family: Squatinidae. Order: Lamniformes represents by 2 species; *Isurus oxyrinchus* (Rafinesque, 1810) and *Isurus paucus* (Guitart, 1966) belong to family: Lamnidae.

By comparing the present results with the previous studies, three shark species out of these eight species were considered as new records in the Egyptian Mediterranean waters. These new records are *Heptranchias perlo, Squalus megalops* and *Isurus paucus*.

According as the global assessment of the IUCN (2018) red list, *Heptranchias perlo* and *Hexanchus griseus* are reported as near threatened species. While *Oxynotus centrina* is considered as vulnerable species. At the same manner, *Isurus oxyrinchus* and *Isurus paucus* are mentioned as endangered species. However, *Squatina squatina* is critically endangered. On the other hand, data was insufficient to state the situation of *Squalus megalops* and *Centrophorus uyato* (Table 1).

On the other hand, *Oxynotus centrina, Squatina squatina* and *Isurus oxyrinchus* has been reported as criticality endangered species in the Mediterranean Sea IUCN (2018) red list assessment. While *Hexanchus griseus* stated as least concern. But the data was critically deficient to state the conservation states of 4 of the investigated species (*Heptranchias perlo, Squalus megalops, Centrophorus uyato* and *Isurus paucus*) revealed the need of more studies and conservation management in the Mediterranean Sea shark populations (Table 1).

Table 1: Classification and IUCN red list situation of the studied shark species collected from Egyptian Mediterranean waters, during the period from May 2017 to June 2018.

Order	Family	Species	No.	Local name	New record	IUCN (global)	IUCN (Med. Sea)
Hexanchiformes	**Hexanchidae**	*Heptranchias perlo*	7	قرش حاد الأنف	+	NT	DD
		Hexanchus griseus	5	قرش عريض الأنف	-	NT	LC
Squaliformes	**Squalidae**	*Squalus megalops*	10	قرش قصير الأنف	+	DD	DD
	Centrophoridae	*Centrophorus uyato*	8	قرش الماعز الصغير	-	DD	DD
	Oxynotidae	*Oxynotus centrina*	1	قرش الخشنة الزاوي	-	VU	CR
Squatiniformes	**Squatinidae**	*Squatina squatina*	8	قرش الملاك	-	CR	CR
Lamniformes	**Lamnidae**	*Isurus oxyrinchus*	2	قرش ماكو ذو الزعنفة القصيرة	-	EN	CR
		Isurus paucus	2	قرش ماكو ذو الزعنفة الطويلة	+	EN	DD

CR: Critically endangered**, DD:** Data deficient, **EN:** Endangered**, LC:** Least concern**, NT:** Near threatened**, VU:** Vulnerable**.**

Morphometric characteristics of shark pectoral fins:

In the present study, pectoral fins of studied shark species are one of broad, wide, moderate width, large, elongate with short or long in length. The pectoral fins are wing-like, semi-rectangular, leaf-like, paddle, and a falcate (sickle-like) shape with protruded lower edge. The edge is rounded, semi-rounded, pointed, pointed darker, concave, tapering and tapering to a point in shape. Posterior margin is concave, truncate, emarginated and nearly straight margin in shape. The anterior margin is longer or shorter than posterior margin (Plate I).

Order: Hexanchiformes:

Family: Hexanchidae:

***Heptranchias perlo* (Bonnaterre, 1788)**

***Synonyms*:**

Squalus perlo Bonnaterre, 1788;

Squalus cinereus Gmelin, 1789;
Heptranchias cinereus (Gmelin, 1789);
Heptranchias angio Costa, 1857;
Heptranchias deani Jordan & Starks, 1901;
Heptranchias dakini Whitley, 1931

***Diagnostic feature*:** Broad pectoral fins, short and wing-like in shape with concave margin (Plate I A).

***Fin measurements and ratios*:** Pectoral fins base (P.B) ranges between 10.51 and 12.85 cm with an average of 12.12±0.95 cm, while fin height (P.K) varies from 20.33 to 26.78 cm with an average of 24.4±2.57 cm (Table 2). Pectoral fins measurements ratios showed that:

- Absolute fin height (P.L) attaining 80.44-83.16%, 71.84-79.42% and 92.84-104.35% of the total fin width (P.F), anterior margin (P.E) and direct fin height (P.K) respectively with averages of 81.88± 0.84%, 74.13± 2.52% and 97.07± 3.98%, respectively.
- Fin posterior height (P.J) and posterior margin depth (P.Bh) ranging from 111.87 to 114.97% and from 5.64 to 7.38% of the posterior margin (P.I) with averages of 112.66±1.06% and 6.53±0.54%, respectively.
- Free rear tip (P.A) fluctuates between 54.01 and 61.41% of the fin base (P.B) with an average of 58.38±2.78%. Anterior margin height (P.Ah) varies from 5.63 to 7.43% of the anterior margin (P.E) with an average of 46.56±0.66%.
- Upper posterior margin concave depth (P.Eh) and upper posterior margin ($P.H_2$) attain 9.77-10.54% and 29.68-33.64% of the lower posterior margin ($P.H_1$) with averages of 10.06±0.27% and 31.29±1.25%, respectively (Table 2).

