Stock Assessment of Turbot (Psetta maxima) by Swept Area Method in the Bulgarian Black Sea Area

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2007
The present study was carried out by a team of experts from the Institute of Oceanology – BAS and the Institute of Fisheries Resources, Varna, during the period 17.03 – 14.04.2007 in execution of a contract between the National Agency of fisheries and Aquaculture – Sofia, MAF and the Institute of Oceanology – BAS, Varna.

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I. Introduction

Among species that inhabit the Black Sea, turbot (*Psetta maxima*) is the most valuable commercially. It is a target of intensive exploitation and the changes in its stocks are highly dependent on the fishing pressure, as well as on the Black Sea environmental state. The sustainable exploitation of the Black Sea turbot requires annual investigations and assessments by direct and analytical methods aiming at accumulation of data that reflects the evolution of stocks. The data gathered is necessary to scientifically underpin the proposal and introduction of measures for sustainable or close to sustainable utilization of this biological resource.

II. Study objective and tasks

The major goal of the present study is to estimate the exploited biomass of turbot stocks by the swept area method in the Bulgarian Black Sea during spring, 2007. The results attained will be compared to previous research results in order to outline the trends in turbot stock temporal changes, as well as its spatial distribution.

The tasks during the study encompass the collection of biological samples for determination of length frequency, weight structure, age structure and sex ratio of turbot population and identification of the species composition and distribution of fishes in by-catch.

III. Fishing vessel and fishing gear

The study was carried out separately in the southern and the northern regions of the Bulgarian Black Sea by two independent teams from the IO-BAS, Varna and IFR, Varna respectively, onboard FV “Elis”. The employment of the same fishing vessel and trawling gear at both regions ensured the consistency of methodology / gear efficiency and the comparability of the results between regions accomplished with the same vessel during 2006.

The dimensions of the bottom trawl (*Pict. 1 and 2*) employed are as follows:
- Length of the head rope – 26 m;
- Vertical spread – 3 m;
- Eye of the net – 10x10 cm;
- Effective part of wing spread – 10-12 m.

At both regions lugs were carried out only during daylight with single haul duration 120 min. at trawl speed 1.8 knots.
Picture 1. Bottom trawl of FV “Elis” employed in the study.

Picture 2. Catch in trawl codend of FV “Elis” trawl
IV. Sampling design

To establish the exploited turbot stock in front of the Bulgarian Black Sea coast a standard methodology for stratified sampling was employed (Gulland, 1966; Sparre, Venema, 1998; Sabatella, Franquesa, 2004). To address the research objectives the region was divided in three strata according to depth – stratum 1 (35 – 50 m), stratum 2 (50 – 75 m) and stratum 3 (75 – 100 m). The study area was partitioned into 128 equal in size not overlying fields, situated at depth 15 - 100 m, of which 70 in the northern region and 58 in the southern region. In the northern region, for the aims of present study, additional forth stratum was introduced, which covered depths between 15 and 35 m. At 36 of the fields chosen at random (22 in the northern region and 14 in the southern region) sampling by means of bottom trawling was carried out (Figure 2).

The seabed area covered during a single haul represents a basic measurement unit, which is very small compared to the total study area, nevertheless deemed representative since turbots do not aggregate in dense assemblages (Martino, Karapekova, 1957). Each field is a rectangle with sides 5' Lat × 5' Long and area around 62.58 km² (measured by application of GIS), large enough for a standard lug extent in meridian direction to fit within the field boundaries. The fields are grouped in larger sectors – so called strata, which geographic and depth boundaries are selected according to the density distribution of the species under study. At each of the fields only one haul with duration 120 min. at speed 1.8 knots was carried out. The arrangement of the swept fields is represented on the map of Figure 2. As a result of the trawling survey a biomass index was calculated.
Figure 2. Research area and plan of the sampling fields.
V. Material and methods

In the northern Bulgarian Black Sea region the survey was carried out during the period 17.03 – 4.04.2007 in accord with the swept area method that uses stratified sampling, the area covered enclosed between the parallels 43°40’ N - 42°50’ N and the meridians 28°05’ E - 28°55’ E. At each of the 22 previously selected swept fields a single haul with duration 120 min. was completed, the results were interpolated over the rest of the area. Bad meteorological conditions and rough sea led to survey interruption for 10 days, after which lugs were resumed. In this region additional forth stratum was introduced between depths 15 m and 35 m.

In the southern Bulgarian Black Sea region the survey was carried out during the period 05.04 – 14.04.2007, the area covered enclosed between the parallels 42°50’ N - 42°05’ N and meridians 27°55’ E - 28°20’ E. Right at the start of first hauls it appeared that turbot fishing nets were cast at the study area, which discontinued the survey until the region would be cleared from fishing gear. On 10.04.2007 the lugs were resumed, however changes in the sampling network had to be made, since the area between 50 m and 75 m depth was still occupied by nets. The hauls were finalised successfully on 14.04.2007.

VI. Onboard sample processing

The data recorded and samples collected at each haul include:
- Depth, measured by the vessel’s echosounder;
- GPS coordinates of start/end haul points;
- Haul duration;
- Abundance of turbots caught;
- Weight of total turbot catch;
- Absolute and standard length, individual weight of turbots. Individuals with size less than the minimal allowable length (45 cm) according to the FAA were released back to the sea.
- Otolyths were collected for age determination;
- Gender was identified;
- Stomachs were collected from part of the individuals for food determination;
- The species composition of the by-catch was identified.
VII. Laboratory analyses

The samples collected onboard were processed in the laboratory for determination of age and food composition.

The age was established in otolyths under binocular microscope.

The food spectrum was determined by separation of the stomach contents into taxonomic groups identified to the lowest possible level.

VIII. Statistical analyses

Swept area method

The swept area method was used for estimation of turbot exploited biomass.

According to this method, the trawl sweeps a well defined path, the area of which is the length of the path multiplied by the width of the trawl, called the "swept area" or the "effective path swept". The swept area, $a$, can be estimated from – equation 1:

$$a = D \cdot hr \cdot X^2$$

$$D = V \cdot t$$

where: $a$ - swept area, $V$ - velocity of the trawl over the ground when trawling, $X^2$ is that fraction of the head-rope length $hr$, which is equal to the width of the path swept by the trawl, the "wing spread", $t$ - is the time spent trawling, $D$ - distance covered.

For the estimation of turbot biomass, the catch per unit of area (CPUA) is used – equation 2:

$$\frac{C_{w/t}}{a/t} = \frac{C_w}{a} \cdot \frac{K^2}{KM^2}$$

where: $C_{w/t}$ – catch in weight per unit of area, $a/t$ – the area swept per hour.

The biomass of the investigated species for each stratum is obtained from – equation 3:

$$B = \left(\frac{C_{w/a}}{a}\right) \cdot A$$

where: $C_{w/a}$ - the mean catch per unit area of all hauls, $A$ – the total size of the area under investigation in stratum.

