Growth and mortality rates for management of the common smooth-hound shark, *Mustelus mustelus* in the Egyptian Mediterranean waters

Ayman M. M. Ahmed, Ahmad M. Azab*; Hassan M. M. Khalaf-Allah, Mohamed A. M. El-Tabakh

Marine Biology and Ichthyology Section, Zool. Dept., Fac. of Sci., Al-Azhar University, Cairo, Egypt

*Corresponding author: amazab2000@yahoo.com

**ABSTRACT**

The present study aimed to provide information on growth and mortality rates for the management of the common smooth-hound shark, *Mustelus mustelus* in the Egyptian Mediterranean waters at Alexandria. The study was based on a total of 311 specimens of *M. mustelus* which were monthly collected from the commercial catch at Alexandria coast of the Mediterranean Sea, during the period from June 2020 to May 2021. Results showed that the total length of male *M. mustelus* ranged from 38.6 to 106.8 cm for males and from 38.6 to 117.5 cm for females. The total weight varied from 155.9 to 3611.7 g for males and from 157.3 to 2828 g for females. The b value (2.88, 2.74, and 2.8 for male, female and whole population, respectively) is slightly lower than the ideal, indicating a tendency towards slightly negative allometric growth. Results showed that the present levels of exploitation represented 0.407, 0.417 and 0.42 for males, females, and the whole population, respectively which were higher than that of *E*\(_{0.5} = \) as 0.30, 0.295, and 0.297 for males, females, and the whole population, respectively. It gives the maximum (Y/R), which means that the stock of *M. mustelus* is highly overexploited, which is needed to maintain 50% of the stock biomass. For management purposes, the exploitation rate of *M. mustelus* should be reduced to be < *E*\(_{0.5}\) i.e., the fishing mortality should be reduced to lower than the current fishing mortality (F=0.39, 0.42 and 0.45 y\(^{-1}\) for male, female, and the whole population respectively) to maintain sufficient spawning biomass for sustainability. Finally, this study concluded that the length of the first capture of *M. mustelus* was calculated at 33.8 cm, while *M. mustelus* doesn’t reach maturity unless reaches 83 cm at least. These indicated that *M. mustelus* in Egyptian Mediterranean waters was captured way before it reached its maturity stage.

**INTRODUCTION**

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). The width of the Eastern continental shelf was greater than that in the West, except in Salloum Bay (Abu-Hatab, 2005).

**FAO (2005)** designed the field identification guide to the sharks of the Mediterranean Sea and mentioned that 49 species of sharks belong to 17 families and 5 orders: Hexanchiformes, Squiliformes, Squatiniformes, Lamniformes, and Carcharhiniformes. El-Tabakh (2019) mentioned that 21 species of sharks collected from Alexandria, Mediterranean Sea; belongs to 9 families and 5 orders; Hexanchiformes, Squiliformes, Squatiniformes, Lamniformes and Carcharhiniformes. The Smooth-hound sharks belong to the genus *Mustelus*
Ahmed et al., 2022

(family Triakidae), which includes 34 valid species occurring in all major oceans. Five of those species can be found in the Mediterranean. *M. Mustelus* (Linnaeus, 1758) is a demersal species inhabiting sandy or muddy bottom down to the depths of 150 m (Golani et al., 2006 and Özcan & Başusta, 2016).

Elasmobranch fish species are exploited for their fins, skin, jaws, or meat. Shark fins were the most valuable of shark products and used to make traditional shark fin soup, a delicacy in the Chinese culture (Clarke et al., 2006).

Sharks are known as animals that are long-lived, slow growing, late maturing and producing few offspring. Overall, sharks have a low productivity that tends to be lower than that of other vertebrate groups of teleosts (Walker, 1998). Although, the decline of smooth hounds in the Mediterranean was acknowledged by IUCN and also confirmed by fishers, the rate of reduction in the different sectors of the Mediterranean is unclear (Stevens, et al., 2000; Barker & Schluessel, 2005; Maynou et al., 2011; Nieto et al., 2015 and Colloca et al., 2017). Although this makes sharks vulnerable to overfishing, a larger problem is, however, the lack of management of shark catches. The management of shark fishing has proven problematic due to a lack of co-ordinated research relating to the biology and stock assessment of commercially valuable sharks. Accurate stock assessment is made difficult by the large amount of illegal fishing and discards because sharks are largely taken as by-catch. The quantity of demersal sharks caught as by-catch in inshore trawl fisheries is higher than sharks caught by the directed demersal shark longline fishery (MCM, 2010).

The catch of elasmobranchs was recorded every year by the general authority for fish resources development in Mediterranean coast, it has been reduced from 3450 Tons during 2006 to 1292 Tons during 2018 (GAFRD, 2018) and reduced to 881 Tones during 2020 (GAFRD, 2020) with no reference to sharks or other elasmobranchs and the identification to the lowest species taxa.

Therefore, the present study aimed to provide the basic information required for the managing the common smoothhound shark (*M. mustelus*) in the Egyptian Mediterranean waters, at Alexandria, such as growth, mortality and exploitation rates.

**MATERIALS AND METHODS**

1. **Samples collection:**

A total of 311 specimens of the common smoothhound shark, *Mustelus mustelus* (Fig. 1) were monthly collected from the commercial catch at the fish land markets in Alexandria of the Mediterranean Sea, during the period from June 2020 to May 2021. Samples were kept in 10% formalin solution before transporting to the Marine Biology Laboratory, Zoology Department, Faculty of Science, Al-Azhar University, Nasr City, Cairo, Egypt, for further study. Sharks were identified in the laboratory using FAO (2005), fork and total lengths were measured to the nearest millimetres. Sharks were also wet weighted in grams and the following studies were carried out.
Observations on food and feeding habits of common smoothhound shark, *Mustelus mustelus*

**Fig. (1):** Picture of common smoothhound shark, *M. mustelus*, collected from the commercial catch at the land fish market in Alexandria of Mediterranean Sea, during the period from June 2020 to May 2021.

