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MANUAL OF PROTOCOLS

ON METHODS USED FOR ASSESSING FISH STOCKS IN THE BLACK SEA BY ANALYTIC METHODS

BULGARIA, ROMANIA, TURKEY, UKRAINE

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INTRODUCTION

The present study is a part of the Project “Strengthening the regional capacity to support the sustainable management of the Black Sea Fisheries” (SRCSSMBSF) created in the frame of the Joint Operational Programme “BLACK SEA 2007-2013”, Priority 2: Sharing resources and competencies for environmental protection and conservation, Measure 2.1 Strengthening the joint knowledge and information base needed to address common challenges in the environmental protection of river and maritime systems.

Overall objective of this Project is the cooperation between the Black Sea riparian countries for knowing and rationally managing the marine ecosystem and its resources, carrying out diagnostics of fish stocks status as well as advice on management strategies. The major task is to develop methods for joint-regional stock assessment for the Black Sea that will ultimately enable researchers to determine the condition of stocks and advice on management strategies.

One of Specific objectives is - Alignment of the common methods for sampling, processing and interpretation data from fisheries and stock assessment using **analytic models.** This Manual, is made according to GA 2.1 of the Project SRCSSMBSF, contains the summary of the usage by Project Partners of the analytical methods and models considering domestic and regional approaches to fishery management in Black Sea.

1. THE BLACK SEA FISHERIES DATA BASE IN BULGARIA, ROMANIA, TURKEY AND UKRAINE

The theory of stock assessment has been developed originally for fish populations. Its basic purpose is to provide management advice on the sustainable exploitation of aquatic living resources.

The type of model to be used depends on the quality and quantity of data. Analytical model should be used if data are available for such advanced model and simple models should be applied in cases when data are limited.

For establishing the population parameters of marine living resources (MLR), annual research is carried out so as to define the length, age and sex composition of their catches. To be representative the sampling should be consistent with the variational statistics. Otherwise the parameters determined will not correspond to the ones inherent to the population as a whole.

The collection of data and information is not an end in itself but is essential for informed decision-making. It is therefore important for the management authority to ensure that the data collected are analyzed correctly, disseminated to where they can best be used, and used appropriately in decision-making. Information is also needed to assure the public at large that resources are managed responsibly and that the objectives are being reached. Approaches to collecting data for fisheries management vary substantially, depending on, for example, the nature of the fishery, the staff and facilities available, and the social and economic importance of the fishery. Whatever methods are used, the quantity and quality of the data collected will have a direct influence on the quality of the management which can be exercised, and so the most effective use must be made of personnel and facilities available for data collection (STECF, 2011a, b).

The Institute of Fish Resources (IFR), Varna, Bulgaria has length and age composition data of the catches of a series of commercial fish species such as sprat, anchovy, horse mackerel, shad, mullets, etc since 1945-1952 on account of the studies of different scientists as Stoyanov, Hadzhiyski, Ivanov, Kolarov, Prodanov, Mikhaylov, Marinov, Daskalov, etc.

At the Romanian Black Sea coast is a routine in implementation of catch sampling, age reading, establish the qualitative and quantitative structure of catches, the population structure on age and length classes and also, to make at sea survey. The National Institute for Marine Research and Development “Grigore Antipa” Constanta (NIMRD) has historical catch data on a period more than 50 years ago and catch structure on length and age classes, more than 40 years ago.

The species for which NIMRD have these data are sprat, whiting, anchovy, horse mackerel, turbot, spiny dogfish, red mullet, Danube shad, blue fish, and gobies (Radu G., 2006; Radu G. and Radu E., 2008).

In Bulgarian and Romanian Black Sea waters were determined all the necessary parameters for participation at the joint assessment of the fish stocks, as follows: catch and effort; structure on length and age classes of the catches; biologic data (maturation degree, relation length/weight, etc.); generally data about the species biology (reproduction season, migration, etc.); growing parameters; mortality ratios; selectivity of gears, standardization of the fishing effort.

Stratified sampling methodology was applied by Institute of oceanology Bulgarian Academy of Science (IO BAS) and NIMRD for the period of 2007-2010 in Bulgarian and Romanian waters (Radu *et al*., 2010a; Radu *et al*., 2010b; Radu *et al.,* 2010c; Raykov *et al.,* 2007; Raykov, 2008; Raykov *et al*., 2008; Raykov *et al*., 2009; Raykov *et al*., 2010; Raykov *et al*., 2011). Taking into account exact depths (isobaths), the whole area was divided to sub areas, “strata”, depending on depth: first stratum 15-35 – second 35- 50 m., third 50-75 m, and fourth 75-100 m. The examined area was divided into equal sized fields - with total number 55; each sector equal to about 63 км^2 (5' Lat. × 5' Long.). The trawling activities were carried out in meridian direction. The duration of each haul was 60 min; average velocity 2.8 knots (5.19 km* h^{-1}).

Biological data collection using mid-water trawl supply scientists with valuable information of population parameters such as size, age, sex composition, condition (Fulton's coefficient) and relative indices of abundance used in tuning later in the analysis. The CPUE derived from pelagic surveys was used for tuning series in the ICA for sprat.

Seasonal experimental surveys (fall-spring) for biomass estimation by the method of 'swept area' is conducted in Turkish littoral waters of the Black Sea on depth of 100 m (Sparre ve Venema, 1992). The samplings are carried out by commercial fishery vessels and the research vessel 'Sürat-1' belonging Trabzon Central Fisheries Research Institute (CFRI).

Samsun Shelf Region "*Classified sampling procedure*" (stratified sub regions) which is applied by EU States to estimate fish stocks methodology are used. The density of catches obtained from experimental surveys realized in depth ranges of 0-20 m, 20-50 m and 50-100 m in spring and fall.

In addition to experimental surveys; monthly sampling studies have been carried out to determine catch effort and amount of landed fish regarding the commercial trawl fishery in the same region for supportive the dates from depend on fisheries.

Southern Scientific Research Institute of Marine Fisheries and Oceanography (YugNIRO) is nominated by Ukrainian Authority as leading scientific institute for MRL researches in the Black Sea and elaboration of scientific advices for its effective and sustainable use on the basis of biological and fisheries (log - books, journals of biological analyses, reports) obtained in the field of investigations of three types:

- Special surveys accomplished for commercial species in certain periods of their life cycles;
- Observations on onshore fishing points (stationary gears);
- Reports of scientific observers aboard of fishing operating vessels.

Beside the actual data YugNIRO possesses great amount of historical data (90-years period). It should be underlined that mainly all data are on paper and should be transformed into digital formats. This is a very important and rather complicated task demanding a lot of man-power and finances. YugNIRO has long-term experience in applying holistic and analytical methods and models, used for the estimation of fish stock and other MLR, and also of the assessment of their total allowable catch (TAC) in Black and Azov Seas.

1.1. Harmonization of the ways and methods for sampling/processing data

In the framework of the bilateral research project (Romania-Bulgaria) "*Knowledge of status and tendencies of evolution of main gregarious fish stocks from the Romanian and Bulgarian marine zones, aiming to the harmonization of assessment methods and measures for their sustainable development*" a joint working meeting was held in Constanta, Romania (October, 2005). The main task of the workshop was referred to data exchanges on information viewing the methods and ways of sampling/processing of data for joint assessment of main gregarious fish stocks.

Sampling of catch

In order to study the fish populations, the method of random extracted samples is used; a sample represents a share from the whole population able to offer sufficient information for characterization the population.

There were established that the sample extracted for to study the biological parameters must have 200 individuals (for small-sized pelagic species: sprat, anchovy, mackerel). For pelagic big-sized species, the number of individuals from sample depend on the circumstances (i.e. size of catch). The Parties established that the sampling frequency must be at least one sample per week.

1.2. Sampling of material for determination of length frequency

The samples analyzing means: counting, biometry (measurements), gravimeter (weightings), sampling of otoliths for aging, determination of sex and gonads maturation.

The characteristics determined by biometry measurements are: plastic characters (length, mass, thickness), and meristic characters (radii, scales, branchial spines). Within these analyses, the elements necessary for growing parameter assessments are important, carrying out:

- the structure on length and age classes;
- the weight on length and age classes;
- sex ratios.

In the fishery biologic studies, the most utilized method is refers to the measurement of liniar dimensions of the fish or different component parts. Among numerous observation which can be made, the easiest is the total length. Other parameters are linked by the total length, such as mass and age, so each of them can be determinated by length data. Measurements for determination the frequency of lengths of the fishing populations are used for assessment of their population stock.

There was established that the measurements will be made on total fish length, and when is necessary the standard length, and at fork for to establish some correlation's can be made.

For small-sized species, the measurements centralization will be carried out on interval classes of 0.5 cm, the measurements being centralized at inferior cm. For instance, the species with total length comprised between 11.0 and 11.4 cm are registered in length class of 11.00 cm. For large- size species, the interval between length classes is 3 cm.

The Parties agreed as if at regional level, the Black and Mediterranean Seas, for some species will be used the centralization at nearly cm, then the new methodology will be adopted, and then the historical data will be correlated (transformed).

1.3. Collecting of material for determination of fish age

The samples for age determination will be collected using the stratified method, meaning providing a constant number of material - 10 individuals (preferably 5 males and 5 females) from the sample for length frequency study the for each length class.

The material used for age determination is represented basically by the otolithhs, being specific for each species.

1.4. Establishing the gonads maturation degree

Once with the biometric measurements, the gonads are weight, both for females and males. It is indicated as these samplings to be made for the same sample collected for age determination. The gonads will be carefully collected from advanced stages females, to not hurt the ovary walls. The samples are labelled: the trawling number, the number of individual from the sample collected.

It was agreed that the scale for visual appreciation with six stages (Nikolski, ICSEAF) will be used for determination of gonads maturation stage.

Determination of spawning intensity and completion level for main pelagic species

The Parties established as the period for research surveys will be established by each Party in accordance with the optimal conditions specific for each geographic zone.

The Parties agreed as they will use the proper networks for sampling, for to have continuity in observation. For each station, the following data will be noted: station, date of sampling, geographic coordinates of station, water depth (m), level to which the net was launched (m), number of rotations registered on the net device (flowmeter). Also, the Parties agreed:

- The spawning intensity for main pelagic species will be determined using the BONGO net for ichtyoplanktonic sampling, using the circular method; the vessel speed - 2.5-3 Nd.

- For the species with intense spawning during the cold season (sprat), the surveys will be planned in the period December-February-March, and for the thermophilic ones (anchovy, horse mackerel, blue fish) in the period June-July-August.

- For the species spawning during the cold season, the eggs and larvae will be sampled from the whole column of water, and for the warm spawning species the sampling will be made from the water column above the thermocline.

- Two surveys/year have to be organized for to establish the completion level of main pelagic species: one in April-May, which will pursue the way of reproduction developing and laying down the eggs in the cold season, the second one in late summer (August-September-October), in order to be qualitative and quantitative inventoried the juveniles occurred following the reproduction of thermophilic species.

- Assessment of eggs, larvae and juveniles abundance will be made using the areas methods.

- The biomass of spawners will be determined using the method of daily eggs and larvae production (Parker, Sette-Ahlstrom).

Determination of growing parameters and mortality ratios

To determining the growing parameters and mortality ratios the following methods will be used: Gulland and Holt, Ford-Walford, Chapman, Bertalanffy, Beverton and Holt, Pauly, Rikhter and Efanov, etc.

1.5. Fishery statistic

Fishing effort - data needed to be collected

- actively fishing / offshore
- number and types of vessels (length and gross tonnage)
- number sea days / month / year
- number trawling hours
- number fishermen / vessel crew
- total catch / month / year
- catch on species
- stationary fishing - trap nets
- number of pound nets / months / year
- number of sea days / month / year
- number of fishermen
- number of boats

- total catch / month / year
- catch on species
- stationary fishing - other fishing gears (gill nets, long lines, angling lines
- number of units / month / year
- total catch / month / year
- catch on species

It is necessary to have the best data of catch and effort.

2. THE STOCK CONCEPT AND MODELS

When describing the dynamics of an exploited aquatic resource, a fundamental concept is that of the *"stock".* A stock is a sub-set of a *"species" y* which is generally considered as the basic taxonomic unit. A prerequisite for the identification of stocks is the ability to distinguish between different species.

By a "stock" we mean a sub-set of one species having the same growth and mortality parameters, and inhabiting a particular geographical area. To this definition we can add that stocks are discrete groups of animals which show little mixing with the adjacent groups. One essential feature is that the growth and mortality parameters remain constant over the distribution area of a stock, so that we can use them for making assessments. A group of animals for which the geographical limits can be defined may be considered a "stock" in terms of fish stock assessment. Such a group of animals should belong to the same race within the species, i.e., share a common gene pool. For species showing little migratory behavior (mainly demersal species) it is easier to identify a stock than for highly migratory species.

A definition of the term "stock" acceptable to everyone with an interest in intraspecific grouping may be unattainable Gushing (1968) defines a fish stock as one that has a single spawning ground to which the adults return year after year. Larkin (1972) defines a stock as "a population of organisms which, sharing a common gene pool, is sufficiently discrete to warrant consideration as a self- perpetuating system which can be managed", while Ihssen *et al.* (1981) define a stock as "an intraspecific group of randomly mating individuals with temporal or spatial integrity".

Perhaps the most suitable definition in the context of fish stock assessment was given by Gulland (1983) who stated that for fisheries management purposes the definition of a "*unit stock"* is an operational matter, i.e., a sub-group of a species can be treated as a stock if possible differences within the group and interchanges with other groups can be ignored without making the conclusions reached invalid.

This means that it is preferable to start by making stock assessments over the entire area of distribution of a species, as long as there are no indications that separate unit stocks exist in that area. If it becomes clear that the growth and mortality parameters differ significantly in various parts of the area of distribution of the species, then it will be necessary to assess the species on a stock by stock basis. The identification of separate stocks is a complex matter, which usually requires many years of data collection and analysis.

Fish stock assessment should be made for each stock separately. The results may (or may not) subsequently be pooled into an assessment of a multispecies fishery. Therefore, the input data must be available for each stock of each species considered.

The stock concept is closely related to the concepts of growth and mortality parameters. The *"growth parameters*" are numerical values in an equation by which we can predict the body size of a fish when it reaches a certain age. The "*mortality parameters*" reflect the rate at which the animals die, i.e., the number of deaths per time unit. The mortality parameters considered in this manual are the *"fishing mortality"*, which reflects the deaths created by fishing and the "*natural mortality"*, which accounts for all other causes of death (predation, disease, etc.).

An essential characteristic of a stock is that its growth and mortality parameters remain constant throughout its area of distribution.

In order to determine whether a species forms one or more distinct stocks, we should examine its spawning areas, growth and mortality parameters and morphological and genetic characteristics.

The following are necessary to assess a fish stock:

- analyses of the available data;
- the appropriate data bases;
- short and long-term projections of the yield and biomass;
- to determine long-term biological reference points;
- to estimate the short and long-term effects on yield and biomass of different strategies of the fishery exploitation.

The different steps to assess a stock can be summarized as follows :

- To define the objectives of the assessment according to the development phase of the fisheries and the available information.
- To promote the collection of information:
- Fisheries commercial statistics: total and by resource landings, catch per effort, fishing effort (number of trips, days, tows, time spent fishing, etc.), and characteristics of the gears used.
- Types of operation of the fleets and of its fishing gears, etc.
- Biological sampling in the landing ports.

- Biological sampling (and information about the fishing operation) on board commercial vessels.
- Biological sampling on board research vessels.
- To analyze the stocks.

The knowledge gained about the resource and the available basic data, determine the type of models that should be used and consequently the type of analyses that can be done.

For historical analysis of the stock (VPA), long and short-term projections with different conditions (scenarios) we need information collected over several years on :

- Biological distribution of the catches by species, by length, by ages, etc.
- Commercial catches
- Fishing effort or CPUE
- Research cruises (distribution of the stock by areas, by length, by ages, etc.).

A description of a fishery consists of three basic elements:

1. The **input** (the fishing effort, e.g. the number of fishing days);
2. The **output** (the fish landed);
3. The **processes** which link input and output (the biological processes and the fishing operations).

Fish stock assessment aims at describing those processes, the link between input and output and the tools used for that are called "*models*". A model is a simplified description of the links between input data and output data. It consists of a series of instructions on how to perform calculations and it is constructed on the basis of what we can observe or measure, such as for example fishing effort and landings.

A model is a good one if it can predict the output with a reasonable precision. The instructions for the calculations that make up the model are given in the form of mathematical equations. These are composed of three elements: ***"variables", "parameters"*** and "operators".

The assumptions to serve as a basis for a model should be:

- simplify reality;
- be simple and mathematically treatable (manageable);
- not be contradictory;
- not be demonstrated;

- be established with the characteristics.

Usually basic assumptions are related to the evolution of the characteristics. So, they are established on the variation rate of those characteristics and they do not need to be proved.

Verification: the results of the model must be coherent (to agree) with reality. This implies the application of statistical methods and sampling techniques to check the agreement of the results with the observations.

Improvement:
- if agreement is approximate, it is necessary to see if the approximation is enough or not;
- if the results do not agree with reality, then the basic assumptions have to be changed;
- the changes can aim to the application of the model to other cases.

Advantages:
- it is easier to analyse the properties of the model than the reality;
- the models produce useful results;
- they allow analysis of different situations or scenarios by changing values of the factors;
- to point out the essential parts of the phenomenon and its causes;
- they can be improved in order to adjust better to the reality.

General flowchart for fish stock assessment is:
I.INPUT: fisheries data (+ assumptions);
II. PROCESS: Analyses of historical data;
III. OUTPUT: Estimates of growth and mortality parameters input;
IV. PROCESS: Predictions of yield for a range of alternative exploitation levels
V. OUTPUT: Optimum fishing level - maximum sustainable yield.

Fish stock assessment involves five basic steps. The first step is to collect data on the fishery, the INPUT to the assessment, which often have to be supplemented by assumptions or qualified guesses.

Then we process the data by applying a model to estimate the growth and mortality parameters, the OUTPUT from the processing of "the historical data". (The term "historical" is used to distinguish it from the subsequent process, the prediction of future yield.)

This prediction is based on the previous OUTPUT (= INPUT) and on a model, and the prediction is repeated for a series of alternative options. (Such options could be, for example, a fishing effort reduction of 10%, 20% and 30%, no change in fishing effort or a fishing effort increase of 10%, 20% and 30%.)

Among the alternative assumptions the best one is eventually selected as the final OUTPUT. The original INPUT data may be research survey data, data from samples drawn from the commercial fisheries or a combination of both.

The type of model to be used depends on the quality and quantity of input data. If data are available for an advanced analytical model then such a model should be used, while the simple models should be reserved for situations when data are limited.

A basic feature of analytical models as developed by, among others, Baranov (1918), Thompson and Bell (1934) and Beverton and Holt (1957), is that they require the age composition of catches to be known. For example, the number of one year old fish caught, the number of two year old fish caught, etc. may form the input data.

The basic ideas behind the analytical models may be expressed as follows:

1. If there are “too few old fish” the stock is overfished and the fishing pressure on the stock should be reduced;
2. If there are "very many old fish" the stock is under fished and more fish should be caught in order to maximize the yield.

The analytical models are "age (or length)-structured models" working with concepts such as mortality rates and individual body growth rates.

The basic concept in age-structured models is that of a "cohort". To put it simply, a "cohort" of fish is a group of fish all of the same age belonging to the same stock. There are thus two major elements in describing the dynamics of a cohort:

1. The average body growth in length and weight;
2. The death process.

3. COHORT

A cohort or annual class or a generation, is a group of individuals born in the same spawning season. The cycle of life of cohort starts with the egg phase. The phases that follow will be larvae, juvenile and adult.

The number of individuals that arrive in the fishing area for the first time is called recruitment to the exploitable phase. These individuals grow, spawn (once or several times) and die. After the first spawning the individuals of the cohort are called adults and in general, they will spawn again every year, generating new cohorts.

The phases of life of each cohort which precede the recruitment to the fishing area (egg, larvae, pre-recruits), are important phases of its life cycle but, during this time they are not usually subjected to exploitation. The variations in their abundances are mainly due to predation and environmental factors (winds, currents, temperature, salinity,…). In these non exploitable phases mortality is usually very high, particularly at the end of the larvae phase (Cushing, 1996). This results in a small percentage of survivors until the recruitment. Notice that this mortality is not directly caused by fishing.

With some exceptions, the forms of recruitment can be simplified by considering that all the individuals are recruited at a certain instant, tr called age of recruitment to the exploitable phase. It was established that recruitments will occur on 1 January (beginning of the year in many countries).

These two considerations do not usually change the results of the analyses, but simplify them and agree with the periods of time to which commercial statistics are referred. It should be mentioned that not all the individuals of the cohort spawn for the first time at the same age. The proportion of individuals which spawn increases with age, from 0 to 100 percent. After the age at which 100 percent of the individuals spawned for the 1st time, all the individuals will be adult. The histogram or curve that represents these proportions is called maturity ogive.

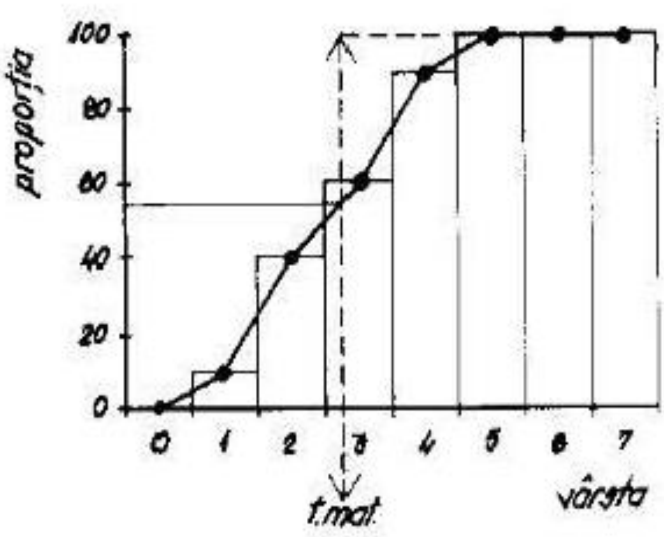


Fig 1 – Maturity ogive

Evolution of the number of a cohort, in an interval of time. Consider the interval (t_i, t_{i+1}) with the size $T_i = t_{i+1} - t_i$ of the evolution of a cohort with time and N_t the number of survivors of the cohort at the instant t in the interval T_i. The available information suggests that the mean rates of percentual variation of N_t can be considered approximately constant, that is, rmr **(Nt) ≈ constant.**

Basic assumption. The relative instantaneous rate of variation of N_t, in the interval T_i is : **rir (Nt) = constant negative**
= - Zi

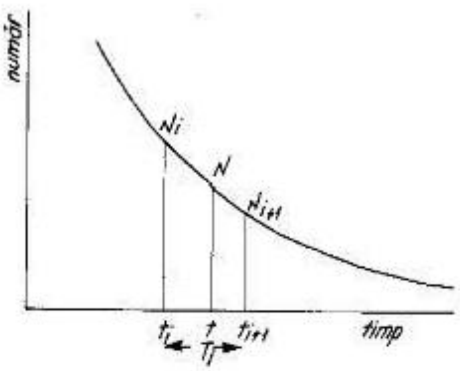


Fig 2 – Evolution of **N** in the interval **T_i**

N_i = number of survivors at the beginning of the interval $(t_{i,\ ti+1})$

N_{i+1} = number of survivors at the end of the interval $(t_{i,\ ti+1})$

The model of the evolution of N_t, in the interval $\mathbf{T_i}$, is an exponential model (because $\mathbf{rir(N_t)}$ is constant).