The variance of biomass estimate for each stratum is (equation 4):

$$VAR(B) = A^2 \cdot \frac{1}{n} \cdot \frac{1}{n-1} \cdot \sum_{i=1}^{n} \left[C_a(i) - \bar{C_a}\right]^2$$
The total area of survey region, equal to the sum of all strata areas, becomes:

\[ A = A1 + A2 + A3 \]

The mean catch for the entire survey area is obtained from – equation 5:

\[ (5) \overline{Ca}(A) = \frac{Ca1 * A1 + Ca2 * A2 + Ca3 * A3}{A} \]

where: \( Ca1 \) - catch per unit area of stratum 1 and etc., \( A1 \) – area of stratum 1 and etc., \( A \) – total area of survey region.

The total biomass in the survey area is estimated by - equation (6):

\[ (6) B = \overline{Ca}(A) * A \]

where: \( \overline{Ca}(A) \) - mean catch for the entire survey area, \( A \) – total area of survey region.

**Estimation of Maximum Sustainable Yield (MSY)**

The Gulland's formula for virgin stocks is used – equation 7:

\[ (7) MSY = 0.5 * M * Bv \]

where: \( M \) – coefficient of natural mortality; \( Bv \) – virgin stock biomass.

**Estimation of Total Allowable Catch (TAC)**

The Ricker’s (1975) method for estimation of catch rate per unit recruitment is used:

\[ (8) Y = F * \sum_{i=t_0}^{t} B_i \left( e^{(G_t - z_t)} - 1 \right) \left( G_t - Z_t \right) \]

where: \( G_t \) - is the the weight-specific growth coefficient by are groups

\[ G_t = \ln(W_{t+1}/W_t) \]

\[ \text{TAC} = Y(\%) \text{ for } F_{0.1}/B \text{ according to Prodanov, Kolarov (1983)} \]

**The Beverton, Holt (1957) method**

\[ (9) Y/R = F * \exp[-M*(T_c - T_r)] * W_\infty * \left[ \frac{1}{Z} - \frac{3S}{Z + k} + \frac{3S^2}{Z + 3k} - \frac{S^3}{Z + 3k} \right] \]

where: \( S = \exp[-K*(T_c-t_0)]; \quad W_\infty, \kappa, t_0 \) - parameters from VBGF; \( T_c \) – age of entering in the exploitation phase; \( T_r \) – age of maturation; \( F \) – fishing
mortality coefficient; $M$ – natural mortality coefficient; $Z = F + M$ – total mortality coefficient.

After series of transformations, Beverton, Holt (1966) worked out a modified form of the equation, but the yield-per-recruit have been estimated as relative $(Y'/R)$.

**Relative yield-per-recruit model**

$$Y'/R = E \cdot U^{M/k} \left\{ 1 - \frac{3U}{(1 + m)} + \frac{3U^2}{(1 + 2m)} - \frac{U^3}{(1 + 3m)} \right\}$$

where: $U = 1 - (L_c/L_{\infty})$
$m = (1-E)/(M/k) = k/Z$
$E = F/Z$ – exploitation coefficient.

**Age and growth**

For the estimation of turbot growth rate, the von Bertalanffy growth function (1938) is used, (according to Sparre, Venema, 1998):

$$L_t = L_\infty \left\{ 1 - \exp[-k(t - t_0)] \right\}$$

$$W_t = W_\infty \left\{ 1 - \exp[-k(t-t_0)] \right\}^n$$

where: $L_\infty, W_\infty$ are the length or weight of the fish at age $t$ years; $L_\infty, W_\infty$ - asymptotic length or weight, $k$ – curvature parameter, $t_0$ - the initial condition parameter.

The length – weight relationship is obtained by the following equation:

$$W_t = qL_t^n$$

where: $q$ – condition factor, constant in length-weight relationship; $n$ – constant in length-weight relationship.

**Fulton’s condition factor** (Ricker, 1975)

$$K = \frac{W}{L^3} \times 100,000$$

where: $W$ – weight in kg.; $L$ – length in cm.

**Coefficient of natural mortality ($M$)**

Pauly's empirical formula (1979, 1980) is applied:

$$\log M = -0.0066 - 0.279 \times \log L_\infty + 0.6543 \times \log k + 0.4634 \times \log T \times C$$

$$\log M = -0.2107 - 0.0824 \times \log W_\infty + 0.6757 \times \log k + 0.4687 \times \log T \times C$$
where: $L_\infty$, $W_\infty$ and $\kappa$ – parameters in von Bertalanffy growth function; $T^\circ C$ - average annual temperature of water, ambient the investigated species.

**Food composition**

To estimate the importance of each food item among the forage, an Index of Relative Importance IRI (Pinkas et al., 1971) was calculated as follows—equation 14:

(14) $IRI = (C_N + C_W)*F$

where: $C_N$ – is the percentage of food item $i$ in total number; $C_W$ - is percentage of food item $i$ in total weight; $F$ – is percentage of occurrence frequency in the food item $i$.

To estimate the importance of each food item among the stomach contents, IRI expressed on a percent basis (Cortes, 1997) was also calculated:

(15) $\%IRI_i = \frac{100*IRI_i}{\sum_i IRI_i}$

where: $n$ – is the total number of food categories considered at a given taxonomic level.

**IX. Results**

**IX.1. Biomass of turbot stocks in the Bulgarian Black Sea area in spring, 2007.**

The trawling survey for turbot stock assessment in the Bulgarian Black Sea area carried out during spring (March – April) 2007 comprised 36 hauls with total duration of 72 hours, during which 362 turbot specimens were caught with total weight of 635.97 kg. The average CPUE in the northern area amounted to 9.24 kg per hour, while in the southern area it was 7.83 kg per hour respectively. The average individual weight of turbot specimens caught in the northern and the southern regions was 1.829 kg and 1.619 kg respectively. The abundance of turbot caught varied from 0 to 21 specimens per haul.

In order to calculate the exploited stock by the swept area method, the Bulgarian Black Sea area was partitioned into 128 fields, which according to their depth belonged to one of the three strata: stratum 1 (35 - 50 m) – 29 fields; stratum 2 (50 - 75 m) – 44 fields and stratum 3 (75 - 100 m) – 40 fields. In the
northern region during the current study an additional stratum 4 (15 - 35 m) was introduced, which encompassed 15 fields. The presence of cast fishing nets in the southern region did not allow the survey to be extended to smaller depths. The total area, in which the turbot exploited stock is deemed to be distributed, amounts to 8010 km$^2$.

Turbot biomass estimation in swept fields requires calculation of the catch per unit effort (CPUE) and the catch per unit area (CPUA) in accord with the methods given (Chapter V.). The results for CPUE (kg/hour), CPUA (kg/km$^2$) and biomass in swept fields are given in Table 1.

The presence of nets not only obstructed sampling in the southern region but reduced the accuracy of the results, since turbot free migration was limited and stocks were affected by catches realized by nets. In view of the distorted results the calculations were made separately for the northern and the southern regions.

Table 1. Catch per unit effort (CPUE), catch per unit area (CPUA) and biomass of turbot by sampling fields in the Bulgarian Black Sea area in spring, 2007.