***Hexanchus griseus* (Bonnaterre, 1788)**

***Synonyms*:**
Squalus griseus Bonnaterre, 1788;
Squalus vacca Bloch & Schneider, 1801;
Hexanchus corinus Jordan & Gilbert, 1880;
Hexanchus griseus australis de Buen, 1960.

***Diagnostic feature*:** Broad pectoral fins; semi-rectangular in shape with rounded edges and truncate margin; anterior margin longer than posterior margin (PLATE IB).

Fin measurements and ratios: Pectoral fin base (P.B) ranges between 10.51-12.85 cm with an average of 12.12±0.95 cm, while fin height (P.K) varies from 20.33-26.78 cm (average: 24.4±2.57 cm).

- Absolute fin height (P.L) is attaining 90.26-93.3%, 80.21-84.38% and 93.3-95.56% of the total fin width (P.F), anterior margin (P.E) and direct fin height (P.K) with averages of 92±1.44%, 82.92±1.71% and 94.54± 0.87%, respectively.
- Fin posterior height (P.J) and posterior margin depth (P.Bh) varies from 117.63 to 129.89% and from 1.74 to 3.26% of the posterior margin (P.I), respectively (average: 123.6±4.41% and 2.6±0.56% respectively).
- Free rear tip (P.A) fluctuates between 79.83 and 86.34% of the fin base (P.B) with an average of 84.17±2.67%.
- Anterior margin height (P.Ah) attains 7.64-10.29% of the anterior margin (P.E) (average: 8.77±1.32%).
- Upper posterior margin convex (P.Dh), upper posterior margin concave depth (P.Eh) and upper posterior margin ($P.H_2$) ranging from 5.97 to 7.13%, from 1.58 to 2.43% and from 19.27 to 20.05% of the lower posterior margin ($P.H_1$) with averages of 6.53±0.45%, 2.06±0.41% and 19.54±0.31%, respectively (Table 2).

Order: Squaliformes:
Family: Squalidae:
***Squalus megalops* (Macleay, 1881)**
***Synonyms*:**
Acanthias megalops Macleay, 1881;
Squalus acutipinnis Regan, 1908;
Squalus probatovi Myagkov & Kondyurin, 1986
***Diagnostic feature*:** Broad pectoral fins; wing like in shape and concave margin (Plate I C).
***Fin measurements and ratios*:** Pectoral fins base (P.B) varies between 1.35-3.02 cm with an average of 1.82±0.51 cm, while fin height (P.K) ranges between 4.87-11.75 cm (average: 6.79±1.99 cm).
- Absolute fin height (P.L) is attaining 96.98-112.24%, 93.12-98.68% and 98.43-100.27% of the total fin width (P.F), anterior margin (P.E) and direct fin height (P.K) with averages of 105.01±4.89%, 96.22±1.72% and 99.35±0.68%, respectively.
- Fin posterior height (P.J) and posterior margin depth (P.Bh) attain 123.87-133.36% and 8.63-10.24% of the posterior margin (P.I), respectively (average: 127.78±3.19% and 9.46±0.59%, respectively).
- Free rear tip (P.A) fluctuates between 239.16 and 249.81% of the fin base (P.B) with an average of 245.6±3.69%.
- Anterior margin height (P.Ah) attains 11.66-14.45% of the anterior margin (P.E) (average: 12.97±0.79%).
- Upper posterior margin convex (P.Dh), upper posterior margin concave depth (P.Eh) and upper posterior margin ($P.H_2$) ranging from 2.68 to 4.42%, from 4.67 to 6,49% and from 21.62 to 30.15% of the lower posterior margin ($P.H_1$) with averages of 3.51±0.65%, 5.69±0.59% and 25.5±2.81%, respectively (Table 2).
Family: Centrophoridae:
***Centrophorus uyato* (Rafinesque, 1810)**
***Synonyms*:**
Squalus uyato Rafinesque, 1810;
Squalus infernus Blainville, 1825;
Acanthias nigrescens Nardo, 1860;
Centrophorus armatus barbatus Teng, 1962
***Diagnostic feature*:** Very long pectoral rear tips; usually, broad, semi-rectangular in shape with protruded lower edge and truncate margin (Plate I D).
***Fin measurements and ratios*:** Pectoral fin base (P.B) ranges between 1.02 and 3.12 cm with an average of 2.13±0.74 cm, while fin height (P.K) ranges between 2.85 and 8.09 cm with an average of 5.44±1.89 cm.
- Absolute fin height (P.L) is attaining 50.21-57.92%, 89.69-94.09% and 92.66-98.8% of the total fin width (P.F), anterior margin (P.E) and direct fin height (P.K) with averages of 53.23±2.69%, 92.02±1.72% and 95.96±2.01%, respectively.
- Fin posterior height (P.J) and posterior margin depth (P.Bh) varies from 91.92 to 99.2% and from 14 to 15.18% of the posterior margin (P.I), respectively (average: 95.34±3.06% and 14.55±0.39%, respectively).
- Free rear tip (P.A) fluctuates between 315.23 and 325.02% of the fin base (P.B) with an average of 319.81±3.62%.
- Anterior margin height (P.Ah) attains 7.64-10.29% of the anterior margin (P.E) (average: 13.78±0.41%).
- Upper posterior margin convex (P.Dh), upper posterior margin concave depth (P.Eh) and upper posterior margin ($P.H_2$) attain 6.94-8.64%, 4.69-6.26% and 72.39-78.01%

of the lower posterior margin ($P.H_1$) with averages of 7.6±0.62%, 5.38±0.63% and 75.71±2.46%, respectively (Table 2).

