

Species Composition, Diversity and Length Frequency of By-Catch Sharks from the Syrian Coast

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Abstract: This study examines the species diversity, abundance, length structure, sex ratio and possible nursery of caught sharks and from Syrian marine waters during the period from November 2014 to October 2016. A total of 17 species were recorded belonging to 11 families. The most abundant family was the Squalidae, contributing 28.33% to the total number of recorded shark species. The species *Galeus melastomus* was the most abundant 26.85%. The two families Hexanchidae and Carcharhinidae contributed 88.59% of the total weight of species, the most weight species was *Hexanchus griseus* 47.02%. The diversity index *H*, qualitative richness factor *D* and evenness factor *J* means \pm S.D. were 1.70 ± 0.22 , 1.88 ± 0.35 and 0.67 ± 0.08 respectively. The seasonally variation of the *H* and *D* means showed a high values in spring, while *J* mean showed a high value in winter. There were three abundant species and five common species off the Syrian coast. Many species comprised a high proportion of juveniles. Length structure analysis showed that sustainable populations for many species, which probably established in the Syrian marine waters, this region could be considered as a possible nursery area for many species.

Keywords: elasmobranches, biodiversity, length structure, nursery areas, Syrian coast.

Abbreviations: *H*: diversity index, *D*: qualitative richness factor, *J*: evenness factor:, *TL*: total length

1. INTRODUCTION

Cartilaginous fishes off the Syrian coast have not been studied systematically as yet. To date, forty-four chondrichthyans species [1, 2, 3, 4, 5, 6] were recorded in Syrian coast. In the Syrian marine waters, information related with the biology, fishery, landings, distribution and abundance of shark populations is scarce or non-existent. There were few studies interested in species survey and taxonomy [1, 2], species biology [7, 8, 9]. Whereas there were no studies on landings, distribution, abundance and structure of shark populations in this area.

Chondrichthyans are vulnerable to overexploitation. Globally, lack of accurate catch data (due to under reporting, lack of by catch recording, poor species identification and species wise catch data, illegal fishing etc.) makes assessment and management of chondrichthyans exploiting difficult, which is a major concern. This issue was addressed by Convention on international Trade in Endangered Species (CTES) in 1994, which requested contracting parties to collect biological and trade information on sharks taken in their fisheries. This was reiterated by FAO in 1999 by its adoption of International Plan of Action (IPOA) for Conservation and management of sharks. At present, only a few countries have management and monitoring programs for chondrichthyans.

Sharks have experienced increased demand in recent years due to rise of bony fish price and the request increasing on fish; despite Syria has no targeted sharks fishery. Although the diversity of cartilaginous fish, there are no studies have been undertaken to determine the biological characteristics of the shark catches or its ability to withstand this increased exploitation, The present study was undertaken as a first step to remedying this situation, which aimed to provide the first detailed assessment of the compositions and abundances of shark in Syrian marine waters. The length structure, sex compositions and possible nursery places of abundant and common species were determined.

2. MATERIALS AND METHODS

During November 2014 to October 2016, daily surveys were made on species and its size structure which caught by all fishing gears (mainly: bottom trawl, bottom longlines, nets) in the main landing of chondrichthyans in Lattakia city. Species identification was made following [10], [11] and [12]. Total length (TL) and weight measurements taken to the nearest cm and kg, respectively. The ecological indices; diversity index H, qualitative richness factor D and Evenness factor J were used to evaluate the levels of shark diversity within the study region by all gear types, diversity index H was calculated following [13]:

$$H = - \sum_{i=1}^S P_i \times \ln(P_i)$$

where S is the number of species in the sample, P_i is the proportion that the i^{th} species contributes to the total abundance of the sample ($P_i = N_i/N$), N_i the number of individuals of the i^{th} species, and N the number of individuals in the sample.

.Qualitative richness factor D by equation: following [14]

$$D = \frac{(S - 1)}{\ln(N)}$$

Evenness factor J by equation: according [15]

$$J = \frac{H}{\ln(S)}$$

SPSS 20 were used to analyze data, all information on total length at first maturity of the Syrian marine fishes or the nearest region to Syrian coast were extracted from peer-reviewed published sources, including 'grey' literature covering the period up to April 2017. Possible nursery places were defined depending on individuals size of species, density of individuals and repeat individuals appearance in the fishing area.

3. RESULTS AND DISCUSSION

A total of 4158 and 3877 individuals of sharks species were recorded in first and second year respectively of study period, there were no significant differences between first and second year (t-test, $t = 0.638$, $P > 0.05$), consequently, samples through two years were studied as a one year totally.

A total of 8035 elasmobranches individuals, comprising 17 species belonging to 11 families, were recorded at main landing site in the Syrian coast between November 2014 to October 2015 (Table 1). Whereas 21 shark species were recorded off Syria marine water throughout the period 2003-2012 [1, 2, 4]. The species that did not record in this study, but it was recorded in prior studies were, *Somniosus rostratus*, *Squatina squatina*, *Cetorhinus maximus* and *Sphyrna zygaena* which could be very rare in Syrian marine waters, or does not existed in the region any more. *Centrophorus granulosus* was recorded in the Syrian marine waters by [1], but wrongly identified as *Centrophorus machiquensis*.