4. BIOSTATISTICS

Let us consider a sample of n fish all of one species caught in one trawl haul and let x(i) be the length of fish no. i, i = l,2,...,n. The *"mean length"* (in general the *"mean value")* of the sample is defined:

$$\bar{\mathbf{x}} = [x(1) + x(2) + \ldots\ldots\ldots + x(n)] / n = (1/n)\cdot \sum_{i=1}^{n} \mathbf{x(i)}$$

The two first columns of Table 1 show an example for $n = 27$.

The variance, which is a measure of the variability about the mean value is defined as follows:

$$S_2 = [1/(n-1)]\cdot[x(1) - \bar{x}^2 + x(2) - \bar{x}^2 + \ldots x(n) - \bar{x}^2] = (1/n)\cdot \sum_{i=1}^{n} \mathbf{x(i)} - \bar{\mathbf{x}}^2$$

Thus, the variance, $\mathbf{S_2}$, is the sum of the squares of the deviations from the mean divided by the number, n, minus one. The third and fourth column of Table 1 illustrate the calculation of the variance. Note that if all fish in the sample had the same length this would equal the mean length and the variance would be zero. The sum of the deviations (not squared) is always zero. The larger the deviations from the mean value, the larger the variance will be. The two largest values of the square of the deviations from the mean in Table 1 occurred for the smallest and the largest observations.

The square root of the variance, s, is called the "standard deviation". Often one is interested in the variance relative to the size of the mean length, and for that purpose s is the relevant quantity as it has the same unit as the mean. This leads to the relative standard deviation, s/x, also called the *"coefficient of variation".*

Table 1 - Calculation of the variance

Fish No	Length (cm) $x(i)$	Deviation from mean $x(i)-\bar{x}$	Square of deviation from mean $[x(i)-\bar{x}^2]$
1	14,2	-0,87	0,75
2	16,3	1,23	1,52
3	14,8	-0,27	0,07
4	13,2	-1,87	3,48
5	16,9	1,83	3,36
6	12,4	-2,67	7,11
7	14,3	-0,77	0,59
8	15,7	0,63	0,40
9	15,3	0,23	0,05
10	11,2 (min)	-3,87	14,95
11	12,9	-2,17	4,69
12	13,5	-1,57	2,45
13	18,2	3,13	9,82
14	11,6	-3,47	12,02
15	18,5	3,43	11,79
16	16,3	1,23	1,52
17	15,5	0,43	0,19
18	15,8	0,73	0,54
19	13,2	-1,87	3,48
20	19,0 (max)	3,93	15,47
21	12,0	-3,07	9,40
22	17,1	2,03	4,13
23	15,4	0,33	0,11
24	14,6	-0,47	0,22
25			
26			
27=n			
Total			
Mean length, x : 406,8/27 = 15,07 Variance, S^2 : 121,48/(27-1) = 4,67 Standard deviation, S : √4,67 = 2,16 Relative standard deviation, S/ $\bar{x}$: 2,16/15,07 = 0,14 Standard error, S/√n : 2,16/√27 = 0,41			

In this section we shall also use the example of a length composition sample of fish from one cohort. We have estimated the mean length of the cohort, x, from the sample. Such an estimate is usually different from the true population mean, the mean we would have obtained if all fish of that cohort in the sea had been measured. Usually the true mean length is unknown.

In practice this also applies to the population of fish caught in a fishery, since we will not be in a position to measure all fish caught. We shall deal with the precision of the estimate of the mean length, in other words how great the deviation between the estimate and the true mean is likely to be. This uncertainty about the true mean is expressed by the "confidence limits". In the case of a normal distribution, the lower and upper confidence limits are given by respectively:

$$\bar{x} - t_{n-1} \cdot S/\sqrt{n} \text{ and } \bar{x} + t_{n-1} S/\sqrt{n}$$

where **n** is the sample size, **S** the standard deviation and t_{n-1} the so-called fractiles in the *"t- distribution"* or *"Student's distribution"*. The argument "f' in the t-distribution is called the *"number of degrees of freedom".* In general the number of degrees of freedom is the number of observations minus the number of

parameters. In this case $\bar{x}$ is the only parameter, so $f = n-1$ and $t_f = t_{n-1}$ (see Table 2).

Table 2 – Fractiles of the t-distribution (Student's distribution)

degrees of freedom f	fractiles			degrees of freedom f	fractiles		
	90% t(f)	95% t(f)	99% t(f)		90% t(f)	95% t(f)	99% t(f)
1	6.31	12.71	63.66	15	1.75	2.13	2.95
2	2.92	4.30	9.93	16	1.75	2.12	2.92
3	2.35	3.18	5.84	17	1.74	2.11	2.90
4	2.13	2.78	4.60	18	1.73	2.10	2.88
5	2.02	2.57	4.03	19	1.73	2.09	2.86
6	1.94	2.45	3.71	20	1.73	2.09	2.85
7	1.90	2.37	3.50	25	1.71	2.06	2.79
8	1.86	2.31	3.36	30	1.70	2.04	2.75
9	1.83	2.26	3.25	40	1.68	2.02	2.70
10	1.81	2.23	3.17	50	1.67	2.01	2.68
11	1.80	2.20	3.11	60	1.67	2.00	2.66
12	1.78	2.18	3.06	80	1.67	1.99	2.64
13	1.77	2.16	3.01	100	1.66	1.98	2.63
14	1.76	2.15	2.98	∞	1.65	1.96	2.58

The confidence limits can be calculated at different levels of precision, usually 90%, 95 % and 99%, as indicated in Table 3.

Returning to the example given, we want to calculate, for example, the 95% confidence limits for the mean length of fish in the population from which the sample was drawn. We use the 95% fractile of the t-distribution (Table 2) with $n-1 = 26$ degrees of freedom.

$\bar{x} - 0.87$ and $\bar{x} + 0.87$ where:

t_{n-1}□□ $\cdot S/\sqrt{n} = 2.06 \cdot 2.2 / \sqrt{27} = 0.87$

$\bar{x} = 15.07$

Thus, we are "95% confident" that the true mean length lies somewhere between 14.20 and 15.94 or in other words, if sampling was repeated 100 times under the same conditions we would expect the means to lie 95 times between 14.20 and 15.94. The interval between the lower limit and the upper limit is called the *"confidence interval".*

Table 3 – Mean and variance from a length-frequency sample

index j	interval (cm) L(j)-L(j)+dL	midpoint L(j)	frequency			
			F(j)	F(j). $\bar{L}$(j)	(L(j)- $\bar{x}$)	F(j). $\bar{L}$(j)- $\bar{x}$)^2
1	10.5-11.5	11	1	11	-4.074	16.60
2	11.5-12.5	12	3	36	-3.074	28.35
3	12.5-13.5	13	3	39	-2.074	12.91
4	13.5-14.5	14	4	56	-1.074	4.61
5	14.5-15.5	15	4	60	-0.074	0.02
6	15.5-16.5	16	5	80	0.926	4.29
7	16.5-17.5	17	3	51	1.926	11.13
8	17.5-18.5	18	2	36	2.926	17.12
9	18.5-19.5	19	2	38	3.926	30.83
	total		27	407		125.86

Mean length, $\bar{x}$: 407/27 = 15.074, say15.07
Variance, S^2 : 125.86/26 = 4.84
Standard deviation, S : √4.84 = 2.20
Relative standard deviation s/ $\bar{x}$: 2.20/15.07 = 0.15

5. ESTIMATION OF POPULATION STRUCTURE OF FISH AND OTHER MARINE LIVING RESOURCES

The peculiarity of exploited fish population analytical models is inner differentiation of recruitment, growth and mortality processes. Such models are structured according to the fish age or length. That's why great attention has been paid to the assessment of marine population length and age structure.

In the present context, "body length" means the average body length of a cohort. Individual fish are not considered in the models. When talking about "the length of an animal" in connection with a model it is always tacitly assumed that it is the "average length of the animals of a cohort". The estimate of average length, however, is derived from averaging the length measurements of individual specimens. The actual measure used for body length is not important as far as the theory behind the growth model is concerned.

Historically in fishery research organizations of Georgia, Russia and Ukraine the length of pelagic fish (sprat, anchovy and horse mackerel) is measured according to Smith – from the top of rostrum (with closed mouth) to the caudal fin hollow (FL, mm), concerning demersal fish standard length is measured – to the beginning of caudal fin middle rays (SL, mm). Concerning gastropod Rapa whelk the total length is measured – maximum height of the shell (TL, mm). Results of the measurements are grouped and averaged according to length frequency with length intervals

- 5 mm for the type 51-55 mm, 56-60 mm, 61-65 mm, etc. (sprat, anchovy, horse mackerel and Rapa whelk);
- 10 mm type 51-60 mm, 61-70 mm, 71-80 m, etc. (whiting, red mullet);
- 20 mm type 161-180 mm, 181-200 mm, 201-220 mm, etc. (shad, mullet)
- 5 cm type 31-35 cm, 36-40 cm, 41-45 cm (turbot, dogfish and rays).

Historical data about fish length structure is kept in the form of length variation rows (Length frequency); it can be ichthyologic logbooks or electronic data base.

In the other three Black sea countries – Bulgaria, Romania and Turkey – the total length is measured (TL) but when variation rows (Length frequency) are built, different systems are used. Thus for example in Bulgaria sprat and anchovy the length class 6.0 cm includes fish with lengths 5.8, 5.9, 6.0, 6.1 and 6.2 cm. The same applies for the remaining length classes. A really important thing is to specify exactly what kind of length measurement has been used, as one may otherwise run into difficulties when comparing results with those of other investigations. It may in certain cases be preferable to work with body weight rather than length, as the former is obviously measureable with greater accuracy. It is easy to transform one type of length measurement into another type for a single individual. In cases where a sample is grouped into length classes it is more cumbersome to change from one measurement to another as far as the computational aspects are concerned.

In 2013 in YugNIRO simple methodological approach to the transformation of variation length rows (Length frequency) from one measurement system and unification of measurement data to another was developed and published (Shlyakhov, Shlyakhova, 2013). Conversing principle is rather universal and suitable for the transformation of any length variation rows (Length frequency) schemes. Its main requirement is collecting of sufficient quantity of individual fish length measurements. When working with analytical models we need to define the concept of *"age".* As was said above in connection with body length, we do not operate at the individual specimen's level, so "age" means the average age of a cohort. To define age we must start with a definition of *"birthday".* The obvious biological definition of the day of birth is the day the larva hatches from the egg. We say that a newly hatched fish has age zero.

In the first part of their life the larvae (or juveniles) are usually little influenced by the fishery. We say that the fish is then in the unexploited phase of life. Because we are interested in the exploited phase of its life the unexploited phase is not important in the present context. Let $\mathbf{T_r}$ be the youngest age at which the fish may be vulnerable to fishing gears. A fish of age $\mathbf{T_r}$ is called a *"recruit".* By "*recruitment*" we mean the number of recruits, i.e. the number of fish that have attained age Tr during a "*recruitment season".* The *"recruitment intensity"* is the number of recruits per time unit.

YugNIRO scientists defined the pelagic fish, whiting and turbot age by the otoliths (Pravdin, 1966), of red mullet, shad and mullets by scales, of dogfish by the second dorsal fin spine annuli or by measuring of the spine basis width (Probatov, 1957), of Rapa whelk – by the vertical shell markers (spawning markers) counting (Chukhchin, 1961, 1970). On the condition of mass length measurements presence the length-age keys were used.

For the most important commercial fish (e.g. sprat) the catch age structure is defined per month (Table 4). Month’s length variation rows (Length frequency) are further averaged and transformed into annual. At the same time they weighted according to the month’s commercial catch. Table 5-11 shows data of some pelagic and demersal fish and Rapa’s age structure of Ukrainian landings (Shlyakhov et al., 2012 a, Shlyakhov, Gutsal, 2012).

Table 4 – Age structure (N, %) and average weight (W_{av}, g) of sprat in Ukrainian trawl catches in 2011, %

Month	Age groups, years						$W_{av.}$, g
	0+	1, 1+	2, 2+	3, 3+	4, 4+	0-4	
I	-	86.5	11.4	2.1	-	100	2.22
II	-	40.5	39.3	19.2	1.0	100	4.27
III	-	68.0	25.9	6.1	-	100	2.61
IV	-	90.9	8.1	1.0	-	100	2.18
V	33.0	56.9	10.1	-	-	100	2.11
VI	50.4	32.4	15.7	1.5	0.1	100	2.27
VII	46.7	46.5	6.6	0.2	-	100	2.53
VIII	70.5	27.6	1.9	-	-	100	2.62
IX	13.5	49.4	29.4	7.7	-	100	2.73
X	9.9	37.5	37.7	14.8	0.1	100	3.96
XI	32.9	59.5	7.1	0.4	0.0	100	4.00
XII	38.9	39.2	18.0	3.9	-	100	2.91
I-XII	32.2	50.8	14.2	2.9	0.0	100	2.88

Table 5 – Age catches structure of anchovy aggregation near Crimean, 2002-2011, %

Age, years	Year						
	2002	2003	2004	2005	2006	2010	2011
0+	27.3	28.1	40.0	9.7	8.6	46.4	3.8
1, 1+	67.2	65.6	55.3	76.2	73.9	52.8	40.7
2, 2+	5.4	6.2	4.4	13.7	16.4	0.8	31.7
3, 3+	0.1	0.1	0.4	0.3	1.1	-	14.6
4, 4+	-	-	-	-	-	-	8.2
5	-	-	-	-	-	-	1.0
0-5	100	100	100	100	100	100	100
$W_{av.}$, g	7.2	7.1	4.1	10.9	9.1	2.6	8.5

Table 6 – Age composition of horse mackerel near Crimean, 2003-2011

Year	Av.weight in catch, g	Age group part in catch (by number), %					
		0+	1, 1+	2, 2+	3, 3+	4, 4+	5, 5+
2003	18,1	0.0	1.0	97.0	2.0	0.0	0.0
2004	29,4	1.0	2.0	6.0	91.0	0.0	0.0
2005	23,3	0.0	30.0	50.0	15.0	5.0	0.0
2006	17,4	0.0	67.7	13.1	18.9	0.3	0.0
2007	18,2	0.0	51.1	20.4	27.7	0.8	0.0
2008	17,9	0.9	24.8	63.3	10.3	0.5	0.2
2009	23,2	0.0	0.0	16.9	55.8	24.0	3.3
2010	12,8	46.4	52.8	0.8	0.0	0.0	0.0
2011	17,5	9.1	80.4	4.5	3.8	2.2	0.0

Table 7 – Black Sea turbot age structure (N, %) and average weight ($W_{av.}$, g) of the legal fishery in Ukrainian waters 2009-2011

Age, years	2009				2010				2011	
	NWBS		NEBS		NWBS		NEBS		NWBS	
	N, %	$W_{av.}$	N, %	$W_{av.}$	N, %	$W_{av.}$	N, %	$W_{av.}$	N, %	$W_{av.}$
3	1.5	1.1	3.7	1.0	4.0	1.2	4.0	1.0	0.3	1.3
4	8.1	1.8	12.9	1.6	16.2	1.7	16.4	1.4	1.7	1.7
5	18.8	2.8	26.3	2.1	25.7	2.3	26.1	1.9	4.1	2.5
6	17.6	3.2	20.7	2.9	30.7	2.7	31.2	2.5	4.6	3.3
7	43.9	4.0	28.5	3.2	13.7	3.5	13.9	3.1	28.4	4.1
8	9.5	4.9	7.2	4.0	4.2	4.7	4.3	3.9	37.1	4.8
9	0.6	5.9	0.7	5.5	4.0	5.7	4.1	5.5	18.1	5.9
10	-	-	-	-	0.4	6.9	-	-	5.7	7.0
11	-	-	-	-	1.1	8.3	-	-	-	-
12	100	-	100	-	100		100	-	100	-
$W_{av.}$	-	3.5	-	2.6	-	4.1	-	2.4	-	4.7

Table 8 – Whiting age structure of Ukrainian landings in the Black Sea in 2002-2011, %

Age, years	Year									
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
0	12.5	22.5	54.6	50.9	17.8	19.0	12.2	54.6	27.8	11.2
1	22.1	26.4	12.5	41.2	48.7	46.5	48.8	12.5	19.1	60.4
2	28.4	26.4	23.6	1.8	27.3	25.5	28.2	23.6	35.3	23.2
3	15.3	10.3	7.4	5.0	3.1	5.0	5.5	7.4	16.4	3.8
4	14.4	8.4	1.7	0.8	1.9	2.0	4.0	1.7	0.9	1.2
5	6.9	5.8	0.2	0.2	1.1	1.5	1.2	0.2	0.5	0.2
6	0.4	0.2	-	0.1	0.1	0.5	0.1	-	-	-
0-6	100	100	100	100	100	100	100	100	100	100
N	1392	168	1419	807	706	300	183	276	207	296
$W_{av.}$, kg	33.2	25.8	13.3	9.2	15.4	16.7	18.0	13.6	19.6	14.3

Table 9 – Dogfish age structure of Ukrainian landings in the Black sea in 2002-2011, %

Age, years	Year								
	2002	2003	2004	2005	2006	2007	2008	2009	2011
4	-	-	-	-	-	-	-	-	12.5
5	-	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	25.0
7	-	-	1.7	3.2	-	-	-	-	-
8	-	-	5.1	9.7	3.8	-	-	-	-
9	-	-	5.3	3.2	3.9	2.5	-	5.3	-
10	2.6	0.4	1.1	-	7.7	5.0	-	28.2	-
11	2.6	0.9	-	-	30.8	5.0	-	20.5	12.5
12	5.2	7.8	-	-	23.1	10.0	4.3	12.0	12.5
13	15.2	18.5	0.3	3.2	19.2	20.0	13.1	11.4	-
14	18.1	20.4	1.9	12.9	3.9	17.5	8.7	10.7	-
15	25.2	21.7	7.6	29.0	-	10.0	13.1	5.9	12.5
16	18.1	9.4	13.4	25.8	3.8	17.5	26.1	4.1	-
17	7.8	11.7	21.0	9.8	3.8	7.5	21.7	1.9	-
18	5.2	8.3	28.3	3.2	-	5.0	8.7	-	12.5
19	-	0.9	14.3	-	-	-	4.3	-	12.5
4-19	100	100	100	100	100	100	100	100	100
N	52	205	38	31	26	40	23	22	8
$W_{av.}$, кg	11.6	8.7	12.1	10.6	5.4	9.6	12	6.4	7.4

Table 10 – Red mullet age structure of Ukrainian landings in the Black Sea and the Kerch Strait in 2000-2008, %

Year	Years				
	0+	1; 1+	2;2+	3;3+	4;4+
2000	-	59.3	27.2	10.4	3.1
2001	70,0	20.0	8.0	2.0	-
2002	2,5	68.6	18.3	7.5	3.1
2003	8,0	92.0	-	-	-
2004	0,5	82.1	14.9	2.5	-
2005	-	86.7	11.7	1.7	-
2006	9,5	45.3	36.9	8.3	-
2007	5,0	38.6	39.3	14.7	2.5
2008	-	61.3	35.5	3.1	0.1

Table 11 – Rapa whelk's age structure dynamic in the Kerch Strait in 2003-2011, %

Age, years	Year						
	2003	2004	2005	2006	2007	2008	2011
0-1	13.5	3.5	1.4	-	93.0	31.2	37.4
2	12.6	3.4	36.7	8.7	3.4	45.6	44.3
3	28.6	34.2	31.6	21.8	2.3	17.5	14.2
4	28.1	34.1	12.7	27.0	1.0	5.1	3.6
5	14.4	18.0	10.8	27.6	0.2	0.5	0.5
6	2.7	6.4	4.6	8.9	0.1	0.1	-
7	0.1	0.4	1.3	3.2	-	-	-
8	-	-	1.0	2.8	-	-	-
0-8	100	100	100	100	100	100	100
N	115	193	73	76	137	189	189

All the basic versions of the methods assume the input data to be derived from *random samples*". A sample of fish, for example a length-frequency sample representing the stock, is a random sample if any fish in the entire stock has the same probability of being drawn as any other.

Usually, it is difficult or even impossible to obtain pure random samples. If, for example, the juvenile fish are located in certain nursery areas, which do not coincide with the fishing grounds from which our samples originate, the juvenile fish will be under-represented in the samples. A similar problem is created by the selectivity of fishing gears. Often the small fish are under-represented because they escape through the meshes, whereas the larger fish are retained. Samples which are not random samples are called "***biased samples***".

A feature of fish behavior which is believed to create the most serious bias is ***"migration".*** The implication of the migratory behavior is that a large sea area must be covered in order to obtain random samples from the entire population. Often samples can be obtained only from the commercial fishery which concentrates on those grounds where the resources are easiest to catch in large quantities. Thus, we are often in the situation that random samples of the population are not available. This bias must be accounted for in the analysis and the basic methods have to be modified to account for it. Some types of bias are easier to deal with than others. Bias created by migration can only be handled properly when the migration routes are known. When they are not we have to make certain assumptions about them in order to get on with the analysis. There are many serious problems in connection with bias.