Family: Oxynotidae:

***Oxynotus centrina* (Linnaeus, 1758)**

***Synonyms*:**

Squalus centrina Linnaeus, 1758;
Centrina salviani Risso, 1827;
Centrina oxynotus Swainson, 1839;
Centrina vulpecula Moreau, 1881

***Diagnostic feature*:** Elongate pectoral fins; leaf like-shape with pointed edge (Plate I E).

***Fin measurements and ratios*:** Pectoral fin base (P.B) is 3.38 cm, while fin height (P.K) measured 9.67 cm.

- Absolute fin height (P.L) is attaining 208.12%, 92.55% and 97.39% of the total fin width (P.F), anterior margin (P.E) and direct fin height (P.K).
- Fin posterior height (P.J) and posterior margin depth (P.Bh) attain 118.13% and 5.27% of the posterior margin (P.I), respectively.
- Free rear tip (P.A) attains 48.86 % of the fin base (P.B).
- Anterior margin height (P.Ah) attains 9.69% of the anterior margin (P.E).
- Upper posterior margin convex (P.Dh) and upper posterior margin ($P.H_2$) attain 3.56% and 28.25 % of the lower posterior margin ($P.H_1$), respectively (Table 2).

Order: Squatiniformes:

Family: Squatinidae:

***Squatina squatina* (Linnaeus, 1758)**

***Synonyms*:**

Squalus squatina Linnaeus, 1758;
Squatina vulgaris Risso, 1810;
Squatina laevis Cuvier, 1816;
Squatina lewis Couch, 1825;
Squatina europaea Swainson, 1839;
Squatina angelus Gronow, 1854

***Diagnostic feature*:** Large pectoral fins; wide with rounded tips; wing-like in shape (Plate I F).

***Fin measurements and ratios*:** Pectoral fin base (P.B) ranges between 5.0 and 26.33 cm with an average of 12.38±7.53 cm, while fin height (P.K) varies from 10.66-40.23 cm with an average of 21.61±10.84 cm.

- Absolute fin height (P.L) is attaining 71.2-76.51%, 69.99-79.24% and 83.18-87.58% of the total fin width (P.F), anterior margin (P.E) and direct fin height (P.K) with averages of 72.91±1.83%, 74.75±3% and 85.53±1.8%, respectively.
- Fin posterior height (P.J) and posterior margin depth (P.Bh) varies from 141.44 to 148.59% and from 9.53 to 10.86% of the posterior margin (P.I), respectively (average: 144.75±2.8% and 10.21±0.53%, respectively).
- Free rear tip (P.A) fluctuates between 100.5 and 107.22% of the fin base (P.B) with an average of 104.29±2.24%.
- Anterior margin height (P.Ah) attains 21.2-28.72% of the anterior margin (P.E) (average: 24.96±2.75%).
- Upper posterior margin concave depth (P.Eh) and upper posterior margin ($P.H_2$) attain 9.93-12.43%, and 40.82-48.57% of the lower posterior margin ($P.H_1$) with averages of 11.4±0.98% and 45.41±2.42%, respectively (Table 2).

Table 2: Morphometric measurements and ratios of pectoral fin in shark species collected from Egyptian Mediterranean waters at Alexandria, during the period from May 2017 to June 2018.