The most abundant family was the Squalidae, contributing 28.33 % to the total number of recorded shark species, with the next most abundant family was the Scyliorhinidae, contributing 28.31 %, whereas the lowest abundant family was Alopidae (0.26%) represented by *Alopias superciliosus* species. The most abundant species in the catch composition were *Galeus melastomus* (26.85%), *Squalus blainvillei* (26.72%) and *Carcharhinus plumbeus* (14.13%) (Table 1). Other species with relatively high occurrence were *Hexanchus griseus* (5.80%), *Mustelus mustelus* (5.20%), *Centrophorus uyato* (5.88%), and *Centrophorus granulosus* (4.23%). Conversely, the most weighted family was Hexanchidae contributing 47.02% of total weight landing, the next weighted family was Carcharhinidae contributing 41.57%. *Hexanchus griseus* was the most weighted species, with next *Carcharhinus plumbeus* contributing 46.15% and 31.14% respectively (Table 1).

Abundant index, status on regional Red List of Mediterranean, and percentage of weight and numeral of sharks were shown in Table 1. There were three abundant species (*C. plumbeus*, *Galeus*

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melastomus and *Squalus blainvillei*), and five common species (*H. griseus*, *Hepranchias perlo*, *Mustelus mustelus*, *Centrophorus moluccensis*, *Centrophorus granulosus*) in Syrian sharks fisheries.

The means of H, D and J through the period of study (mean \pm S.D.) were (1.73 \pm 0.21), (2.03 \pm 0.40) and (0.67 \pm 0.09) respectively. Seasonally variations of the three ecological indices were shown in Figure 1. The highest mean of H values was in spring (1.79 \pm 0.33), followed by autumn (1.78 \pm 0.19), winter (1.75 \pm 0.24), and summer (1.60 \pm 0.09). Additionally, the highest mean of D values was in spring (2.54 \pm 0.25), followed by autumn (1.93 \pm 0.42), summer (1.87 \pm 0.24), and winter (1.79 \pm 0.21). While the highest mean of J values was in winter (0.75 \pm 0.09), followed by autumn (0.68 \pm 0.06), spring (0.63 \pm 0.10), and summer (0.62 \pm 0.03). This study provided first details on diversity indices and length structure of shark fishery in the Syrian marine waters and in Mediterranean Sea.

Table1. The contribution by number, biomass, index of abundance and status on regional Red List of Mediterranean at the major landing sites for each by-catch species off the Syrian waters

| Scientific name | Percentage of numeral | Percentage of weight | Abundance index | Status on regional Red List of Mediterranean |
|--------------------------------|-----------------------|----------------------|-----------------|--|
| Hexanchidae | 9.12 | 47.02 | | |
| <i>Hexanchus griseus</i> | 5.80 | 46.15 | C | VU |
| <i>Hepranchias perlo</i> | 3.32 | 0.87 | C | VU |
| Carcharhinidae | 15.85 | 41.57 | | |
| <i>Carcharhinus plumbeus</i> | 14.13 | 31.14 | A | EN |
| <i>Carcharhinus obscurus</i> | 1.72 | 10.43 | F | DD |
| Lamnidae | 1.28 | 1.25 | | |
| <i>Isurus oxyrinchus</i> | 1.28 | 1.25 | F | CR |
| Triakidae | 5.20 | 1.87 | | |
| <i>Mustelus mustelus</i> | 5.20 | 1.87 | C | EN |
| Scyliorhinidae | 28.32 | 1.14 | | |
| <i>Galeus melastomus</i> | 26.85 | 1.11 | A | LC |
| <i>Syliorhinus canicula</i> | 1.47 | 0.03 | F | LC |
| Squalidae | 28.33 | 2.88 | | |
| <i>Squalus blainvillei</i> | 26.72 | 2.68 | A | DD |
| <i>Squalus megalops</i> | 1.61 | 0.2 | F | DD |
| Alopiidae | 0.26 | 0.76 | | |
| <i>Alopias superciliosus</i> | 0.26 | 0.76 | O | DD |
| Centrophoridae | 10.35 | 2.77 | | |
| <i>Centrophorus granulosus</i> | 4.48 | 1.47 | C | VU |
| <i>Centrophorus uyato</i> | 5.87 | 1.29 | C | * |
| Dalatiidea | 0.65 | 0.31 | | |
| <i>Dalatius licha</i> | 0.65 | 0.31 | O | DD |
| Oxynotidae | 0.17 | 0.04 | | |
| <i>Oxynotus centrina</i> | 0.17 | 0.04 | O | CR |
| Squatiniidae | 0.47 | 0.39 | | |
| <i>Squatina aculeata</i> | 0.16 | 0.19 | O | CR |
| <i>Squatina oculata</i> | 0.31 | 0.20 | O | CR |

Index of abundance: A, abundant (>1000); C, common (200–1000); F, frequent (100–200); O, occasional (10–100). Status: CR: Critically Endangered, VU: Vulnerable, DD: Data Deficient, EN: Endangered, C: Least Concern, *: Not Evaluated.