2. **Length - weight relationship:**

Length-weight relationship was determined according to Le Cren (1951) for males and females separately and for the whole populations of each species according to the following equation:

\[ W = a \cdot L^b \]

The length-weight relationship was transformed to logarithmic modification according to the following equation:

\[ \log W = a \pm b \log L \]

**Where:** \( W \) = Total weight of fish (g); \( L \) = Total fish length (cm); \( a \& b \) = Constants, whose values are estimated by the least square method.

3. **Condition factors:**

Condition factor (K) is given by the following formula:

\[ K = 100 \frac{W}{+L^3} \]  
(Le Cren, 1951):

**Where:** \( W \) = Total weight of fish (g); \( L \) = Total fish length (cm).

The relative condition coefficient factor (Kn) was determined by the following equation:

\[ Kn = \frac{W}{W'} \]  
(Hile, 1936)

**Where:** \( W \) = Observed fish weight (g) and \( W' \) = Calculated weight estimated from the length-weight relationship.

4. **Fishery and stock assessment studies:**

4.1. **Estimation of the theoretical growth in length:**

The Von Bertalanffy (1938) for growth model was applied to describe the theoretical growth in length and weight.

- Von Bertalanffy growth in length equation can be expressed as follows:

\[ L_t = L_\infty [1 - e^{-k(t-t_0)}] \]

**Where:** \( L_t \) = Mean length at age \( t \); \( L_\infty \) = Asymptotic length, i.e. the (mean) length of a given stock would reach if they were left to grow forever; \( k \) = Growth coefficient that determines
the rate at which $L_\infty$ is attained; $t$ = Age at length $L_t$; $t_0$ = Age at which the length is theoretically equals zero.

4.2. Von Bertalanffy growth parameters:

The values of $L_\infty$ and $k$ were estimated from the linear regression between $(L_t)$ and $(L_{t+1})$ using the Ford (1933) and Walford (1946) method as the following:

$$L_{t+1} = L_\infty (1-e^{-k}) + e^{-k} * L_t$$

$$L_\infty = \frac{a}{1-b}$$

Where: $a$ & $b$ are the intercept and the slope of the regression, respectively.

This method was applied by plotting $(L_{t+1})$ against $(L_t)$ which gives a straight line with a slope (b) equals to $(e^{-k})$ and an intercept (a) equals to $[L_\infty (1-e^{-k})]$. The constants (a) and (b) of this linear relationship were estimated by using the least square method.

5. Estimation of growth performance index ($\Phi$):

For comparing the growth performance of the species with that of the same species in other region, the growth performance index ($\Phi$) was estimated according the formula of Pauly (1984) as follows:

$$\Phi = \log K + 2 \log L_\infty$$

Where: $\Phi$ = Phi-prime, i.e., a length-based index of growth performance; $K$ and $L_\infty$ are von Bertalanffy growth parameters.

6. Population dynamics:

6.1. Total mortality ($Z$):

It was estimated by Pauly’s method (1983): This method is based on the analysis of catch curve using length frequency data. The catch curve is constructed through the conversion of length to age by using the growth parameters of the Von Bertalanffy growth model. The total mortality coefficient was estimated through the following relationship:

$$\ln (N/\Delta t) = a + b*t$$

Where: $N$= Frequency of each length class; $\Delta t$= Time needed to grow from $t_1$ to $t_2$ of a given length class; $t$= Relative age corresponding to the mid-point of the length class; $a$ & $b$ are constants. This is a linear relationship, where: $Y= \ln (N/\Delta t)$ and $X= (t_1 + t_2)/2$

The constants (a) and (b) can be calculated by linear regression between $\ln (N/\Delta t)$ and $X= (t_1 + t_2)/2$. The slope (b) of this regression is equal to (-$Z$) and estimated by Bevorton & Holt (1956) model. This method is based on the analysis of catch curve using length frequency data. The total mortality coefficient was estimated using the following relationship:

$$Z = K (L_\infty - L_{\text{mean}}) / (L_{\text{mean}} - L_\prime)$$

Where: $K$= curvature parameter of the VBGF; $L_\infty$= Asymptotic length, i.e., the (mean) length of a given stock would reach if they were left to grow forever.
L\textsubscript{mean} = Mean length of fish in a sample representing a steady-state population.

L\textsuperscript{'} = Cut-off length or the lower limit of the smallest length class included in the computation, and estimated by Beverton and Holt model, in the Ault and Ehrhardt model, Z from mean length, is: The total mortality coefficient was estimated through the following relationship:

\[
\frac{Z}{L_{\text{max}} - L_{\text{mean}}} = \frac{Z(L' - L_{\text{mean}}) + K(L_{\text{max}} - L_{\text{mean}})}{Z(L_{\text{max}} - L_{\text{mean}}) + K(L_{\text{max}} - L_{\text{mean}})}
\]

Where: \(L_{\infty}\) = Asymptotic length, i.e., the (mean) length of a given stock would reach if they were left to grow forever; \(K\) = curvature parameter of the VBGF; \(L_{\text{mean}}\) = the mean length of the fish in a sample representing a steady-state population; \(L'\) = cut-off length or the lower limit of smallest length class included in the computation; \(L_{\text{max}}\) = largest fish in the sample.

6.2 Natural mortality (M):

The coefficient rate of natural mortality (M) refers to the natural decrease in late juvenile and adult phases of a population. It was calculated from Pauly (1980) based on the parameters \((L_{\infty}\) and \(K\)) of the von Bertalanffy growth function and average temperature (T) according to Pauly’s Empirical Equation (1980) as following:

\[
\log M = -0.0066 - 0.279 \log L_{\infty} + 0.6543 \log k + 0.4634 \log T
\]

Where: \(L_{\infty}\) = Asymptotic length; \(k\) = Growth coefficient; \(T\) = Average annual temperature (°C) of stock’s habitat.