Species	No	Desc. Stat.	P.B	P.K	P.L/P.F	P.L/ P.E	P.L/ P.K	P.J/ P.I	P.A/ P.B	P.Bh/ P.I	P.Dh/ P.H1	P.Eh/ P.H1	P.Ah/ P.E	P.H2/ P.H1
H. perlo	7	**Range**	10.51-12.85	20.33-26.78	80.44-83.16	71.84-79.42	92.84-104.35	111.87-114.97	54.01-61.41	5.64-7.38	--	9.77-10.54	5.63-7.43	29.68-33.64
		Mean± SD	12.12±0.95	24.4± 2.57	81.88± 0.84	74.13± 2.52	97.07± 3.98	112.7± 1.06	58.38± 2.78	6.53± 0.54	--	10.06± 0.27	6.56± 0.66	31.29± 1.25
H. griseus	5	**Range**	10.51-12.85	20.33-26.78	90.26-93.3	80.21-84.38	93.3-95.56	117.63-129.89	79.83-86.34	1.74-3.26	5.97-7.13	1.58-2.43	7.64-10.29	19.27-20.05
		Mean± SD	12.12±0.95	24.4± 2.57	92.00±1.44	82.92± 1.71	94.54± 0.87	123.6± 4.41	84.17± 2.67	2.6± 0.56	6.53± 0.45	2.06± 0.41	8.77± 1.32	19.54± 0.31
S. megalops	10	**Range**	1.35-3.02	4.87-11.75	96.98-112.24	93.12-98.68	98.43-100.27	123.87-133.36	239.16-249.81	8.63-10.24	2.68-4.42	4.67-6.49	11.66-14.45	21.62-30.15
		Mean± SD	1.82± 0.51	6.79± 1.99	105.01±4.89	96.22± 1.72	99.35± 0.68	127.8± 3.19	245.6± 3.69	9.46± 0.59	3.51± 0.65	5.69± 0.59	12.97± 0.79	25.5± 2.81
C. uyato	8	**Range**	1.02-3.12	2.85-8.09	50.21-57.92	89.69-94.09	92.66-98.8	91.92-99.2	315.23-325.02	14-15.18	6.94-8.64	4.69-6.26	13.3-14.45	72.39-78.01
		Mean± SD	2.13± 0.74	5.44± 1.89	53.23± 2.69	92.02± 1.72	95.96± 2.01	95.34± 3.06	319.8± 3.62	14.55± 0.39	7.6± 0.62	5.38± 0.63	13.78± 0.41	75.71± 2.46
O. centrina	1	**Range**	--	--	--	--	--	--	--	--	--	--	--	--
		Mean± SD	3.38	9.67	208.12	92.55	97.39	118.13	48.86	5.27	3.56	--	9.69	28.25
S. squatina	7	**Range**	5-26.33	10.66-40.23	71.2-76.51	69.99-79.24	83.18-87.58	141.4-148.59	100.5-107.22	9.53-10.86	--	9.93-12.43	21.2-28.72	40.82-48.57
		Mean± SD	12.38±7.53	21.61± 10.84	72.91± 1.83	74.75±3	85.53± 1.81	144.75±2.8	104.29±2.24	10.21± 0.53	--	11.4± 0.98	24.96± 2.75	45.41± 2.42
I. oxyrinchus	2	**Range**	4.15-5.15	14.23-23.7	164.9-168.05	87.56-88.03	90.86-93.22	128.43-129.2	170.0-174.25	1.9-3.39	10.89-11.97	0.66-1.13	3.03-3.21	19.92-20.85
		Mean± SD	4.65± 0.7	18.97±6.69	166.5± 2.2	87.8± 0.33	92.04± 1.67	128.8±0.54	172.13±3	2.64± 1.05	11.43± 0.76	0.9± 0.33	3.12± 0.12	20.38± 0.65
I. paucus	2	**Range**	13.76-18.19	46.56-53.58	176.3-177.28	88.13-88.55	94.88-95.4	98.67-99.29	83.52-85.67	14.65-14.7	2.15-2.38	2.46-2.62	8.26-8.64	22.2-23.76
		Mean± SD	15.97±3.13	50.07±4.95	176.78±0.69	88.34± 0.29	95.14± 0.36	98.98± 0.43	84.6± 1.52	14.68± 0.03	2.26± 0.16	2.54± 0.11	8.45± 0.27	22.98± 1.1

Order: Lamniformes:
Family: Lamnidae:
***Isurus oxyrinchus* Rafinesque, 1810**
***Synonyms*:**
Isurus spallanzani Rafinesque, 1810;
Squalus cepedii Lesson, 1831;
Isurus cepedii (Lesson, 1831);
Oxyrhina glauca Müller & Henle, 1839;
Isurus glaucus (Müller & Henle, 1839);
Carcharias tigris Atwood, 1869;
Isurus guentheri (Murray, 1884);
Isurus bideni Phillipps, 1932;
Isurus africanus Smith, 1957
***Diagnostic feature*:** Broad pectoral fins; wing like in shape with rounded edges (Plate I G).
***Fin measurements and ratios*:** Pectoral fin base (P.B) ranges between 4.15 and 5.15 cm with an average of 4.65±0.7 cm; while fin height (P.K) varies from 14.23-23.7 cm (average, 18.97±6.69 cm).
- Absolute fin height (P.L) is attaining 164.94-168.05%, 87.56-88.03% and 90.86-93.22% of the total fin width (P.F), anterior margin (P.E) and direct fin height (P.K) with averages of 166.5±2.2%, 87.8±0.33% and 92.04±1.67%, respectively.
- Fin posterior height (P.J) and posterior margin depth (P.Bh) varies from 128.43 to 129.2% and from 1.9 to 3.39% of the posterior margin (P.I), respectively (average: 128.82±0.54% and 2.64±1.05%, respectively).
- Free rear tip (P.A) fluctuates between 170.0 and 174.25% of the fin base (P.B) with an average of 172.13±3%.
- Anterior margin height (P.Ah) attains 3.03-3.21% of the anterior margin (P.E) (average: 3.12±0.12%).
- Upper posterior margin convex (P.Dh), upper posterior margin concave depth (P.Eh) and upper posterior margin ($P.H_2$) attain 10.89-11.97%, 0.66-1.13% and 19.92-20.85% of the lower posterior margin ($P.H_1$) with averages of 11.43±0.76%, 0.9±0.33% and 20.38±0.65%, respectively (Table 2).