<table>
<thead>
<tr>
<th>Region</th>
<th>Stratum</th>
<th>Field</th>
<th>CPUE kg/h</th>
<th>CPUA kg/km$^2$</th>
<th>Biomass (in tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>North</td>
<td>1 (35 – 50 m)</td>
<td>E9</td>
<td>7.99</td>
<td>199.61</td>
<td>12.49</td>
</tr>
<tr>
<td></td>
<td></td>
<td>F8</td>
<td>9.11</td>
<td>227.73</td>
<td>14.25</td>
</tr>
<tr>
<td></td>
<td></td>
<td>H6</td>
<td>2.20</td>
<td>55.00</td>
<td>3.44</td>
</tr>
<tr>
<td></td>
<td></td>
<td>G7</td>
<td>15.59</td>
<td>389.61</td>
<td>24.38</td>
</tr>
<tr>
<td></td>
<td>2 (50 – 75 m)</td>
<td>G9</td>
<td>14.65</td>
<td>366.27</td>
<td>22.92</td>
</tr>
<tr>
<td></td>
<td></td>
<td>F10</td>
<td>10.77</td>
<td>269.14</td>
<td>16.84</td>
</tr>
<tr>
<td></td>
<td></td>
<td>I5</td>
<td>3.71</td>
<td>92.81</td>
<td>5.81</td>
</tr>
<tr>
<td></td>
<td></td>
<td>L1</td>
<td>15.58</td>
<td>389.47</td>
<td>24.37</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N1</td>
<td>9.76</td>
<td>244.03</td>
<td>15.27</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M2</td>
<td>13.49</td>
<td>337.11</td>
<td>21.10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>L3</td>
<td>6.22</td>
<td>155.36</td>
<td>9.72</td>
</tr>
<tr>
<td></td>
<td></td>
<td>K4</td>
<td>12.12</td>
<td>302.98</td>
<td>18.96</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M4</td>
<td>8.39</td>
<td>209.74</td>
<td>13.13</td>
</tr>
<tr>
<td></td>
<td>3 (75 – 100 m)</td>
<td>H10</td>
<td>13.39</td>
<td>334.66</td>
<td>20.94</td>
</tr>
<tr>
<td></td>
<td></td>
<td>I9</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>H8</td>
<td>10.29</td>
<td>257.17</td>
<td>16.09</td>
</tr>
<tr>
<td></td>
<td></td>
<td>I7</td>
<td>15.75</td>
<td>393.59</td>
<td>24.63</td>
</tr>
<tr>
<td></td>
<td></td>
<td>J6</td>
<td>12.34</td>
<td>308.41</td>
<td>19.30</td>
</tr>
<tr>
<td></td>
<td></td>
<td>L5</td>
<td>4.17</td>
<td>104.24</td>
<td>6.52</td>
</tr>
<tr>
<td></td>
<td></td>
<td>K6</td>
<td>2.80</td>
<td>70.07</td>
<td>4.38</td>
</tr>
<tr>
<td></td>
<td>4 (15 – 35 m)</td>
<td>F7</td>
<td>4.06</td>
<td>101.53</td>
<td>6.35</td>
</tr>
<tr>
<td></td>
<td></td>
<td>E7</td>
<td>12.09</td>
<td>302.23</td>
<td>18.91</td>
</tr>
</tbody>
</table>
The mean values of catches per unit area by strata, the respective standard deviations and standard errors, Student’s distribution and confidence intervals of the mean (CI, 95%) are given in Table 2.

**Table 2. Statistics of CPUA by strata**

<table>
<thead>
<tr>
<th>Region stratum</th>
<th>Hauls</th>
<th>$\bar{Ca}$ kg/km²</th>
<th>Std.deviation (s)</th>
<th>Std. error $s / \sqrt{n}$</th>
<th>Student distribution $t_{n-1}$</th>
<th>CI of $\bar{Ca}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>North</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>4</td>
<td>217.99</td>
<td>137.177</td>
<td>68.589</td>
<td>3.18</td>
<td>(-0.13, 436.1)</td>
</tr>
<tr>
<td>2</td>
<td>9</td>
<td>262.99</td>
<td>98.45</td>
<td>32.82</td>
<td>2.31</td>
<td>(187.18, 338.79)</td>
</tr>
<tr>
<td>3</td>
<td>7</td>
<td>209.73</td>
<td>150.57</td>
<td>56.91</td>
<td>2.45</td>
<td>(70.31, 348.99)</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>201.88</td>
<td>141.91</td>
<td>100.35</td>
<td>12.71</td>
<td>(-1073.54, 1477.30)</td>
</tr>
<tr>
<td>South</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>127.16</td>
<td>65.17</td>
<td>37.63</td>
<td>4.30</td>
<td>(-34.65, 288.96)</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>292.52</td>
<td>186.29</td>
<td>107.55</td>
<td>4.30</td>
<td>(-169.97, 755)</td>
</tr>
<tr>
<td>3</td>
<td>8</td>
<td>204.75</td>
<td>91.41</td>
<td>32.31</td>
<td>3.37</td>
<td>(95.83, 313.65)</td>
</tr>
</tbody>
</table>

Figure 2 represents the spatial distribution of CPUE in the Bulgarian Black Sea area in spring, 2007.

It is made evident by the figure that in both regions highest catches were achieved at depth between 50 m and 75 m. In the northern area the maximum catches exceeding 15 kg per hour were attained in front of c. Galata and Krapets.
village. Comparative results from 2006 study suggest that the area in front of c. Galata is characterised by constantly high turbot biomass in both seasons – spring and autumn. The shelf in front of Krapets is the broadest in the Bulgarian Black Sea and extends to 35 miles off the coastline. High catches in the area suggest that turbot probably could find favourable environmental conditions and could be distributed beyond 30 miles off the coast at depth even greater than 100 m. Inclusion of this offshore area in next surveys would be appropriate (despite less easily accessible due to greater distance and longer duration of shipping time from Kavarna port), since turbot population is probably less affected by fishing and therefore would be of biological interest in terms of age structure and population parameters. In front of c. Kaliakra the catches per hour are lower in spring compared to autumn-winter results.

The catch per unit effort in the northern region varied from 0 to 15.59 kg/h, relatively high catches realized in front of Shabla, Shkorpilovtsi and Byala. The average CPUE in the northern region amounts to 9.24 kg/h, the average individual weight of turbot specimens was 1.829 kg.

In the southern region CPUE varies from 3.41 to 19.71 kg/h, with an average of 7.83 kg/h - lower compared to the northern region, the average individual weight of turbot specimens also lower - 1.631 kg. The maximum catch of 19.71 kg/h was achieved in front of c. Maslen nos at depth 55 m. Catches in the order of 5 – 15 kg/h were realized in front of Sozopol, Tsarevo and Ahtopol at depth 75-90 m. Higher catches were expected in front of c. Emine, Burgas and Sozopol but trawling in the respective sampling fields was cancelled due to the presence of nets cast in the area.
Figure 2. Distribution of turbot CPUE in the Bulgarian Black Sea during spring, 2007.
The calculated CPUA for the entire Bulgarian Black Sea area is presented on Figure 3.