6.3. Fishing mortality (F):

The instantaneous mortality rate is caused by the fishing operations. According to Beverton and Holt (1957), the total mortality rate (Z) is sum of fishing (F) and natural (M) mortalities (Z = F + M). With the values of (Z) and (M) are available, the coefficient of fishing mortality could be calculated by simple subtraction:

\[F = Z - M\]

6.4. Rate of exploitation (E):

It is calculated from the fishing mortality (F) during some specified period when all causes of the death are affecting the population by the following relationship:

\[E = \frac{F}{Z}\quad \text{Gulland (1971)}\]

Where: \(Z\) is the total mortality.

6.5. Length at first capture (Lc):

The length at the first capture (L\(_c\)) is the length at which 50% of the catch retains in the gear. It was estimated by plotting the curve for probability of capture by length using the method of Pauly (1984), while the first capture was obtained by using the length at first capture (L\(_c\)) and Von Bertalanffy growth parameters (k, \(L_{\infty}\) and \(t_0\)) from growth in length equation as follows:

\[T_c = -\frac{1}{k} \ln [1 - (L_c/L_{\infty})] + t_0\]
6.6. Relative yield per Recruit (Y’/R):

The relative yield per recruit and relative biomass per recruit were estimated according to the Beverton & Holt model (1966) as incorporated in FiSAT software.

7. Statistical data analysis:

Statistical analysis and graphics of data were conducted by using Microsoft Excel and FiSAT software, under windows programs.

RESULTS

1. Length - weight relationship:

Results showed that the total length of male *M. mustellus* ranges from 38.6 to 106.8 cm, while the total weight varied from 155.88 to 3611.66 g. The weight of the fish increases with the increasing length of the fish (Table 1 and Fig. 2). The length-weight relationship of this fish is represented by the following equation:

\[
\log(W) = 2.8826 \times \log(L) - 2.336 \\
W = 2.336L^{2.88} \quad (R^2 = 0.8683) \text{ for male}
\]

Consequently, the values of “a” and “b” in male *M. mustellus* were 2.34 and 2.88 respectively. From the above findings, it is clear that the b value (2.88) is slightly lower than the ideal, thus indicating a tendency towards slightly negative allometric growth. The correlation coefficient “R^2” was highly correlated (0.87) (Table 1 and Fig. 2).

On the other hand, the total length of female *M. mustellus* ranges from 38.6 to 117.5 cm, while the total weight varied from 157.28 to 2828.02 g. The weight of the fish increases with the increasing length of the fish (Table, 1 and Fig. 2). The length-weight relationship of this fish is represented by the following equation:

\[
\log(W) = 2.7364 \times \log(L) - 2.0901 \\
W = 2.0901L^{2.7364} \quad (R^2 = 0.8268) \text{ for female}
\]

Consequently, the values of “a” and “b” in female *M. mustellus* were 2.09 and 2.74 respectively. From the above findings, it is clear that the b value (2.74) is slightly decreased than the ideal, thus indicating a tendency towards slightly negative allometric growth. The correlation coefficient “R^2” was highly correlated (0.8268) (Table 1 and Fig. 2).

In the same manner, the present data showed that the total length of the whole population of *M. mustellus* ranges from 38.6 to 117.5 cm, while the total weight varied from 157.28 to 2828.02 g (Table, 1 and Fig. 2). Fish weight increases with the increasing length of the fish. The length-weight relationship of this fish is represented by the following equation:

\[
\log(W) = 2.8025 \times \log(L) - 2.2014 \\
W = 2.20L^{2.80} \quad (R^2 = 0.8464) \text{ for combined sexes}
\]

Consequently, the values of “a” and “b” for whole population of *M. mustellus* were 2.20 and 2.80 respectively. From the above findings, it is clear that the b value (2.80) is...
Observations on food and feeding habits of common smoothhound shark, *Mustelus mustelus*

slightly lower than the ideal, thus indicating a tendency towards slightly negative allometric growth. The correlation coefficient “$R^2$” was highly correlated (0.85) (Table 1 and Fig. 2).

![Graphs showing length-weight relationship for male, female, and whole population of *Mustelus mustelus*.](image)

**Fig. (2):** Length-weight relationship of *M. mustellus* (male, female and whole population), collected from Alexandria, Mediterranean Sea, during the period from June 2020 to May 2021.

2. **Condition factors according to size class:**

Data revealed that the composite coefficient “K” and the relative condition factor “Kn” of male *M. mustellus* varied significantly with the fish size. Values of composite coefficient of condition “K” fluctuated between 0.26 and 0.4; values of relative condition factor “Kn” varied from 0.66 to 1.12 for different length groups (Table 1 and Fig. 3).

On the other hand, the composite coefficient “K” and the relative condition factor “Kn” of female *M. mustellus* varied significantly with the fish size. Values of composite coefficient of condition “K” fluctuated between 0.19 and 0.36; values of relative condition factor “Kn” varied from 0.75 to 1.2 for the different length groups (Table 1 and Fig. 3).

At the same manner, composite coefficient “K” and relative condition factor “Kn” of whole population of *M. mustellus* varied significantly with the fish size. Values of composite coefficient of condition “K” fluctuated between 0.19 and 0.39. Values of relative condition factor “Kn” varied from 0.71 to 1.19 for different length groups (Table 1 and Fig. 3).
Table 1: Length-weight relationship and condition factors of *M. mustellus* (male, female and whole population), collected from Alexandria, Mediterranean Sea, during the period from June 2020 to May 2021.