***Isurus paucus* Guitart, 1966**
***Synonyms*:**
Lamiostoma belyaevi Glückman, 1964;
Isurus alatus Garrick, 1967
***Diagnostic feature*:** Very long pectoral fins; paddle in shape; round edges; concave posterior margin (Plate I H).
***Fin measurements and ratios*:** Pectoral fin base **(**P.B) ranges between 13.76 and 18.19 cm with an average of 15.97±3.13 cm, while fin height (P.K) varies from 46.56 to 53.58 cm with an average of 50.07±4.95 cm.
- Absolute fin height (P.L) is attaining 176.3-177.28%, 88.13-88.55% and 94.88-95.4% of the total fin width (P.F), anterior margin (P.E) and direct fin height (P.K) with averages of 176.78±0.69%, 88.34±0.29% and 95.14±0.36%, respectively.
- Fin posterior height (P.J) and posterior margin depth (P.Bh) attain 98.67-99.29% and 14.65-14.7% of the posterior margin (P.I), respectively (average: 98.98±0.43% and 14.68±0.03%, respectively).
- Free rear tip (P.A) fluctuates between 83.52 and 85.67% of the fin base (P.B) with an average of 84.6±1.52%.
- Anterior margin height (P.Ah) attains 8.26-8.64% of the anterior margin (P.E) (average: 8.45±0.27%).
- Upper posterior margin convex (P.Dh), upper posterior margin concave depth (P.Eh) and upper posterior margin ($P.H_2$) attain 2.15-2.38%, 2.46-2.62% and 22.2-23.76% of the lower posterior margin ($P.H_1$) with averages of 2.26±0.16%, 2.54±0.11% and 22.98±1.1%, respectively (Table 2).

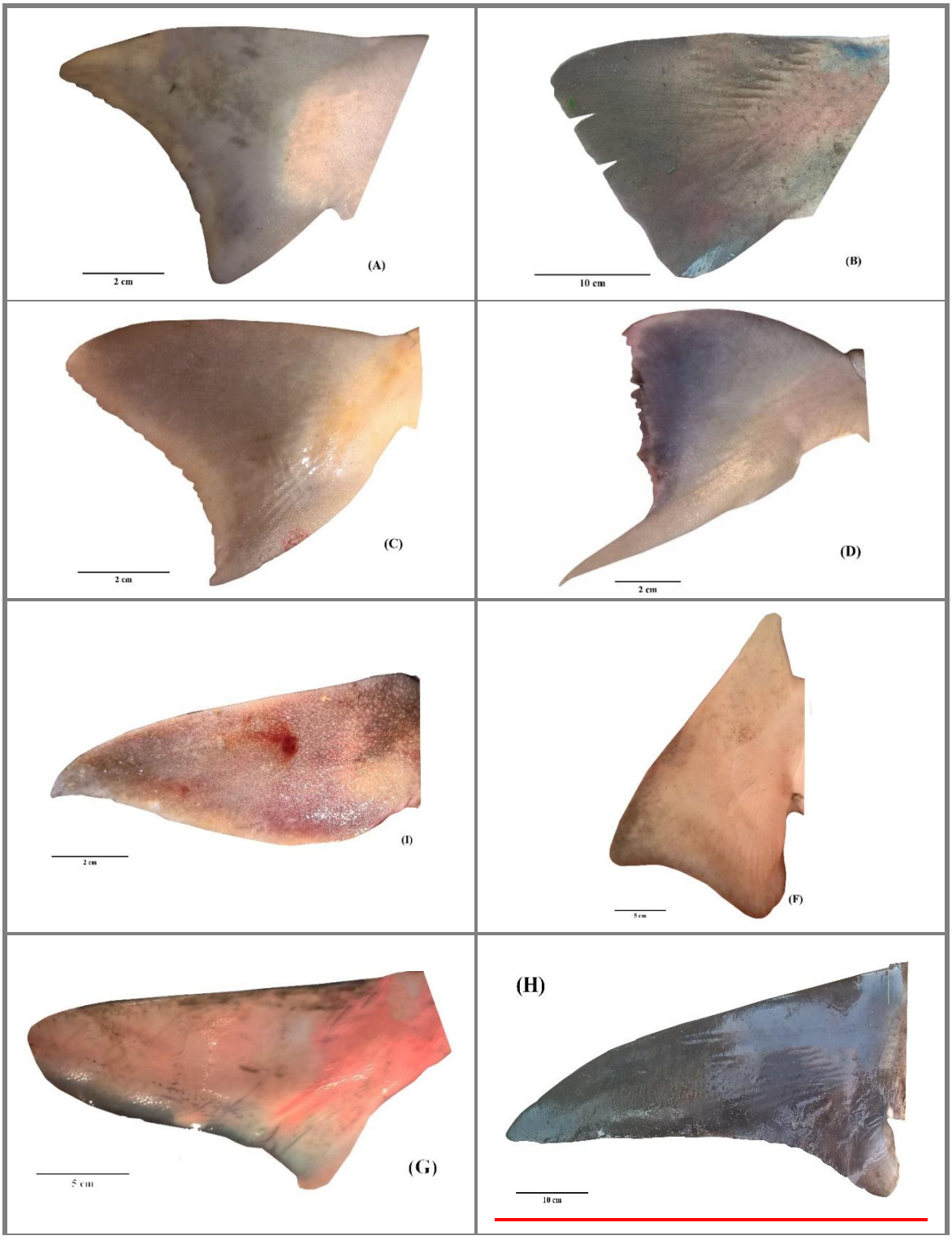

Plate (I): Pectoral fin of (A) *Heptranchias perlo*, (B) *Hexanchus griseus*, (C) *Squalus megalops*, (D) *Centrophorus uyato*, (E) *Oxynotus centrina*, (F) *Squatina squatina*, (G) *Isurus oxyrinchus*, (H) *Isurus paucus.*