It is evident from the figure that the maximum value of CPUA in the northern region was lower compared to the southern - 393.59 and 492.65 kg/km$^2$ respectively. However, the average CPUE was higher in the northern region than in the southern - 223.15 and 214.95 kg/km$^2$ respectively.

Figure 3 shows that the average CPUA was higher at depth 50 - 75 m in comparison with other depth zones. With increasing the depth the values of CPUA remained relatively high. The maxima in the northern region were situated in the depth interval between 50 and 95 m, except from the area in front of c. Galata where there was another maximum at 40 m. The CPUA in the latter region was high even at depth 15-20 m. The average CPUAs by strata in the northern region were as follows: stratum 1 (35 – 50 m) – 218 kg/km$^2$; stratum 2 (50 – 75 m) – 263 kg/km$^2$; stratum 3 (75 – 100 m) – 210 kg/km$^2$; stratum 4 (15 – 35 m) – 202 kg/km$^2$.

In the southern region the maximum of CPUA was achieved in front of c. Maslen nos at depth 50 m. At depth between 50 and 75 m CPUA varied from 124.2 to 492.7 kg/km$^2$, the values comparable to those in the northern region. The average CPUAs in the southern region by strata were as follows: stratum 1 (35 – 50 m) – 127 kg/km$^2$; stratum 2 (50 – 75 m) – 293 kg/km$^2$; stratum 3 (75 – 100 m) – 205 kg/km$^2$. The presence of fishing nets cast during the study over considerable part of the southern region hindered sample collection, respectively data analysis and reduced the accuracy of the overall picture of turbot stock distribution.

A comparison of the current results with the turbot stock assessments made in spring 2006 reveals that there is a zone of higher catches along the line linking c. Kaliakra to Byala with maxima realized at depth between 50 and 75 m. The average CPUA in the northern region in spring 2006 at depth 35 – 50 m were 98.28 kg/km$^2$, at depth 50 – 75 m – 170.19 kg/km$^2$ and at depth 75 – 100 m - 94.88 kg/km$^2$. During autumn-winter the values for CPUE by strata in the same region were respectively 339.5, 266.96 and 35.07 kg/km$^2$. Therefore, at depth between 50 - 75 m in spring 2007 and autumn-winter 2006 catches higher than 250 kg/km$^2$ were realized.
Figure 3. Distribution of turbot CPUA in the Bulgarian Black Sea during spring, 2007.
In the southern region of the Bulgarian Black Sea the average CPUE by strata during autumn-winter 2006 were respectively: stratum 1 (35 – 50 m) – 243 kg/km²; stratum 2 (50 – 75 m) – 224 kg/km²; stratum 3 (75 – 100 m) – 137 kg/km², the result comparable to the current study.

The analyses of the two parameters CPUE and CPUA reveal that both during spring and autumn-winter the most suitable depth for commercial fishing of turbot is in the range of 50 – 75 m.

Based on the results from the survey carried out in spring 2007 the biomass of turbot exploited stock in the Bulgarian Black Sea was estimated – Table 3.

**Table 3. Biomass of turbot exploited stock in the Bulgarian Black Sea, spring 2007**

<table>
<thead>
<tr>
<th>Region</th>
<th>Stratum</th>
<th>Fields</th>
<th>Area km²</th>
<th>( \bar{Ca} ) kg/km²</th>
<th>Biomass (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SPRING</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>North</td>
<td>1</td>
<td>14</td>
<td>876.11</td>
<td>217.99</td>
<td>190.98</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>24</td>
<td>1501.91</td>
<td>262.99</td>
<td>394.99</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>17</td>
<td>1063.85</td>
<td>209.73</td>
<td>223.13</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>15</td>
<td>938.69</td>
<td>201.88</td>
<td>189.50</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>70</strong></td>
<td><strong>4380.56</strong></td>
<td><strong>223.15</strong></td>
<td><strong>998.59</strong></td>
</tr>
<tr>
<td>South</td>
<td>1</td>
<td>15</td>
<td>938.69</td>
<td>127.15</td>
<td>119.36</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>20</td>
<td>1251.59</td>
<td>292.51</td>
<td>366.11</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>23</td>
<td>1439.33</td>
<td>204.74</td>
<td>294.69</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>58</strong></td>
<td><strong>3629.61</strong></td>
<td><strong>214.95</strong></td>
<td><strong>780.16</strong></td>
</tr>
<tr>
<td><strong>GRAND TOTAL</strong></td>
<td></td>
<td><strong>128</strong></td>
<td><strong>8010.16</strong></td>
<td><strong>214.95</strong></td>
<td><strong>1778.76</strong></td>
</tr>
</tbody>
</table>

According to the calculations made the biomass of turbot in spring 2007 in the northern region of the Bulgarian Black Sea amounted to 998.59 t and in the southern region it was 780.16 t respectively. The total exploited biomass was estimated at 1778.76 t, however, in view of the fact that in the southern region less number of lugs were realized and 4 fields at depth between 50 -75 m were skipped (due to the presence of fishing nets), where the biomass of turbot was expected to be higher, we deem that the biomass of turbot in the southern region was higher than the estimated.

In the northern region turbot biomass in strata 1, 2 and 3 amounted to 809.09 t, the biomass in same being strata estimated at 735.16 t during autumn-winter study in 2006. The difference of the calculated biomasses during the both assessments is acceptable and is probably due to the following factors: the accuracy of the method, the different number of fields during the studies, the variable meteorological conditions during the field study – waves and currents, which affect the trawl fishing efficiency, recruitment with juvenile specimens,
which joined the exploited stock. The introduction of additional stratum, encompassing smaller depths made evident that considerable part of the stock was localized in that zone, the biomass of turbot in the new stratum amounting to 189.50 t. The proximity of stratum 4 to the coast (within 12 nautical miles) makes it easier for guarding during the reproduction season from illegal fishing and fishing with illegal gears. Simultaneously, the presence of both juvenile and adult specimens makes the zone a suitable donor and biologically important area for the conservation and distribution of turbot to greater depth. The present study registered increase of turbot biomass in the northern region.

In the southern region the exploited biomass of turbot during spring 2007 was estimated at 780.16 t as compared to 705.9 t during autumn-winter 2006. The difference also can be contributed to the accuracy of method, number of fields, recruitment, etc.

The trawling survey for turbot stock assessment in 2008 should be preferably carried out in February or the beginning of March in order to avoid the effect of fishing on the assessed turbot biomass, since around the end of march fishers already cast nets and thus impede the studies.

The studies on the distribution and size structure of turbot population in the Bulgarian Black Sea during spring 2007 revealed mixed distribution of different ages – at all investigated depths both juvenile and adult specimens occurred together. On the overall 54% of caught specimens had absolute length below 45 cm, therefore those should not be a commercial target. For the calculation of the exploited biomass undersized specimens were also included since until the end of 2007 part of them would reach the standard size according to the FAA (2005) and thus recruit the stock. Using the additional biological information for size frequency of turbot catches in the two regions we reduced the calculated biomass to 762.73 t for the northern region and to 534.80 t for the southern region, since the undersized specimens represented respectively 23.62% and 31.45% of the biomass of catches and juveniles should not be commercially exploited.

