Stock assessment of the horse mackerel, *Trachurus indicus* in the Gulf of Suez, Egypt

SAHAR FAHMY MEHANNA

National Institute of Oceanography and Fisheries, P.O. Box 182, Suez, Egypt

ABSTRACT

Otoliths were used to estimate age composition, growth rate and mortality rates of *Trachurus indicus* in the Gulf of Suez. Age composition varied between sexes. The oldest males were five years old and the oldest females were four years old. Mean back calculated lengths at the end of each year of life were estimated for males and females. The von Bertalanffy Growth Equation was \( L_t = 24.48 (1 - e^{-0.41243(t + 0.3539)}) \) for males and \( L_t = 22.26 (1 - e^{-0.5689(t + 0.9224)}) \) for females.

The mean total mortality coefficient \( Z \) determined by two methods was found to be 1.02 year \(^{-1}\) for males and 1.14 year \(^{-1}\) for females. The natural mortality coefficient was computed to be 0.35 year \(^{-1}\) for males and 0.38 year \(^{-1}\) for females.

Introduction

The fishes of the family Carangidae, popularly known as horse mackerel and scads are a fairly important group of pelagic fishes caught by purse seiners operating in the Gulf of Suez. They contribute about 34% of the total catch of the purse-seine fishery.

Despite the economic importance of fishes belonging to the family Carangidae in the Gulf of Suez, relatively little is known about their biology and population dynamics. Sanders *et al.* (1984) studied the stock assessment of *Trachurus indicus* in the Gulf of Suez during the period from 1979 to 1982. El-Gammal *et al.* (1995) investigated age, growth and mortality of *T. indicus* in the Gulf of Suez.

The present study discusses and estimates the basic parameters required for assessing and managing *T. indicus* stock in the Gulf of Suez.

Materials and methods

Monthly random samples were collected from the landing site at Ataka where all the catches from the Gulf of Suez were landed during the fishing season 1996/1997. In the laboratory, total length to the nearest millimeter, total weight to the nearest 0.1 gram, sex and otoliths were taken for each individual horse mackerel.

Otoliths were removed, cleaned and sorted dry in labelled vials. Annual rings on otoliths were counted using optical system consisting of Nikon Zoom-Stereomicroscope focusing block, Heidenhain's electronic bidirectional read out system VRX 182, under transmitted light. The total radius of the otolith "S" and the distance between the focus of the otolith and the successive annuli were measured to the nearest 0.001 mm. Lengths by age were back-calculated using Lee's (1920) equation.
The relation between length and weight was computed using the formula 
\[ W = a \cdot L^b \]  
where \( W \) is the total weight, \( L \) the total length and \( a \) and \( b \) constants whose values were estimated by the least square method.

The von Bertalanffy growth model 
\[ L_t = L_{\infty} \cdot (1 - e^{-K \cdot (t - t_0)}) \]  
as applied to describe the theoretical growth of \( T. \text{indiclus} \). The growth parameters \( L_{\infty} \) and \( K \) were computed by fitting the Ford (1993)-Walford (1946) plot while \( t_0 \) was estimated by the equation:

\[ t_0 = t + \frac{1}{K} \ln \left( \frac{L_t}{L_{\infty}} \right) - \frac{L_t}{L_{\infty}} \]

where \( L_t \) is the length at age \( t \).

The total mortality coefficient \( "Z" \) was estimated using the following methods:

- Analysis of catch curve based on age composition data using the method of Ricker (1975).
- Analysis of catch curve based on length frequency data using the method of Jones and Van Zalinge (1981).

The natural mortality coefficient \( "M" \) was estimated using the formula suggested by Ursin (1967) which expressed as \( M = W^{1/2} \) where \( W \) is the total weight of fish while the fishing mortality coefficient \( "F" \) was estimated by the equation \( F = Z - M \).

Yield per recruit was estimated using the model of Beverton and Holt (1957).