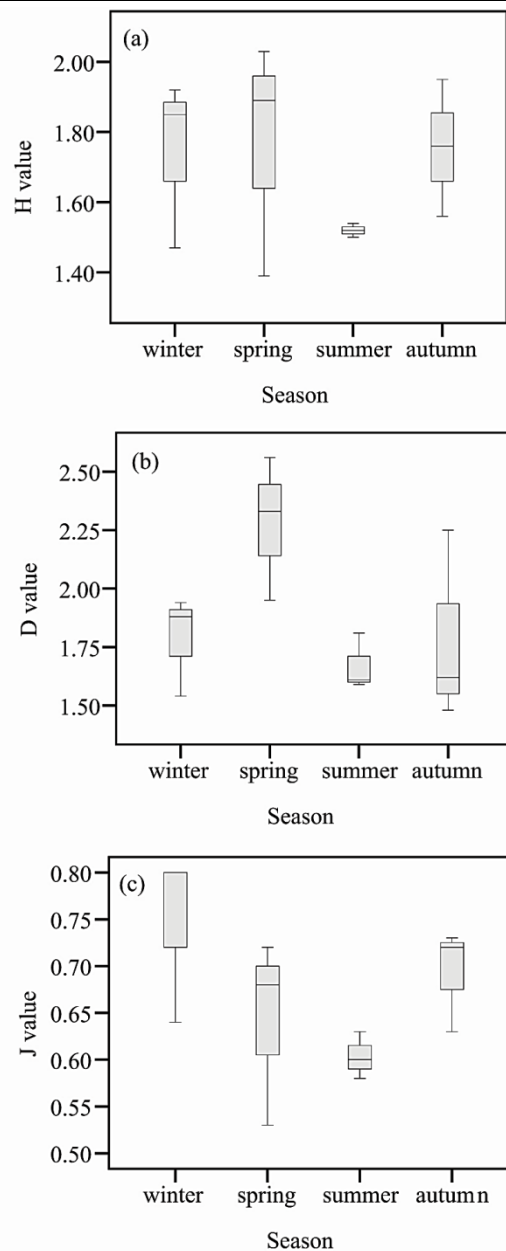


Figure 1. Changes of diversity indices seasonally for by-catch sharks: (a); diversity index H , (b); qualitative richness factor D , (c); evenness factor

The highest values of H and D were in spring because of caught high numbers of species S and numbers of species individuals N in this season, which can be caused by the movements of species individuals toward coast to bearing and searching for feeds. While the highest value of J was in winter due to the low numbers of species S .

[14] reported that the mean H value for the sharks species caught by longlines (25 species, $N = 2601$) of Caribbean and Atlantic (Venezuela) during the period 1994 to 2003 were between (1.17 ± 0.09) and (2.10 ± 1.09) and between (0.38 ± 0.17) and (1.90 ± 0.13) , respectively. Additionally, they stated that the shark diversity levels in both geographic areas were higher at the beginning of the time series, from approximately 1995 to 1998. [15] analyzed the diversity of oceanic predatory fishes, including sharks, in the western Atlantic and found a diminishing trend in diversity with respect to time.

Estimates of diversity levels in fishery studies can be useful as changes can be detected in the structure of commercially exploited populations. The application of diversity indices in chondrichthyans fisheries is rarely in general. [14] reported that the application of diversity indices in fisheries biology is relatively recent, and few studies using this technique have been reported.

Total length, weight, sex ratio and fishing gear types of the abundant and common sharks species landed are summarized in table 2.

Table 2. Length, weight and sex ratio of the abundant and common by-catch sharks landed by fishing gears at main landing site during (Syria) November 2014 - October 2016.

| Species | Main type of fishing gears | Length range (cm) | Weight range (kg) | Sex ratio (M:F) | Peak of season landing |
|--------------------------------|----------------------------|-------------------|-------------------|-----------------|------------------------|
| <i>Hexanchus griseus</i> | longlines-trawls | 85-345 | 4-335 | 1:1.74 | autumn |
| <i>Hepranchias perlo</i> | trawls- nets | 20-124 | 0.1-6 | 1:1.14 | spring |
| <i>Carcharhinus plumbeus</i> | nets- longlines | 45-300 | 1-161 | 1:2 | autumn |
| <i>Mustelus mustelus</i> | trawls | 50-141 | 0.2-9 | 1:1.36 | autumn |
| <i>Galeus melastomus</i> | trawls | 27-70 | 0.1-1 | 1:1.17 | autumn |
| <i>Squalus blainvillei</i> | trawls | 28-82 | 0.1-4 | 1:1.37 | summer |
| <i>Centrophorus granulosus</i> | trawls- longlines | 46-105 | 0.4-6 | 1:1.48 | summer |
| <i>Centrophorus uyato</i> | trawls-longlines | 47-100 | 0.4-5.6 | 1:1.15 | summer |