Maximum sustainable yield (MSY) by regions, according to the method of Gulland (1970), was calculated for both exploitation biomasses – the added biomass of undersized and standard individuals and the biomass of only the standard individuals. The results obtained are given as follows:

**North**

MSY = 0.5*0.25*998.59 = 124.82 tons undersized and standard
MSY* = 0.5*0.25*762.73 = 95.34 tons standard

**South**

MSY = 0.5*0.25*780.16 = 97.52 тона undersized and standard
MSY* = 0.5*0.25*534.80 = 66.85 тона standard
In other words MSY should not exceed 95 - 125 t in the northern region, and 66 – 98 t in the southern region of the Bulgarian Black Sea.

The method of Ricker (1975) was employed for calculation of the catch per unit recruitment of the exploitation stock of turbot (2 – 12 years). Table 4 represents the Ricker’s method results, which reveal the influence of fishing mortality on the initial and mean turbot biomass, as well as on the catch quantity in case that the recruitment abundance (1 year old individuals) is constantly equal to 100 milliard fishes.

Table 4. Initial ($B_i$) and mean ($\bar{B}$) biomass and turbot yield ($Y$).

<table>
<thead>
<tr>
<th>$F$</th>
<th>$B$</th>
<th>$\bar{B}$</th>
<th>$Y$</th>
<th>$Y/Bt$ (%)</th>
<th>$Y/\bar{B}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>956.5</td>
<td>934.0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0.1</td>
<td>578.4</td>
<td>545.4</td>
<td>54.54</td>
<td>9.43</td>
<td>10</td>
</tr>
<tr>
<td>0.2</td>
<td>377.4</td>
<td>343.4</td>
<td>68.69</td>
<td>18.20</td>
<td>20</td>
</tr>
<tr>
<td>0.3</td>
<td>262.5</td>
<td>230.3</td>
<td>69.08</td>
<td>26.32</td>
<td>30</td>
</tr>
<tr>
<td>0.4</td>
<td>192.1</td>
<td>162.2</td>
<td>64.90</td>
<td>33.78</td>
<td>40</td>
</tr>
<tr>
<td>0.5</td>
<td>146.3</td>
<td>118.8</td>
<td>59.41</td>
<td>40.62</td>
<td>50</td>
</tr>
<tr>
<td>0.6</td>
<td>114.8</td>
<td>89.7</td>
<td>53.81</td>
<td>46.85</td>
<td>60</td>
</tr>
<tr>
<td>0.7</td>
<td>92.4</td>
<td>69.3</td>
<td>48.51</td>
<td>52.52</td>
<td>70</td>
</tr>
<tr>
<td>0.8</td>
<td>75.7</td>
<td>54.6</td>
<td>43.64</td>
<td>57.65</td>
<td>80</td>
</tr>
<tr>
<td>0.9</td>
<td>63.0</td>
<td>43.6</td>
<td>39.23</td>
<td>62.30</td>
<td>90</td>
</tr>
<tr>
<td>1.0</td>
<td>53.0</td>
<td>35.3</td>
<td>35.27</td>
<td>66.49</td>
<td>100</td>
</tr>
<tr>
<td>1.1</td>
<td>45.1</td>
<td>28.8</td>
<td>31.71</td>
<td>70.28</td>
<td>110</td>
</tr>
<tr>
<td>1.2</td>
<td>38.7</td>
<td>23.8</td>
<td>28.52</td>
<td>73.70</td>
<td>120</td>
</tr>
<tr>
<td>1.3</td>
<td>33.4</td>
<td>19.7</td>
<td>25.66</td>
<td>76.78</td>
<td>130</td>
</tr>
<tr>
<td>1.4</td>
<td>29.0</td>
<td>16.5</td>
<td>23.09</td>
<td>79.56</td>
<td>140</td>
</tr>
<tr>
<td>1.5</td>
<td>25.3</td>
<td>13.9</td>
<td>20.79</td>
<td>82.06</td>
<td>150</td>
</tr>
</tbody>
</table>

It is evident from Table 4 that according to $F_{0.1}$ the optimal value of the fishing mortality coefficient is achieved at $F_{opt} = 0.3$. For this value of F, the catches constitute 26.32 % of the initial biomass. According to the estimated value of the exploited biomass of turbot calculated by the swept area method, the sustainable yield in the northern region should not exceed 200.75 t if only the biomass of the standard specimens is considered or 262.83 t in the case of mixed stock and for the southern region the sustainable yield should be 140.76 t or 205.34 t respectively.

The value of MSY estimated by the above approach is too high and could lead to decline in the abundance and biomass of turbot stock, as well as to affect negatively the age-size structure of turbot population. For this reason we recommend a two-fold reduction of the fishing mortality coefficient to a value of $F_{opt} = 0.15$. In this case the catches constitute 13.89 % of the initial biomass. Thus for the northern region the sustainable catch represents 105.94 t or 138.70 t.
for the standard size or mixed population respectively, and for the southern region the catches should not exceed 74.28 t and 108.36 t respectively.

In conclusion, the total allowable catch of turbot in 2007 calculated according to Ricker’s method and \( F_{0.1} \) should not exceed 105 -138 t for the northern region and 74 – 108 t for the southern region.

The model yield-per-recruit by Beverton, Holt (1957) was employed, which incorporates the following suggestions:

- the stock of the species under study is in a „balanced state”, or the model describes the stock state on the condition that the fishing effort is constant for long enough period of time so that all survived fishes are exposed to its influence after they have entered the stock;
- the recruitment is constant;
- the fishes from each cohort have hatched in the same day;
- the fishing and natural mortality are constant since the moment of entering in exploitation phase;
- there is full mixing within the stock;
- the length-weight relationship is a third power function.

The model allows the calculation of \( Y/R \) for different values of the initial parameters (\( F \) and \( t_c \)) and estimates the effect of those values on the relationship yield-per-recruit of the investigated species. Moreover, the two parameters \( F \) and \( t_c \) can be managed by humans since the fishing mortality is proportional to the fishing effort, and \( t_c \) is a function of gear selectivity.

The model of Beverton, Holt (1957) was employed for turbot stock.

In order to calculate yield-per-recruit relationship for 2007 the following values of the parameters were used: \( W_\infty =27.44 \) kg, \( k=0.173 \), \( M=0.239 \), \( t_0=-1.561 \), \( t_r=4 \). The results for the relationship \( Y/R \) at three different exploitation levels (\( t_c=2, 3 \) and 4 years) are represented graphically on Figure 4.

It is evident from the plot on Figure 4 that the curves yield-per-recruit have a clear maximum at \( F = 0.3 \) when entering the exploited biomass at the age of 2 \( n \) 3 years and at \( F = 0.4 \) when entering the exploitation phase at age 4 years. Therefore, for achieving maximum sustainable yields (MSY), when exploiting 2- and 3-years old specimens (as suggested by the study results), the fishing mortality coefficient should not exceed 0.3. The value of the fishing mortality coefficient could be raised to 0.4, if only the age groups elder than 4 years are exploited, however we deem that the latter level of exploitation is too high and represents a threat to the stock, therefore it should be decreased.
Figure 4. Yield-per-recruit relationship of turbot for 2007 in three different levels for entering in exploitation phase.