Statistical analysis:

Due to the rarity and hard to find *Oxynotus centrina*, only represented by one specimen. However, the statistical analysis came along to what to be expected refusing null hypothesis, and proving the validation of pectoral fin morphometric measures to separate and classify studied shark species. Revealing that, in the future the finding of more replicates from this species could improve what already have been obtained.

The difference in the mean values among the different levels of Species is greater than would be expected by chance after allowing for effects of differences in factors. There is a statistically significant difference (P = <0.05). To isolate which group(s) differ from the others use a multiple comparison procedure. Power of performed test with alpha = 0.0500: for Species: 0.999, ratios show significant variance between different species revealed its capability as classifying tool (Table 3). Multi-variant data analysis was conducted to evaluate the potential of species separation using pectoral fin morphometric measurements.

As shown in (Fig. 3), 2-way cluster analysis (Heat map) shows color graded variables on which the species has been clustered, showing the similarities and the differentiations between contribute variables. pectoral fin morphometric ratios result in perfect claustration of Hexanchiformes, Lamniformes, Squatiniformes and Squaliformes species into separate clades, with exception for *O. centrina* which tend to cluster with family Lamniformes clade due to the near close similarity of its pectoral fin with this order species. The pectoral fin morphometric ratios show great potentiality in classification.

2-D ordination graph (Fig. 4) shows species specimens represented as triangular points, while different variables represented as arrows with direction towards its positive correlated species within ordination and the variable length reveal more or less correlation value. Reveal the ratios on which closely related species share positive correlation with. 3-D ordination (Fig. 5) explains that, the species is actually localized in 3D dimensional space with the effecting variables adding more clarification on the understanding of the simplified 2D dimensional ordination. ordination clearly shows the separation and close grouping of the shark species in the 2D and 3D dimension, with clear reference to the correlation between shark species and pectoral fin morphometric ratios. Shows that, (P.H2/P.H) has the highest correlation value among other contributed ratios, while the lowest correlation value was (P.L/P.K).

Table 3: Fisher pairwise comparisons: species grouping information using Fisher LSD method and 95% Confidence for pectoral fin morphometric ratios of shark species, collected from Egyptian Mediterranean waters, during the period of study.

Species	Grouping				
Centrophorus uyato	A				
Squalus megalops	A	B			
Isurus oxyrinchus	A	B	C		
Oxynotus centrina		B	C	D	
Isurus paucus		B	C	D	E
Squatina squatina			C	D	E
Hexanchus griseus				D	E
Heptranchias perlo					E

Means that do not share a letter are significantly different.

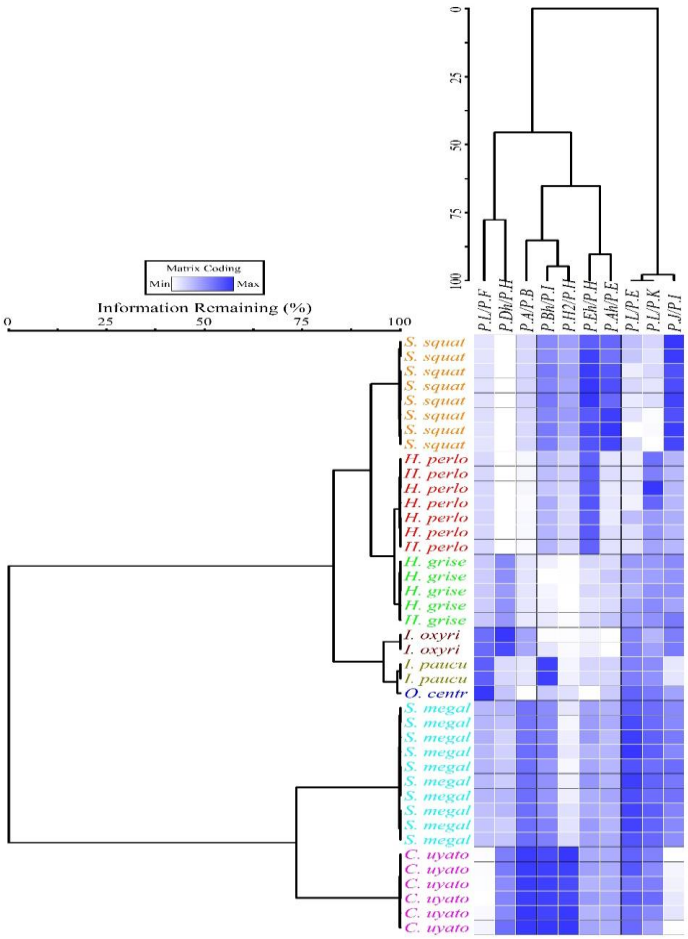

Fig. 3: Tow way cluster analysis (Heat map) for pectoral fin morphometric ratios using Euclidean distance measure with Ward's group linkage method of shark species (color coded to their orders), collected from Alexandria, during the period from May 2017 to June 2018.