Hexanchus griseus

TL ranged between 102 and 310 cm for males and between 85 and 345 cm for females. Common TL ranged from 155 to 230 cm for males and from 175 to 275 cm for females. This species was recorded in all months through the period of study. Females constituted 63.5% of species catches. Its caught appeared a significant difference between seasons ($X^2 = 11.441$, $P = 0.010$), peak of season landing was in autumn (Fig. 2a), a high proportion of juveniles was recorded in spring (Fig. 3a). [16] suggested that males and females of *H. griseus* maturing at 300 and 350 cm TL, respectively. In Mediterranean Sea. Consequently, about 97% of males and 100% of females were immature of catches (Fig. 4a).

Hepranchias perlo

TL ranged between 27 and 117 cm for males and between 20 and 124 cm for females. Common TL ranged from 60 to 100 cm for males and from 55 to 100 cm for females. *H. perlo* was presented in all months through year except February. Percentage of females catches was 53.2%. There was a significant difference between caught seasons ($X^2 = 16.400$, $P = 0.001$), peak of season landing was in spring (Fig. 2b) with a high percentage of juveniles (Fig. 3b). [17] reported that males and females of *H. perlo* maturing at 81 cm TL and 97 cm TL, respectively in Syrian marine waters. Therefore, about 50% of males and 74% of females were immature of catches (Fig. 4b).

Carcharhinus plumbeus

TL ranged between 46 and 250 cm for males and between 45 and 300 cm for females. Common TL ranged from 125 to 150 cm for males and from 135 to 160 cm for females. *C. plumbeus* was recorded in all months through year. Females contributed 66.8% of species catches. A significant difference between caught seasons was founded ($X^2 = 11.644$, $P = 0.009$), peak of season landing was in autumn (Fig. 2c), a high percentage of juveniles was recorded in winter (Fig. 3c). Males and females of *C. plumbeus* maturing at 160 cm and 172 cm TL, respectively in Mediterranean Sea (Tunisian coast) [18]. Based on this information, about 85% of males and 88% of females were immature of catches (Fig. 4c).

Mustelus mustelus

TL ranged between 55 and 133 cm for males and between 50 and 141 cm for females. Common TL ranged from 73 to 88 cm for males and from 77 to 100 cm for females. This species was founded in all months of year. Females constituted 57.7% of species catches. Its caught appeared a significant difference between seasons ($X^2 = 11.600$, $P = 0.009$), peak of season landing was in winter (Fig. 2d), while a high percentage of juveniles was recorded in spring (Fig. 3d). According to [7] males and females of *M. mustelus* (Syrian coast) species matured at 101 cm and 105 cm TL, respectively. Thus, immature males and females contributed 90% and 83% of species catches (Fig. 4d).

Galeus melastomus

TL ranged between 27 and 63 cm for males and between 32 and 70 cm for females. Common TL ranged from 41 to 50 cm for males and from 44 to 55 cm for females. *G. meastomus* was recorded in all months of year. Percentage of females catches was 53.9%. Its caught appeared no significant difference between seasons ($X^2 = 10.800$, $P = 0.013$), peak season of landing was in autumn (Fig. 2e),

while a peak season of juveniles landing was in winter (Fig. 3e). [19] noted that males and females of *G. melastomus* matured at 38 and 43 cm TL, respectively. Based on this information, immature males and females constituted about 10 % and 21%, respectively. (Fig. 4e).