6. METHODS FOR ASSESSING OF THE BASIC POPULATION CHARACTERISTICS

6.1. Estimation of the growth's equation parameters

Using analytical methods (models) for the estimation of MLR stocks it necessary to know the function of weight-length dependence and also length-age and age-weight dependence. Here the population growth is meant. The function of weight (W) and length (l) relation is usually described by the equation.

$$W = Al^{B}. \qquad [1]$$

In case $B \neq 3$ this is the allometric growth equation; in case $B = 3$ it describes the isometric growth. The method of calculation of the dimensionless parameters A and B is the logarithm of the equation [1]:

$$\lg W = \lg A + B \lg l \qquad [2]$$

members of which ($\lg A$ и B) is found by the least squares method. In most cases input data are the individual average weights according to the classes of length frequency.

In practice the equation parameters, [1] that are usually calculated concerning the calendar year or period of years, are used. Project partner' estimations for parameters of the certain fish are presented in the Table 12.

Table 12 – "Weight-length" dependence parameters (A, B) of some commercial fish in Black Sea

Species, area*, years period, length	A	B
Sprat BGBS (1998), TL	0.00742	2.87
Sprat BGBS (1998), TL	0.01031	2.73
Sprat BGBS (2000), TL	0.00996	2.74
Sprat UkrBS (1976-1980), FL	0.01168	3.12
Sprat UkrBS (1990-1994), FL	0.00583	3.16
Sprat UkrBS (2005-2009), FL	0.00848	2.97
Anchovy BGBS (1998), TL	0.01887	2.52
Anchovy BGBS (1999), TL	0.02037	2.53
Anchovy BGBS (2000), TL	0.01118	2.73
Horse mackerel BGBS (2003), TL	0.18950	1.74
Horse mackerel BGBS (2004), TL	0.18956	1.74
Horse mackerel BGBS (2005), TL	0.18830	1.74
Turbot NEBS (1992-2004), SL	0.00022	2.48
Turbot, NWBS (1992-2004), SL	0.00144	1.94
Red mullet NEBS (1981-1989), SL	0.00850	3.34
Whiting BGBS (2007-2008), TL	0.00480	3.11
Whiting UkrBS (1975-1985), SL	0.00980	3.02
Golden mullet UkrBS (1991-1995), SL	0.01440	2.91
Dogfish UkrBS (1971-2001), FL	0.0000068	2.96
Dogfish UkrBS (2002-2012), FL	0.0000064	3.00

* - BGBS – Bulgarian sector of the Black Sea; UkrBS – Ukrainian sector of the Black Sea; NEBS – North-Eastern part of the Black Sea; NWBS – North-Western part of the Black Sea

For a more detailed description of weight growth of sprat in the years 1976-2009 monthly parameters depending on the "length-weight were calculated (Table 13). In

1976-1980 power coefficient B was the closest to 3 (range of monthly averages was 2.96-3.28). In 1990-1994 coefficient B lying in a wider range of from 2.80 to 3.45, and 2005-2009 most of its average monthly values were less than 3.0

Table 13 – Sprat dependence parameters “length-weight” (*A*, *B*) in the Ukrainian sector of the Black sea 1976-2008 (monthly estimates)

Month	1976-1980		1990-1994		2005-2009	
	A	*B*	*A*	*B*	*A*	*B*
I	0.0039	3.2795	0.0042	3.2419	0.0094	2.8374
II	0.0055	3.1164	0.0028	3.4383	0.0096	2.8539
III	0.0050	3.1475	0.0054	3.1318	0.0028	3.4043
IV	0.0058	3.1109	0.0110	2.8042	0.0055	3.1028
V	0.0050	3.2070	0.0029	3.4331	0.0106	2.8014
VI	0.0007	2.9587	0.0030	3.4487	0.0050	3.2072
VII	0.0840	2.9807	0.0042	3.2706	0.0081	2.9092
VIII	0.0072	3.0275	0.0095	2.9006	0.0072	2.9984
IX	0.0076	3.0248	0.0063	3.0749	0.0113	2.7529
X	0.0047	3.2266	0.0044	3.2188	0.0044	3.2345
XI	0.0058	3.1274	0.0050	3.1773	0.0079	2.9921
XII	0.0049	3.2101	0.0113	2.7967	0.0199	2.5355
I- XII	**0.0117**	**3.1181**	**0.0058**	**3.1614**	**0.0085**	**2.9691**

From the great number of dependences of length from age and weight from age YugNIRO uses only the Bertalanffy equation. For the dependence “length-age” and “weight-age” looks like the following:

$$L_t = L_\infty\left[1 - e^{-k(t-t_0)}\right], \quad [3]$$

$$W_t = W_\infty\left[1 - e^{-k(t-t_0)}\right]^n, \quad [4]$$

where: L_t and W_t are respectively the length and weight of fish at age t years;
L_∞ - termed “L infinity”' in fisheries science is the asymptotic length at which growth is zero;
W_∞- “W infinity”, asymptotic weight, corresponding to the asymptotic length
k - growth rate;
t_0 - age at which the organisms would have had zero size
n - power coefficient

Different growth curves will be created for each different et of parameters, therefore it is possible to use the same basic model to describe the growth of different species simply by using a special set of parameters for each species.

The parameters can to some extent be interpreted biologically. L_∞ is interpreted as *"the mean length of very old (strictly: infinitely old) fish"*, it is also called the *"asymptotic length"*. K is a *"curvature parameter"* which determines how fast the fish approaches its L_∞**.** Some species, most of them short-lived, almost reach their L_∞ in a year or two and have a high value of K. Other species have a flat growth curve with a low **k** - value and need many years to reach anything like their L_∞, This is illustrated in Fig. 3 (for different species) and Fig. 4 (for sprat in Bulgarian waters of the Black Sea).

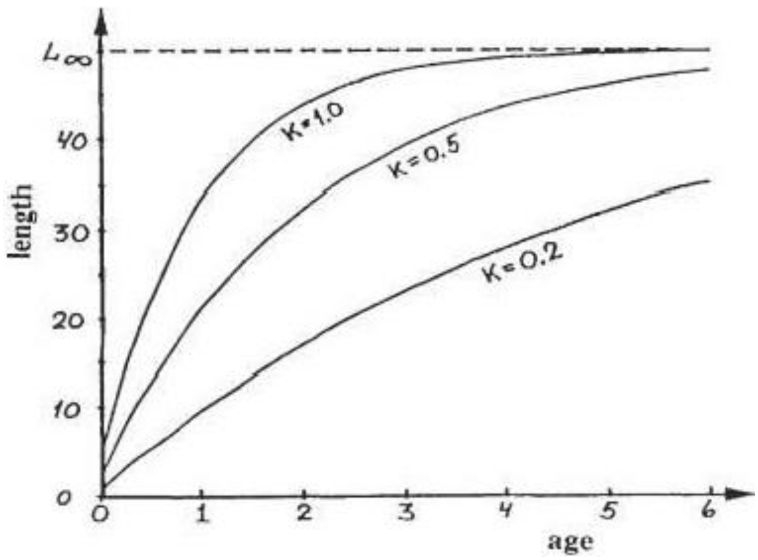


Fig 3 – A family of growth curves with different curvature parameters, different K values

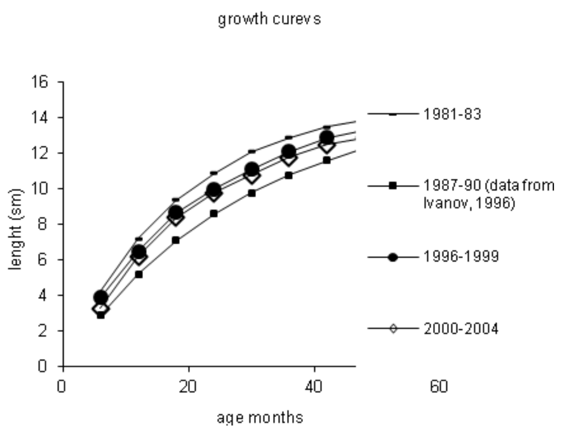


Fig 4 – Growth curves for the average cohorts of sprat for the periods: 1981- 83 (data from L. Ivanov, 1996), 1987-1990 (data from L. Ivanov, 1996), 1996-1999 (Daskalov)

There are various methods for estimating the parameters of the equation Bertalanffy. Growth parameters can be derived from pairs of observations of age and length data by graphical methods or plots, which are always based on a conversion to a linear equation. These plots are named after the authors of the papers wherein they were first described, *viz.* Gulland and Holt (1959), Chapman (1961), Ford-Walford (1933 and 1946 respectively) and von Bertalanffy (1934). The other method that will be discussed is the *"least squares method".*

In YugNIRO Bertalanffy equation parameters estimation is made according to the Hohendorf methodic (Hohendorf, 1966) through building of the linear regression L_{t+1} by L_t. Average length data points of age groups act as input data. When calculating Bertalanffy equation parameters for the “weight-age” dependence L_t is replaced by $\sqrt[3]{W_t}$, and L_∞ by $\sqrt[3]{W_\infty}$. Algorithm of Bertalanffy equation parameters calculation was implemented in ECM programs and in Microsoft EXCEL electronic tables.

The results of Partners Project estimations for the most significant species of MLR are presented in table 14. The growth parameter K is related to the metabolic rate of the fish. Pelagic species are often more active than demersal species and have a higher K.

Different growth curves will be created for each different set of parameters, therefore it is possible to use the same basic model to describe the growth of different species simply by using a special set of parameters for each species.

The Bertalanffy equations have been criticized due to the fact that t_0 is very often negative and differ significantly from 0. Nevertheless these growth equations explain very precisely the growth rate at ages more than one year.

Other growth equations are more appropriate for defining the larval growth during the first month after hatching. These are the Gompertz (1825) and Laird-Gompertz growth equations (Laird et al., 1965), that are commonly employed in larval growth analysis and suitably describe the growth during the first month after hatching using daily increments on otoliths. The form of the Gompertz equation is:

$$l_t = ae^{-be^{-ct}}, \qquad [5]$$

where l_t is length of larvae in time t;
a is the asymptote; while b and c are constants
The form of Laird-Gompertz equation is:

$$l_t = L_0 . e^{[(A_0/a.(1-e.exp(\alpha t)]} \qquad [6]$$

$$l_t = L_0 . e^{[(A_0/a.(1-e.exp(\alpha t)]} \qquad [7]$$

where l_t is length of larvae in time t; L_0 is length when $t=t_0$;
a is instantaneous growth rate when t = t_0; t = age (number of daily increments);

A_o and $\alpha = c$ – constants

Table 14 – Bertalanffy's equation parameters for the most significant species of MRL in the Black Sea

MLR, years period, length	Equation parameters		
	L_∞, cm	K	**t_0**
Bulgaria			
Sprat: data1998 (TL) data 1999 (TL) data 2000 (TL)	**14.8** **16.6** **15.9**	**0.201** **0.146** **0.159**	
Anchovy: data1998 (TL) data1999 (TL) data 2000 (TL)	**14.7** **15.6** **17.6**	**0.411** **0.302** **0.186**	
Horse mackerel: data 1992 (TL)	**19.3**	**0.348**	
Horse mackerel: data 2003-2005 (TL)	**19.9**	**0.291**	
Turbot: data 2006-2007 (TL)	**79.3**	**0.173**	**-1.56**
Whiting data 2004-2008 (TL)	**29.8**	**0.157**	**-2.49**
Turkey			
Sprat: data 2011 (TL)	**9.58**	**0.521**	**-1.38**
Anchovy: data 1996-1997 (TL)	**16.82**	**0.319**	**-2.23**
Anchovy: data 1996-1997 (TL)	**15.40**	**0.414**	**-2.64**
Whiting: (TL)	**39.51**	**0.115**	**-2.21**
Red mullet: (TL)	**24.22**	**0.218**	**-1.71**
Ukraine			
Sprat: data 2008 (FL) data 2005-2009 (FL) data 2010 (FL)	**11.7** **12.4** **12.1**	**0.286** **0.286** **0.272**	**-1.59** **-1.50** **-1.66**
Anchovy: (*E. e. ponticus*) data 1989 (FL)	**13.9**	**0.985**	**-0.74**
Horse mackerel: data 2008 (FL)	**18.5**	**0.343**	**-0.66**
Whiting: data1985-1986 (SL)	**39.0**	**0.127**	**-1.32**
Turbot: data 2008-2009 (SL)	**74.0**	**0.136**	**-1.73**
Red mullet: data1989 (SL)	**18.0**	**0.316**	**-1.88**
Golden mullet: data1991-1995 (SL)	**70.2**	**0.080**	**-1.02**
So-iuy Mullet: data 1997 (SL)	**71.0**	**0.267**	**-0.99**
Dogfish,females: data 1971-2001 (FL)	**303.0**	**0.026**	**-3.32**
Dogfish,males:data 1971-2001 (FL)	**272.0**	**0.029**	**-3.84**
Dogfish(both genders): data 1971-2001 (FL)	**282.0**	**0.028**	**-3.66**
Rapa whelk: data 1992 (Kerch Strait) (TL)	**9.6**	**0.687**	**-0.01**

Mikhailov and Prodanov (1983) showed that the values of parameters in Gompertz and Laird-Gompertz equations for the Black Sea anchovy larvae are as follows:

Gompertz equation	$a=38.2040$	$b=2.4413$	$c=0.0802$	$r=0.992$	$P>0.001$
Laird_Gompertz equation	$L_0=3.3255$	$A_0=0.1957$	$\alpha=0.0802$	$r=0.997$	$P>0.001$

6.2. Mortality rates evaluation methods

In the population dynamics theory it is widely accepted that mortality (total mortality) consists of two components – fishing mortality and natural mortality (i.e., mortality from any reasons, not related to fishery: predators, including cannibalism, disease, reproductive stress, lack of food, age, and so on). Prey and mortality due to lack of food and several are related to ecosystem environment. Same species can have various mortality rates in different areas depending on the density of predators and competitors whose density is influenced by fishing.

Two coefficient types are used in practice: instantaneous mortality coefficients (or rates) – Z, M and F, which characterize relational mortality rate, and coefficients of diminution, which represent a number of individuals that died during the year from the number of alive individuals at the beginning of the year (φ, φ_M and φ_F). Coefficients of diminution are used much less frequently than instantaneous coefficients.

As it was shown $Z = M+F$. The total number of deaths can be split into a number dying due to fishing, the catch (C) and the number dying due to natural causes (D). The number dying due to fishing, the catch, during the time period t_1 to t_2 is:

$$C(t_1, t_2) = \frac{F}{Z}[N(t_1) - N(t_2)] \qquad [8]$$

The equation is called the "catch equation" (also called Baranov's equation), under the assumption of constant F and M between ages t_1 and t_2 (Baranov, 1918). The fraction of deaths caused by fishing, F/Z, is called "the exploitation rate", E or $E = \frac{F}{Z}$
This equation can be rearranged in a way that the catch is related to the number present at the beginning of time span, $N(t_1)$.

Natural mortality and fishing mortality rates are included in all the analytical methods and models, used for fish stock assessment. But natural mortality values in the models are almost always defined (by special preliminary assessments), and fishing mortality rates are usually calculated from the analysis of the fishery-biological data.

A number of natural mortality assessment methods reduced to total mortality calculation. In such cases, when total mortality assessments were performed on the basis of materials, collected during the period of low stock exploitation ($F \rightarrow 0$, stock is closed to “virgin”), they were regarded as natural mortality assessments ($Z = M$). The total mortality coefficient Z can be estimated using different methods:

1. Heinke method (Heinke, 1913; Ricker, 1975)

$$Z = -\ln \sum_{t=1}^{\infty} N(t) / \sum_{t=0}^{\infty} N(t) \qquad [9]$$

Eq. 8 is Heinke's formula. If CPUE is proportional to the stock number, N can be replaced by CPUE. Therefore Eq. 9 can be used in the form:

$$Z = -ln \frac{CPUE(1) + CPUE(2) + CPUE(3)}{CPUE(0) + CPUE(1) + CPUE(2) + CPUE(3)} \qquad [10]$$

where the CPUE of the oldest groups is combined together.
We can use Bulgarian data for the anchovy catches (Table 15) to demonstrate Heinke's method.

Table 15 – Anchovy catches by age (x10^6 ind.), fishing effort f (in hp of the fishing vessels) in Bulgarian sector of the Black Sea and the total mortality rate (Z) estimated by Heinke's method

Years	Age				f	Z
	1	2	3	4		
1982	15095.0	4180.3	1124.9	298.3	131809	1.307
1983	17028.2	5146.8	1523.1	298.3	159355	1.237
1984	23267.7	4660.1	1088.2	245.5	187494	1.586
1985	15513.4	3296.2	682.4	135.0	213960	1.563
1986	19432.8	3506.7	549.4	82.9	228039	1.740
1987	18299.3	3938.3	519.6	93.8	257191	1.613
1988	24866.4	4004.7	484.0	50.3	280039	1.868
1989	8485.7	1071.8	125.5	14.4	180443	2.080
1990	2655.7	775.8	189.7	55.4	90700	1.282
Mean						**1.586**

2. Robson and Chapman's method (1961)

They estimated Z using population age structure data i.e. the number caught per age group:

$$Z = -\ln \frac{A}{B + A - 1}. \qquad [11]$$

where A = N(1) + 2N(2) + 3N(3) +......; B = N(0) + N(1) + N(2) +N(3) +......

Using data from Table 15 there are possibility to obtain the values of the total mortality coefficient (Table 16).

Table 16 – Anchovy total mortality rate (Z) estimated by Robson and Chapman's method

Years	Z
1982	1.342
1983	1.292
1984	1.582
1985	1.584
1986	1.767
1987	1.676
1988	1.908
1989	2.092
1990	1.330
Mean	**1.619**

3. Sparre and Venema's method (Sparre and Venema, 1992)

This method is based on the catch per unit of effort data (CPUE). This is possible when the number of fish in the cohort are available for two different periods during its exploitation phase. t_1 and t_2.

$$Z = \frac{1}{t_2 - t_1} \ln \frac{CPUE(t_1)}{CPUE(t_2)} \qquad [12]$$

CPUE is also estimated as mean value for a longer time period. This happens when data are collected from the commercial fishery.

4. Chapman-Robson method (1960, 1961)

$$Z = \ln (1 + t_{av} - 1/n) - \ln t_{av}. \qquad [13]$$

where: t_{av} – conditional average age in the yields. i.e. $t = 0$ is assigned to the youngest age group, completely represented in the sample;

n – number of fish in the age sample.

Performing age sampling by the same fishing gear, preferably with low selectivity (usually trawls with 6.5 mm mesh size were used) was a mandatory condition.

5. Beverton-Holt method (1956) based on catch mean lengths data

$$Z = (L_\infty - l_{av}) \cdot K / (l_{av} - l'). \qquad [14]$$

where: l' – length of the individual in the least size group;

l_{av} – average length of the caught individuals;

L_∞, K – parameters of the Bertalanffy equation.

When using this method for whiting in former USSR waters, definition of l_{av} was made for the integrated variational series of the length related to the "virgin" period ($Z = M$). Sampling by the same fishing gear, preferably with low selectivity (usually trawls with 6.5 mm mesh size were used). was a mandatory condition.

6. Beverton and Holt's method (1956) based on age data

$$Z = \frac{1}{\bar{t} - t'} \quad [15]$$

where: $\bar{t}$ is the mean age of all fish of age t' and older;

t' (t_c) - age for which all fish of that age and older are under full exploitation / i.e. they enter the exploitation phase.

7. Gulland method (1969)

$$Z = \ln C_{i.j} - \ln C_{i+1.\ j+1}. \quad [16]$$

where: C – average catches per effort for year classes in the yields (measured in pieces);

i, j – indices of the year and year class (age of individuals).

YugNIRO used the data of trawling surveys as C, on condition that the surveys were performed during the adjacent years (Shlyakhov, 1986; 2010). This method is applicable only for those ages, which are completely represented in the catches.

8. Baranov method (Baranov, 1971; Efimov, 1980)

$$Z = (\ln n_1 - \ln n_2) / (l_2 - l_1). \quad [17]$$

where: n_1 and n_2 – individuals number in the examined age groups of the representative sample from catches;

l_1 and l_2 – corresponding individuals average lengths.

The main assumption of the method is as follows: there is a linear dependence between fish length and their age. YugNIRO used this method only in one case – for natural mortality assessment of whiting for the period between its pelagic stage and recruitment (Shlyakhov, 1983) because the other methods appeared to be not usable.

The above methods are the most commonly used Project partners and not only used to estimate the total mortality of fish, but also to determine the natural mortality (in such cases. when no fishing mortality was admitted and $M = Z$). Below we consider methods to directly assess the rate of natural mortality M.

9. Alverson-Carney method (1975)

$$M = 3K / [\exp (K \cdot T_{max}) - 1]. \qquad [18]$$

where: T_{max} – theoretical age, at which the year-class biomass reaches its maximum; if we designate the eldest age group in the catches as T_M (this age must be not less than 0.5% of the sample value), then for the virgin stock $T_{max} = 0.38 \cdot T_M$, but for the exploited stock $T_{max} = 0.25 \cdot T_M$;

K – growth coefficient in Bertalanffy equation.

10. Rikhter-Efanov method (Rikhter and Efanov, 1976; Babayan et al, 1984)

$$M = (1.521 / t_{mat}^{0.72}) - 1. \qquad [19]$$

where: t_{mat} – age of the first maturity for 70% of fish.

This method is empirical. and is applicable only for fish, it used for different species of the Black Sea fish.

11. Pauly method (1980)

$$\lg M = -0.0066 - 0.279 \lg L_\infty + 0.6543 \lg k + 0.4634 \lg T^\circ. \qquad [20]$$

where: L_∞, K – parameters of Bertalanffy equation;

T° - average annual water temperature in the fish habitat.

This method is also empirical, and applicable only for fish. it used for different species of the Black Sea fish.

12. Caddy method (1984)

$$M_A = b / [(K_B/K_A) - a] \quad \text{and} \qquad [21]$$
$$M_B = M_A (K_B/K_A). \qquad [22]$$

where: M_A, M_B - natural mortality for two stock components – A and B;

K_A, K_B – growth coefficients in the Bertalanffy equation;

a, b - coefficients of functional linear regression equation ($Z_B = a + b\ Z_A$).

This method used for natural mortality assessment of turbot. based on the data of YugNIRO trawling surveys in 1979-1985 (Efimov et al, 1989). The turbot males and females were chosen as components A and B. For each of them growth parameters (for the whole period of 1979-1984) and total mortality rates (for separate years of the same period from [16]) were determined. From the set of 6 pairs of total mortality value of a and b parameters were defined by least-squares method. Substitution of the found values in [21] and [22] allowed to calculate natural mortality rates of the turbot males $M_♂ = 0.135$ and females $M_♀ = 0.102$.