**Results and discussion**

**Age determination**

Otoliths were used to age horse mackerel \( T. \text{indiclus} \) in the Gulf of Suez. The otoliths of \( T. \text{indiclus} \) are relatively thin and translucent and all the rings are visible. Therefore the whole otolith immersed in water was used for reading. By examining the mounting otoliths, the focus appears as a dark point followed by an alternating hyaline and opaque zones. Each hyaline zone and opaque zone together make an annual ring. Several findings indicate that rings on horse mackerel otoliths are true annuli. These findings are:

- The increase of fish size is accompanied by an increase in the number of annuli on the otolith. Thus, the otoliths of larger fish show more annuli than those of smaller ones.
- The presence of alternatively wide and close narrow spaced circuli indicate the rapid and slow growth during summer and winter seasons, respectively.
- Samples collected during February have a true annuli on the marginal region or close to it. Samples collected from March to the following January showed variation in the marginal growth of the otolith. The marginal increment increased progressively from March till January of the next year, where the highest value was recorded.
- The close approximation between the observed and calculated lengths for any age group is an additional evidence of the validity of the annulus as a true year mark.

In the present study, otolith’s readings of 354 males and 345 females were analysed to determine the age of \( T. \text{indiclus} \) in the Gulf of Suez and the obtained results indicated that, the maximum life span of males was five years and that of females four years.
Table 1. Age composition of Trachurus indicus from the Gulf of Suez

<table>
<thead>
<tr>
<th>Age group</th>
<th>Males</th>
<th></th>
<th></th>
<th>Females</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>%</td>
<td>Number</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>39</td>
<td>11.02</td>
<td>33</td>
<td>9.56</td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>159</td>
<td>44.91</td>
<td>197</td>
<td>57.10</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>113</td>
<td>31.92</td>
<td>95</td>
<td>27.54</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>35</td>
<td>9.89</td>
<td>20</td>
<td>5.80</td>
<td></td>
</tr>
<tr>
<td>V</td>
<td>8</td>
<td>2.26</td>
<td>--</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>354</td>
<td></td>
<td>345</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Age composition

Age composition of horse mackerel in the Gulf of Suez varied between the two sexes (Table 1). The results indicated that, the oldest males belonged to age group V while the oldest females belonged to age group IV. It was also noticed that, age group II was the dominant age group in the catch for both sexes and constituted 44.19% for males and 57.10% for females. This means that, T. indicus stock in the Gulf of Suez is fully recruited to the purse-seine fishery at age group II.

Growth in length

Body length - otolith radius relationship

The otolith measurements of 354 males and 345 females of T. indicus were used to describe the relationship between the total length and the otolith radius. This relationship is linear and can be represented by the following equations:

Males:

\[ L = 3.36025 + 4.32499 S \text{ with } r = 0.9768 \]

Females:

\[ L = 3.58542 + 4.25953 S \text{ with } r = 0.9855 \]

Sexes combined:

\[ L = 3.49535 + 4.29162 S \text{ with } r = 0.9865 \]

where \( L \) is the total length in centimeter, \( S \) the otolith radius in millimeter and \( r \) the correlation coefficient.

Back-calculation of fish length

The total lengths at the end of each year of life were back-calculated using Lee's equation (1920) as follows:

Males:

\[ L_n = (L - 3.36025) \frac{S_n}{S} + 3.36025 \]

Females:

\[ L_n = (L - 3.58542) \frac{S_n}{S} + 3.58542 \]

Sexes combined:

\[ L_n = (L - 3.49535) \frac{S_n}{S} + 3.49535 \]

Table 2. Mean back-calculated lengths (cm) of Trachurus indicus (males) from the Gulf of Suez

<table>
<thead>
<tr>
<th>Age group</th>
<th>No. of fish</th>
<th>Mean back-calculated-lengths at the end of each year of life</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>I</td>
<td>39</td>
<td>10.50</td>
</tr>
<tr>
<td>II</td>
<td>159</td>
<td>10.41</td>
</tr>
<tr>
<td>III</td>
<td>113</td>
<td>10.38</td>
</tr>
<tr>
<td>IV</td>
<td>35</td>
<td>10.23</td>
</tr>
<tr>
<td>V</td>
<td>8</td>
<td>10.15</td>
</tr>
</tbody>
</table>
TABLE 3. Mean back-calculated lengths (cm) of Trachurus indicus (females) from the Gulf of Suez

<table>
<thead>
<tr>
<th>Age group</th>
<th>No. of fish</th>
<th>Mean back-calculated lengths at the end of each year of life</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1  2  3  4</td>
</tr>
<tr>
<td>I</td>
<td>33</td>
<td>10.86 15.75 18.70</td>
</tr>
<tr>
<td>II</td>
<td>197</td>
<td>10.85 15.57 18.53</td>
</tr>
<tr>
<td>III</td>
<td>95</td>
<td>10.81 15.49 18.53</td>
</tr>
<tr>
<td>IV</td>
<td>20</td>
<td>10.73 15.49 18.53</td>
</tr>
</tbody>
</table>

where \( L_n \) is the length at the end of the \( n \)th year, \( S_n \) the radius of otolith to \( n \)th annulus, \( S \) the total radius of otolith and \( L \) the total length at capture.