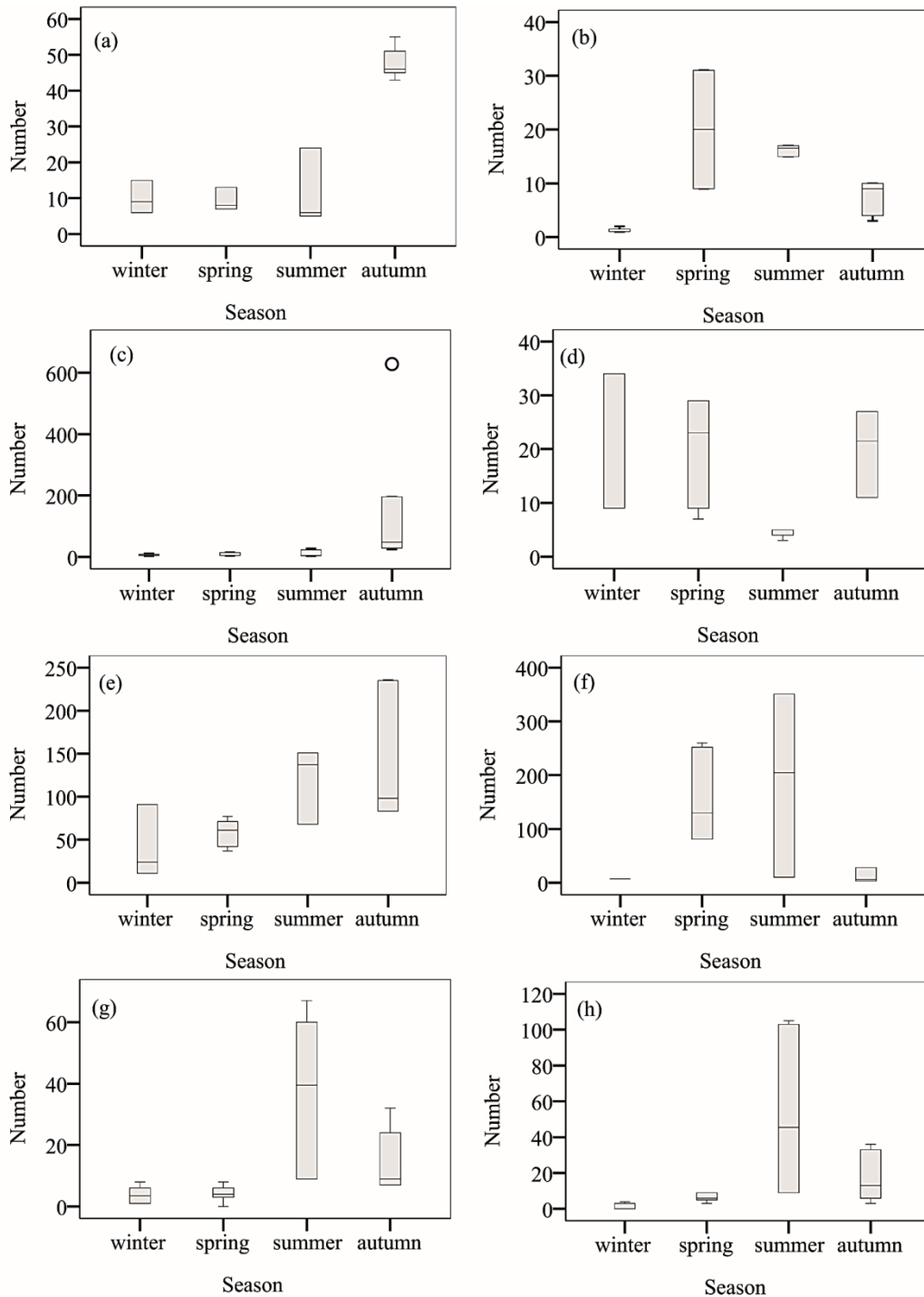


Figure 2. Changes of caught specimens number per season; (a) *H. griseus* , (b); *H. perlo* , (c); *C. plumbeus*, (d); *M. mustelus* (e); *G. melastomus* , (f); *S. blainvillei*, (g); *C. moluccensis* , (h); *C. granulosis*

Squalus blainvillei

TL ranged between 28 and 78 cm for males and between 29 and 82 cm for females. Common TL ranged from 44 to 53 cm for males and from 46 to 58 cm for females. This species was presented in all months of year except December and January. Females contributed 57.3% of species catches. Its caught appeared a significant difference between seasons ($X^2 = 10.800$, $P = 0.013$), peak of season landing was in summer (Fig. 2f), while a peak of juveniles landing was in spring (Fig. 3f). Males and females of *S. blainvillei* matured at 46 and 56 cm TL [20], respectively. Therefore, about 33% of males and 71% of females were immature in species catches (Fig. 4f).