13. Gulin-Rudenko method (1973)

$$M(t) = \lambda_1 t^{\alpha_1 - 1} + \lambda_2 t^{\alpha_2 - 1}. \qquad [23]$$

where: λ_1, α_1 and λ_2, α_2 – parameters, found by the least-squares method using abundance of the most reliable age groups;

t – age group.

This formula describes the curve of fish population natural mortality, which has the minimum (point of inflection) at the age of sexual maturity incoming, the left descending part (it is described by the first summand) and the right ascending part. This method gives the best results for the fish with the long life history (life cycle), and was used by YugNIRO for natural mortality assessment of the piked dogfish (Kirnosova, 1990).

14. Bulgakova-Efimov method (1982)

$$M(t) = A_1 t^2 - (2A_1 t_M)\cdot t + x_1. \qquad [24]$$

where: A_1 and x_1 – parameters, found by the least-squares method using abundance of the age groups;

t - age group;

t_M - age group, when sexual maturity comes.

According to this formula, the curve of fish population natural mortality is a quadratic parabola with vertical axis, goes through the point $t = t_M$. This method can be applied to the fish with any life cycle and was used by YugNIRO for natural mortality assessment of the sprat (Efimov et al, 1985).

M estimations, defined by the methods mentioned above, are very close to each other for some species and have scattered results for the other species. Because there is no criterion for choosing a specific method (Babayan et al. 1984), YugNIRO researchers use averaged estimations of M, defined by different methods (table 17). According to Bulgarian investigation, the average value of natural mortality (M) of sprat was evaluated at 0.90 for the whole period, showing a slight decrease in comparison with the period 1976-1992 (table 18, data of Daskalov et al, 1996).

As it was specified at the beginning of this subsection, fishing mortality rates are usually calculated from the analysis of the fishery-biological data. It will be shown how it is performed in section 5. Here we will mention an assessment method of average annual fishing mortality coefficient F_{av} with known values of the initial stock (N_{in}. B_{in}).

Table 17 - Natural mortality M estimations (accepted in YugNIRO) and age at first capture t_c for the most important marine living resources species of the Black Sea Ukrainian sector

Species	M	t_c (years)	
		by Kutty-Qasim	by partial recruitment
Sprat	0.64	1.4	1.5
Anchovy	0.82	0.8	-
Horse mackerel	0.40	3.0	1.3
Whiting	0.73	2.0	-
Turbot	0.11	9.7	4.4
Red mullet	0.80	0.6	0.4
Golden grey mullet	0.43	4.6	4.0
So-iuy mullet	0.68	1.9	3.8
Piked dogfish	0.11	7.9	8.0
Rapana venosa	0.65	2.1	-

Table 18 - Long term data about total mortality of sprat of the Black Sea Bulgarian sector and its components-natural and fishing mortality for the period 1996-2004

	M-natural morality	F-fishing mortality	Z-total moratlity
1996	0.93	0.19	1.12
1997	0.97	0.14	1.11
1998	0.71	0.40	1.11
1999	0.91	0.18	1.09
2000	0.82	0.21	1.03
2001	0.95	0.16	1.11
2002	0.85	0.25	1.10
2003	0.90	0.24	1.14
2004	0.96	0.15	1.11

annual yields (C, Y), natural mortality (M), fishing mortality coefficient (F). It can be calculated by the method of iterations from expression (Shlyakhov et al, 1990. Shlyakhov, 2010):

$$\{F_{av} [1 - \exp -(M + F_{av})] / (F_{av} + M)\} - C / N_{in} = 0 \quad \text{and} \qquad [25]$$

$$\{F_{av} [1 - \exp -(M + F_{av})] / (F_{av} + M)\} - Y / B_{in} = 0. \qquad [26]$$

where: N_{in} and C – initial stock at the beginning of the year and catch during the same year in a piece units;

B_{in} – initial stock at the beginning of the year in weight units;

Y – catch during the same year in a weight units.

The average annual fishery mortality coefficient F_{av} is defined from formulas [25] and [26] by iterative method. Expression [25] is true only if average mass of an individual is identical both in the stock and in the catch. In this case the relation of the annual catch to the initial stock will be also the value of exploitation coefficient u in Ricker's terminology (Ricker, 1975) and the value of fishery diminution coefficient φ_F:

$$C / N_{in} = Y / B_{in} = F_{av} [1 - \exp -(M + F_{av})] / (F_{av} + M) = u = \varphi_F . \qquad [27]$$

YugNIRO used expression [26] for assessment and analysis of the fishery mortality rate of the Black Sea anchovy and turbot (Shlyakhov et al, 1990; Shlyakhov, 2010).

7. ASSESSMENT OF AGE AT FIRST CAPTURE

Age at first capture t_c is one of the important parameters in the analytical models. It is usually considered that age at first capture corresponds to the age group. which is fished off only by 50%. Its significance is determined by essential influence on the calculations of the possible catch curve and by the fact that it establishes the boundary of a fishery stock. In the real situation the transition of fish into fishery stage wholly depends on the fishing gears selectivity. The moment of first capture is determined by the point on the selectivity ogive, which corresponds to fifty percent length of selectivity $L_{50\%}$ that can be obtained by experimental estimation of fishing gears selectivity. When $L_{50\%}$ is known, it is easy to find t_c from the Bertalanffy equation:

$$t_c = t_0 - 1/K \cdot \ln (1 - L_{50\%} / L_\infty). \quad [28]$$

where: L_∞, K, t_0 – parameters of the Bertalanffy equation;

Because Project partners (except NIMRD) has not carried out specific research on fishing gears selectivity in the Black Sea for the last 30 years, we used two following methods for t_c estimation.

1. Using modified Kutty-Qasim equation (1965)

$$t_c = \{1/K \cdot [\ln (3K + M) - \ln M]\} + t_0. \quad [29]$$

where: K, t_0 – parameters of the Bertalanffy equation;
M– natural mortality.

In this case t_0 corresponds to the "optimal exploitation" age. An example of the approximation depends on the t_c value and natural mortality M for horse mackerel is shown in Fig. 5.

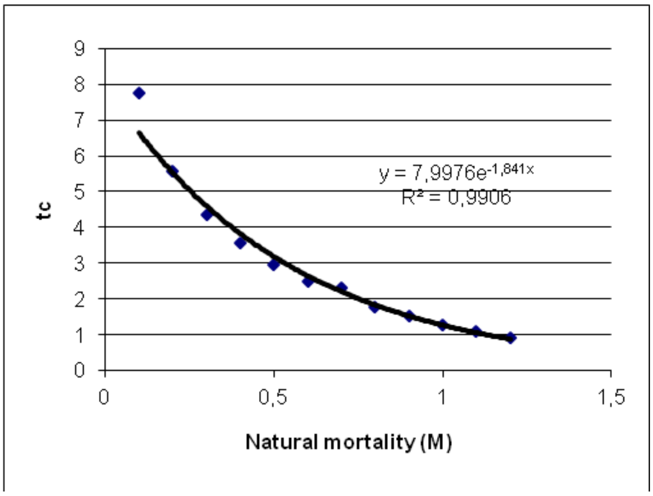


Fig 5 – Optimal exploitation age vs. instantaneous rate of natural mortality estimated by Kutty and Quasim (1965) method for Horse mackerel (2003-2005) in Bulgarian Black Sea territorial waters

2. Using estimation of partial stock recruitment from the VPA data.

VPA method (its modifications are structured by age) gives an opportunity to calculate age-related changes of fishery mortality rate F_i. The maximum value of fishery mortality F_{max} corresponds to the age group, which completely entered into fishery. It is taken as 1 (or 100%). All values of the fishery mortality, following after F_{max} and corresponding to elder age-groups. are also taken as 1. Then the fraction of younger age-groups F in relation to F_{max} is calculated (i.e., F / F_{max}). On the basis of the obtained results the graph is built: abscissa axis corresponds to the age and ordinate axis – to the relation F / F_{max}. The resulting curve represents a curve of fishery stock recruitment. The point on the abscissa axis, which corresponds to 50% recruitment, is equal to t_c age.

If the VPA modifications structured by length are used (i.e., LCA), then the abscissa axis corresponds not to the age but to the length while building the stock curve. That's why the length at first capture L_c is defined from the graph, and afterwards t_c is estimated from the Bertalanffy equation:

$$t_c = t_0 - [\ln (1 - L_c / L_\infty)]/K. \qquad [30]$$

It is obvious from table 14 that t_c estimations, derived from Kutty-Qasim equation and from partial recruitment are close for the sprat, red mullet and picked dogfish but significantly disperse for the turbot. so-iuy mullet and horse mackerel. In such cases we preferred partial recruitment estimations. because they are based on the data about the yield structure of the recent fishery years.

8. ANALYTICAL MODELS OF BEVERTON-HOLT

Mathematical models of the fish populations are successfully used for the estimation of stock and fishery status. If a model examines the population on the whole – when natural increase of stock (productivity) is determined by its size, this model belongs to production' models class. In such models internal relations in the population are ignored.

In contrast to examining the population on the whole, analytical models take internal relations in the population into consideration. In such models the processes of recruitment. growth and mortality are divided.

The founder of the analytical models creation is F.I. Baranov, who defined dependence of change of the fish generations abundance from the age. Using Baranov's model and equation of Bertalanffy, Beverton and Holt (1957) created mathematical model for the estimation of possible catch depending on fishing intensity. The model describes equilibrium state of stock. when natural mortality and catch are compensated by recruitment and growth. One of the main assumptions of the model is a constancy of recruitment and natural mortality rate. The most frequently used equation of the model looks like:

$$Y/R = F \cdot W_\infty \cdot \exp(-M_r) \cdot \sum_{n=0}^{3} \{(-1)^n \cdot \Omega_n \cdot \exp[-nK(t_c - t_0)] / (F + M + nK)\} \cdot [1 - \exp[-(F + M + nK) \cdot \lambda]. \quad [31]$$

In the 1970s and 1980s this equation and its modifications were used in YugNIRO for estimation of the sprat possible catch and also for estimation of the specific maximum sustainable catch coefficients F_{max} and sparing the level of fishing mortality $F_{0.1}$ of sprat, anchovy, turbot, picked dogfish and other fishery objects of the Black Sea (more details on this - see section 11). Calculations were performed both "manually" (using special tables and calculators) and "electronically" (using computer).

As an example of the practical use of Beverton-Hold model we demonstrate here diagram of catches on recruitment and SSB of the Black Sea turbot (fig. 6-7), curve of the sprat possible catch from fishery mortality coefficient (fig. 8) and anchovy (fig. 9).

For creating Y-curves characterizing absolute values of the possible catch on fig. 9, both classical model of Beverton-Holt and its modification were used. The average value of recruitment was taken from data of YugNIRO trawling surveys on the counting of sprat juveniles in 1974-1981 ($R = 48 \cdot 10^9$ pieces).

Modification of the model was performed on the basis of formalization of natural mortality rate dependence on age (see method 14 in section 6.2). Calculated curves demonstrate evidently. how assumption that $M = const$ influences their form.

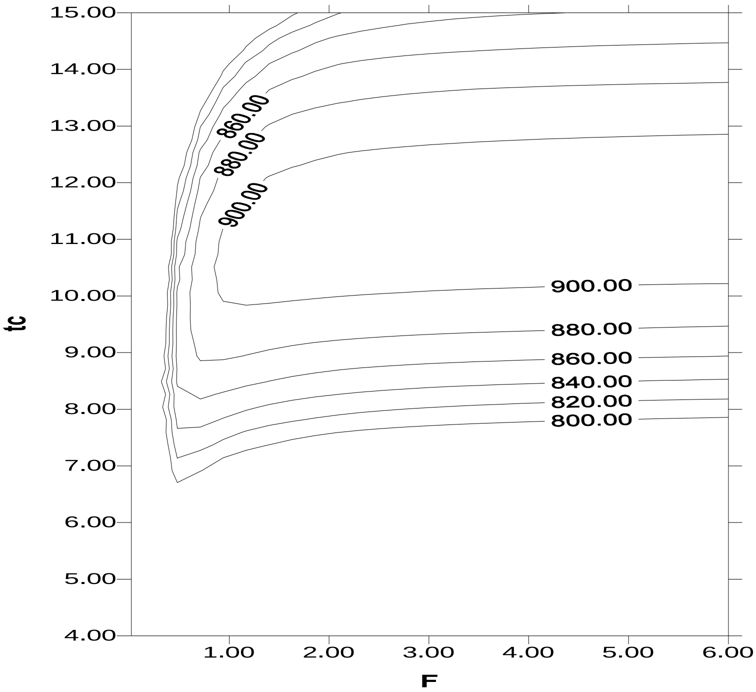


Fig 6 – Isopleth diagram of catches on recruitment (Y/R, g)
of the Black Sea turbot (from Kokoz et al, 1996)

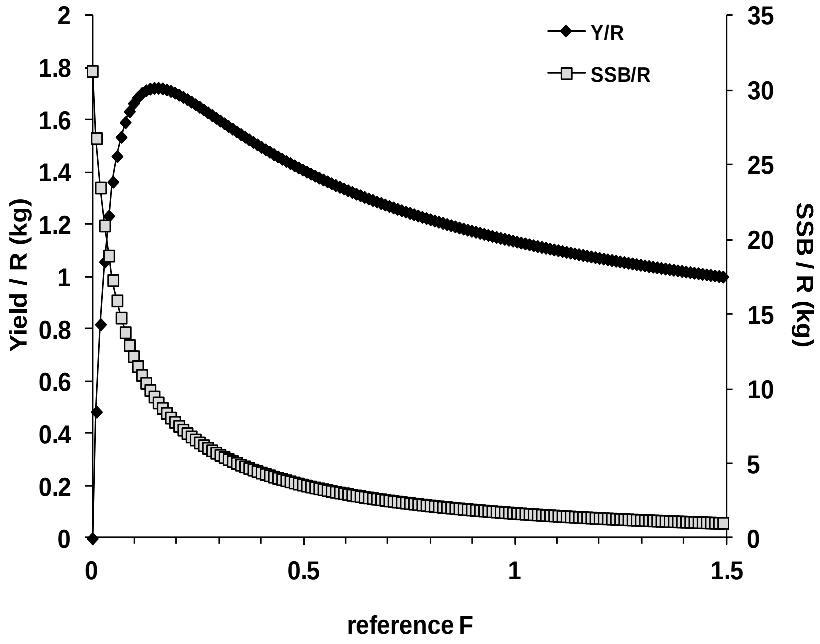


Fig 7 – Turbot in the Black Sea. Y/R and SSB/R v F (STECF EWG Black Sea 12 16 from Daskalov et al, 2012)

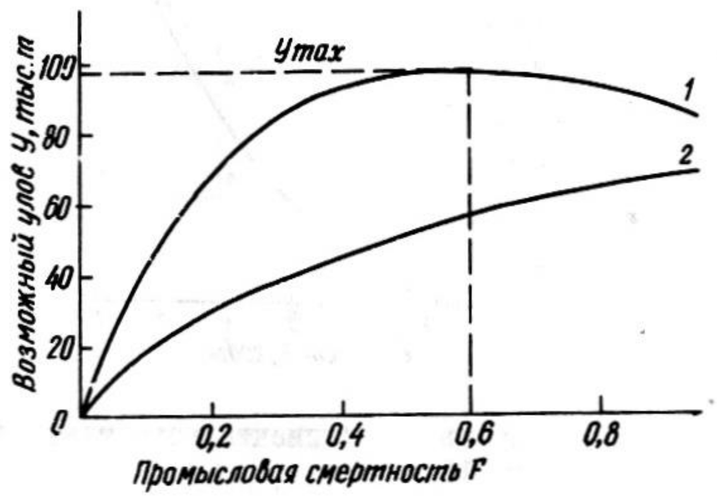
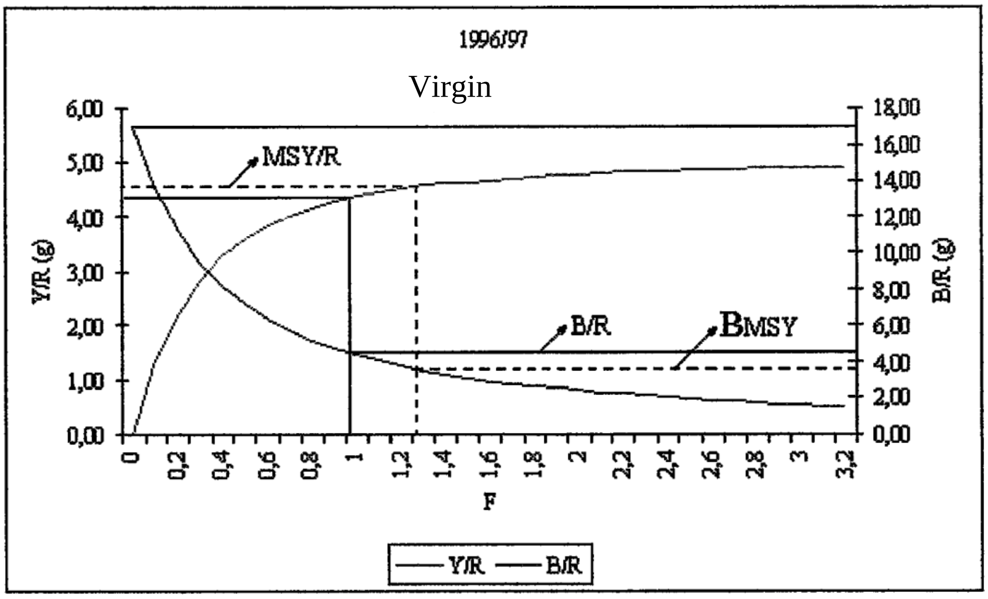


Fig 8 – Dependence of the sprat possible catch Y on F:
1 – modified model of possible catch; 2 – Beverton-Holt model (from Efimov et al, 1985)



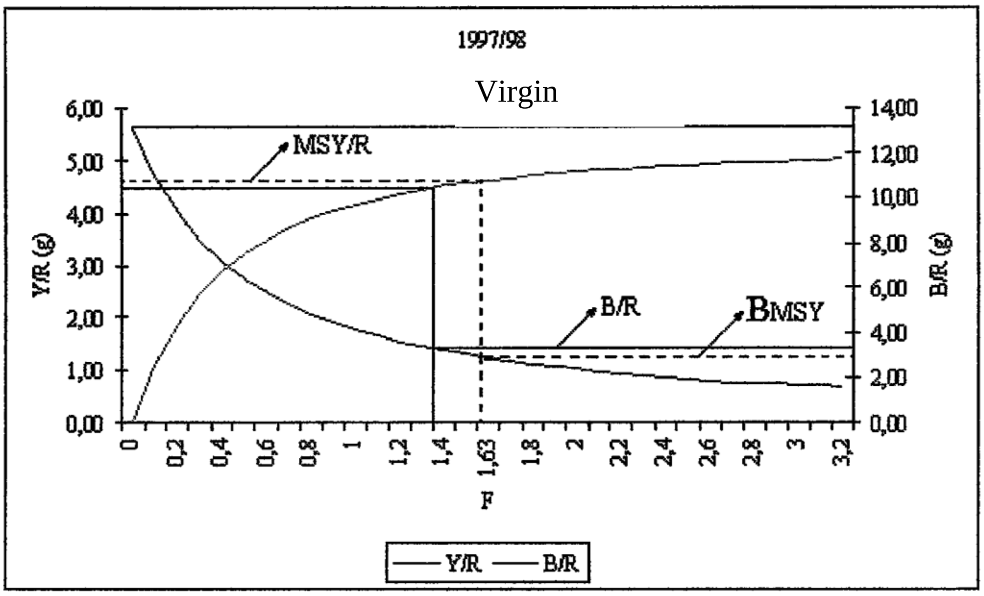


Fig 9 – Beverton Holt's yield for per recruitment (Y/R) and biomass (B/R) of the anchovy in 1996/97 and 1997/98 in the South-eastern Black Sea (Turkey)

9. BIOSTATISTICAL METHODS OF STOCK ASSESSMENT

Assessment methods of the commercial stocks size, based on the consequent recruitment of certain generation number due to the analysis results of the age or length composition of catches, are referred to as bio-statistical methods. They are nominally referred to as analytical methods as well, and after creating of the formal theory of the fish life by Baranov (1918), they are based on the core equations:

$$N_{i+1} = N_i \cdot \exp -(M + F) \text{ and} \qquad [32]$$

$$C_i = [N_i \cdot F_i / (F_i + M)] \cdot [1 - \exp -(M + F)], \qquad [33]$$

where: i is an index of the catch year.

In the second of the 1960s, after the works of Gulland (1965) and Murphy, the virtual population analysis (VPA) was formed. Now VPA is one of main stock assessment methods. There are a great number of varieties divided into two groups, which anal either age composition of the commercial catch or their size composition. While assessing stocks of the marine living resources of the Azov and Black Seas, the leading role belonged historically to the holistic methods. YugNIRO began to apply VPA only in the 1980s, although long before that the classic biostatistical method of Derzhavin was used for some fish species (Danube shad, sturgeons, turbot).

9.1. Virtual Population Analysis structured by age

VPA is mainly an analysis of fisheries catch from commercial fisheries statistics obtained combined with detailed information on the contribution of each cohort to capture, data are obtained by sampling programs and reading age.

The idea of the method is to analyze what we see - capture, in order to calculate population would have to be in the sea to produce the catch. With an estimate of M, we can calculate retroactive and how many fish of each year cohort existed and ultimately how many recruits were. At the same time determine the mortality coefficient values F.

Steps to follow in the analysis VPA by age class:

1) Establish annual quantities fished of the species analyzed;
2) Determination through sampling the frequency by age class;
3) Determine the number of specimens of each year age classes (catch in numbers C_i);
4) Making tables (matrices) for data:
- catch matrix in number of individuals;
- matrix F_i;
- Matrix N_i;
5) The calculation of Z (in several ways);
6) Calculation of natural mortality M (in several ways)

In general, this group of VPA methods is reduced to formulation and decision of the following task (Babayan et al, 1984). Known: age composition of landings (catches) per fishing years; coefficient of natural mortality (M = const is usually accepted for all age groups); coefficient of fishing mortality F of one of the age groups (usually starting value F_n, are given for the eldest age n). It is necessary to determine: coefficients of mortality F and Z for all age groups; number of age groups.