For estimation of the yield-per-recruit in relative units the equation of Beverton, Holt (1966) and the parameters of von Bertalanffy function were used. As a result the values of the exploitation coefficient were calculated according to the criteria: $E_{0.1}$ (level of exploitation at which the boundary increase of the relative yield-per-recruit constitutes 1/10 from its value at $E=0$), $E_{max}$ (level of exploitation producing maximum yield) and $E_{0.5}$ (value of $E$, under which the stock will be reduced to 50 % compared to the biomass in unexploited state). The exploitation coefficient values for turbot in 2007 were calculated. The values of the criteria are given in Table 5 and Figure 5.

Table 5. Values of exploitation coefficient (E) for turbot in 2007.

<table>
<thead>
<tr>
<th>Species</th>
<th>Parameters</th>
<th>$M/k$</th>
<th>$L_c/L_\infty$</th>
<th>$E_{0.1}$</th>
<th>$E_{0.5}$</th>
<th>$E_{max}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>turbot</td>
<td></td>
<td>1.3818</td>
<td>0.362</td>
<td>0.463</td>
<td>0.324</td>
<td>0.563</td>
</tr>
</tbody>
</table>
According to the method of Beverton, Holt (1966), the level of exploitation (E=F/Z) for turbot could be selected dependent on fisheries demands, the most protective being that at E_{0.1}.

Figure 5. Relative yield-per-recruit for turbot in 2007.

The results for F_{opt} achieved by the method of Beverton, Holt correspond to those attained by the method of Ricker.

The method of simulation was also employed (Beverton, Holt). According to this method F_{max} = 0.23 – Figure 6, and F_{opt} = 0.14. The value of F_{opt} is comparable with the values for turbot in the northwestern Black Sea (personal communication – Romanian (NIMRD) and Ukrainian researchers (YugNIRO)).

Figure 6. Yield-per-recruit versus fishing mortality.
The total biomass-per-recruit versus fishing mortality is represented on Figure 7.

\[ \text{Figure 7. Total biomass-per-recruit versus fishing mortality.} \]

The calculated values for the exploitation biomass of turbot in the northern and southern region, their respective values for maximum sustainable yield and the quotas proposed are given in Table 6.

\[ \text{Table 6. Biomass, maximum sustainable yield and quota for turbot.} \]

<table>
<thead>
<tr>
<th>Region</th>
<th>Biomass (t)</th>
<th>MSY</th>
<th>Quota (t)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Gulland,</td>
<td>Ricker,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>F_{0.1}</td>
<td>Holt</td>
</tr>
<tr>
<td>North</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mixed biomass</td>
<td>998.59</td>
<td>124.82</td>
<td>138.70</td>
</tr>
<tr>
<td>Biomass (mature ind.)</td>
<td>762.73</td>
<td>95.34</td>
<td>105.94</td>
</tr>
<tr>
<td>South</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mixed biomass</td>
<td>780.16</td>
<td>97.52</td>
<td>108.36</td>
</tr>
<tr>
<td>Biomass (mature ind.)</td>
<td>534.80</td>
<td>66.85</td>
<td>74.28</td>
</tr>
</tbody>
</table>
In accord with the present study results, the results from autumn-winter survey 2006 and based on the analysis of the population state during spring 2006 we deem that the state of the population is relatively stable and the percentage share of undersized specimens in the biomass and abundance of catches has decreased. The relatively stable population state allows the annual quota to be set at 30 – 70 tones for the entire Bulgarian Black Sea area, but according to the additional biological data for size structure of catches, we consider for expedient to reduce quota to the lower values. We recommend separate quotas of different size to be introduced for the northern and southern regions in 2008, fixing it to the levels between 20 – 30 tones for all Bulgarian Black Sea area, which is deemed appropriate with the aim of reducing the fishing effort exerted on turbot stocks. An additional rationale to keep the current year quota is the fact that the turbot catch quota for 2006 was not reached.

IX.2. Distribution of turbot in the Bulgarian Black Sea area in spring, 2007

The trawling survey in front of the Bulgarian Black Sea coast were carried out during the period 17.03 – 14.04.2007, the study area limited by the parallels 42°05’ and 43°40’ N and the meridians 27°55’ and 28°55’ E. The area studied covered depths between 15 and 95 m. 36 hauls were accomplished during which 362 turbot specimens were caught, 154 of them, with size smaller than the minimum allowable length according to the FAA (2005), were released back to the sea. The total weight of the catch was 635.97 kg, and the average weight of one turbot specimen was 1.757 kg.

The observations revealed that turbot forms mixed shoals during spring with juvenile and adult specimens occurring together at all depths. The abundance of caught specimens in different swept fields varied between 0 and 21. The small numbers of individuals caught during some of the hauls were due to bad meteorological conditions and strong bottom currents which impeded the trawl performance.

Turbot occurres at all studied depths between 15 and 95 m in the area of the Bulgarian Black Sea with maximum density registered in front of Shabla and c. Galata at depth between 40 and 75 m.


The population parameters include the length frequency, age structure and sex ratio of turbot, as well as the growth rate, mortality, etc.
IX.3.1. Length frequency

The length frequency of turbot population in the Bulgarian Black Sea area in spring 2007 includes size groups that range from 26.5 cm to 74.5 cm, the percentage share of specimens from each size group in the total abundance represented on Figure 8.

As evident from Figure 8 highest frequency had the size groups from 41.5 to 50.5 cm, while specimens with length over 62.5 cm were only few. Specimens with length below the minimum allowable by the FAA (2005) constitute 42.54% of the total abundance of caught turbots, which suggests that fishing by bottom trawling degrades the stocks due to significant ratio of undersized individuals in catches.

The size structure of turbot catches in the study fields is given on Figure 9. The size structure was analysed in accord with the regulations determined by the FAA (2005) – individuals with absolute length below 45 cm are treated as undersized and those longer than 45 cm – as standard. Diameter of circles reflects the total abundance of turbot caught in the respective field.
Figure 9. Size structure (according to FAA, 2005) and abundance of turbot in survey fields, spring 2007. Circle diameter corresponds to total abundance.
The figure demonstrates that higher abundance of undersized specimens in the northern region was observed in the area along the line connecting Krapets to c. Kaliakra at depth around 50 m and in front of c. Galata at depth 15 – 25 m.

In the southern area the undersized individuals predominate in the area in front of c. Emine at depth between 70 and 90 m and in front of Ahtopol at depth between 65 and 80 m.

In the northern region the abundance ratio undersized:standard specimens is 39.13:60.87 %. In the southern area the ratio is respectively 48.87:51.13 % with generally lower percentage of undersized individuals compared to autumn-winter 2006.

It is evident from Figure 9 that higher abundance of catches was achieved at depth 50 - 75 m, a week trend of abundance decrease manifested to the south.