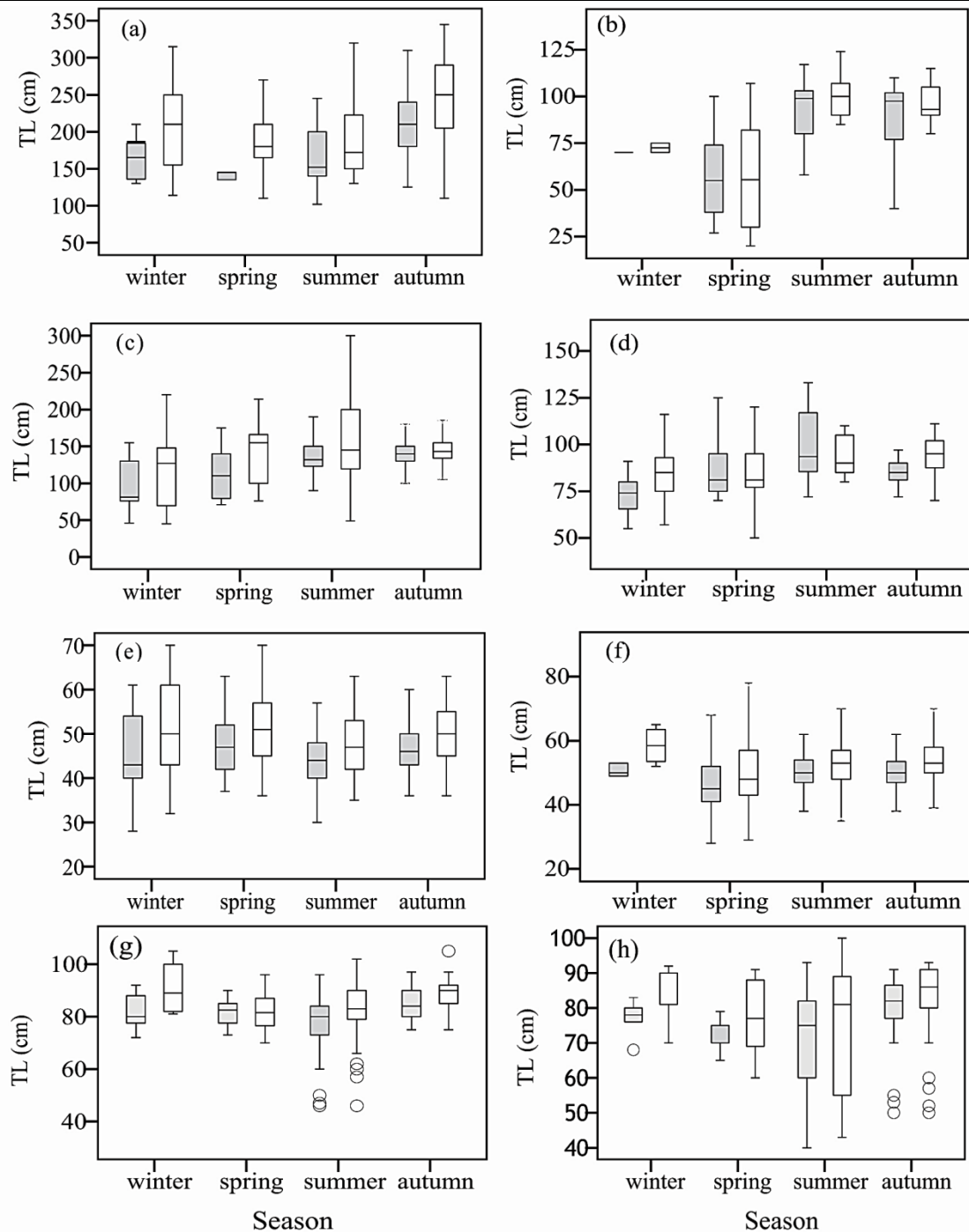


Figure 3. Size (TL) variations of abundant and common of by-catch sharks per season off Syria coast. Males (gray), females (white): (a); *H. griseus*, (b); *H. perlo*, (c); *C. plumbeus*, (d); *M. mustelus* (e); *G. melastomus*, (f); *S. blainvillei*, (g); *C. granulosus*, (h); *C. uyato*

Cenrophorus uyato.

TL ranged between 47 and 90 cm for males and between 50 and 100 cm for females. Common TL ranged from 70 to 80 cm for males and from 75 to 80 cm for females. This species was recorded in all months of year except January. Females constituted 53.4% of species catches. Its caught appeared no significant difference between seasons ($X^2 = 13.448$, $P = 0.004$), peak of season landing was in summer (Fig. 2g), while a peak of juveniles landing was in spring (Fig. 3g). Males and females of *C. uyato* off Syrian marine warts matured at 79.2 cm and 86.7 cm TL [17], respectively. Therefore, about 62% of males and 66% of females were immature (Fig. 4g).

Centrophorus granulosus

TL ranged between 46 and 97 cm for males and between 46 and 105 cm for females. Common TL ranged from 77 to 85 cm for males and from 80 to 90 cm for females. *C. granulosus* was recorded in

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all months of years. Females constituted 59.6% of species catches. A significant difference between caught seasons was founded ($X^2 = 15.915$, $P = 0.001$), peak of season and juveniles landing were in summer (Fig. 2h and Fig. 3h). [21] reported that males and females of *C. granulatus* matured at 80 and 90 cm TL, respectively. Consequently, about 37% of males and 68% of females were immature in species catches (Fig. 4h).