<table>
<thead>
<tr>
<th>Size class</th>
<th>No.</th>
<th>Observed weight (g)</th>
<th>Calculated weight</th>
<th>Condition factor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Range</td>
<td>Mean ± S.D.</td>
<td>Range</td>
</tr>
<tr>
<td><strong>Female</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>4</td>
<td>154.62-200.22</td>
<td>170.10±21.21</td>
<td>182.38±7.79</td>
</tr>
<tr>
<td>40</td>
<td>30</td>
<td>154.01-385.17</td>
<td>218.42±44.58</td>
<td>199.87±65.47</td>
</tr>
<tr>
<td>45</td>
<td>39</td>
<td>217.12-550.19</td>
<td>325.24±70.43</td>
<td>307.72±25.79</td>
</tr>
<tr>
<td>50</td>
<td>30</td>
<td>344.51-679.9</td>
<td>450.63±78.64</td>
<td>416.98±31.27</td>
</tr>
<tr>
<td>55</td>
<td>24</td>
<td>411.66-702.59</td>
<td>546.92±71.21</td>
<td>533.85±42.18</td>
</tr>
<tr>
<td>60</td>
<td>9</td>
<td>530.46-798.18</td>
<td>662.69±88.09</td>
<td>673.26±54.25</td>
</tr>
<tr>
<td>65</td>
<td>3</td>
<td>819.97-923.8</td>
<td>888.92±59.71</td>
<td>794.58±53.4</td>
</tr>
<tr>
<td>70</td>
<td>6</td>
<td>976.8-1301.2</td>
<td>1156.8±149.6</td>
<td>1060.6±146.2</td>
</tr>
<tr>
<td>75</td>
<td>1</td>
<td>-</td>
<td>1375.84</td>
<td>1351.84</td>
</tr>
<tr>
<td>80</td>
<td>6</td>
<td>352.5-1713.2</td>
<td>1316.3±496.9</td>
<td>1495.3±106.9</td>
</tr>
<tr>
<td>85</td>
<td>4</td>
<td>530.4-3215.2</td>
<td>2155.5±1307.8</td>
<td>1911.0±466.6</td>
</tr>
<tr>
<td>105</td>
<td>1</td>
<td>-</td>
<td>3611.66</td>
<td>3247.57±727</td>
</tr>
<tr>
<td><strong>Female</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>1</td>
<td>-</td>
<td>157.28</td>
<td>178.42</td>
</tr>
<tr>
<td>40</td>
<td>36</td>
<td>167.36-395.86</td>
<td>228.28±43.55</td>
<td>241.98±19.80</td>
</tr>
<tr>
<td>45</td>
<td>30</td>
<td>221.06-964.1</td>
<td>329.47±26.70</td>
<td>309.77±26.70</td>
</tr>
<tr>
<td>50</td>
<td>21</td>
<td>179.52-612.2</td>
<td>442.49±105.61</td>
<td>420.61±32.76</td>
</tr>
<tr>
<td>55</td>
<td>25</td>
<td>422.34-841.8</td>
<td>557.49±101.8</td>
<td>520.68±31.2</td>
</tr>
<tr>
<td>60</td>
<td>18</td>
<td>564.11-799.9</td>
<td>706.66±65.75</td>
<td>656.99±54.46</td>
</tr>
<tr>
<td>65</td>
<td>8</td>
<td>791.11-996.81</td>
<td>869.25±80.30</td>
<td>827.69±40.27</td>
</tr>
<tr>
<td>75</td>
<td>3</td>
<td>1259.98-1673</td>
<td>1456.7±207.21</td>
<td>1225.2±66.61</td>
</tr>
<tr>
<td>80</td>
<td>5</td>
<td>1322.71-2660</td>
<td>1691.06±550.73</td>
<td>1413.82±80.46</td>
</tr>
<tr>
<td>90</td>
<td>4</td>
<td>427.8±3260</td>
<td>1804.55±932.42</td>
<td>1879.05±44.12</td>
</tr>
<tr>
<td>95</td>
<td>2</td>
<td>427.8±3260</td>
<td>1843.8±2002.68</td>
<td>2202.1±35.25</td>
</tr>
<tr>
<td>115</td>
<td>1</td>
<td>-</td>
<td>2828.02</td>
<td>3752.77</td>
</tr>
<tr>
<td><strong>Whole population</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>5</td>
<td>154.62-200.22</td>
<td>167.53±19.24</td>
<td>183.39±7.90</td>
</tr>
<tr>
<td>40</td>
<td>66</td>
<td>154.01-395.86</td>
<td>223.80±43.96</td>
<td>238.50±19.87</td>
</tr>
<tr>
<td>45</td>
<td>69</td>
<td>217.12-964.1</td>
<td>327.08±103.74</td>
<td>308.62±25.89</td>
</tr>
<tr>
<td>50</td>
<td>51</td>
<td>179.52-679.9</td>
<td>447.28±89.80</td>
<td>417.74±31.69</td>
</tr>
<tr>
<td>55</td>
<td>49</td>
<td>411.66-841.8</td>
<td>552.32±87.41</td>
<td>526.43±36.18</td>
</tr>
<tr>
<td>60</td>
<td>27</td>
<td>530.46-799.9</td>
<td>692±75.24</td>
<td>665.24±48.00</td>
</tr>
<tr>
<td>65</td>
<td>11</td>
<td>791.11-996.81</td>
<td>874.61±72.87</td>
<td>826.86±48.64</td>
</tr>
<tr>
<td>70</td>
<td>6</td>
<td>976.84-1301.8</td>
<td>1156.78±149.63</td>
<td>1026.05±57.50</td>
</tr>
<tr>
<td>75</td>
<td>4</td>
<td>1259.89-1673</td>
<td>1436.48±173.95</td>
<td>1273.31±60.00</td>
</tr>
<tr>
<td>80</td>
<td>11</td>
<td>352.45-2660</td>
<td>1486.65±528.68</td>
<td>1447.18±90.26</td>
</tr>
<tr>
<td>85</td>
<td>4</td>
<td>530.39-3215.2</td>
<td>2155.49±1307.76</td>
<td>1818.74±43.09</td>
</tr>
<tr>
<td>90</td>
<td>4</td>
<td>412.78-2375</td>
<td>1806.55±932.42</td>
<td>1959.81±47.13</td>
</tr>
</tbody>
</table>
Observations on food and feeding habits of common smoothhound shark, *Mustelus mustelus*

Male

Female

Whole population

**Fig. (3):** Condition factors of *M. mustellus* (male, female and whole population), collected from Alexandria, Mediterranean Sea, during the period from June 2020 to May 2021.