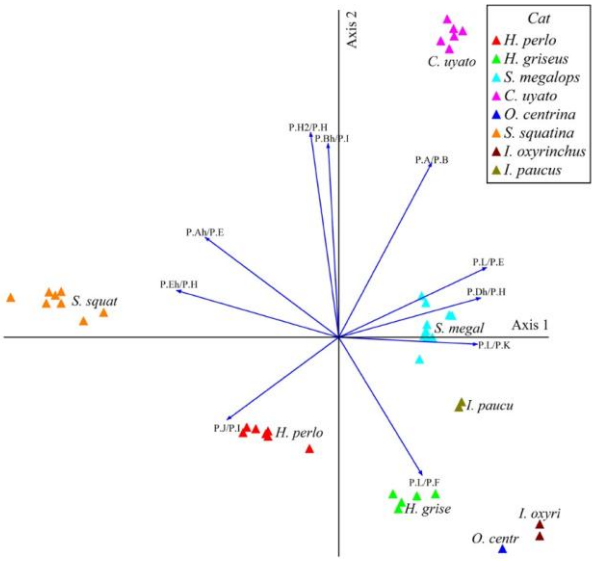

Fig. 4: 2D principal component analysis (PCA) for pectoral fin morphometric ratios of shark species (color coded to their species), collected from Alexandria, during the period from May 2017 to June 2018.

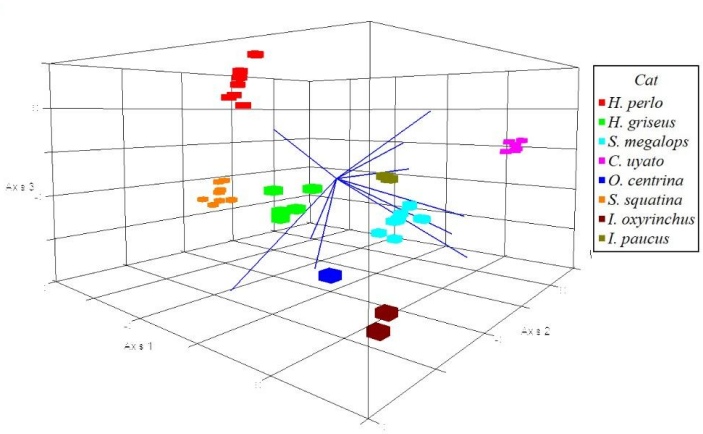

Fig. 5: 3D principal component analysis (PCA) for pectoral fin morphometric ratios of shark species (color coded to their species), collected from Alexandria, during the period from May 2017 to June 2018.

DISCUSSION

The shark's pectoral fin considered a key feature in taxonomical and identification of sharks. In the present study, the morphological aspects of pectoral fin of *Heptranchias perlo*, *Hexanchus griseus*, *Squalus megalops*, *Centrophorus uyato*, *Oxynotus centrina*, *Squatina squatina*, *Isurus oxyrinchus* and *Isurus paucus* proved the potential capability for shark species identification. Three species of them (*Heptranchias perlo*, *Squalus megalops* and *Isurus paucus*) are new records in the Egyptian Mediterranean waters (Akel and Karachle, 2017). In addition, the danger of extinction of some investigated species and the lake of data and information to make decision of stating some investigated shark species in IUCN (2018) red list.

Using the description of fins in studied shark species were taxonomically effective and these findings match with the findings that obtained by Consoli *et al*. (2004), Dragicevic *et al.* (2009), Dragicevic *et al.* (2010), Marouani *et al.* (2012), Reynaud and capapé (2014), Yığın *et al.* (2016) and Becerril-García *et al*. (2017).

In the present study, the average of pectoral fin height (P.K) and anterior margin (P.E) of *Heptranchias perlo* were matching with the result recorded at the same species from Northern Tunisian coast, Central Mediterranean Sea (Reynaud and capapé, 2014). While, the Pectoral fin base (P.B) of *Heptranchias griseus* ranges between 10.51-12.85 cm with an average of 12.12±0.95 cm. This result was higher than that recorded at the same species from Baja California Sur, Mexico (Becerril-García *et al*., 2017).

In the present study, the pectoral fins measurements of *Oxynotus centrina* were nearly similar with the results recorded at the same species from Mediterranean Sea (Brrull and Mate, 2001) and lower than that recorded from Eastern Mediterranean Sea (Megalofonou and Damalas, 2014); Eastern Adriatic Sea (Dragicevic *et al*., 2009) and in Saros Bay, North Aegean Sea, Turkey (Yığın *et al.*, 2016). The differences in measurements may be due to differences in size or replicate of data.

In the present study, the average of pectoral fin base (P.B) and posterior margin (P. I) of *Squatina squatina* were higher than that recorded at the same species from Tyrrhenian coast of the Strait of Messina (Cavallaro *et al*., 2015). On the other hand, the average of pectoral fin base (P.B) and posterior margin (P.I) of *Scyliorhinus canicula* were lower than that recorded at the same species from Mediterranean Sea (Barrull *et al*., 2002).

