Methodology for bottom trawl survey in the Bulgarian Black Sea area

The methodology and techniques that were used for collection, verification, processing, and data analysis and for overall turbot stock assessment follow the generally applied methodology during the previous turbot data collection programs in the Bulgarian Black Sea zone.

The filed data were collected by standard techniques (bottom trawl) and methodology, which remained constant through the survey. The GPS system of the ship was connected to NAFA satellite system for monitoring of the fishing vessels (VMS) and the ship location was strictly controlled during the trawling.

Data analysis was performed by the "swept area method" and the obtained results can be reproduced and compared.

1.1. Information collected through the bottom trawling

- ✓ Depth - measured with the echo-sounder;
- ✓ GPS coordinates of the trawling - starting and end points;
- ✓ Trawling duration;
- ✓ Abundance of fish species in the trawl;
- ✓ Weight of the total catch in the trawl;
- ✓ Absolute and standard length; weight of collected specimens;
- ✓ Collection of otoliths for age determination;
- ✓ Sex identification;
- ✓ By-catch species composition;
- ✓ Turbot stomachs;

Specimens with absolute length under the minimum, permitted by Fisheries and Agriculture Act (FAA, 2005), (below 45 cm), were immediately returned into the sea, after the measurements.

For turbot biomass calculations, data for catch per unit effort (CPUE) (kg/h) and catch per unit area (CPUA) (kg/km^2) were used.

The results are presented in the form of maps and tables that include data for:

- ✓ Surface area (km^2);
- ✓ Average mass per unit area (t/km^2);
- ✓ Limits of variation of mass pet unit area;
- ✓ Total biomass (t.);
- ✓ Abundance index (individual/km^2).

1.2. Sampling scheme

To establish the abundance and biomass of the reference species *Scophthalmus maximus* off the Bulgarian Black Sea coast, a standard methodology for stratified sampling (Gulland, 1966; Sparre, Venema, 1998; Sabatella, Franquesa, 2004) was applied.

The surveyed region off the Bulgarian coast was divided into four strata, depending on the depth – Stratum 1 (15 - 35 m), Stratum 2 (35 - 50 m), Stratum 3 (50 - 75 m) and Stratum 4 (75 - 100 m). For assessment of turbot abundance and biomass, the surveyed territory was divided into 143 squares, each of them with sides 5 x 5 Nm, area 25 Nm^2 (or 85.8569 m^2).

On the ship board, the absolute and standard length, as well as the individual weight of each specimen were measured to determine the size and weight structure of the turbot stock and to estimate the share of specimens with length below the allowable fishing length in the catches.

1.3. Laboratory analysis

After collecting the samples on shipboard, the age, maturity of the reproductive system, stomach food composition, and fillet chemical composition were determined in laboratory.

The turbot age was established by otoliths reading under binocular microscope.

To identify the composition of the food stomachs were collected. The stomach content analysis included identification of the taxonomic composition and total number of food components, weight and frequency of occurrence of each food component. The index of relative importance (IRI) was used to determine the significance of food components in the trophic spectrum (Pinkas et.al., 1971):

$IRI = (C_N + C_W)*F$

C_N - percentage share of the food item i in total number; C_W - percentage share of the food item i in the total weight; F – frequency of occurrence.

IRI expressed as a percentage was calculated by the equation (Cortes, 1997):

$$\%IRI_i = \frac{100 * IRI_i}{\sum_i^n IRI_i}$$

n – total number of the taxonomic categories at a given taxonomic level.

1.4. Statistical method

1.4.1 Swept areas method

To determine the relative biomass of the reference species (*Scophthalmus maximus*), the “swept area method” was applied. According to this method, trawl sweeps a well-defined path, the area of which is the length of the path times the width of the trawl, called the "*swept area*" or the "effective path swept", thus the swept area can be estimated from equation:

$a = D*hr*X2$, $D = V*t$

V is the velocity of the trawl over the ground when trawling, t is the time spent trawling, hr is the length of the head-rope. X2 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", hr*X2, D-distance covered.

To calculate turbot biomass, the catch per unit area (CPUA) was used:

$$\frac{C_{w/t}}{a/t} = \frac{Cw}{a} kg/km^2$$

Cw/t – catch in units of weight per trawling hour, a/t – area swept per trawling hour.

The biomass for each stratum was obtained from equation:

$$B = \left(\overline{C_{w/a}}\right) * A$$

$\overline{C_{w/a}}$ - mean catch per unit of area for all trawl sweeps in the stratum, A – stratum area.

The variance of biomass estimated for each stratum is:

$$VAR(B) = A^2 * \frac{1}{n} * \frac{1}{n-1} * \sum_{i=1}^{n} \left[Ca(i) - \overline{Ca}\right]^2$$

The total area of the surveyed region is equal to the sum of the areas of every stratum:

A = A1+A2+A3

The mean catch for the entire survey area was obtained from equation:

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

Ca1- catch per unit area in stratum 1; A1 – stratum 1 area, etc.; A – total water area.

The total biomass in the survey area is estimated by equation:

$$B = \overline{Ca}(A) * A$$

$\overline{Ca}(A)$ - mean weighted catch for the entire surveyed water area, A – total area surveyed.

1.4.2 Maximum sustainable yield

Gulland's formula for virgin stock is:

MSY = 0.5*M*Bv

M – coefficient of natural mortality, Bv- biomass of virgin stock.

A generalized version of Gulland was proposed by Cadima (in Troadec, 1971) for exploited fish stocks for which only limited data are available for stock assessment:

MSY = 0.5 * Z * $\overline{B}$

$\overline{B}$ - mean annual biomass,Z – total mortality.

Because Z = F + M and Y = F * $\overline{B}$, Cadima suggested that in the absence of data for Z, the equation can be rewritten:

MSY = 0.5 * (y + M * $\overline{B}$)

y – total catch in one year, $\overline{B}$ - mean biomass in the same year.

Age and growth

For the estimation of turbot growth rate, the von Bertalanffy growth function (1938) was used, (per Sparre, Venema, 1998):

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

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

Lt, Wt are the length or weight of the fish at age **t** years; L∞ , W∞ - asymptotic length or weight; k – curvature parameter; to - the initial condition parameter.

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

$W_t = qL_t^n$

q –constant in length-weight relationship; n – constant in length-weight relationship.

Natural mortality (M)

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

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

$$\log \mathrm{M} = -0.2107 - 0.0824 * \log \mathrm{W}_\infty + 0.6757 * \log \mathrm{k} + 0.4687 * \log \mathrm{T}^\circ\mathrm{C}$$

$$\mathrm{lnM} = -0.0152 - 0.279 * \mathrm{lnL}\infty + 0.6543 * \mathrm{lnk} + 0.463 * \mathrm{lnT}^0$$

L∞, W∞ and k – parameters in von Bertalanffy's equation; TºC - the annual average temperature of the seawater in the horizons of habitation and reproduction of the species.

***Method of Richter - Efanov* (1976)**

$$M = \frac{1.521}{(t_{mat.50\%})^{0.720}} - 0.155$$

t_{mat} – age at first maturation;

***Method of Lukashev* (1970)**

$$\mathrm{M}=1-\left[\frac{1-\mathrm{e}^{-\mathrm{k}(t-t_o)}}{1-\mathrm{e}^{-\mathrm{k}(t_{+1}-t_o}}\right]^3$$

t = age of mature fish

Method of Alverson - Carney (1975)

$$\mathrm{M}=\frac{3.\mathrm{k}}{\mathrm{e}^{t_{mb}.\mathrm{k}}-1}$$

t_{mb}= age at which biomass is maximal;