### 3. Condition factors according to months:

Data in **Table (2)** showed that the highest value of condition factor “Kc” of male *M. mustellus* was recorded in July (0.34) and the lowest one (0.27) occurred in December and January. The maximum value of relative condition factor “Kn” was recorded during July (1.18) and the minimum value (0.91) occurred during December.

In the same manner, data in **Table (2)** showed that the highest value of condition factor “Kc” of female *M. mustellus* was recorded in July (0.33) and the lowest one (0.26) occurred in December and January. The maximum value of relative condition factor “Kn” was recorded during November (1.18) and the minimum value (0.89) occurred during January.

Finally, data represented in **Table (2)** showed that the highest value of condition factor “Kc” of whole population of *M. mustellus* was recorded in July (0.34) and the lowest one (0.27) occurred in December, January, April and May. The maximum value of relative condition factor “Kn” was recorded during July (1.18) and the minimum value (0.90) occurred during December and January.
4. Fishery and stock assessment studies:

4.1. Fishery statistics:

The catch is sorted out before landing by species group. The fishing catch composite of many fish catch (cartilaginous fish, bogue, sole common, shrimp, jack, European seabass, octopus, striped piggy, common cuttlefish, little tunny, spine feet, bluefish, white seabream, groupers nei, large head hairtail, gray mullets nei, sardinellas nei, and sigan). Cartilaginous fish was represented in the catch by 2.16% of the total catch in the Egyptian Mediterranean water in 2019 and 1.77% in 2020 (GAFRD, 2020).

Results showed that annual total fish catch in the Egyptian Mediterranean waters during the period from 2010 to 2020 was fluctuated between 77799 tons during the fishing season in 2011 and 48018 tons during the fishing season of 2019, with a total value of 625532 tons throughout the whole period. The annual cartilaginous fish catch caught from the Egyptian Mediterranean waters fluctuated between 3333 tons (representing 4.28 % of the total catch) in 2011 and 881 tons (representing 1.77%) during 2020 with a total value of 18827 tons (representing 3.01 %) throughout the 10 years of fishery statics (Table, 3).

Finally, results showed monthly variations in cartilaginous fish catch as a percentage of total catch in Egyptian Mediterranean waters. It was varied during the fishing seasons 2019 and 2020 with 3.48 % and 2.91 % of the total catch, during February 2019 and January 2020, respectively. While the minimum catches of cartilaginous fish (1.48 % and 1.22 %) was recorded during September 2019 and October 2020, respectively (Table, 4).

Table (2): Monthly condition factors of male, female and whole population M. mustellus, collected from Alexandria, Mediterranean Sea, during the period from June 2020 to May 2021.

<table>
<thead>
<tr>
<th>Months</th>
<th>Male</th>
<th>Female</th>
<th>Whole population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nov-20</td>
<td>12.3±0.03</td>
<td>1.04±0.09</td>
<td>1.11±0.11</td>
</tr>
<tr>
<td>Dec-20</td>
<td>13.27±0.02</td>
<td>0.91±0.07</td>
<td>0.94±0.09</td>
</tr>
<tr>
<td>Jan-21</td>
<td>9.27±0.08</td>
<td>0.89±0.24</td>
<td>0.9±0.25</td>
</tr>
<tr>
<td>Feb-21</td>
<td>7.30±0.10</td>
<td>1.01±0.32</td>
<td>0.97±0.07</td>
</tr>
<tr>
<td>Mar-21</td>
<td>8.28±0.08</td>
<td>0.98±0.30</td>
<td>0.99±0.35</td>
</tr>
<tr>
<td>Apr-21</td>
<td>8.27±0.03</td>
<td>0.91±0.10</td>
<td>0.99±0.32</td>
</tr>
<tr>
<td>May-21</td>
<td>16.28±0.06</td>
<td>0.97±0.22</td>
<td>0.95±0.21</td>
</tr>
</tbody>
</table>

Table (3): Annual total catch (tons) of cartilaginous fish from the Egyptian Mediterranean waters, during the period from 2010 to 2020 (as mentioned in GAFRD, 2020).

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Catch</th>
<th>Cartilaginous fish catch</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>77388</td>
<td>3056</td>
<td>3.95</td>
</tr>
<tr>
<td>2011</td>
<td>77799</td>
<td>3333</td>
<td>4.28</td>
</tr>
<tr>
<td>2012</td>
<td>69332</td>
<td>2338</td>
<td>3.37</td>
</tr>
<tr>
<td>2013</td>
<td>63027</td>
<td>2112</td>
<td>3.35</td>
</tr>
<tr>
<td>2014</td>
<td>62746</td>
<td>1843</td>
<td>2.94</td>
</tr>
<tr>
<td>2015</td>
<td>57602</td>
<td>1141</td>
<td>1.98</td>
</tr>
<tr>
<td>2016</td>
<td>53964</td>
<td>1300</td>
<td>2.41</td>
</tr>
<tr>
<td>2017</td>
<td>58926</td>
<td>1375</td>
<td>2.33</td>
</tr>
<tr>
<td>2018</td>
<td>56730</td>
<td>1292</td>
<td>2.28</td>
</tr>
<tr>
<td>2019</td>
<td>48018</td>
<td>1037</td>
<td>2.16</td>
</tr>
<tr>
<td>2020</td>
<td>49896</td>
<td>881</td>
<td>1.77</td>
</tr>
<tr>
<td>Total</td>
<td>625532</td>
<td>18827</td>
<td>3.01</td>
</tr>
</tbody>
</table>
Observations on food and feeding habits of common smoothhound shark, *Mustelus mustelus*

### Table (4): Monthly variations in cartilaginous fish catch (tons) in the Egyptian Mediterranean waters during the fishing seasons 2019-2020.