The obtained results are given in Tables 2 and 3. It is obvious that, both males and females attain their highest growth rate in length during the first year of life after which, a gradual decrease in growth increment was noticed with further increase in age.

The only previous work dealing with age and growth of males and females of \( T. indicus \) in the Gulf of Suez is that of El-Gammal et al. (1995). They found that, the life span of males is four years while that of females is three years. They gave the following back-calculated lengths: 10.75, 13.14, 14.86 and 16.24 cm at the end of the first, second, third and fourth year of life respectively for males and 11.05, 13.46 and 15.14 cm at the end of the first second and third year of life respectively for females.

**Length-weight relationship**

Length and weight measurements of 354 males and 345 females were used to describe the length-weight relationship of \( T. indicus \) in the Gulf of Suez. For males, the total length varied from 7 to 22.5 cm while the total weight ranged between 3 and 107 g. For females, the total length ranged between 8 and 20.7 cm while the total weight varied between 5 and 102 g. The obtained equations were as follows:

- Males: \( W = 0.008339 \times L^{3.65672} \)
- Females: \( W = 0.007557 \times L^{3.10049} \)
- Sexes combined: \( W = 0.007947 \times L^{3.07738} \)

The values of the constant \( "b" \) obtained from this study are more or less similar to those mentioned in the previous studies. Sanders et al. (1984) estimated the \( "b" \) value as 3.152 for both sexes combined of \( T. indicus \) in the Gulf of Suez. El-Gammal et al. (1995) gave a \( "b" \) value equal to 2.775 for males and 2.874 for females of \( T. indicus \) in the Gulf of Suez.

TABLE 4. Calculated weights (gm) of Trachurus indicus (males) from the Gulf of Suez

<table>
<thead>
<tr>
<th>Age group</th>
<th>No. of fish</th>
<th>Calculated weights at the end of each year of life</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1  2  3  4  5</td>
</tr>
<tr>
<td>I</td>
<td>39</td>
<td>11.09 34.42 60.08 84.38 102.58</td>
</tr>
<tr>
<td>II</td>
<td>159</td>
<td>10.72 34.01 60.09 84.38</td>
</tr>
<tr>
<td>III</td>
<td>113</td>
<td>10.62 34.08 59.19 82.75</td>
</tr>
<tr>
<td>IV</td>
<td>35</td>
<td>10.16 34.08 59.19 82.75</td>
</tr>
<tr>
<td>V</td>
<td>8</td>
<td>9.92 33.69 57.62 82.75</td>
</tr>
</tbody>
</table>
Table 5. Calculated weights (g) of Trachurus indicus (females) from the Gulf of Suez

<table>
<thead>
<tr>
<th>Age group</th>
<th>No. of fish</th>
<th>Calculated weights at the end of each year of life</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>33</td>
<td>12.44</td>
</tr>
<tr>
<td>2</td>
<td>197</td>
<td>12.62, 38.85</td>
</tr>
<tr>
<td>3</td>
<td>95</td>
<td>12.13, 37.59</td>
</tr>
<tr>
<td>4</td>
<td>20</td>
<td>11.55, 36.77, 66.33</td>
</tr>
</tbody>
</table>

**Growth in weight**

The calculated weights at the end of each year of life for males and females of *T. indicus* were estimated by applying the corresponding length-weight equations to the back-calculated lengths and the resulting values are given in Tables 4 and 5.

The obtained results indicated that the growth rate in weight for both males and females was much slower during the first year of life. The annual growth increment in weight increased with further increase in age until it reached its maximum value at the end of the third year of life after which, a decrease in the growth increment was observed.

**Theoretical growth**

The growth parameters (*L*∞, *K* and *t*0) are of great importance in the field of fisheries management. They are the basic input data into the analytical models used in assessing and managing the status of the exploited fish stocks.