In the present study, the average of pectoral fin base (P.B) and posterior margin (P.I) of *Mustelus mustelus* were higher than that recorded from the Black Sea (Eryılmaz *et al*., 2011). Also, the average of pectoral fin base (P.B) and posterior margin (P.I) of *Carcharhinus plumbeus* were higher than that recorded at the same species from Southern Tyrrhenian Sea (Consoli *et al.,* 2004) and Middle Adriatic Sea (Dragicevic *et al*., 2010). On the other ways, the pectoral fins measurements of *Prionace glauca* were matching with McKBwzln and Tibbo (1964) from Canadian Atlantic waters.

CONCLUSION

The morphological aspects of pectoral fin of studied shark species proved the potential capability for shark species identification. The statistical analysis of morphometric ratios showed significant differences between investigated species. Our study attempted to add more information and update on the shark's pectoral fin morphological and dimension scaling.

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ARABIC SUMMARY

تحديد حالة ووصف الزعنفة الصدرية لثمانية أنواع من أسماك القرش مع بيان الأنواع التي تسجل لأول مرة في المياه المصرية للبحر المتوسط

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تهدف الدراسة الحالية الى تصنيف القروش داخل نطاق المياه المصرية بالبحر المتوسط باستخدام تقنيات وصف وتحليل الزعنفة الصدرية لهذه القروش وقياساتها ثم بعد ذلك تحديد موقف الأنواع التي تسجل من أسماك القرش من قائمة الأنواع المهددة بالانقراض واستخراج قائمة بالأنواع التي تسجل لأول مرة في المياه المصرية. قامت الدراسة الحالية بوصف وتحليل شكل الزعنفة الصدرية وقياساتها المورفومترية لعدد ٤٣ عينة من أسماك القرش تم جمعها من الإسكندرية، على ساحل البحر المتوسط ، خلال زيارات منتظمة لمدة عام كامل في الفترة من مايو ٢٠١٧ إلى يونيو ٢٠١٨. تم التقاط العديد من الصور لكل عينة من أسماك القرش محل الدراسة لتتم معالجتها بواسطة تطبيق باستخدام الحاسوب لحساب النسب المختلفة للجوانب المورفومترية للزعنفة الصدرية. وبعد التعرف على هوية جميع عينات اسماك القرش التي جمعت، تم تحديث البيانات البيئية الخاصة بالأنواع وحددت مواقف الأنواع من قائمة الخطر وفقا للقائمة الحمراء للاتحاد الدولي لحماية الطبيعة وكذلك تم تحديث قائمة الأنواع المسجلة بالمياه المصرة المتوسطية.

أظهرت النتائج أن العينات التي تم جمعها هي لثمانية أنواع من القروش والتي تنتمي الى ستة عائلات مختلفة في أربعة رتب. وكانت قائمة الأنواع المسجلة في هذه الدراسة تشتمل على: *Heptranchias perlo*, *Hexanchus griseus*, *Squalus megalops*, *Centrophorus uyato*, *Oxynotus centrina*, *Squatina squatina*, *Isurus oxyrinchus* and *Isurus paucus*.

بمقارنة النتائج الحالية مع الدراسات السابقة ، وجد أن ثلاثة أنواع من هذه الأنواع الثمانية تسجل للمرة الأولى في المياه المصرية للبحر المتوسط هي: *Heptranchias perlo, Squalus megalops and Isurus paucus*.

بالنسبة لموقف انواع القروش من القائمة الحمراء للاتحاد الدولي لحماية الطبيعة فقد بينت الدراسة الحالية أنها تنقسم الى ما يلي: ١- الأنواع المهددة بالانقراض بشكل حرج تشمل: *Squatina squatina*

٢- الأنواع المهددة للانقراض تشمل: *Isurus oxyrinchus* and *Isurus paucus*

٣- الأنواع المعرضة للانقراض تشمل: *Heptranchias perlo* and *Hexanchus griseus*

٤- الأنواع تحت المعرضة للانقراض تشمل: *Oxynotus centrina*

٥- الأنواع التي لا تتوفر عنها معلومات كافية للحكم عليها: *Squalus megalops* and *Centrophorus uyato*.

هذا وكانت الجوانب المورفولوجية للزعنفة الصدرية، بالنسبة لأنواع أسماك القرش الثمانية المدرجة في هذا العمل، متنوعة بشكل كبير في الشكل الذي أثبت القدرة المحتملة على استخدام هذه التقنية الجديدة كأداة هامة لتصنيف القروش محل الدراسة والتعرف على أنواعها. كما تدعم نتائج التحليل الإحصائي لبيانات النسب المورفومترية الخاصة بالزعنفة الصدرية هذا الاتجاه حيث أظهرت النتائج والتحاليل الاحصائية مدى التباين والاختلاف بين الأنواع للدرجة التى تكفي للفصل بينهم تصنيفياً. هذا وقد تم من خلال هذه الدراسة تحديث البيانات المورفولوجية والبيولوجية وابعاد الزعنفة الصدرية لاضافة المعلومات عن تباين تشكلاتها واحجامها.