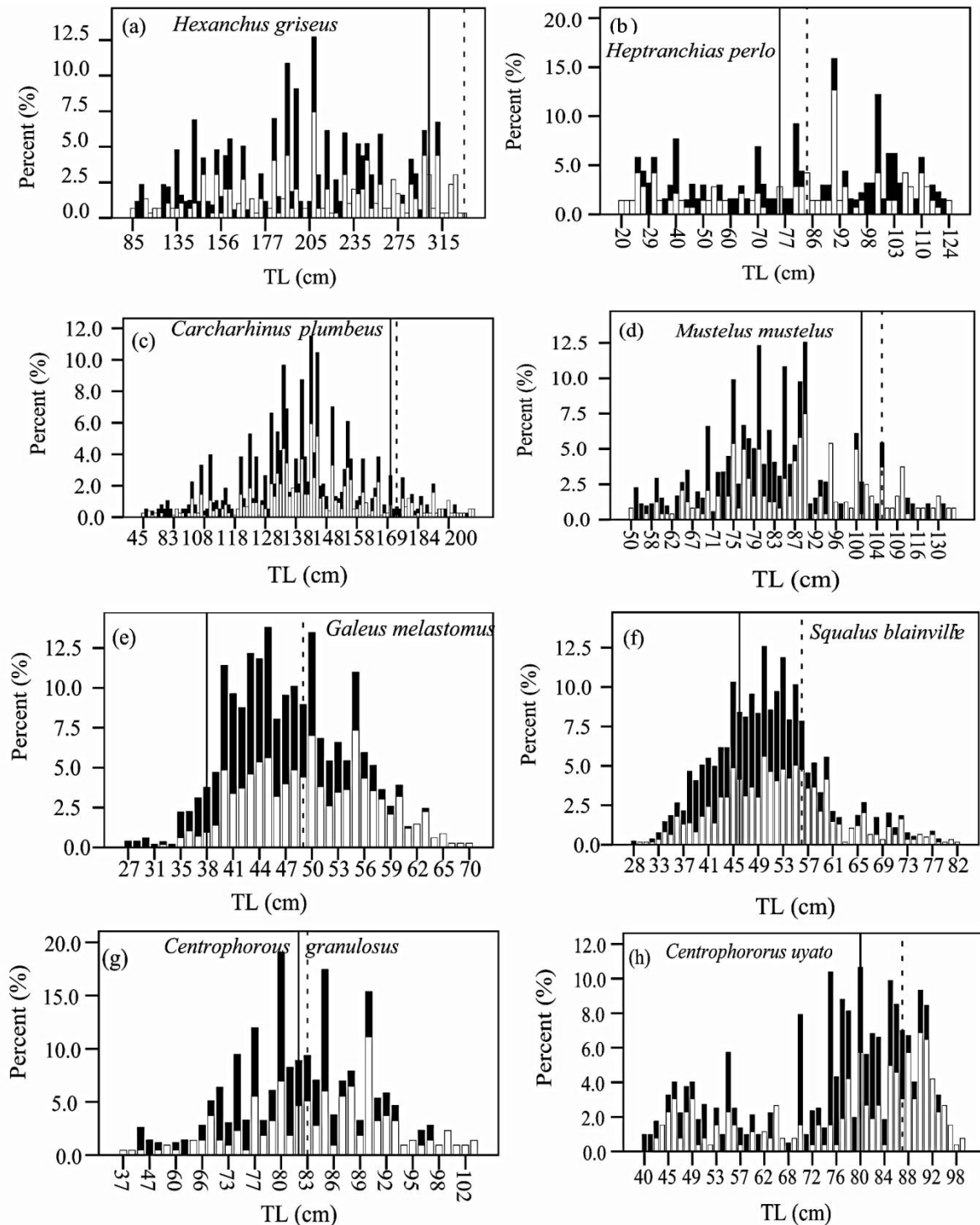


Figure 4. Total length (TL) frequency distributions (percent of species catch) of the abundant and common by-catch sharks off Syrian coast. Males (black), females (white). Vertical lines indicate maturity size of males (sporadic) and females (continuous) following literature: (a); *H. griseus*, (b); *H. perlo*, (c); *C. plumbeus*, (d); *M. mustelus* (e); *G. melastomus*, (f); *S. blainvillei*, (g); *C. granulatus*, (h); *C. uyato*

There were three possible nursery areas for *H. griseus* (northern Ras Albassit, northern Lattakia and northern Tartous) in Syrian marine waters. Moreover, three possible nursery areas were in the region for *C. plumbeus* (one area southern Lattakia and two areas southern Tartous). While there were two

possible nursery areas for *M. mustelus* (against Lattakia and middle distance between Jablah and Banias) (Fig. 5).