**IX.3.2. Sex ratio**

The sex ratio of turbot catches in the Bulgarian Black Sea area in spring 2007 was characterised by 41.07:27.98 % female:male specimens, for 30.95% of the individuals the gender was not possible to be determined, due to their immaturity – Figure 10.

![Sex ratio](image.png)

**Figure 10.** Sex ratio of turbot.

The distribution of the two genders by size groups represented on Figure 11 shows that for the sizes 26.5 - 44.5 cm gender is difficult to be identified, in size class 44.5 cm the male individuals predominate over the
female, in size class 47.5 cm the share of females’ increases and the specimens longer than 60 cm are exclusively female. The results suggest that females grow to larger length and respectively weight than males.

Figure 11. Length frequency of turbot by gender.

IX.3.3. Age composition and growth

The age composition of turbot catches in the Bulgarian Black Sea area in spring 2007 encompassed 1, 2, 3, 4, 5, 6, 7 and 8-years old individuals. The age structure was dominated by individuals 2-5 years old, which altogether represented 75.41 % of the total abundance – Figure 12. The share of immature individuals of age up to 3 years is around 44.20 %, and individuals of age 4 and elder accounts for 55.80 % of the total abundance of turbot caught during the study. Individuals senior than 8 years, did not occur in the catches.
In the northern region the turbot specimens caught were 2 - 8 years old. The share of immature individuals younger than 3 years constitutes 35.22% of the total turbot abundance in catch.

In the southern region turbot specimens were 1 – 7 year old, the share of immature individuals being as high as 59.85%.

The results regarding the age structure of turbot catches suggest that bottom trawling is an unsustainable fishing practice given that on the average 44 % of the catches represents immature specimens, which has degrading effect on the stocks. It is necessary to monitor the age and size structure of catches in nets as well in order to assess the impact of this fishing method on turbot stocks and to regulate the number of nets cast and fishing grounds if needed.

To calculate turbot growth rate during spring 2007 the data for the average length and weight by age groups for each separate gender were used. The values of the parameters in von Bertalanffy growth function, which describe the linear and weight growth are given in Table 7.

Figure 12. Age structure of turbot.
Table 7. Values of parameters in VBGF for both genders

<table>
<thead>
<tr>
<th>Parameters</th>
<th>M</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>$L_\infty$ (cm)</td>
<td>66.83</td>
<td>124.27</td>
</tr>
<tr>
<td>k</td>
<td>0.218</td>
<td>0.080</td>
</tr>
<tr>
<td>$t_0$</td>
<td>-1.703</td>
<td>-2.136</td>
</tr>
<tr>
<td>q</td>
<td>0.0000103</td>
<td>0.000021254</td>
</tr>
<tr>
<td>n</td>
<td>3.106</td>
<td>2.936</td>
</tr>
<tr>
<td>$W_\infty$ (kg)</td>
<td>3.552</td>
<td>27.441</td>
</tr>
<tr>
<td>k</td>
<td>0.338</td>
<td>0.085</td>
</tr>
<tr>
<td>$t_0$</td>
<td>-0.664</td>
<td>-1.941</td>
</tr>
</tbody>
</table>

The growth rate was calculated separately for each gender, resulting in asymptotic length and weight of females higher than those of males. For males the length-weight relationship is positive allometric, i.e. the weight is higher than the corresponding to the given length, while for females the relationship is negatively allometric.

The linear and weight growth of both genders in spring 2007 at age 2-12 is according to the relationship represented on Figure 13 and Figure 14.

Figure 13. Length growth of turbot by ages
According to the results illustrated on the above figures it is evident that males grow slightly faster in length and weight than females until the age of 3-4 years, and subsequently the females have significantly higher growth rate.

**IX.3.4. Fulton’s condition factor**

The Fulton’s condition factor was calculated, used as a measure of the physiological state of the fish. Figures 15 and 16 represent the changes in Fulton’s condition factor with age and with length respectively for the two genders.

It is evident from the fig.15 that Fulton’s condition factor (K) for female turbot decreases with age. For males the opposite trend is observed – K increases with age since the parameter n in the length-weight relationship is higher than 3.
**Figure 15.** Relationship between Fulton’s condition factor and age of turbot.

**Figure 16.** Relationship between Fulton’s condition factor and length of turbot.

Fulton’s condition factor decreases with absolute length for females, while for males it increase. \( K \) varies between 1.676 and 1.729 for females, and for males its values are lower ranging from 1.451 to 1.578 dependent on length.
IX.3.5. Natural mortality coefficient (M)

The natural mortality coefficient of turbot is calculated by the Pauly’s empirical equation (1980), which describes the natural mortality as a function of \( k, L_\infty \), and the ambient temperature (T).

The results obtained for the natural mortality coefficient of the two genders are listed as follows:

*From the parameters in the equation describing the length growth*

<table>
<thead>
<tr>
<th></th>
<th>Male</th>
<th>Female</th>
<th>Total for both genders</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{M} )</td>
<td>0.291</td>
<td>0.127</td>
<td>0.239</td>
</tr>
</tbody>
</table>

*From the parameters in the equation describing the weight growth*

<table>
<thead>
<tr>
<th></th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{M} )</td>
<td>0.698</td>
<td>0.232</td>
</tr>
</tbody>
</table>

IX.3.6. Diet composition

The diet composition was determined from stomachs fixed in 4 % formalin. The food components were divided into taxonomic groups – molluscs, crustaceans and fish and identified to the lowest possible taxonomic level. For each component the share in the total abundance and biomass was determined and the occurrence frequency was calculated. The most important diet component was determined according to the index of relative importance (IRI). The results for the Northern and Southern regions are given in Table 8 and Table 9 respectively.

*Table 8. Diet composition of turbot from the Northern region.*

<table>
<thead>
<tr>
<th>Species</th>
<th>( C_N )</th>
<th>( C_W )</th>
<th>( F )</th>
<th>IRI</th>
<th>%IRI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crustaceans</td>
<td>7.69</td>
<td>1.80</td>
<td>11.76471</td>
<td>111.66</td>
<td>0.66</td>
</tr>
<tr>
<td><em>C. crangon</em></td>
<td>7.69</td>
<td>1.80</td>
<td>11.76471</td>
<td>111.66</td>
<td></td>
</tr>
<tr>
<td>Fishes</td>
<td>92.31</td>
<td>98.20</td>
<td>88.23529</td>
<td>16809.64</td>
<td></td>
</tr>
<tr>
<td><em>M.merlangus</em></td>
<td>80.77</td>
<td>74.78</td>
<td>64.70588</td>
<td>10065.16</td>
<td>99.34</td>
</tr>
<tr>
<td><em>A.pontica</em></td>
<td>7.69</td>
<td>8.22</td>
<td>11.76471</td>
<td>187.20</td>
<td></td>
</tr>
<tr>
<td>Gobiidae</td>
<td>3.85</td>
<td>11.76</td>
<td>5.882353</td>
<td>91.78</td>
<td></td>
</tr>
<tr>
<td>Semi-digested unidentified components</td>
<td>0.00</td>
<td>3.44</td>
<td>11.76471</td>
<td>40.50</td>
<td></td>
</tr>
</tbody>
</table>
The diet composition of turbot from Northern region was determined from 30 stomachs, out of which 67.39 % were empty. The crustaceans in turbot food were represented by a single species and fishes – by three species. The mollusc were absent from the food of turbot during the current study. The observations revealed that in spring 2007 the dominant food item were fishes, mainly represented by whiting, which frequency of occurrence was 64.71 % - Table 8.