To solve this task, the reverse calculation scheme is used, that is, estimation N_i and F_i is driven from the eldest ages to the youngest and from the recent catch years to the early ones. Usually the initial matrix contains the catch values C according to the ages and catch years as well as terminal values of coefficients F for the last catch year and the eldest ages during the previous catch years.

The basic calculation scheme is the following:

1. Virtual coefficient of exploitation $\acute{E}_n$ is calculated for the eldest age group N_n.

$$\acute{E}_n = [F_n / (F_n + M)] \cdot [1 - \exp -(M + F)]. \qquad [34]$$

2. The number of the eldest age group N_n is calculated.

$$N_n = C_n / \acute{E}_n , \qquad [35]$$

where C_n is a number of the caught fish of the eldest age n.

3. The relative quantity of generation r_{n-1} is calculated in the end of the $n - 1$ year.

$$r_{n-1} = N_n / C_{n-1} \qquad [36]$$

4. The coefficient values of the fishing mortality F_{n-1} and true coefficient of exploitation E_{n-1} , which are most correlated with the estimation $r_{n-1,}$ are calculated. These estimations are taken from the tables of the function values $r = r(F)$ or calculated from the equations

$$r_i = (F_i + M) \cdot \exp -(M + F_i) / F_i \cdot [1 - \exp -(M + F)], \qquad [37]$$

$$r_i = N_{i+1} / C_i = V_{i+1} / E_{i+1} \cdot C_i,\ V_i = \sum_{j=1}^{n} Cj \qquad [38]$$

where V_i is a used (virtual) number of generation j in the beginning of the year i.

5. The virtual coefficient of exploitation of the age group $n - 1$ is calculated.

$$\acute{E}_{n-1} = E_{n-1} + \acute{E}_n \cdot \exp -(M + F_{n-1}) \qquad [39]$$

6. The used assessment of the age group $n - 1$ is calculated.

$$V_{n-1} = \sum_{1 = n-1}^{n} Ci. \qquad [40]$$

7. The initial number of the age group $n - 1$ is calculated.

$$N_{n-1} = V_{n-1} / \acute{E}_{n-1}, \qquad [41]$$

8. To estimate the number of generations N_i and mortality F_i of the remaining age groups, the cycle of operations 3-7 is consistently repeated in the direction from $(n - 2)$ to the 1st (the youngest) age group.

For the generations, which were not fully caught, rather reliable estimations of the starting values F can be received with the help of the adjustment procedure. There have been a lot of adjustment methods developed by now and we do not consider them in this report.

Pope method. Pope (1972) presented a simple method for estimating the number of survivors at the beginning of each class by age cohort life, starting from the last age class. It is enough to apply successively backward expression:

$$N_i \approx (N_{i+1} \cdot e^{Mt/2} + C_i) \cdot e^{Mt/2}$$
[42]

Pope shows that the expression is good when $Mt \leq 0.6$. Pope's expression is obtained assuming that the capture is made exactly in the center of the interval T_i. (Fig. 10).

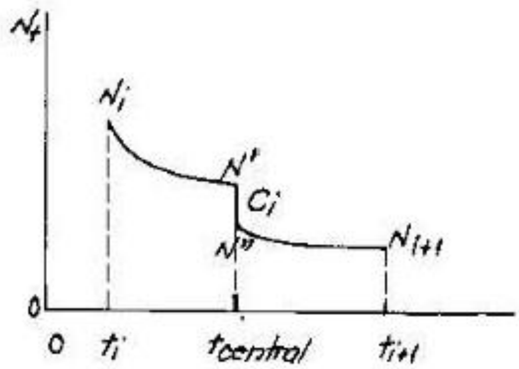


Fig 10 – Number of survivors during the interval $T_i = t_{i+1} - t_i$, capture extracted in the enter of the interval (FAO, 2003)

Proceeding from beginning to end, is calculated successively:

$N'' = N^{i+1} \cdot e^{+Mti/2}$

$N' = N'' + C_i$

$Ni = N' \cdot e^{+Mti/2}$

Replacing N' by $N''+C_i$, the expression will be:

$Ni = (N'' + C_i) \cdot e{+}M^{ti/2}$

Finally, replacing N'' by $N_{i+1} \cdot e^{+Mti/2}$ we obtain the expression [42]. Now suppose that capture matrix [C], mortality matrix [M] and the vector size intervals [T] are known for a period of years.

Suppose also that the values of F in the last age class of all years represented in the matrix and the values of F from all age classes of the last year were adopted. These values are expressed through $F_{terminal}$ (Table 19).

Table 19 – With catches matrix [C], with $F_{terminal}$ in the last row and last column of the matrix C. Shaded areas illustrate the catches of a cohort (FAO, 2003)

Years					
Ages	2000	2001	2002	2003	
1	C	C	C	C	$F_{terminal}$
2	C	C	C	C	$F_{terminal}$
3	C	C	C	C	$F_{terminal}$
	$F_{terminal}$	$F_{terminal}$	$F_{terminal}$	$F_{terminal}$	

Note that in this matrix diagonal elements correspond to values of the same cohort because an element of a certain age and a certain year will be followed in diagonal by an element which is one year older.

Through different modifications of VPA (Ivanov, 1983; Prodanov, 1984; Kolarov, 1985; Prodanov, Daskalov, 1992; Daskalov et al., 1996, Prodanov et al., 1997), including also the so called "combined method" suggested by Ivanov (1994, 1995 and 1996), were estimated the stocks of sprat, anchovy, horse mackerel, spiny dogfish, turbot, shad, mackerel, Russian sturgeon, in the Bulgarian area, western area and in the whole Black Sea. There are large differences between the estimates of those authors due to different input parameters (M, F_{st}, catch age composition) or different modifications of VPA used.

In YugNIRO scientists had the first experience of the VPA method application, structured due to the age, in the second half of the 1980s, while assessing the stock size and coefficients of the Black Sea turbot fishing mortality (fig. 10).

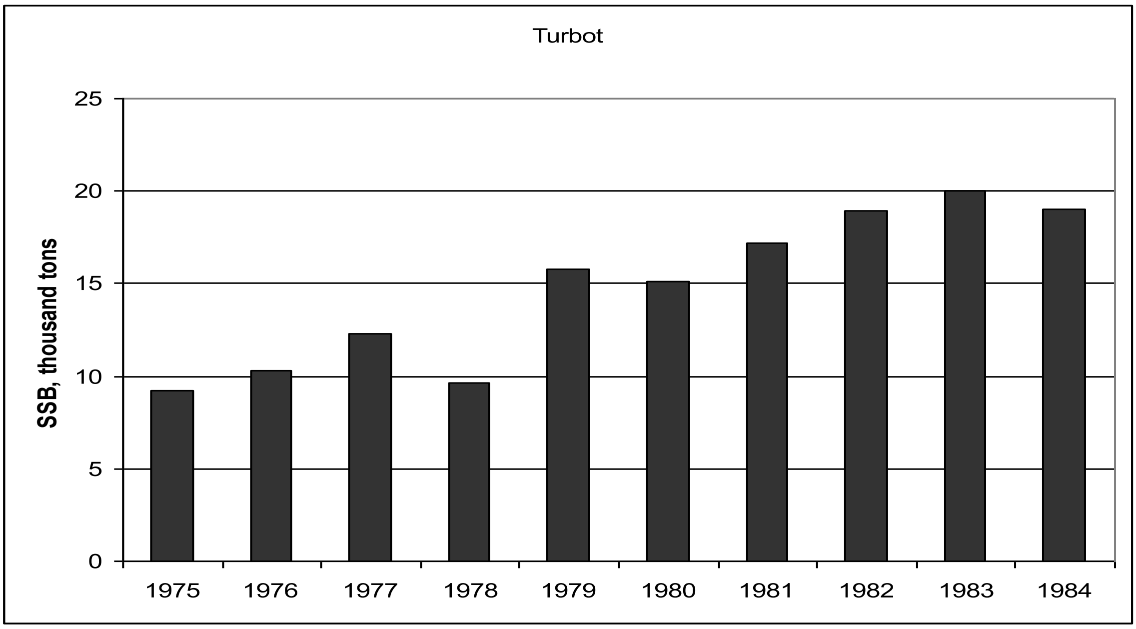


Fig. 10 – SSB s of the Black Sea turbot using the VPA method in modification of Babayan (from Efimov et al, 1989)

Afterwards this method in its various modifications was applied for the red mullet, golden grey mullet and thornback ray (figs 11-13). The calculations were made both manually (with the help of the specific tables and calculators) and electronically.

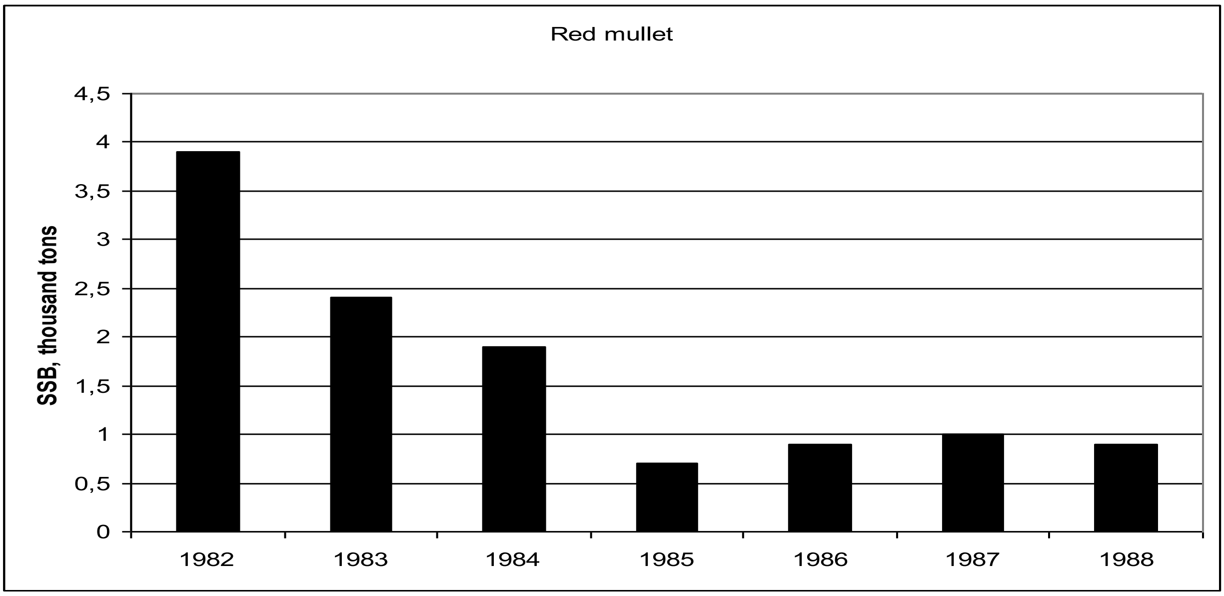


Fig. 11 – SSB s of the red mullet using the VPA method with adjustment of the catch per effort for the fixed nets, ATLANTNIRO software (from Domashenko, 1990)

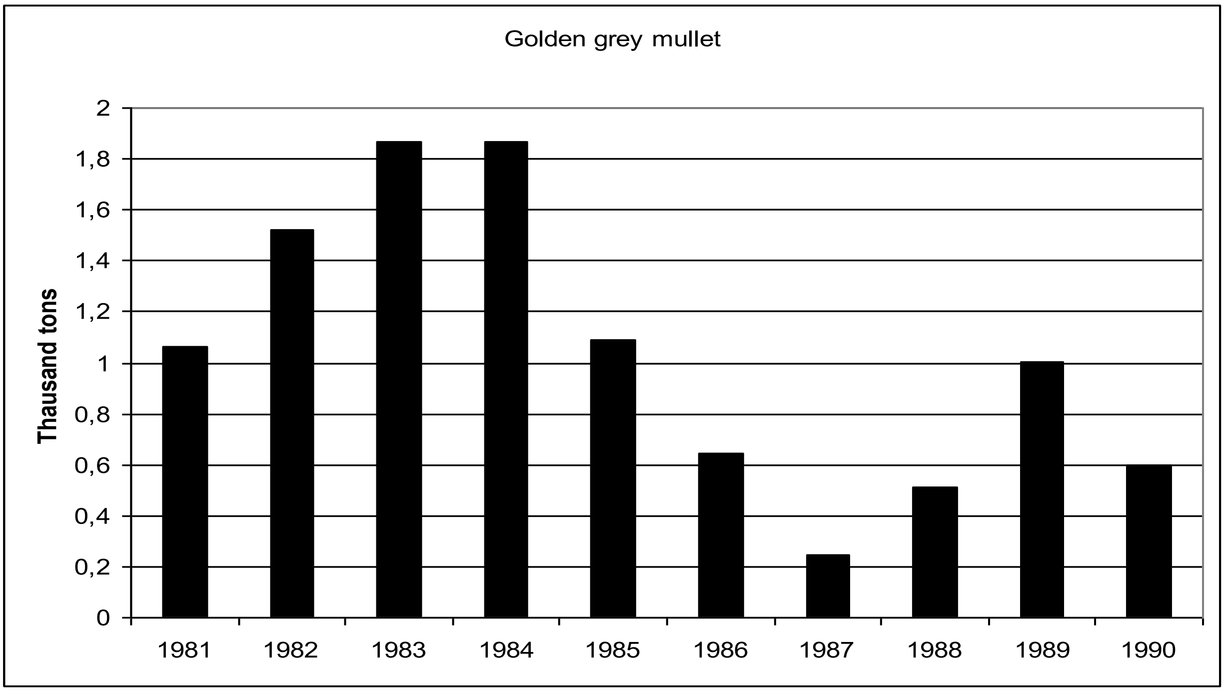


Fig. 12 – SSB s of the golden grey mullet using the Pope cohort analysis with adjustment of the catch per effort for the grey mullet hoisting traps, ATLANTNIRO software (from Serobaba et al, 1991)

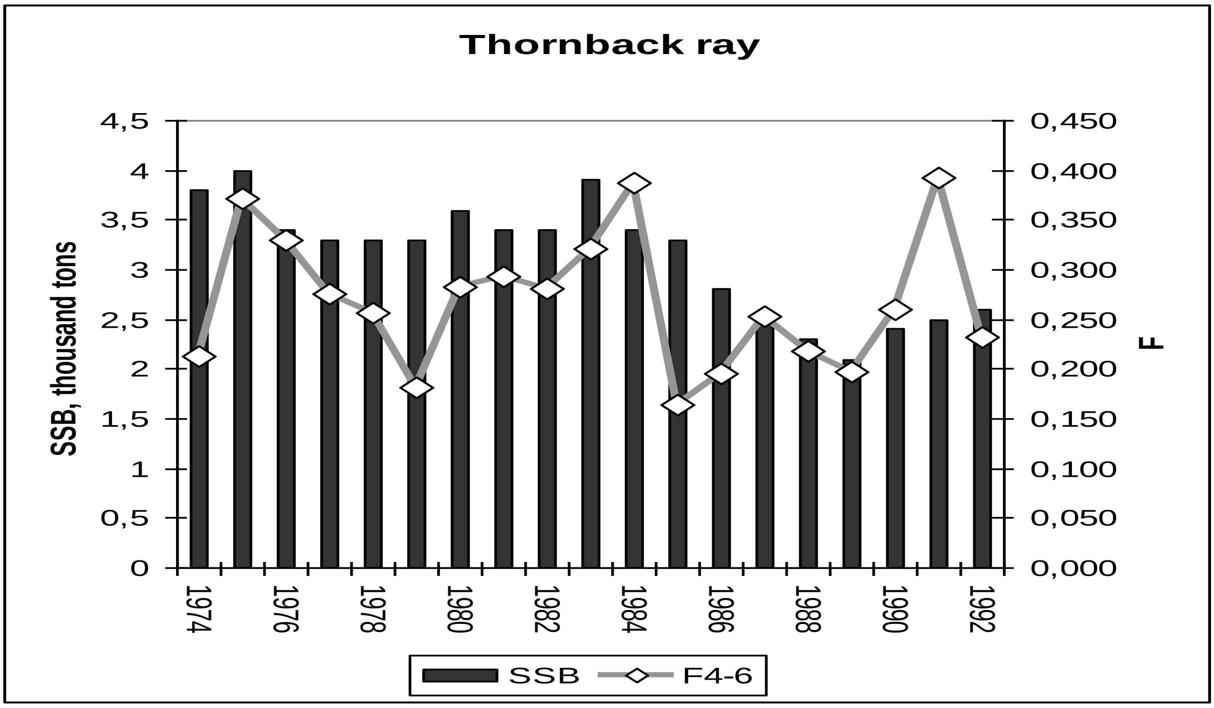


Fig. 13 – SSB due to the cohort analysis data, software of FAO and ANACO (from Shlyakhov, Lushnikova, 1996)

Below is a list of software that is used to stocks assessment of exploited populations of marine living resources (including analytical methods and models).

EARLIER COMPUTER PROGRAMS

LFSA - Length - based Fish Stock Assessment. FAO Fisheries Technical Paper. Rome, 1987

ANACO - Software for the analysis of catch data by age group. FAO Fisheries Technical Paper. Rome, 1989

ANALEN - Logiciels pour l'evaluation des stocks de poisson. FAO Document Technique Sur Les Peches. Rome, 1990

NAN-SIS - Software for fishery survey data logging and analysis. FAO. Computerized Information Series. Rome, 1992

CLIMPROD - Experimental interactive software for choosing and fitting surplus production models including environmental variables. FAO. Computerized Information Series. Rome, 1993

BEAM 4 - Analytical bio-economic simulation of space - structured multispecies and multifleet fisheries. FAO. Computerized Information Series. Rome, 1993

POPDYN - Population dynamic database. FAO. Computerized Information Series. Rome, 1994

SPATIAL - Spatial - time dynamics in marine fisheries. FAO. Computerized Information Series. Rome, 1994

BIODYN - Biomass dynamic models. FAO. Computerized Information Series. Rome, 1996

FISAT - FAO - ICLARM stock assessment tools. FAO. Computerized Information Series. Rome, 1996

VIT - Software for fishery analysis. FAO. Computerized Information Series. Rome, 1997

BAYES - SA - Bayesian stock assessment methods in fisheries. FAO. Computerized Information Series. Rome, 2001

CURRENTLY AVAILABLE MODELS (NOAA Fisheries Toolbox**)**

Estimation of Stock Size and Mortality

- A Stock Production Model Incorporating Covariates (ASPIC - 5.34.9)

- Age Structured Assessment Program Model (ASAP - 2.0.21)

- Assessment Method from Alaska (AMAK- 1.07.1)

- Collie-Sissenwine Analysis (CSA - 3.1.1)

- Dual Zone Virtual Population Analysis (VPA-2BOX - 3.05)

- Statistical Catch at Age Model (STATCAM - 1.4.1)

- Statistical Catch at Length Model (SCALE- 1.0.3)
- Stock Synthesis Version 3 (SS3 - 3.23b)

- Virtual Population Analysis (VPA - 3.1.1)

Management Scenario Projections

- Age Structured Projection Model (AGEPRO - 3.4.1)

Biological Reference Points

- Age Based Yield Per Recruit (YPR - 2.7.2)

- An Index Method (AIM- 2.4.0)

- Length Based Yield Per Recruit (YPRLEN - 1.4)

- Stock Recruitment Fitting Model (SRFIT - 7.0.1)

Model Performance Evaluation

- Population Simulator (POPSIM - 7.4)

- Management Strategy Evaluation (MSE - 3.3)

- Visual Report Designer (VisRpt - 1.6.1)

Models for Data Limited Situations
- Depletion Corrected Average Catch Model (DCAC - 2.1)

- Survival Estimation in Non-Equilibrium situations (SEINE - 1.3)

Additional Tools
- Kalman Filter (KALMAN- 2.3)

- Productivity and Susceptibility Analysis (PSA- 1.4)

- Rivard Weights Calculator (RIVARD- 2.0)

9.2. Virtual Population Analysis structured by length

In the Mediterranean Sea, the LCA method is used while assessing stocks and regulating catches of small pelagic commercial fish according to the recommendations of the Scientific Consulting Committee of the General Fisheries Mediterranean Commission under FAO (Oliver, 2002). The simplest and most widespread variety of the LCA is the method of Jones (Jones, 1981), applied by YugNIRO for stock assessment and fishing mortality of the Black Sea fish species.

Time intervals, during which the fish length is increased at the beforehand driven value ΔL, are used in the cohort analysis of Jones. Having agreed on the initial length L_0, the number dynamics of a certain generation can be considered as a sequence of size groups, including the specimens, whose lengths fall into the intervals $(L_0 + (i-1)\Delta L, L_0 + i\Delta L)$, where $i = 1, 2, ...n$ is an ordinal cohort number. Denoting the period of time by Δt, during which the specimen's length is increased at the ΔL value, the main equation of the cohort analysis is written as follows:

$$N_t = N_{t+\Delta t} \cdot \exp(\Delta t \cdot M) + C_t \cdot \exp(\Delta t \cdot M/2), \qquad [43]$$

where N_t is an initial number of a certain length group;
$N_{t+\Delta t}$ is a final number of the same length group;

C_t is the accumulated catch of the given length group during the time Δt.

In order to complete transition from the age cohorts to the length ones, equation of Bertalanffi is used. After the transformations, for convenient calculations this equation is assumed in the following way:

$$N_1 = (N_2 \cdot X_1 + C_1) \cdot X_1, \qquad [44]$$

where N_1 and N_2 is number of fish with length $L_1$and L_2;
C_1 is a number of fish caught during the year in the range of lengths (L_1, L_2);
$X_1 = [(L_\infty - L_1) / (L_\infty - L_2)]^{M/2K}$.

The input data for the method of Jones are:
- length composition of catches in items, averaged for a number of years;
- Bertalanffi equations coefficients L_∞ and K;
- instant coefficient of natural mortality, identical for all length groups;
- coefficient $(F/Z)_n$ or number of the last length group (in case of no information, it can be accepted as $2 \cdot C_n$, where n is an index of the eldest length group).

The method allows to obtain:
- assessment of the stock number as a sum of numbers of each length group;
- coefficients of fishing and total mortality for each length group.