In the present study, the growth model of von Bertalanffy was applied to describe the theoretical growth of both males and females of *T. indicus* in the Gulf of Suez. The constants of the model (*L*∞ and *K*) were estimated using the method of Ford (1993) and Walford (1946). In this method the von Bertalanffy growth equation is rearranged as follows: -

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

where *L*0 and *L*t+1 are the lengths at age *t* and *t*+1, respectively.

The von Bertalanffy growth values for *T. indicus* in the Gulf of Suez were:

For growth in length

\[ L_t = 24.48 (1 - e^{-0.41243 (t + 0.3519)}) \]

for males

Table 6. Estimated values of growth parameters of Trachurus indicus

<table>
<thead>
<tr>
<th>Locality</th>
<th><em>L</em>∞*</th>
<th><em>K</em></th>
<th><em>t</em>0</th>
<th>Author</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gulf of Aden</td>
<td>34.04**</td>
<td>0.39</td>
<td>0.06</td>
<td>Edwards and Shaker, 1991</td>
</tr>
<tr>
<td>Gulf of Suez</td>
<td>24.2</td>
<td>0.19</td>
<td>-1.82</td>
<td>Sanders et al., 1984</td>
</tr>
<tr>
<td>Males</td>
<td>20.3</td>
<td>0.28</td>
<td>-1.64</td>
<td>El-Gamal et al., 1995</td>
</tr>
<tr>
<td>Females</td>
<td>19.0</td>
<td>0.36</td>
<td>-1.41</td>
<td>The present study</td>
</tr>
<tr>
<td>Gulf of Suez</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>24.5</td>
<td>0.41</td>
<td>-0.35</td>
<td></td>
</tr>
<tr>
<td>Females</td>
<td>22.3</td>
<td>0.56</td>
<td>-0.19</td>
<td></td>
</tr>
<tr>
<td>Sexes combined</td>
<td>23.8</td>
<td>0.50</td>
<td>-0.20</td>
<td></td>
</tr>
</tbody>
</table>

*Total length  **Forked length.
$L_t = 22.26 \left( 1 - e^{-0.56460 (t + 0.19341)} \right)$ for females

$L_t = 23.80 \left( 1 - e^{-0.49682 (t + 0.19341)} \right)$ for sexes combined

For growth in weight

$W_t = 146.19 \left( 1 - e^{-0.41243 (t + 0.35319)} \right)$ for males

$W_t = 113.85 \left( 1 - e^{-0.56460 (t + 0.19341)} \right)$ for females

$W_t = 136.91 \left( 1 - e^{-0.49682 (t + 0.1967)} \right)$ for sexes combined.

The obtained results indicated that, females have a higher K-value than males. This means that, females approach their asymptotic length faster than males. Table 6 demonstrated the values of growth parameters obtained from the present study compared with those reported by other authors.

Mortality rates

Total mortality coefficient "Z"

The instantaneous total mortality coefficient "Z" of *T. indicus* was estimated by two different methods. The first depends on the analysis of catch curve based on age composition data (Ricker, 1975) and the second depends on the analysis of catch curve based on the length frequency data (Jones and Van Zalinge, 1981) (Fig. 1&2).

The instantaneous total mortality coefficient "Z" and the survival rate "S" of males, females and sexes combined are given in Table 7. The obtained results indicated that, the estimated values of "Z" and "S" from applying the two methods are very close to each other. It is obvious also that, females are characterised by a relatively higher Z values than males ($Z = 1.0241$ year$^{-1}$ for males and 1.1441 year$^{-1}$ for females).

Natural mortality coefficient "M"

In the present study, the formula suggested by Ursin (1967) was applied

<table>
<thead>
<tr>
<th>Method</th>
<th>Males</th>
<th>Females</th>
<th>Sexes combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ricker, 1975</td>
<td>0.2626</td>
<td>0.3186</td>
<td>0.2804</td>
</tr>
<tr>
<td>Jones &amp; Van Zalinge, 1981</td>
<td>0.3555</td>
<td>0.3184</td>
<td>0.2933</td>
</tr>
<tr>
<td>Mean</td>
<td>0.3591</td>
<td>0.3185</td>
<td>0.2868</td>
</tr>
</tbody>
</table>
to estimate the natural mortality coefficient $M$ of males, females and sexes combined of *Trachurus indicus* in the Gulf of Suez. This formula is based on the fact that the natural mortality coefficient $M$ is a simple decreasing function of body weight as follows:

$$M = W^{-1/3}$$

where $M$ is the natural mortality coefficient and $W$ the total weight of fish.