According to the results represented in Table 8 during spring turbot fed mainly on fish, which constitutes 92.31 % of food items abundance and 98.20 % of food biomass. The second important food components were the crustaceans, which constitute 7.69 % of food abundance and 1.80 % of food biomass.

The most important prey species in the northern region were the whiting *M. merlangus* (IRI = 10065.16), the shad *A. pontica* (IRI = 187.20) and the shrimp *C. crangon* (IRI = 152.33). Of the two groups identified in turbot stomachs – fishes and crustaceans, the fishes are of dominant importance with 99.34 % of food composition. In conclusion, the diet ration of turbot in spring includes mainly fish, the feeding intensity being relatively low. Representatives of molluscs in the diet were absent in contrast to spring 2006.

In the stomachs of all inspected fishes parasites were encountered, mainly nematodes.

For determining the diet ration of turbot in the southern region 15 stomachs were inspected, the percentage of empty stomachs encompassing 60 %. (Table 9). The observations gave evidence that dominant in the abundance food component were the crustaceans with 66.7 %, while in the biomass dominant were fishes with 62.27 %.

The most important food component according to IRI were the crustaceans (IRI=8699.019), followed by the fishes (IRI=3186.348). Among fishes highest importance had the whiting (IRI=682.136).

Despite the presence of nematodes in turbot stomachs they were not regarded as food item but as parasites. The occurrence of the sea star *Amphiura stepanovi* in turbot stomachs suggests that the habitat of *Modiolula phaseolina* silt was entered during some of the hauls carried out in the southern region.
In comparison to previous studies, during which fish was dominant food component with occurrence frequency 91.43 %, current research shows predominance of crustaceans with frequency 83 %.

IX.3.7. Species composition of by-catch

Demersal fishes which were caught in trawl nets as a by-catch of turbot in the Northern region are listed as follows:

*Squalus acantbias* Linnaeus, 1758 – Piked dogfish
*Raja clavata* Linnaeus, 1758 – Thornback ray
*Sprattus sprattus* (Linnaeus, 1758) – European sprat
*Alosa pontica* (Eichwald, 1838) – Pontic shad
*Gaidropsarus mediterraneus* (Linnaeus, 1758) – Shore rockling
*Merlangius merlangus* (Linnaeus, 1758) – Black Sea whiting
*Hippocampus guttulatus* Cuvier, 1829 – Long-snouted seahorse
*Syngnathus variegates* Pallas, 1814 – Pipefish
*Scorpaena porcus* Linnaeus, 1758 – Black scorpionfish
*Mullus barbatus* Linnaeus, 1758 – Red mullet
*Symphodus roissali* (Risso, 1810) – Five-spotted wrasse
*Trachinus draco* Linnaeus, 1758 – Greater weever
*Aphias minuta* (Risso, 1810) – Transparent goby
*Gobius cobitis* Pallas, 1814 – Giant goby
*Neogobius melanostomus* (Pallas, 1814) - Round goby
*Platichthys flesus* (Linnaeus, 1758) – Flounder
Turbot by-catch in the Southern region included the following fish species:

- *Squalus acanthias* Linnaeus, 1758 – Piked dogfish
- *Raja clavata* Linnaeus, 1758 – Thornback ray
- *Sprattus sprattus* (Linnaeus, 1758) – European sprat
- *Merlangius merlangus* (Linnaeus, 1758) – Black Sea whiting
- *Mullus barbatus* Linnaeus, 1758 – Red mullet
- *Trachinus draco* Linnaeus, 1758 – Greater weever

Gobiidae
The most abundant by-catch was composed of Piked dogfish and Thornback ray (Pic.7) - 260 и 130 specimens respectively, 240 of the former caught during one of the hauls. Those species are the main competitor of turbot for the food resources.

X. Conclusions and recommendations

In agreement with the results of the survey carried out in spring 2007 for turbot stock assessment by the swept area method the following conclusions and recommendation were made:

- The exploitation biomass of turbot in the northern Bulgarian Black Sea region was estimated at 998.59 tons for the entire population and at 762.73 tons for the standard size part of the population.
- The exploitation biomass of turbot in the southern Bulgarian Black Sea region was estimated at 780.16 tons for the entire population and at 534.80 tons for the standard size part of the population.
- We recommend the quotas allowed for 2008 to not exceed those for 2007, the quota should be in the order of 20-30 tons for the all Bulgarian Black Sea area;
- The turbot has a patchy distribution on the Bulgarian shelf with most abundant assemblages recorded in front of Shabla and cape Galata at depth around 50 – 70 m.
- The size composition of turbot caught in the Bulgarian Black Sea area included length classes from 26.5 to 74.5 cm, highest abundance of undersized immature individuals in the northern region was encountered in the area between Krapets and c. Kaliakara at depth around 50 m and in front of c. Galata at depth 15-25 m. In the southern region the undersized specimens predominate in the area in front of c. Emine at depth 70-90m and in front of Ahtopol at depth 65-80 m.
- The ratio female: male: unidentified gender in catches was 41.07 : 27.98 : 30.95 %, specimens with absolute length 44.5 cm were predominantly male, starting from size class 47.5 cm the females share increased and above absolute length 62.5 cm the individuals were exclusively female.
- The age composition of turbot in catches encompassed ages 1, 2, 3, 4, 5, 6, 7 and 8 – years, the predominant number of specimens being 2-5 years old. The percentage share of mature specimens at age 3 and 4 years was around 67 %, and specimens at age 5 years and elder constituted 11 % of total turbot abundance in catches. The percentage share of immature specimens at age up to
3 years was around 44.20 %, and specimens of age 4 years and elder constituted 55.80 % of the total abundance.

- The parameters in the equations describing the length and weight growth were calculated for the two genders, the result showing that the females grow faster in length and weight than the males.
- Fulton’s condition factor decreases with length and age for the females, by contrast to males for which it increases with age and length.
- The natural mortality coefficient for the two genders, calculated by the method of Pauly, takes values 0.291 for males, 0.127 for females and 0.234 for the two genders mixed.
- The diet composition of turbot in spring includes crustaceans and fishes.
- By-catch includes 16 fishes, the most abundant of which are the Piked dogfish and the Thornback ray.
- We recommend the studies on turbot stocks by the swept area method in the northern and southern area of the Bulgarian Black Sea to be continued but to be carried out in February or the beginning of March in order to avoid the net fishing impact on the stocks and the assessment results.

XI. References


Amaoka K.,Yosedk K., Sahin T., Ustundag C., Ciftci Y., 2001. Field guide: Flatfishes (Order:Pleuronecteformes) found in Black Sea and its adjacent waters. Special publication 1, CFRI, Trabzon, Turkey; JICA, 4-7.