The sequence of calculations (according to Babayan et al, 1984) is the following:

1. For each interval i (of the length group) the coefficients X_i are calculated

$$X_i = [(L_\infty - L_i)/(L_\infty - L_{i+1})]^{M/2K}. \qquad [45]$$

2. The initial number of the eldest length group n is estimated

$$N_n = C_n / (F/Z)_n. \qquad [46]$$

3. Consequently, the values of the initial numbers of all the other length groups **n** from the eldest to the youngest are assessed

$$N_{n-1} = (N_n \cdot X_{n-1} + C_{n-1}) \cdot X_{n-1};$$

$$N_{n-2} = (N_{n-1} \cdot X_{n-2} + C_{n-2}) \cdot X_{n-2}. \qquad \text{etc.}$$

4. The values $(Z_{\Delta t})_i$, correlating with the value of the total mortality coefficient during the time period when a specimen grows from the upper to the low bound of the size range ΔL_i, are estimated:

$$(Z_{\Delta t})_i = -\ln (N_{i+1}/ N_i). \qquad [47]$$

5. The percentage of fishing mortality in the total mortality for the intervals during the period $(\Delta t)_i$ to the total specimens' number, lost for the same period, is esimated

$$(F/Z)_i = C_i / (N_i - N_{i+1}). \qquad [48]$$

6. The values $(F\Delta t)_i$, correlating with the value of the fishing mortality coefficient during the time period when the sprat specimen grows from the upper to the low bound of the size range ΔL_i , are estimated

$$(F_{\Delta t})_i = (F/Z)_I \cdot (Z_{\Delta t})_i. \qquad [49]$$

7. The coefficients of total mortality Z_i for the size groups are estimated

$$Z_i = M / [1 - (F/Z)_i]. \qquad [50]$$

8. The coefficients of fishing mortality F_i for the length groups are estimated

$$F_i = Z_i - M. \qquad [51]$$

9. The average numbers N_i* of the length groups at sea are estimated

$$N_i^* = (N_i - N_{i+1}) / Z_{i.}. \qquad [52]$$

The sum of the calculated values N_i is an initial stock for the chosen time period, estimated in specimens. For transiting to the stock weight indices, the specimens' average mass according to the age groups is used.

The advantage of the length cohort analysis method, in comparison with the analysis of the age cohorts, is the fact that length composition of the catches is determined with less calculating errors than the age composition. At the cohort analysis of Jones the tuning procedure is not required.

To assess the mean exploited biomass of sprat and anchovy off the Bulgarian coast in the period 1998-2000 Length-based VPA (LCA) was applied (Prodanov, 2003). The input data and results are presented in Fig 14.

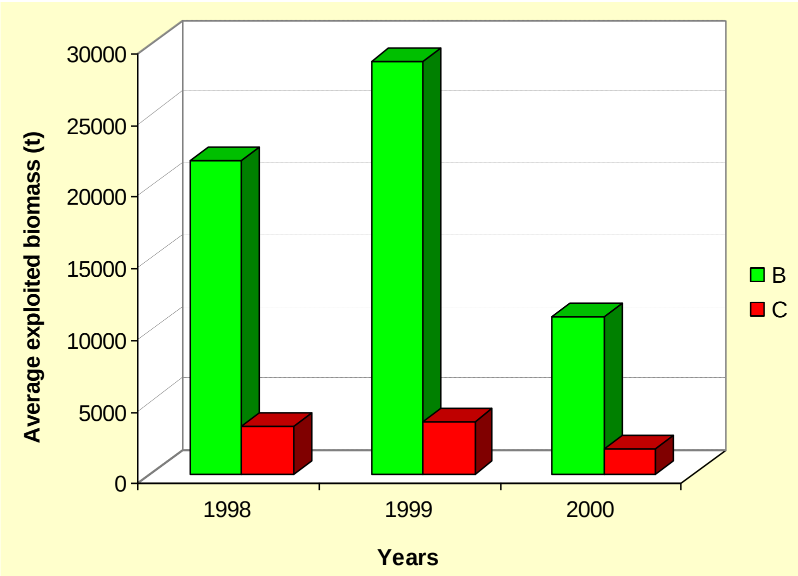


Fig 14 – Bulgarian sprat catches in the Black Sea and average exploited biomasses in 1998, 1999 and 2000 under LCA

On the basis of the Bulgarian fishery statistics the mean exploited sprat stock in 1998, 1999 and 2000 off Bulgarian coast was determined to be 21 892.2, 28 733.4 and 10 948.1 tons, respectively. The catches in corresponding years represent about 14.96 %, 12.51 % and 15.87 % from the average exploited sprat stock off Bulgarian Black Sea coast.

As the optimum value of the coefficient of fishing mortality of sprat is 0.435 the total allowable catch (TAC) for this fish species has to represent about 33% of the biomass in the beginning of the corresponding year. In this case, TAC for the sprat calculated by mean exploited biomasses for the had to be 7 224.4 (1998), 9482 (1999) and 3612.9 (2000) tons. During these years the Bulgarian sprat catches was 3 646, 3595 and 1 737, respectively. Therefore, although significant share of the catches probably remain unrecorded, the impact of fishery on the sprat stocks is not strong and thus no over fishing occurred in the period 1998-2000.

On the basis of the Bulgarian fishery statistics the anchovy mean exploited stock off the Bulgarian coast in 1998, 1999 and 2000 was estimated at 260.6, 186.4 and 967.1 tons. The Bulgarian catches in the corresponding years represent about 18.42 %, 19.31 % and 6.62 % from the average exploited anchovy stock of in front the Bulgarian Black Sea coast – Fig. 15.

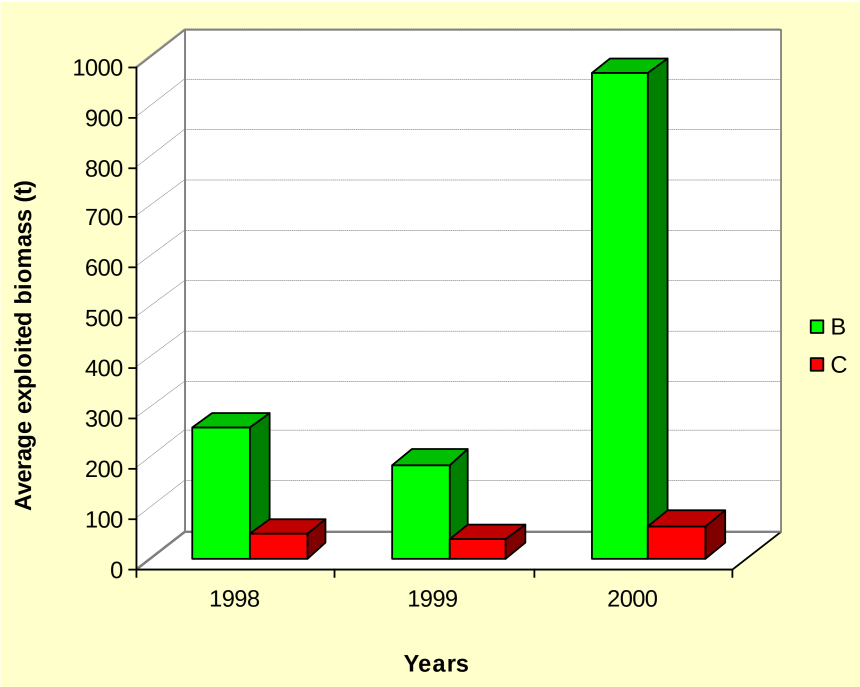


Fig 15 – Bulgarian anchovy catches in the Black Sea and average exploited biomasses in 1998, 1999 and 2000 under LCA

LCA has been applied to anchovy, whiting and red mullet in the South eastern Black Sea of Turkey (Mutlu, 2000). The mean anchovy biomasses in 1996/97 and 1997/98 were estimated at 326 and 252 thousand tons, respectively (Table 20, 21). The catches in 1996/97 and 1997/98 were 156.2 and 94.2 thousand tons, respectively. Catch for per unit fishing effort seemed to high for small and medium size vessels and the catch for per unit effort during 1996/97 fishing season was higher than that of the following season.

The mean whiting and red mullet biomasses in 1996/97 were estimated at 8.6 thousand tons and 1.1 thousand tons, in 1997/98 – 15.6 and 1.9 thousand tons respectively (Table 22-25).

Table 20 – Length frequency data of the Black Sea anchovy used for LCA of 1996/97 and the output results

Length classes	**$C_N(10^6)$**	**N (10^6)**	**$\bar{B}$ (tons)**	**F**
5.5-6.0	19	73277	12118	0.002
6.0-6.5	135	67644	13913	0.014
6.5-7.0	434	62100	17717	0.047
7.0-7.5	905	56481	19570	0.102
7.5-8.0	1433	50653	20661	0.173
8.0-8.5	2292	44606	24356	0.301
8.5-9.0	2097	38083	25784	0.306
9.0-9.5	1624	32173	27477	0.264
9.5-10.0	1612	27124	28732	0.293
10.0-10.5	2739	22452	29762	0.582
10.5-11.0	2535	17094	27140	0.668
11.0-11.5	2023	12449	23667	0.683
11.5-12.0	1617	8779	20522	0.721
12.0-12.5	1951	5915	15475	1.287
12.5-13.0	1338	3122	9381	1.616
13.0-13.5	610	1323	4769	1.592
13.5-14.0	218	500	2282	1.308
14.0-14.5	74	190	1181	0.990
14.5-15.0	26	74	599	0.721
15.0-15.5	12	28	324	0.729
15.5-16.0	5	8	111	0.941
$\sum C_N$, N, $\bar{B}$	23699	524075	325541	-
F av. (weighted by C_N)	-	-	-	0.610

Since the data on length composition of the catches, averaged for a certain time period, served as the input data, it results in bringing the real situation to the balanced one. However, with no information on the stock dynamics it is difficult to give recommendations on its management. In YugNIRO eliminate this error of the cohort analysis of Jones by accepting that the period of averaging (number of catch years) for the stock being assessed is commensurable with duration of the life cycle (life history) of the fish species, or, at least, with the number of annual classes which give the main catch of the stock.

Table 21 – Length frequency data of the Black Sea anchovy used for LCA of 1997/98 and the output results

Length classes	**$C_N(10^6)$**	**N (10^6)**	**$\bar{B}$ (tons)**	**F**
5.5-6.0	3	52155	8072	0.001
6.0-6.5	2	48048	12439	0.000
6.5-7.0	22	44072	12311	0.004
7.0-7.5	166	40207	12515	0.030
7.5-8.0	458	36342	14736	0.087
8.0-8.5	626	32353	16850	0.126
8.5-9.0	423	28392	18697	0.091
9.0-9.5	598	24832	20630	0.137
9.5-10.0	802	21301	22036	0.199
10.0-10.5	973	17801	23568	0.269
10.5-11.0	1695	14399	23460	0.547
11.0-11.5	2088	10624	20900	0.864
11.5-12.0	1410	6915	16635	0.806
12.0-12.5	1130	4331	12646	0.943
12.5-13.0	959	2396	8164	1.375
13.0-13.5	408	969	4176	1.246
13.5-14.0	123	341	1999	0.840
14.0-14.5	33	120	1070	0.472
14.5-15.0	10	41	532	0.318
15.0-15.5	3	9	119	0.523
$\sum C_N$, N, $\bar{B}$	11932	385648	251555	-
F av. (weighted by C_N)	-	-	-	0.633

Thus, while assessing stocks of sprat, horse-mackerel and red mullet we usually used data averaging for three-year periods (Shlyakhov, 2009; Shlyakhov, Gutsal, 2012), of turbot – for four-year periods (fig. 26-28).

As an example, the diagram of Fig. 26 shows the dynamics of the stock and fishing mortality red mullet.

If during some time fishery indexes are stable (fishery gears of the same type are used and their selectivity and fishery effort dimension are constant), Jones' cohort analysis for certain years of fishery can be used. In 2012 we conducted the series of estimations of turbot for 1997-2012 by averaging input fishery-biological data according to four years periods (SSB') and calendar years (SSB). The results of modeling were compared to trawl survey stock assessment (Fig. 27).

Table 22 – Length frequency data of the Whiting caught by trawls used for Length-based Cohort Analysis (LCA) of the output results

(a=0.0000058 kg/cm^3, b=3.08, k=0.12 per year, L_∞=39.5 cm, M=0.25 per year)

Length group cm	Mean lenght cm	relative age	Δ t	M factor	sample	number caught (1000)	number of survivors (1000)	exploitation rate	fishing mortality	total mortality	mean body weight (kg)	mean N* Δ t (1000)	mean biomass*Δ t tons	yield tons
L_1-L_2	$\bar{L}$	$t(L_1)$		H (L_1, L_2)	C(L_1, L_2)	C(L_1, L_2)	N(L_1)	(F/Z)	F	Z	W(L_1, L_2)	N(L_1, L_2)* Δt	B*Δt	Y(L_1, L_2)
7-8	7.5	1.70	0.27	1.03454	8	544	462445	0.018	0.004	0.254	0.0029	121391	349.0	1.6
8-9	8.5	1.97	0.28	1.03568	45	3063	431552	0.095	0.026	0.276	0.0042	116457	492.3	12.9
9-10	9.5	2.25	0.29	1.03689	174	11842	399375	0.301	0.108	0.358	0.0060	109955	654.7	70.5
10-11	10.5	2.54	0.30	1.03818	384	26135	360044	0.511	0.261	0.511	0.0081	100143	811.5	211.8
11-12	11.5	2.84	0.31	1.03957	479	32601	308873	0.599	0.373	0.623	0.0107	87308	936.3	349.6
12-13	12.5	3.15	0.32	1.04107	536	36480	254446	0.667	0.500	0.750	0.0139	72959	1011.6	505.8
13-14	13.5	3.47	0.33	1.04268	654	44511	199726	0.758	0.784	1.034	0.0176	56778	997.8	782.2
14-15	14.5	3.80	0.35	1.04443	604	41108	141020	0.804	1.028	1.278	0.0219	39972	875.4	900.3
15-16	15.5	4.15	0.36	1.04632	405	27564	89919	0.808	1.050	1.300	0.0269	26258	706.2	741.3
16-17	16.5	4.51	0.38	1.04838	304	20690	55790	0.835	1.269	1.519	0.0326	16302	531.5	674.6
17-18	17.5	4.89	0.40	1.05063	189	12863	31024	0.848	1.399	1.649	0.0391	9193	359.3	502.7
18-19	18.5	5.29	0.41	1.05311	96	6534	15863	0.842	1.328	1.578	0.0464	4920	228.2	303.0
19-20	19.5	5.70	0.43	1.05584	57	3879	8099	0.861	1.542	1.792	0.0545	2515	137.2	211.6
20-21	20.5	6.14	0.46	1.05886	35	2382	3591	0.903	2.329	2.579	0.0636	1023	65.1	151.6
21-39.5	-	6.59	-	-	7	476	953	0.500	0.250	0.500	0.2109	1906	401.9	100.5
TOTAL					3977	270675						767080	**8557.9**	**5520.0**

Table 23 – Length frequency data of the Whiting caught by gillnet boats used for Length-based Cohort Analysis (LCA) of the output results (a=0.0000058 kg/cm^3, b=3.08, k=0.12 per year, L_∞=39.5 cm, M=0.25 per year)

Length group cm	Mean lenght cm	relative age	Δ t	M factor	sample	number caught (1000)	number of survivors (1000)	exploitation rate	fishing mortality	total mortality	mean body weight (kg)	mean N* Δ t (1000)	mean biomass*Δ t tons	yield tons
L_1-L_2	$\bar{L}$	$T(L_1)$		$H(L_1, L_2)$	$C(L_1, L_2)$	$C(L_1, L_2)$	$N(L_1)$	(F/Z)	F	Z	$W(L_1, L_2)$	$N(L_1, L_2)^*\Delta t$	$B^*\Delta t$	$Y(L_1, L_2)$
8-9	8.5	1.97	0.28	1.03568	1	17	411624.2	0.001	0.000	0.250	0.0042	111479.4	471.2	0.1
9-10	9.5	2.25	0.29	1.03689	2	34	383737.3	0.001	0.000	0.250	0.0060	107264.1	638.7	0.2
10-11	10.5	2.54	0.30	1.03818	19	323	356887.3	0.012	0.003	0.253	0.0081	103028.1	834.9	2.6
11-12	11.5	2.84	0.31	1.03957	45	766	330807.0	0.030	0.008	0.258	0.0107	98707.7	1058.6	8.2
12-13	12.5	3.15	0.32	1.04107	96	1633	305364.4	0.065	0.017	0.267	0.0139	94210.0	1306.2	22.6
13-14	13.5	3.47	0.33	1.04268	242	4118	280178.5	0.156	0.046	0.296	0.0176	89198.0	1567.5	72.4
14-15	14.5	3.80	0.35	1.04443	698	11876	253761.4	0.365	0.144	0.394	0.0219	82493.9	1806.6	260.1
15-16	15.5	4.15	0.36	1.04632	1510	25692	221261.7	0.588	0.356	0.606	0.0269	72074.5	1938.3	691.0
16-17	16.5	4.51	0.38	1.04838	2337	39763	177551.0	0.737	0.701	0.951	0.0326	56695.5	1848.5	1296.5
17-18	17.5	4.89	0.40	1.05063	2296	39066	123613.8	0.800	1.002	1.252	0.0391	38979.5	1523.4	1526.8
18-19	18.5	5.29	0.41	1.05311	1653	28125	74803.3	0.826	1.185	1.435	0.0464	23743.8	1101.2	1304.4
19-20	19.5	5.70	0.43	1.05584	1022	17389	40742.1	0.841	1.327	1.577	0.0545	13102.3	714.6	948.4
20-21	20.5	6.14	0.46	1.05886	523	8899	20077.6	0.842	1.328	1.578	0.0636	6701.6	426.4	566.2
21-22	21.5	6.59	0.48	1.06223	267	4543	9503.5	0.848	1.394	1.644	0.0737	3258.9	240.1	334.7
22-23	22.5	7.08	0.51	1.06601	99	1684	4145.9	0.811	1.071	1.321	0.0848	1572.9	133.3	142.8
23-24	23.5	7.59	0.54	1.07027	47	800	2068.2	0.792	0.951	1.201	0.0969	840.7	81.5	77.5
24-25	24.5	8.13	0.58	1.07513	17	289	1058.3	0.702	0.590	0.840	0.1102	490.1	54.0	31.9
25-39.5	32.3	8.71	-	-	19	323	646.56	0.500	0.250	0.500	0.2569	1293.1	332.2	83.0
TOTAL					10893	185341						905134.1	15606.0	7369.2

Table 24 – Length frequency data of the Red mullet caught by trawls used for Length-based Cohort Analysis (LCA) of the output results (a=0.0000086 kg/cm^3, b=3.06, k=0.218 per year, L_∞=24.22 cm, M=0.37 per year)

Length group cm	Mean lenght cm	relative age	Δ t	M. factor	sample	number caught (1000)	number of survivors (1000)	exploitation rate	fishing mortality	total mortality	mean body weight (kg)	mean N* Δ t (1000)	mean biomass*Δ t tons	yield tons
L_1-L_2	$\bar{L}$	$T(L_1)$		$H(L_1,L_2)$	$C(L_1,L_2)$	$C(L_1,L_2)$	$N(L_1)$	(F/Z)	F	Z	$W(L_1,L_2)$	$N(L_1,L_2)^* \Delta t$	$B^*\Delta t$	$Y(L_1,L_2)$
7-8	7.5	1.56	0.27	1.05208	14	204	84203.7	0.025	0.009	0.379	0.0041	21946.5	89.9	0.8
8-9	8.5	1.84	0.29	1.05549	97	1414	75879.4	0.155	0.068	0.438	0.0060	20794.3	124.9	8.5
9-10	9.5	2.13	0.31	1.05937	312	4548	66771.5	0.393	0.240	0.610	0.0084	18971.3	160.1	38.4
10-11	10.5	2.44	0.33	1.06384	588	8571	55204.1	0.592	0.536	0.906	0.0115	15978.2	183.2	98.3
11-12	11.5	2.78	0.36	1.06903	731	10656	40720.9	0.708	0.896	1.266	0.0151	11894.5	180.1	161.4
12-13	12.5	3.14	0.39	1.07514	612	8921	25664.2	0.759	1.163	1.533	0.0195	7671.6	149.9	174.4
13-14	13.5	3.53	0.43	1.08244	397	5787	13904.6	0.784	1.341	1.711	0.0247	4315.2	106.7	143.1
14-15	14.5	3.96	0.47	1.09132	221	3222	6520.9	0.806	1.536	1.906	0.0308	2097.5	64.6	99.2
15-16	15.5	4.43	0.53	1.10233	88	1283	2523.4	0.797	1.449	1.819	0.0377	885.6	33.4	48.4
16-17	16.5	4.96	0.60	1.11637	23	335	912.9	0.697	0.853	1.223	0.0457	393.1	18.0	15.3
17-18	17.5	5.55	0.68	1.13487	6	87	432.2	0.504	0.375	0.745	0.0547	233.0	12.8	4.8
18-19	18.5	6.24	0.80	1.16037	6	87	258.5	0.616	0.595	0.965	0.0649	147.1	9.5	5.7
19-24.2	21.6	7.04	-	-	4	58	116.62	0.500	0.370	0.740	0.1042	157.6	16.4	6.1
TOTAL					3099	45174.1						105485.5	1149.5	804.3

Table 25 – Length frequency data of the red mullet caught by gillnet boats used for Length-based Cohort Analysis (LCA) of the output results (a=0.0000086 kg/cm^3, b=3.06, k=0.218 per year, L_∞=24.22 cm, M=0.37 per year)