<table>
<thead>
<tr>
<th>Months</th>
<th>2019 Catch</th>
<th>2020 Catch</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total catch</td>
<td>Cartilaginous catch</td>
</tr>
<tr>
<td></td>
<td>Tons</td>
<td>Tons</td>
</tr>
<tr>
<td>January</td>
<td>1909</td>
<td>60</td>
</tr>
<tr>
<td>February</td>
<td>1494</td>
<td>52</td>
</tr>
<tr>
<td>March</td>
<td>2326</td>
<td>71</td>
</tr>
<tr>
<td>April</td>
<td>3307</td>
<td>112</td>
</tr>
<tr>
<td>May</td>
<td>4313</td>
<td>111</td>
</tr>
<tr>
<td>June</td>
<td>5295</td>
<td>113</td>
</tr>
<tr>
<td>July</td>
<td>5585</td>
<td>113</td>
</tr>
<tr>
<td>August</td>
<td>5595</td>
<td>91</td>
</tr>
<tr>
<td>September</td>
<td>5469</td>
<td>81</td>
</tr>
<tr>
<td>October</td>
<td>4796</td>
<td>73</td>
</tr>
<tr>
<td>November</td>
<td>4245</td>
<td>71</td>
</tr>
<tr>
<td>December</td>
<td>3684</td>
<td>89</td>
</tr>
<tr>
<td>Total</td>
<td>48018</td>
<td>1073</td>
</tr>
</tbody>
</table>

### 5. Growth performance:

#### 5.1. Growth estimation:

For growth curves, parameters of Von Bertalanffy were estimated according to Ford (1933) and Wallford (1946). Asymptotic length ($L_\infty$) and growth coefficient ($k$), of *M. mustelus* were theoretical lengths at each year ($L_{25}= 20.57$, $L_{50}= 32.80$, $L_{75}= 34.49$ cm) for Male, ($L_{25}= 20.66$, $L_{50}= 33.73$, $L_{75}= 35.67$ cm) for Female and ($L_{25}= 20.93$, $L_{50}= 33.80$, $L_{75}= 35.70$ cm) for whole population.

$L_\infty$ and $k$ were estimated in *M. mustelus* from the Ford-Walford plot, and they were 110.25 cm and 0.30 year$^{-1}$, respectively for males. While, it is estimated to be 120.75 cm and 0.14 year$^{-1}$, respectively for females. In the same manner, it’s calculated to be 120.75 cm and 0.24 year$^{-1}$ respectively for the whole population.

#### 5.2. Growth performance index ($\Phi$):

Growth performance indices are used as an indicator of the growth of fish and for comparing its growth with the same species in other sites or with other fish populations. The value of the growth performance index of *M. mustelus* according to $L_\infty$ ($\Phi$) was 3.562 for males, while it was estimated to be 3.311 for females and calculated to be 3.544 for the whole population.

#### 5.3. Mortality rates:

The determination of mortality is essential as it is considered one of the basic input parameters for population dynamic models used in fishery analysis and management. The total mortality coefficient is defined as the total loss by death of individuals from a population during a certain time interval.

The total mortality coefficient ($Z$) is composed of two components namely fishing mortality ($F$) by man and natural mortality ($M$) by all other causes other than fishing, such as predation, ecological conditions, and diseases.

#### 5.4. Total mortality coefficient ($Z$):

The values of total mortality coefficients for *M. mustelus* were estimated from the length converted catch curve of Pauly (1983) to be 0.88, 0.45, and 0.86 for male, female, and whole populations, respectively, it has been calculated by Ault & Ehrhardt model and
valued at 0.891 y\(^{-1}\), 0.424 y\(^{-1}\), and 0.836 y\(^{-1}\) for male, female, and whole population respectively (Fig. 4). While it is estimated to be 0.90 y\(^{-1}\), 0.451 y\(^{-1}\), and 0.846 y\(^{-1}\) for male, female, and whole population respectively according to Beverton & Holt model (1957).

5.5. Natural mortality (M):

The value of the natural mortality coefficient was 0.49 y\(^{-1}\), 0.29 y\(^{-1}\), and 0.42 y\(^{-1}\) for male and female and whole population *M. mustellus* estimated from the length converted catch curve of Pauly (1983) (Fig. 4).

5.6. Fishing mortality (F):

The mean value of fishing mortality was 0.39 y\(^{-1}\) for males while it has been calculated to be 0.42 y\(^{-1}\) for females and estimated to be 0.42 y\(^{-1}\) for the whole population of *M. mustellus* (Fig. 4). This fishing mortality is indicating a high level of exploitation.

![Length-converted catch curve for estimation of total mortality of male, female and whole population of *M. mustellus*, collected from Alexandria, Mediterranean Sea, during the period from June 2020 to May 2021](image)
5.5. Exploitation ratio (E):

The exploitation ratio is very important to estimate the state of the stock, which is optimum, underexploited, and overexploited. The values of exploited rates were 0.44, 0.35, and 0.52 for males, females, and the whole population of *Mustelus mustelus*. From this result, the exploitation level is very high and exceeds the optimum one (E0.5 = 0.30, 0.295, 0.297) for the male, female, and whole population of *Mustelus mustelus* respectively.

5.6. Length at first capture (Lc):

The length group frequency percentage of samples was cumulated separately, and a cumulative curve was drawn to estimate the length at 50 % (Lc) as shown in Figure (13). From this figure, the length at first capture was (32.8, 33.73, and 33.8 cm) for male, female, and whole population of *Mustelus mustelus* respectively (Fig. 5).

5.7. Relative yield per recruit (Y/R)’ and relative biomass/recruit (B/R):

Relative yield per recruit for *Mustelus mustelus* was estimated based on the model of Beverton & Holt (1966). This model describes the exploited population in terms of growth and natural mortality and allows a relative prediction of the long-term catch weights and stock biomass under different exploitation rates. It expresses the yield on a per recruit basis,
and hence the yield is relative to recruitment. \((Y/R)\) can be calculated for given input values of \(M/K\), \(L_c\), and \(L_\infty\) for values of \(E\).

The maximum \((Y/R)\)' was obtained at \((E_{\text{max}} = 0.518, 0.513, \text{and } 0.506)\) for male, female, and whole populations respectively, as the exploitation rate increases beyond this value, the relative yield per recruit decreases (Fig. 6).