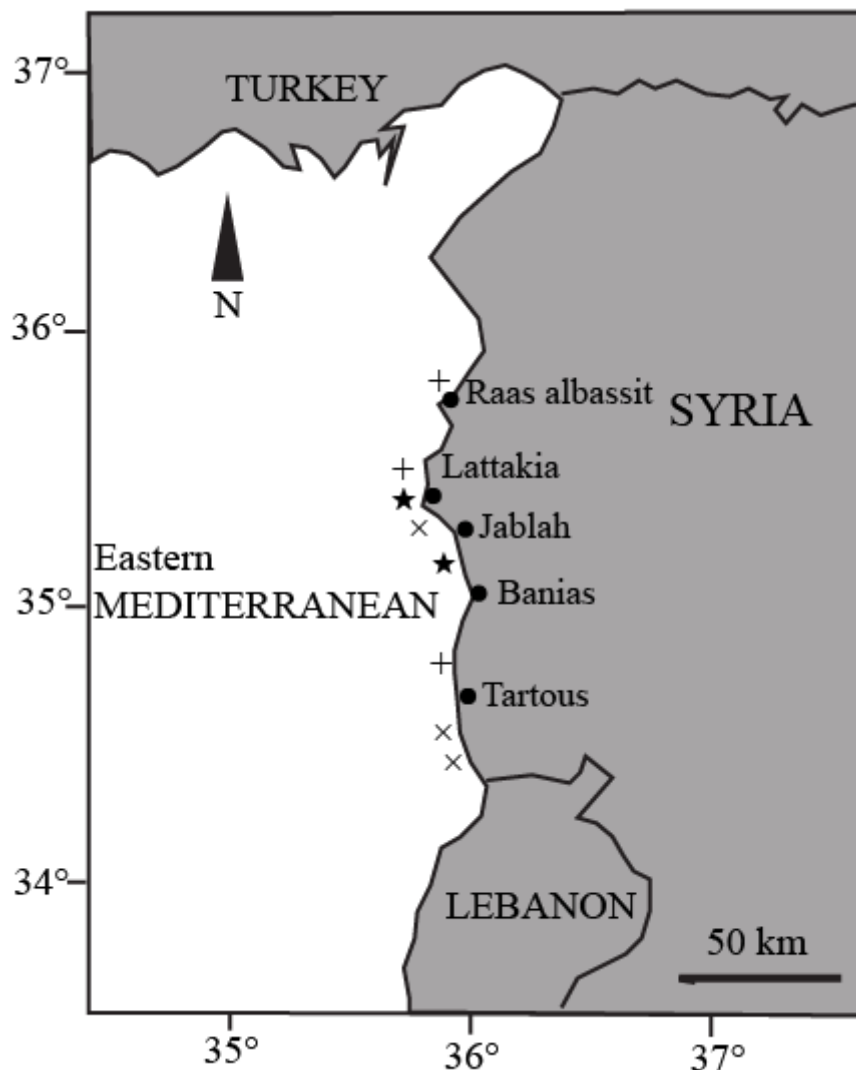


Figure 5. Geographic distribution of possible nursery areas for three species (*H. griseus*; +, *C. plumbeus*; ×, *M. mustelus*; *, black circles; main cities) in Syrian marine waters.

The very economically important species being caught in plentiful quantities and highly consumable: *C. plumbeus*, *M. mustelus*, *C. uyato*, *H. griseus*, and *S. blainvillei*. Moderate economically important species either for being caught in little quantities with high efforts in fishing, or for their little demand for human consumption, or may be both reasons: *H. perlo*, *I. oxyrinchus*, *A. superciliosus*, *C. obscurus*, *D. licha*, *S. squatina*, *S. oculata*, *S. aculata*, in Syrian marine waters [2].

The seasonal variation findings are in agreement with [22] Buencuerpo et al. (1998) and [23] Megalofonou (2005), who reported maximum catch rates in April (spring) and September (autumn). Certain water temperature preferences of sharks force them to shift to deeper, cooler water masses, especially in tropical and subtropical areas. In these depths they are less vulnerable to surface longlining and that reflects in lower catch rates [24, 25, 26, 27].

The two pelagic species *H. griseus* (common), *C. plumbeus* (abundant) and the deep-water species *M. mustelus* (common) fishery were dominance by juveniles, which considered as vulnerable, endangered and endangered, respectively, on regional Red List of Mediterranean Sea. These species were occurrence every month round year that totally composed about 25% of Syrian sharks landing. The females catches of the pelagic species *H. perlo* (common), also the three deep-water species *S. blainvillei* (abundant), *C. uyato* (common) and *C. granulosus* (common) were mostly comprised by juveniles. Which considered as vulnerable, data deficient, unknown and vulnerable, respectively, on regional Red List of Mediterranean Sea. Conversely, catches of the deep-water species *G. melastomus*

was comprised by a little numbers of juveniles in both sexes. The presence of recruits both between 200 and 650 m, a greater percentage of mature individuals in the mesobathyal than in epibathyal and homoeothermic condition in the bathyal environment of Mediterranean, this may cause by that the reproduction occurs at the lowest depths at which the species is found. More ever, the use of long-lining scatter baits made them more accessible to smaller species [2]. The low percentage of *G. melastomus* recruits caused by discarding of small individuals after catch immediately because of it has no economical important.

In addition, the investigations with fishermen showed a major decline in the quantity (number and size of individuals) of shark fishery throughout last ten years, this situation caused by overfishing with the historical life characterizes of shark, represented by; large size at maturity, slow growth rate and low fecundity. These reasons make this fish group suffering from disability to complete its life cycle, as result a high proportion of juveniles were found in its catches, reached to 83%-100% for three species. [28] reported that there is increasing evidence that indirect effects of fishing are affecting the composition and diversity of chondrichthyan and total fish assemblages through trophic interactions, so we have to set up a monitoring program for chondrichthyan fishery and its landing.

4. CONCLUSIONS

The five shark species: *H. griseus*, *H. perlo*, *C. plumbeus*, *M. mustelus* and *C. uyato*, are facing over fishing, which probably established sustainable populations in the Syrian coast, this region could be an important resource for these species. Additionally, there is decline of species number and the quantity in the region by the time. These are serious signs threaten shark species sustainability. Consequently, major efforts, accurate marine surveys and more biological studies would be needed to management and conservation these species.

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