Length group cm	Mean lenght cm	relative age	Δ t	M factor	sample	number caught (1000)	number of survivors (1000)	exploitation rate	fishing mortality	total mortality	mean body weight (kg)	mean N* Δ t (1000)	mean biomass* Δ t tons	yield tons
L_1-L_2	$\bar{L}$	$T(L_1)$		H (L_1,L_2)	$C(L_1,L_2)$	$C(L_1,L_2)$	$N(L_1)$	(F/Z)	F	Z	$W(L_1,L_2)$	$N(L_1,L_2)^* \Delta t$	$B^*\Delta t$	$Y(L_1,L_2)$
9-10	9.5	2.13	0.31	1.05937	1	20	64138.4	0.003	0.001	0.371	0.0084	18881.9	159.4	0.2
10-11	10.5	2.44	0.33	1.06384	6	119	57132.3	0.018	0.007	0.377	0.0115	17955.6	205.8	1.4
11-12	11.5	2.78	0.36	1.06903	38	752	50369.9	0.107	0.045	0.415	0.0151	16881.9	255.7	11.4
12-13	12.5	3.14	0.39	1.07514	123	2435	43371.4	0.300	0.159	0.529	0.0195	15352.4	300.1	47.6
13-14	13.5	3.53	0.43	1.08244	231	4573	35256.0	0.487	0.351	0.721	0.0247	13020.6	322.1	113.1
14-15	14.5	3.96	0.47	1.09132	440	8710	25865.3	0.718	0.943	1.313	0.0308	9239.5	284.4	268.1
15-16	15.5	4.43	0.53	1.10233	359	7107	13736.2	0.800	1.484	1.854	0.0377	4789.6	180.8	268.3
16-17	16.5	4.96	0.60	1.11637	134	2653	4857.1	0.795	1.436	1.806	0.0457	1846.7	84.4	121.3
17-18	17.5	5.55	0.68	1.13487	48	950	1521.1	0.807	1.548	1.918	0.0547	613.8	33.6	52.0
18-19	18.5	6.24	0.80	1.16037	8	158	343.7	0.704	0.880	1.250	0.0649	179.9	11.7	10.3
19-24.2	21.6	7.04	-	-	3	59	118.8	0.500	0.370	0.740	0.1042	160.5	16.7	6.2
TOTAL					1391	27537						98922.5	1854.6	899.8

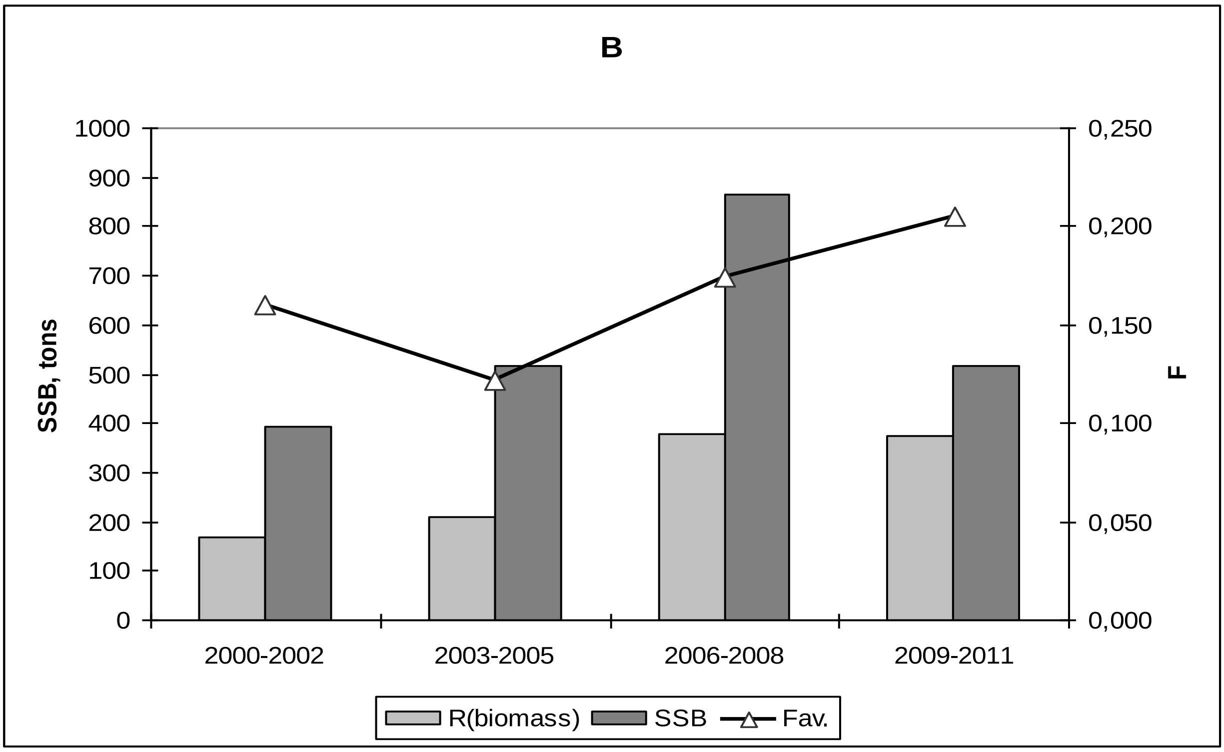


Fig 26 – Estimation of SSB, R and F_{av} of Crimean Red mullet stock using Johnes' cohort analysis method (from Shlyakhov, Gutsal, 2012)

As fishery rate increased (in the mentioned period the usage of turbot gillnets was officially allowed, in thousands: in 1997-2000 – 1.8, in 2001-2004 – 3.9, in 2005-2008 – 8.0, in 2009-2012 – 7.5) the results of mathematical modeling come closer to direct trawl survey estimation (2005-2007). In condition of extremely high IUU level in Ukrainian waters of the Black Sea it is hard to interpret the results of turbot stock dynamic modeling. So, significant increase of its average level for 2009-2012 according to cohort analysis data is hardly connected with its real growth. Most likely, it reflects the legalization level growth of illegal catches.

The diagram clearly shows that both variants LCA (without averaging and with 4-years averaging) in 1997-2007 gave the lower stock assessments than trawl surveys. Estimating turbot stock using YugNIRO surveys data we took the catchability coefficient $q=0.15$ (Shlyakhov et al. 2012a). According to our assessments official statistic of Ukrainian turbot landings reflected near 14% of official landing in 2005; as input data in the cohort analysis namely official statistic was used. It's obvious that greatly understated catch input data will give high level of stock underestimation.

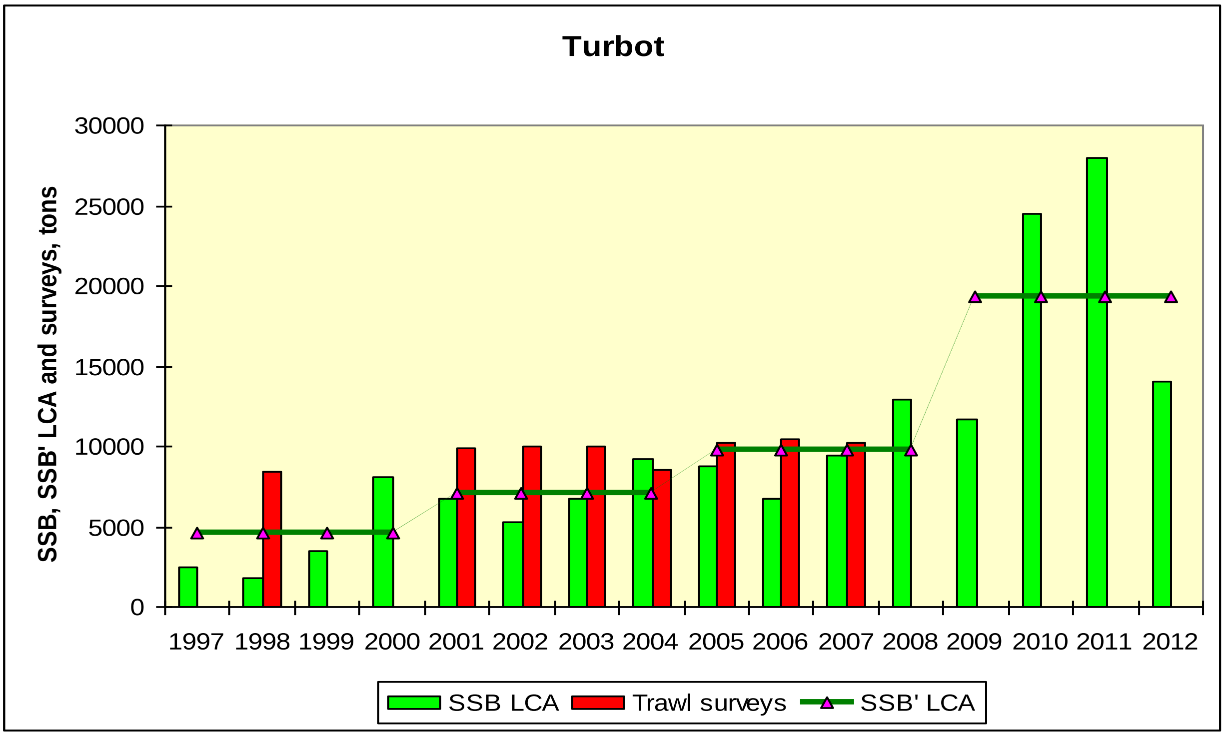


Fig. 27 – Turbot stock assessment in Ukrainian sector of the Black Sea using Jones cohort analysis method: SSB – without averaging by years of fishery (green columns), SSB' – with averaging the input data by 4-years periods (horizontal segments). Red columns – stock by the trawl survey data (after Shlyakhov et al, 2012b.

Meanwhile for 2005-2008 SSB and turbot assessment using trawl surveys and LCA almost coincided. So, as for turbot for the survey trawl used by YugNIRO the coefficient $q=0.15$ was understated.

Another important result derived from the comparison of SSB и SSB' assessments is in their closeness. It's interesting that averaged turbot SSB assessments were lower than SSB' assessments for the same periods.

Also the initial sprat stock assessments for 2008-2014 (last three years - forecast) using LCA method for Ukrainian waters of the Black Sea were compared with EWG STECF assessments using ICA methods for the all sea (Daskalov et al, 2012). SSB sprat dynamic shows satisfying resemblance in both methods (Fig. 28).

Bulgarian, Turkish and Ukrainian experience of the practical usage of the Jones cohort analysis shows the prospects of the LCA method development for the Black Sea fishery stock assessment. As the support of its usage acts the possibility of catch length structure data involvement almost in all the Black Sea countries.

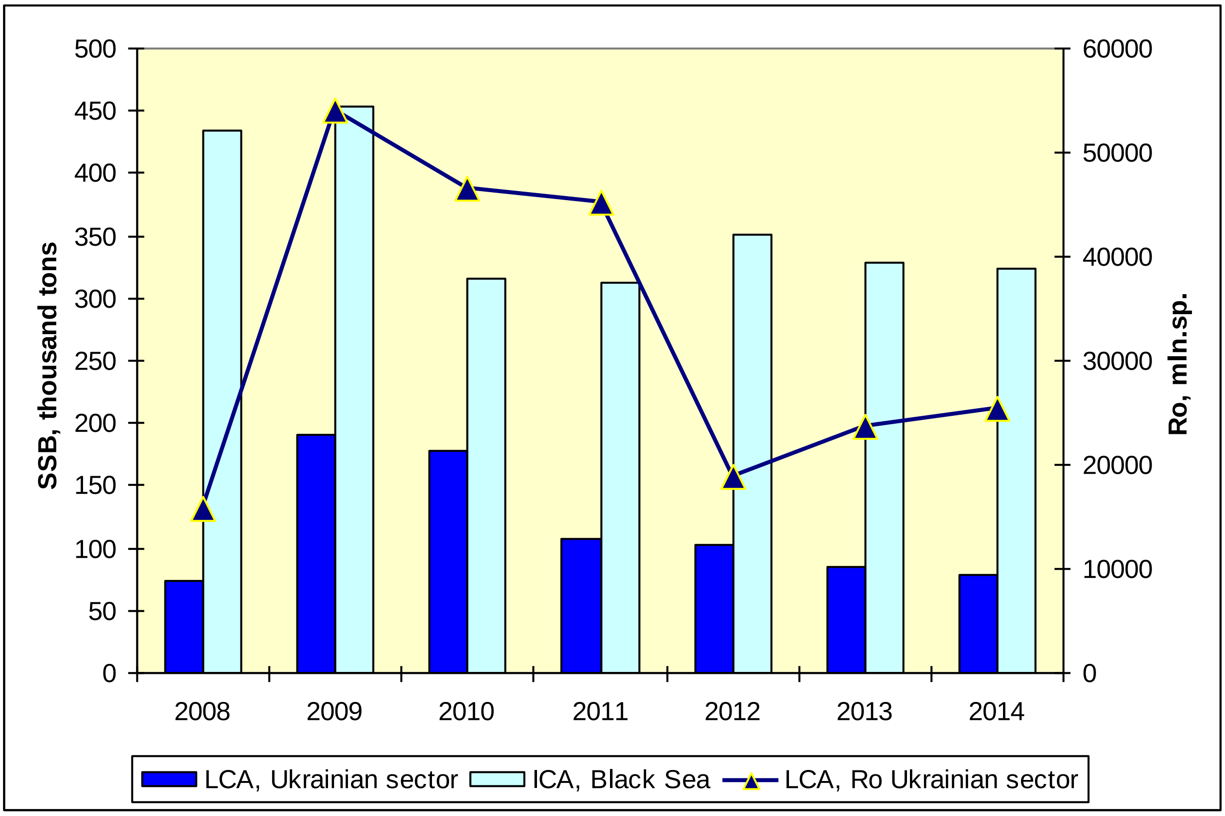


Fig. 28 – Estimation of SSB (initials), and R_0 sprat for Ukrainian sector of the Black Sea using the Jones cohort analysis method (blue columns and line) and EWG STECF SSB sprat estimation for the whole sea using ICA method (light-blue columns) – from year report of YugNIRO, 2012).

9.3. Models used by the Expert Working Group on Assessment of Black Sea Stocks

The report of the Expert Working Group on Assessment of Black Sea Stocks (EWG 12-16) was reviewed by the STECF during October 8-12, 2012 in Ispra (Italy), evaluate the findings and make any appropriate comments and recommendations. The following observations, conclusions and recommendations represent the outcomes of Black Sea Countries; Bulgaria, Romania, Ukraine and also Turkey sharing of common stocks of the Black Sea sprat, whiting and turbot. Each country has represented their fisheries data and assessments were based on the use of all fisheries data which have been evaluated together for further analyses.

The available data from both fisheries dependent and fisheries independent sources are considered good enough in order to perform a reliable assessment of the stock. However, the unknown share of unreported landings makes the analysis very sensitive to different options.

Source of data came from International landings data at age were constructed and three methods applied:

1. The Integrated Catch Analyses (ICA; Patterson and Melvin, 1996);
2. Extended Survivors Analysis (XSA; Shepherd, 1999);
3. The State-space Assessment Model (SAM; Nielsen et al., 2012).

EWG 12-16 ASSESSMENT OF THE BLACK SEA SPRAT (ICA METHOD). ICA is a statistical catch-at-age method based on the Fournier and Deriso models (Deriso et al., 1985). It applies a statistical optimization procedure to calculate population numbers and fishing mortality coefficients-at-age from data of catch numbers-at-age and natural mortality. The dynamics of a cohort (generation) in the stock are expressed by two non-linear equations referred to as a survival equation (exponential decay) and a catch equation:

$$N_{a+1,y+1} = N_{a,y} * exp(-F_{a,y} - M),$$

$$C_{a,y} = N_{a,y} * [1 - exp(-F_{a,y} - M)] * F_{a,y} / (F_{a,y} + M),$$

where C, N, M, and F are catch, abundance, natural mortality, and fishing mortality, respectively, and a and y are subscript indices for age and year. The algorithm initially estimates population numbers and fishing mortality fitting a separable model, when F is assumed to conform to a constant selection pattern (fishing mortality-at-age), but fishing mortality by year is allowed to vary. The F matrix is then modeled as a multiplication of the year-specific F and the specified selection pattern. This procedure substantially diminishes the number of parameters in the model.

In its second stage, the ICA algorithm minimizes the weighted Sum of Square Residuals (SSR) of observed and modeled catch and relative abundance indices (CPUE), assuming Gaussian distribution of the log residuals:

$$min\ [\sum_{a,y} pc_{a,y} (log\ C_{a,y} - log\ \hat{C}_{a,y})^2 + \sum_{a,y,f} pi_{a,f} (log\ I_{a,y,f} - log\ \hat{I}_{a,y,f})^2,$$

where C, Ĉ, I, and Î are observed and estimated catch and age-structured index, respectively, and a, y, and f are subscript indices for age, year, and fleet, respectively. Weights associated with catches and different indices (pc, pi) are ideally set equal to the inverse variances of catch and index data, and can be calculated based on the residuals between modeled and observed values. However, weights are usually set by the user on the basis of some information about the reliability of different indices and current experience with modeling the stock. Indices are defined as related to population numbers by the equations:

$\hat{I}_{a,y} = N_{a,y} * exp(-F_{a,y} - M)$

$\hat{I}_{a,y} = q_a * N_{a,y} * exp(-F_{a,y} - M)$

$\hat{I}_{a,y} = q_a * (N_{a,y} * exp(-F_{a,y} - M))^{k_a}$.

The two unknown parameters (q_a, an age-specific catchability, and k, a constant) are estimated according to the assumed relationship between the population and the abundance index, which has to be specified as being one of the above-identity, linear, or power, respectively.

ICA combines the power and accuracy of a statistical model with the flexibility of setting different options of the parameters (e.g. a separable model accounting for age effects) and for this raison is suitable for a short living species (age 5 at maximum) such as the Black Sea sprat. ICA has previously been applied to Black Sea sprat by Daskalov (1998), Pilling et al. 2008, and Daskalov et al. 2010.

Catch and weight at age, natural mortality, and 4 age structured indices are used to run ICA.

Total catch at age data were compiled by summing catch at age matrices from Bulgaria, Romania, Turkey and Ukraine total tuning data. Catch at age matrix from Russia was derived by applying age composition and mean weight in the catch of Ukraine to Russia catch. Tuning index from the Bulgarian Pelagic Trawl Survey (PTS) was applied for 2007-2010.

According to the present assessment the SSB ranges at medium to high levels: in the range of 300 - 400 000 t in recent years. Under a constant recruitment scenario and status quo F, SSB is expected to stay at the approximate same level by 2014. Since no precautionary level for the stock size of sprat in GSA 29 was proposed, EWG 12-16 cannot fully evaluate the stock status in relation to the precautionary approach.

Recruitment estimates since 2007 are estimated to range at a high level as compared with a long term trend. Such estimates are considered rather imprecise due to the lack of survey data.

EWG 12-16 proposes the exploitation rate $E \leq 0.4$ ($=F \leq 0.64$) as limit management reference point consistent with high long term yields (F_{MSY} proxy). Over the last few years the fishing mortality has piqued in 2004-2005 and 2009-2011 at a level of 0.6 - 0.8. The current 2011 $F=0.811$, that equals an exploitation rate of about $E=0.46$ (natural mortality $M=0.95$) makes the EWG to considers the stock of being at risk of overexploitation (Fig 29).

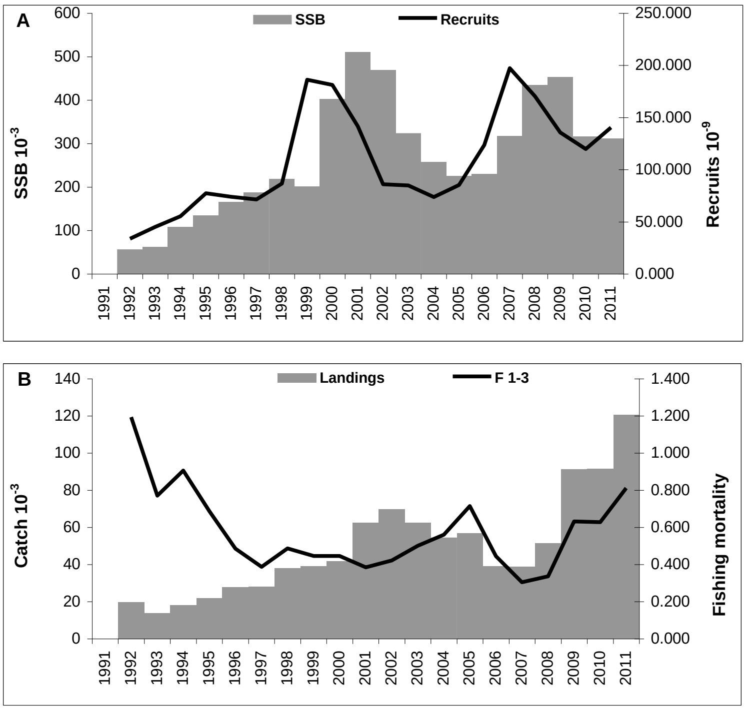


Fig. 29 – Time-series of sprat population estimates: **A.** recruitment (line) and SSB (grey); **B.** landings (grey) and average fishing mortality (ages 2–4, line)

*EWG 12-16 ASSESSMENT OF THE BLACK SEA WHITING, ANCHOVY (*XSA *METHOD).* We applied Extended Survivors Analysis (XSA) (Shepherd, 1999). The method fits regressions between abundance-at-age and CPUE for multi-fleet tuning data, assuming power functional relationship for recruitment and a constant catchability with respect to time for fully recruited age groups. XSA is less rigid than VPA about constant exploitation pattern assumption, setting down the catchability to be constant (independent of age) above a certain age. Catchability estimated at a certain age is then used to derive abundance estimates to all subsequent ages including the oldest one. The fleet derived population abundance-at-age is used to estimate survivors at the end of the year for each cohort, which later initiate a modified cohort analysis in each iteration. XSA is considered to be superior than VPA in assuming the error in the catch data and being less sensitive to the last year data quality. In addition it uses an year-class-strength-dependent model to tune recruitment.

The technique called "shrinkage to the mean" could be used in order to stabilize additionally the analysis. It takes into account the mean F (or N) over the recent years in the calculation of the last year F's or N's, which means an additional constraint on the last year estimates. In the case of VPA the last year F's are shrunk to the arithmetic mean of the previous years F's for each age. In XSA two shrinkage options are available: shrinkage to the population mean or N shrinkage applied to recruitment and shrinkage to the mean F (F shrinkage) which is applied to all last year F's as well as to the oldest age F's. A shrinkage coefficient of variation (CV) has to be supplied by the user in order to weight the F shrinkage mean (by the inverse variance). The N shrinkage mean is weighted by the inverse of the variance of weighted geometric mean. Within XSA, when the analysis is extended to past years not covered by tuning data , it is necessary in most cases to use F shrinkage to the oldest age F, that is equivalent to the backward extension constraint used in VPA.

CAA estimates simultaneously abundance (N)- and fishing mortality (F)-at-age, and one of the problems with these models is the over parameterisation. XSA deals with over parameterisation in two ways. One way is to decrease the number of parameters estimated by CAA e.g. to assume a constant exploitation pattern for the oldest ages (see below), another way is to estimate some parameters (e.g. the last year fishing mortality) using additional information (CPUE, survey indices): to estimate F in the terminal year.