\(E_{0.4}\): is estimated as 0.407, 0.417, and 0.42 for male, female and whole population \(M.\ mustellus\), respectively. \(E_{0.5}\): is estimated as 0.30, 0.295, and 0.297 for male, female, and whole population respectively.

![Diagram](image)

**Fig. (6).** Relative yield and biomass per recruit (below) and virtual population analysis (above) of male, female, and whole population \(M.\ mustellus\), collected from Alexandria, Mediterranean Sea, during the period from June 2020 to May 2021

These results indicated that the present levels of \(E\) (0.407, 0.417 and 0.42 for male, female, and whole population, respectively) are higher than that \((E_{0.5} = \text{as } 0.30, 0.295, \text{and } 0.297\) for male, female and whole population, respectively). It gives the maximum \((Y/R)\), which means that the stock of \(M.\ mustellus\) is highly overexploited, which is needed to maintain 50% of the stock biomass.

For management purposes, the exploitation rate of \(M.\ mustellus\) should be reduced to be \(< E_{0.5}\) i.e., the fishing mortality should be reduced to lower than the current fishing mortality
Observations on food and feeding habits of common smoothhound shark, *Mustelus mustelus*

(F=0.39, 0.42 and 0.45 y⁻¹ for male, female, and the whole population respectively) to maintain sufficient spawning biomass for sustainability.

Therefore, for management purposes and to maintain the stocks of *M. mustellos* in the Egyptian Mediterranean Sea, the fishing mortality should be decreased by at least 31.81, 43.27 and 42.88% of male, female and the whole population respectively of its current level to maintain a healthy population structure. In addition, the length of first capture of *M. mustellos* calculated at 33.8 cm, while *M. mustellos* doesn’t reach maturity unless reach 83 cm at least. These indicate that *M. mustellos* at Egyptian Mediterranean waters captured way before its reach its maturity stage. Therefore, for management purposes and to maintain the stocks of *M. mustellos* in the Egyptian Mediterranean Sea, a regulation must be obtained to prevent the early capture of *M. mustellos* population.

**DISCUSSION**

In the present study, the maximum total length of *M. mustellos* (male, female and whole population) was 106.8, 117.6 and 117.6 cm, respectively. It was lower than that observed for the same species which recorded by Goosen & Smale (1997) at South Africa; Smale & Compango (1997) at South Africa; Capape (2006) at the Coast of Senegal; Saidi et al. (2008) at South central Mediterranean Sea; and Da Silva (2018) at South Africa and Ozcan & Basusta (2018) at North eastern Mediterranean Sea. It was higher than that recorded by Morte et al. (1997) at Gulf of Valencia, Spain and Filiz & Mater (2002) at North Aegean Sea.

In the present study, the “b” value found to be 2.80 for *M. mustellos* and showed a slightly negative allometric growth. It was close to which reported by Dulcic & Kraljevic (1996) at Eastern Adriatic; Ozaydin et al. (2007) at Gulf of Izmir, Aegean Sea; Guven et al. (2012) at Gulf of Antalya in Mediterranean Sea and Bilge et al. (2014) at southern Aegean Sea. While it was lower than which estimated by Filiz & Mater (2002) at Nort Aegean Sea; Filiz & Bilge (2004) at Northern Aegean Sea; Capape et al. (2006) at Eastern Tropical Atlantic, Senegalese coast; Ismen et al. (2009) at Gulf of Saros, North Aegean Sea; Pereira et al. (2012) at North Atlantic; Wilhelms (2013) at north-eastern Atlantic; Eronat & Ozaydin (2014) at sigacik Bay, Aegean and Ozcan & Basusta (2018) at Turkey coasts.

The highest values of condition factor “K” of *M. mustellos* (male, female and whole population) were recorded in July and the lowest values were recorded in December and January. It was higher than which estimated by Goosen & Smale (1997) at South Africa; Yamaguchi et al. (1999) at Japan; Malcolm (2015) at South Africa; Ozcan & Basusta (2018) at Turkey, Mediterranean Sea (0.14) and Da Silva (2018) at South Africa.

In the present study, the average relative condition factor (Kn) in male, female and combined sexes of *M. mustellos* are nearly equal one, indicating that the ecological conditions at the Egyptian Mediterranean waters are nearly suitable for the growth of these fishes.
For the last 10 years, cartilaginous fish catch decreased from 3333 tons (representing 4.28% of the total sea catch) during 2011 to be only 881 tons (representing 1.77%) in 2020 (GAFRD, 2020).

In the present study, the growth performance index value was estimated to be Φ = 3.56, 3.311 and 3.544 for *M. mustellus* (male, female and whole population, respectively) at Mediterranean Sea, Egypt. This value was higher than that estimated by Da Silva (20 • V) in South Africa (0.062).

For growth curves, parameters of Von Bertalanffy were estimated according to Ford (1933) and Wallford (1946). Asymptotic length (L∞) and growth coefficient (k), of *M. mustellus* were theoretical lengths at each year (L25 = 20.57, L50 = 32.80, L75 = 34.49 cm) for Male, (L25 = 20.66, L50 = 33.73, L75 = 35.67 cm) for Female and (L25 = 20.93, L50 = 33.80, L75 = 35.70 cm) for whole population.

From the Ford-Walford plot L∞ was estimated, and it was 110.25, 120.75 and 120.75 cm for *M. mustellus* (male, female and whole population). It was lower than that recorded by Francis (1981); Yamaguchi et al. (1996) at Japan; Goosen & Smale (1997) at South Africa; Da Silva (2007) at South Africa and Da Silva & Bürgener (2007) at South Africa; Ozcan & Basusta (2018) at Turkey, Mediterranean Sea. It was higher than that estimated by Yamaguchi et al. (1999) at Japan.