The obtained results indicated that, $M$ values of males, females and sexes combined of *Trachurus indicus* are 0.3470, 0.3798 and 0.3582 year$^{-1}$ respectively.

The only work found in the available literature concerning the estimation of $M$ value of *T. indicus* in the Gulf of Suez is that of Sanders *et al.* (1984). They gave a value of $M$ equals to 0.5 per year for the combined sexes.

**Fishing mortality coefficient $F$**

The available data are not sufficient to produce a direct estimation of the fishing mortality coefficient $F$. So, it was estimated by subtracting the value of $M$ from the value of $Z$. The obtained results were found to be:

$$F = 0.6771 \text{ year}^{-1} \text{ for males}$$
$$F = 0.7643 \text{ year}^{-1} \text{ for females}$$
$$F = 0.8910 \text{ year}^{-1} \text{ for sexes combined}.$$

**Yield per recruit $Y/R$**

The yield per recruit of *Trachurus indicus* from the Gulf of Suez was estimated by applying the model of Beverton and Holt (1957) to the pooled data of the both sexes combined. This model was as follows:

$$Y/R = F_e \cdot M \cdot W_\infty \left[ 1/Z - 3S/ \right. Z+K + 3S^2/Z+2K - S^3/Z+3K \left. \right]$$

where $Y/R =$ yield per recruit

$S = e^{-K(T_C - t_R)}$

$K =$ the von Bertalanffy growth parameter

$T_C =$ age at first capture

$T_R =$ age at recruitment

$t_R =$ age at which the length is nil

$W_\infty =$ asymptotic body weight

$F =$ fishing mortality coefficient

$M =$ natural mortality coefficient

$Z =$ total mortality coefficient

The two parameters $F$ and $T_C$ can be controlled by the fishery managers because $F$ is related to the fishing
effort and "$T_c$" is related to the mesh size.

In the present study, the input parameters used in the calculations were as follows:

- $K = 0.49682 \text{ year}^{-1}$
- $W_\infty = 138.91 \text{ g}$
- $M = 0.3582 \text{ year}^{-1}$
- $F = \text{variable}$
- $Z = 1.2492 \text{ year}^{-1}$
- $T_r = 0.5652 \text{ year}$
- $T_c = \text{variable}$
- $t_0 = -0.1967 \text{ year}$

The mean age at recruitment $T_r$ is estimated by the conversion of $L_r$ (mean length at recruitment) by means of the following equation:

$$T_r = -\frac{1}{K} \ln \left(1 - \frac{L_r}{L_\infty}\right) + t_0$$

The results are represented graphically in Figure 3. As seen from the Figure, the curve starts at the origin where the yield per recruit is zero where the fishing mortality is zero. Then the yield per recruit increases with the increase of fishing mortality and reaches its maximum value at fishing mortality coefficient equal to 0.6, after which, the yield per recruit decreases with further increase in fishing mortality. It is noticed also that, the present level of fishing mortality coefficient ($F = 0.891$), age at first capture ($T_c = 1.5$ year) and natural mortality coefficient ($M = 0.358 \text{ year}^{-1}$) gave a yield per recruit equal to 20.71 g. This means that, the present level of fishing mortality is higher than that which gives the maximum "Y/R" and it must be reduced by about 32.66% to obtain the maximum yield per recruit.

To determine the most appropriate age at first capture, which is related to the estimation of the optimum mesh size, the yield per recruit of *Trachurus indicus* was computed using different values of $T_c$ ($T_c = 1.5$ and 2 years with the present value). The results (Fig. 3) indicated that, when $T_c$ increased the yield per recruit also increased. It is also noticed that, if $T_c$ was 1.5 year a maximum Y/R of 24.41 g can be possible at fishing mortality 0.891 while if $T_c$ was 2 years a maximum Y/R of 26.75 g can be obtained at fishing mortality of 1.4. This means that, the present value of $T_c$ is unsuitable for this stock and $T_c = 1.5$ is more appropriate to that fishery than the present level where at $T_c = 1.5$ the maximum Y/R was obtained at the present level of fishing mortality.

The obtained results indicated that the horse mackerel stock in the Gulf of Suez is in a situation of overexploitation.
and the fishing effort must be reduced as well as the age at first capture must be raised to maintain the productivity of this stock.

References