The present study recorded that growth coefficient (K) estimated from length frequency analysis (ELEFAN I) was 0.30 and 0.24 year⁻¹, for male and whole population of *M. mustellus*. It was higher than that recorded by Francis (1981); Yamaguchi et al. (1996 & 1999) at Japan; Goosen & Smale (1997) at South Africa; Da Silva & Bürgener (20 • V) at South Africa (0.08 year⁻¹) and Ozcan & Basusta (2018) at Turkey, Mediterranean Sea. While, growth coefficient (K) estimated from length frequency analysis (ELEFAN I) was 0.14 year⁻¹ for female of *M. mustellus*. It was higher than that recorded by Goosen & Smale (1997) at Mediterranean Sea; Da Silva (20 • V) at South Africa and it was lower than which estimated by Francis (1981) at Mediterranean Sea; Ozcan & Basusta (2018) at Turkey, Mediterranean Sea and Yamaguchi et al. (1999) at Japan.

The total mortality coefficients (Z) for of *M. mustellus* (male, female and whole population) in Egyptian Mediterranean Sea were estimated from the length converted catch curve of Pauly (1983) to be 0.88, 0.45 and 0.86 respectively according to Ault & Ehrhardt model. While, it is estimated to be 0.90, 0.45 and 0.85 year⁻¹ respectively, according to Beverton & Holt model (1957). It was higher than that estimated by Da Silva & Bürgener (2007) at South Africa.

Natural mortality is defined as the death created by all causes other than fishing such as disease, predation, competition, starvation, spawning stress and salinity. Since a direct measurement of natural mortality coefficient is often impossible to obtain. It has been attempted to identify values which can be assumed proportional to natural mortality (Mehanna, 1996).

The natural mortality coefficient in the present study was 0.49 year⁻¹, 0.29 and 0.42 for male and female and whole population respectively of *M. mustellus* estimated from the length
Observations on food and feeding habits of common smoothhound shark, *Mustelus mustelus*

converted catch curve of *Pauly* (1983). It was higher than that estimated by *Da Silva & Bürgener* (2007) at South Africa (M= 0.05 y⁻¹).

The fishing mortality in the present study was 0.39, 0.16 and 0.45 y⁻¹ for *M. mustellus* (male, female and whole population respectively). This fishing mortality is indicating a high level of exploitation. It was higher than that recorded by *Da Silva & Bürgener* (2007) at South Africa (F = 0.08 y⁻¹).

The need for management is acute with evidence of serious overexploitation widespread (*Sadovy, 1989*). Use of marine reserves (areas protected from fishing) has been proposed as a management approach which can overcome the above difficulties. Among the most important advantages claimed for them are: (1) protection of spawning stock biomass, (2) supply of recruits to fished areas, (3) enhancement of catches in adjacent areas through emigration, (4) insurance against stock collapse due to successive years of poor recruitment, (5) reduced data collection needs and (6) simplified enforcement (*Roberts & Polunin, 1991*).

Several of these advantages stem from the prediction that under zero fishing, target species will increase in abundance and average size. It is well known that management strategies and techniques are usually classified into two distinct categories namely: the regulation of catch-age composition and the regulation of the fishing effort (*Mehanna, 1996*).

For the regulation of catch-age composition, several analytical models have been developed. These models are based on the estimation of the yield per recruit under a particular set of fishing conditions. In the present study, estimation of the parameters of recruitment, yield per recruit and yield is very essential in fisheries management. These parameters with that of growth and mortality are widely used in assessment of the states of the fish stocks.

Practically, fisheries are dealing with the data collected to answer two main questions: “How much fish is there in the area that is intended to fish; and 'what is the maximum number of fishes which can be caught annually without affecting the ability of the stock to produce that yield’” (*Holden & William, 1974*).

If the number of fishes a single year-class entering the exploitable phase of a stock in given period by growth of smaller individuals (i.e., recruit) is known, it will be possible to predict the yield throughout the life span of this cohort and known its growth and morality. The yield-per-recruit (YPR) pattern eliminates the uncertain recruitment number from calculate and provides a mean to assess the status of the stock (*Sparre & Venema, 1998*).

In the present study, the fishing mortality of *M. mustellus* (F= 0.45) showed an over exploitation of this species (E= 0.52). The exploitation rate is very important to estimate the state of the stock which optimum, underexploited, and overexploited. The obtained results showed that *M. mustellus* was overexploited where the estimated E value was 0.52 in the Egyptian Mediterranean Sea. *Gulland (1971)* suggested that a fish stock is optimally exploited at a level of fishing mortality that generates E = 0.50, where optimum fishing mortality equal the natural mortality (F= M). *Pauly (1980)* proposed a lower optimum fishing mortality (E = 0.40).
Therefore, for management purposes and to maintain the stocks of *M. mustellus* in the Egyptian Mediterranean Sea, the fishing mortality should be decreased by at least 31.81, 43.27 and 42.88% of male, female, and the whole population respectively of its current level to maintain a healthy population structure.

In addition, the length at first capture of *M. mustellus* was calculated as 33.8 cm, while the *M. mustellus* doesn’t reach maturity unless reach 83 cm at least. These indicated that *M. mustellus* at Egyptian Mediterranean waters captured before its reach its maturity stage. Therefore, for management purposes and to maintain the stocks of *M. mustellus* in the Egyptian Mediterranean Sea, a regulation must be obtained to prevent the early capture of *M. mustellus* population.

The relative yield per recruit (\(\text{Y/R}^{*}\)) model has the great advantage of requiring fewer parameters allowing the authors to calculated (\(\text{Y/R}^{*}\)) for different values of \(E/L_c/L_{\infty}\). Mortality, exploitation, and yield per recruit are essential in order to reveal the effect of fishing on the present stock of *M. mustellus* in the Egyptian Mediterranean Sea to contribution of their fishing management. It is well known that effective management of a fish stock is important for the sustainable of that stock ([Beverton & Holt, 1957](#) and [Sparre & Venema, 1992](#)).

### REFERENCES


Observations on food and feeding habits of common smoothhound shark, *Mustelus mustelus*


GAFRD (General Authority for Fish Resources Development) (2018): Book Year of Fishery Statistic. Egyptian Ministry of Agriculture, Cairo

GAFRD (General Authority for Fish Resources Development) (2020): Book Year of Fishery Statistic. Egyptian Ministry of Agriculture, Cairo