The method has previously been successfully applied to sprat and whiting by Daskalov (1998) and ICES area (ICES 2007).

The results of stock assessments, recruitment and fishing mortality whiting and Black Sea anchovy by XSA are given in Fig 30-31.

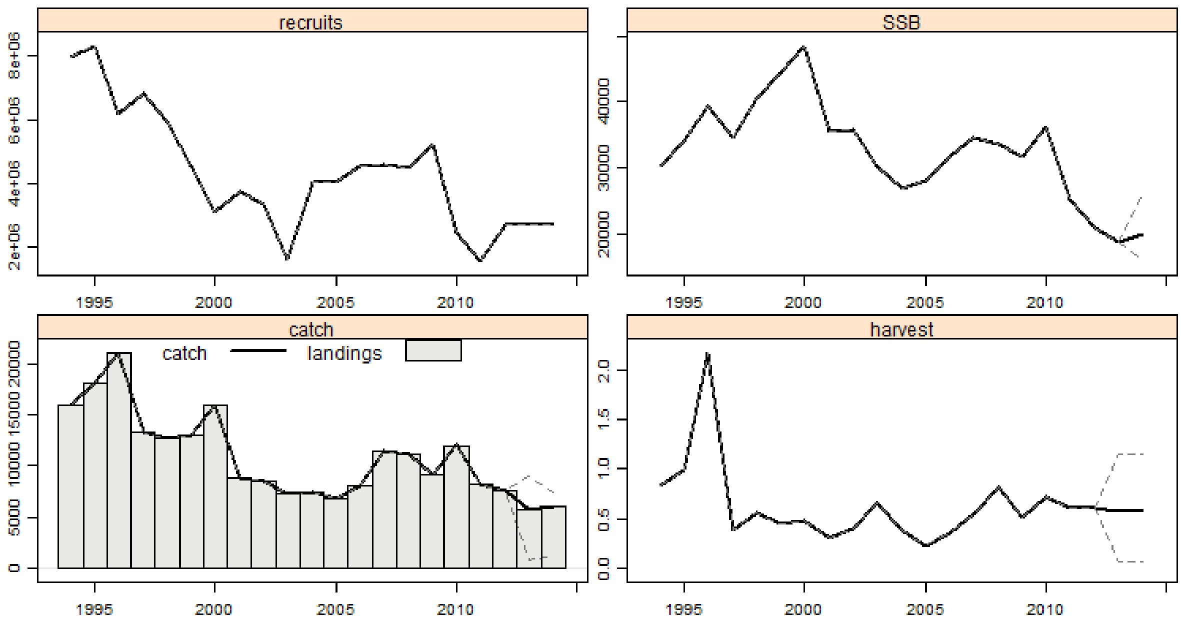


Fig. 30 – Historic trends and short term prediction (status quo) of relevant whiting stock parameters

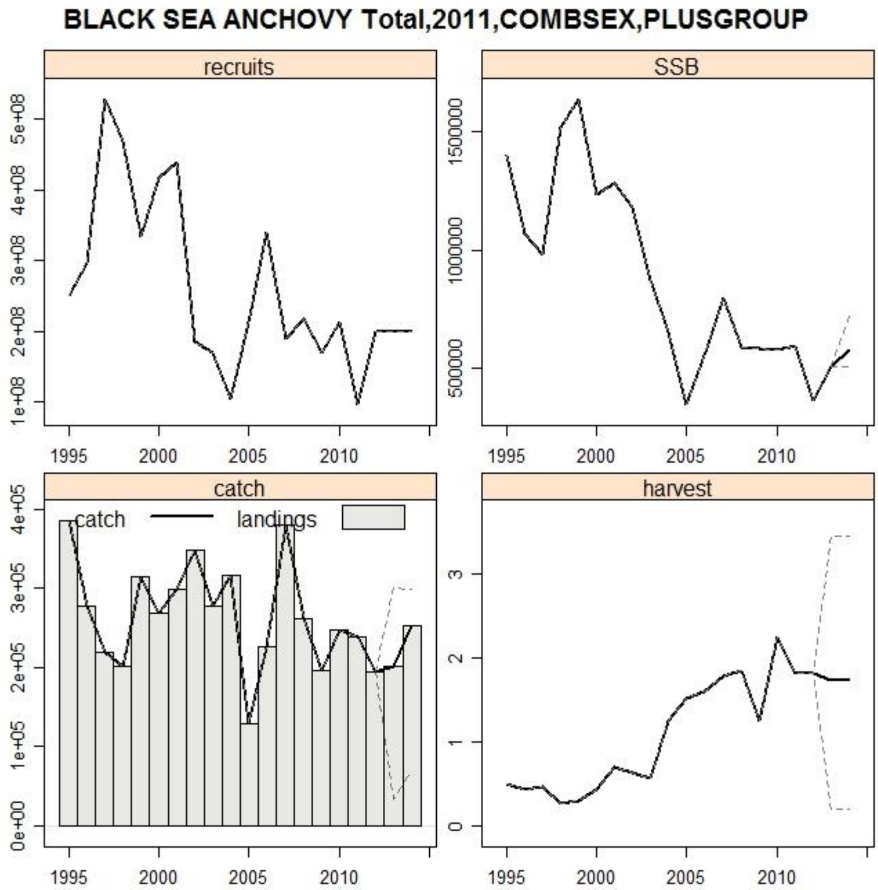


Fig. 31 – Short term prediction of the Black Sea anchovy stock parameters assuming status quo fishing in 2012 and F_{msy} in 2013

Since 1994 the recruitment and SSB has varied without a trend. In the absence of a biomass biological reference points the EWG 12-16 is unable to fully evaluate the stock status in respect to it. There is no fishery independent recruitment index (survey) available as none of the surveys cover the entire stock area.

The EWG 12-16 proposes F_{msy} $(1\text{-}4) \leq 0.4$ as limit reference point consistent with high long term yields and low risk of fisheries collapse. As the estimated $F_{(1\text{-}4)} = 0.66$ exceeds F_{msy} the EWG 12-16 classifies the stock of whiting in the Black Sea as being exploited unsustainably. If the stock is fished at $F_{msy(1\text{-}4)} = 0.4$ the status quo catch for 2013/2014 would be 4218 and 4971 t respectively. The EWG 12-16 therefore recommends a total catch not larger than 4971 t corresponding to catches at Fmsy. The EWG 12-16 notes the geographically uneven pattern in the catches of this stock. Given that this is not a highly migratory species we may conclude that the resident population is more exploited in the southern part (Turkish waters) than in the rest of the Black Sea- an effect that has been demonstrated by Prodanov et al. (1997) who performed separate VPA analyses of the western/northern and eastern/southern components of the whiting stock.

Due to somehow contradictory results from XSA, and not entirely reliable age composition and CPUE data the STESF EWG 12 16 consider the assessment to be indicative of relative trends in anchovy stock in the Black Sea.

After dropping from about 1 500 000 in 1995-2000 the anchovy SSB has remained rather stable around 800 000 t since 2007. In the absence of a precautionary reference point the EWG cannot fully evaluate the stock size. During the period 2002 to 2009 the recruitment has varied without a clear trend.

STECF EWG-12-16 proposes $E \leq 0.4$ as limit reference point consistent with high long term yield and low risk of fisheries collapses. The EWG classifies the stock as being subject to overfishing as the estimated $F_{(1-3)} = 1.81$ exceeds such exploitation rate $E \leq 0.4$, which equals $F_{(1-3)} = 0.53$ ($F_{msy\ proxy}$).

<u>EWG 12-16 ASSESSMENT OF THE BLACK SEA TURBOT (SAM METHOD)</u>.

The Black Sea turbot stock was assessed using the XSA (Extended survirors analysis) for the period 1970 – 2010 by STECF EWG 11 16 Black Sea, but exploration analysis of input data was not completed. STECF EWG 12 16 evaluated the “state-space” modelling approach for Black Sea Turbot. The model is based on the state-space assessment model (SAM) (Nielsen et al., 2012).This modelling framework is more robust and has a number of highly desirable characteristics, such as the stochastic treatment of all observations, a full statistical framework for evaluating model results, open source and cross platform source code, and an extremely high degree of flexibility allowing ready customisation to the peculiarities of the stock. Both models were applied on the same data set to explore the effect on SSB, recruitment and fishing mortality (Figure 32).

The SAM estimated recruitment has four peaks in 1965-1968, 1974-977,1991-1994 and 2003-2006 and three lows in 1982-85, 1996–1997 and 2001. Correspondingly, SSB attained higher values up to 12,000 t in 1977–1981 and very low values after 1989. For the recent period however the STECF EWG 12 16 Black Sea is aware of misreporting of actual catches which could have contributed to the underestimation of stock abundance. Fishing mortality F_{4-8} has a peak of $F \sim 1.4$ in 2000-2001 and keeps as high as $F = 0.6 - 0.8$ thereafter (Figure 33).

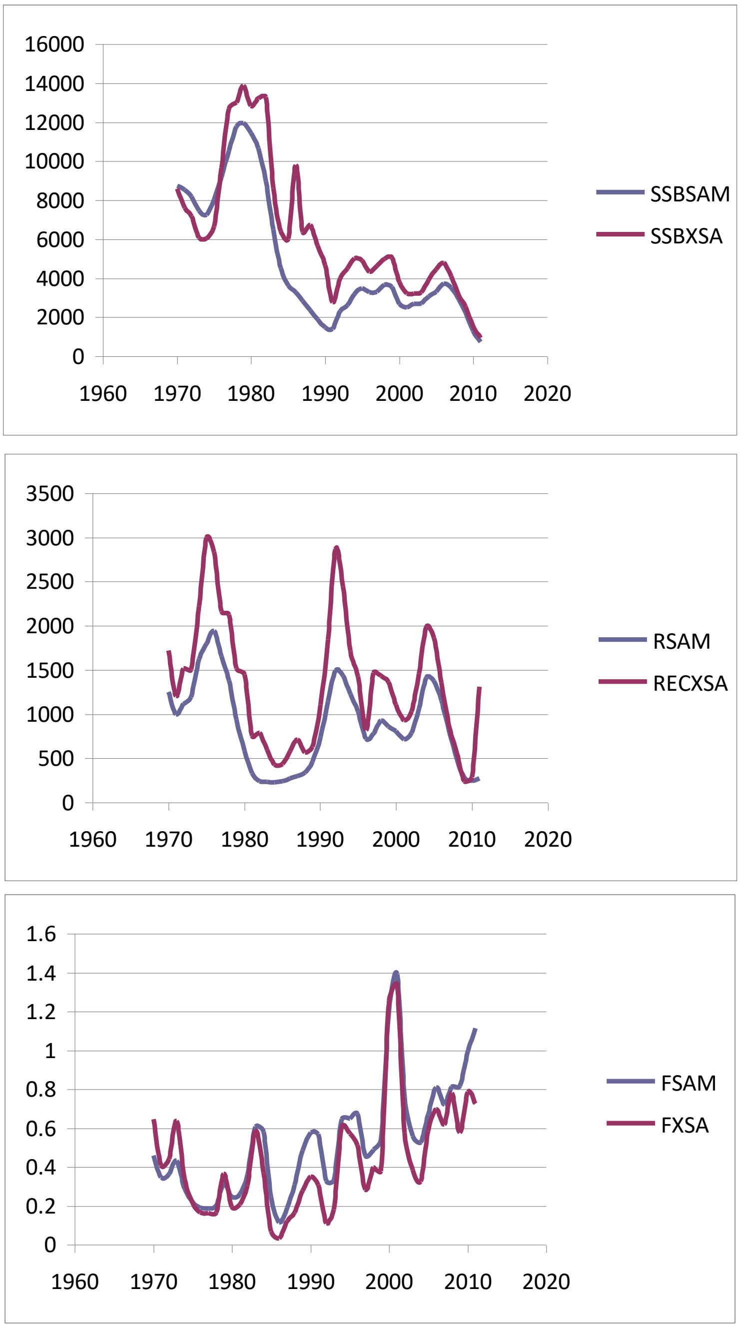


Fig. 32 – Trends in SSB, recruitment and fishing mortality according to SAM model and XSA.

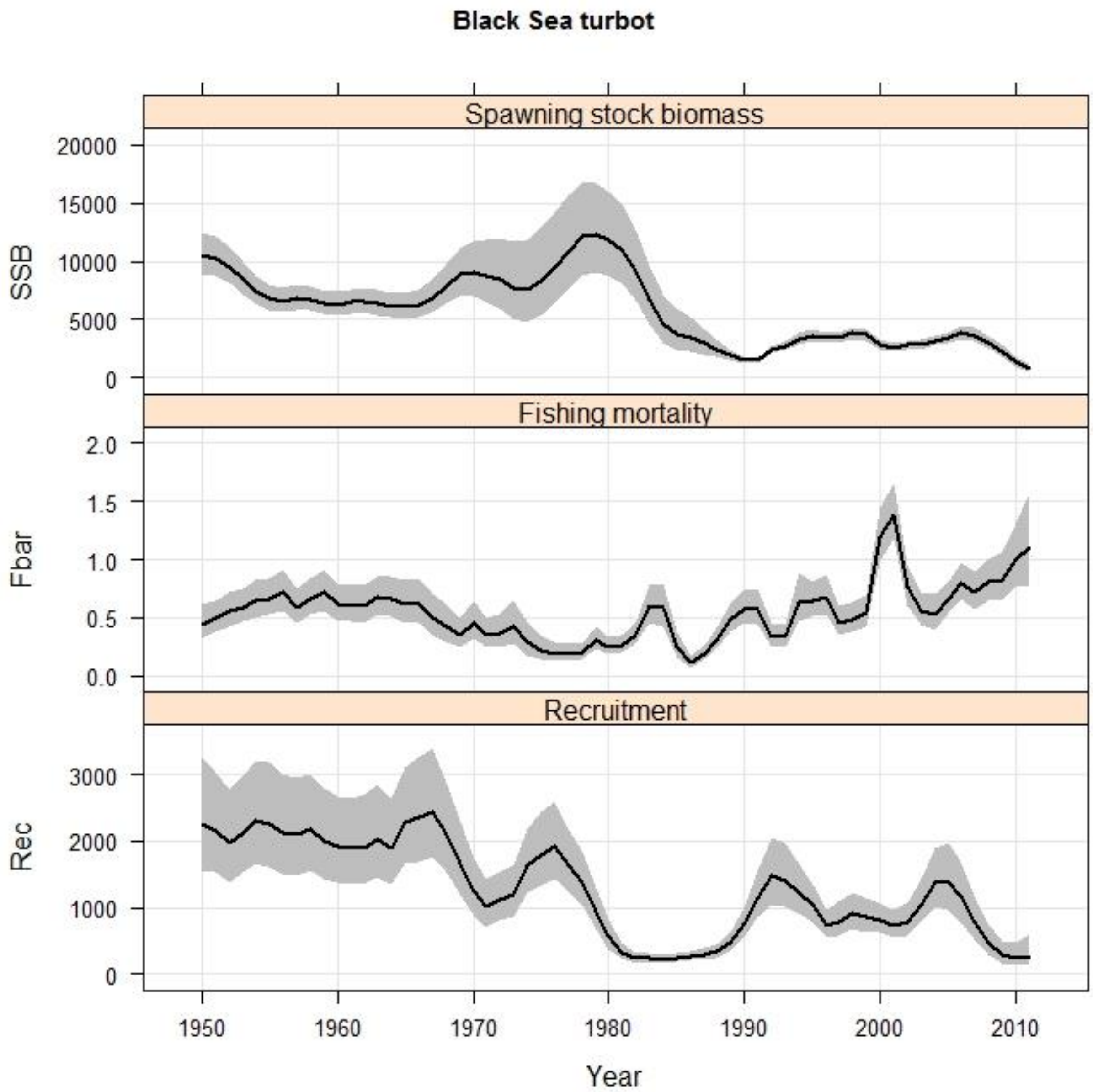


Fig. 33 – Time-series of turbot population estimates of total stock in the Black Sea (SAM model) including estimated IUU catches: recruitment, SSB and average fishing mortality (ages 4–8) with estimate of uncertainty.

The uncertainty of estimates of SSB, recruitment and fishing mortality are at acceptable levels (Figure 34).

The STECF EWG Black Sea 12-16 made qualitative assumptions about the IUU (Illegal, Unregulated and Unreported) fishing of turbot and estimated the Potential Unreported Catch in 2011.

Because of uncertainties about actual catch the STECF EWG Black Sea 12-16 interprets the assessment only in relative terms – i.e. they are considered indicative of trends only.

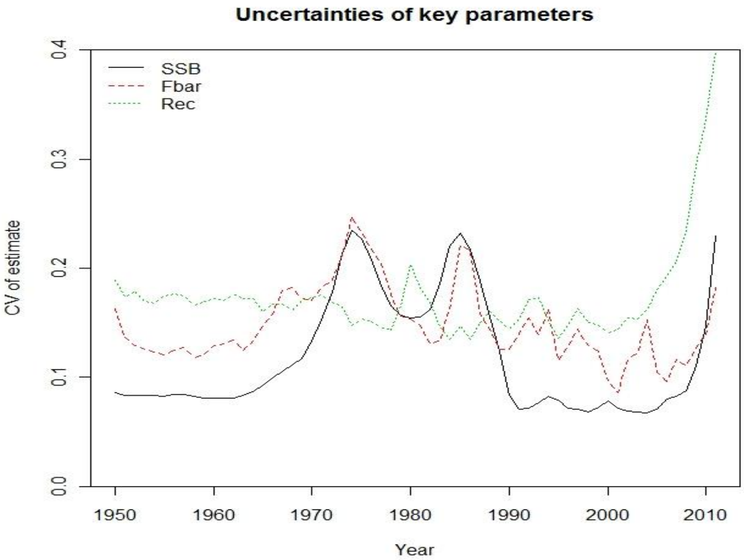


Fig. 34 – Uncertainties of key parameters

10. PREDICTION MODELS

These models are applied to predict future yields and biomasses and are similar to those used in virtual population analysis and cohort analysis. The mathematical formulas used for VPA can be transformed in such a way that the knowledge of the past can be used to forecast future yields and biomass at different level of fishing effort.

The first prediction models were developed in the thirties by Thomson and Bell (1934). However due to the high number of calculations required their model did not reach high popularity until the introduction of computers. A simpler model requiring less calculations was developed by Beverton and Holt (1957) but now it has been replaced by Thomson and Bell model where in places where VPA are being applied. The final purpose of the predictive models is to provide the responsible for management of fishery resources with information on the biological and economical effect of fishing on the stocks.

Regarding the final goal of the models, the Thomson and Bell model has just the opposite functions of VPA and cohort analysis. It is used to forecast the effects of changes in the fishing effort on future yields while VPA and cohort analysis are used to determine the numbers of fish that must have been present in the sea to account for a known sustained catch and the fishing effort that must have been expended on each age or length group to obtain the numbers caught. Therefore, VPA and cohort analysis are called historic or retrospective models, although they also could be applied to predict the yield in the future years, while Thomson and Bell model is a predictive model.

1. Age-based Thomson and Bell model (1934).

The application of Thomson and Bell model includes two main steps:

- provision of basic and optional inputs;
- calculation of outputs and their transforming in a form of prediction of future yields, biomass and even cost price of future yields.

Provision of inputs: The main input is the so called "reference F-at-age-array" i.e. an array of F values for each age group. In principle any recommended value of F (F-array) could be used as input but not any F-array will give results that reflect the real situation of a fishery. Thus it is usual using an F-array that has been obtained from historical data analysis. Other sources also could be used in this respect as well. Another important input parameter is the number of recruits which may also be obtained from VPA or cohort analysis. This parameter is needed to predict the yields in absolute quantities. If this input is not available the model still can be used to provide relative figures as output.

The model requires a "weight-at-age array', the weights of individual fish per age group. For economical analysis the model also requires inputs of values in the form of the price per kilogram by age group, etc.

Outputs: The output of the model is in the form of predictions of: the catch in numbers, the total number of deaths, the yield, the mean biomass and the value, all of them per age group, related to values of F for each age group. New values of F can be obtained by multiplying the reference F-array by a certain factor, usually called X or by applying such factors only to a part of the reference F-array.

An important characteristics of the model is that it allows for the incorporation of the catch value. Thus the model has become the basis for the development of the so called bio-economic models which are very useful for the ensuring of predictions needed for managements decisions.

2. Age-based Thomson and Bell model including X (F-factor)

2.1. Estimation of the population number at the beginning of the period.

$I = (t_i, t_i + \Delta t)$ age interval where

t_i is start of the interval;
$t_i + \Delta_t$ is the end of the interval

$$N(t_i + \Delta t) = N(t_i).\exp(-Z_{i.}\Delta_t)$$

2.2 Estimation of the total number of deaths in each period.

Zi = M + X.Fi

2.3. Estimation of the number caught in each period.

$$C_i = [N(t_i) - N(t_i + \Delta t)].X.F_i/Z_{i\,,}$$

2.4. Estimation of the yield in weight in each period.

$$\bar{Y}_i = \bar{C}_i.\bar{W}_i,$$
$$\bar{W}_i = W(t_i + \Delta t/2)$$

2.5. Estimation of the mean biomass in each period.

$\bar{B}_i = Y_i/(F_i.\Delta t.X)$ It is obtained from:

$$C = F.\Delta t.\bar{N}$$
$$Y = F.\Delta t.\bar{B}$$
$$\bar{B} = Y/(F.\Delta t)$$

2.6. Estimation of value of yield in each period

$$V_i = Y_i.\bar{V}$$

2.7. Estimation of mean biomass and total yield in the whole period

$$\bar{B} = \sum_{t=1}^{12} [\bar{B}(t).\Delta t] \Big/ \sum_{t=1}^{12} \Delta t$$

3. Length-based Thomson and Bell model

This model takes its input data from Jones' cohort analysis. The inputs are: the fishing mortality by length group, the F-at-length array, the number of fish in the smallest length group, growth parameter K and the natural mortality factor H by length group which must be the same as those used in the cohort analysis. Additional inputs are the parameters of length- weight relationship.

The outputs are the same as for the age-based model i.e. for each length group: the number of fish in the lower limit of length group $N(L1)$; the catch in numbers; the yield in weight; the biomass multiplied by Δt i.e the time needed to grow from length $L1$ to $L2$. Finally, the totals of the catch, the yield, mean biomass $*\Delta t$ are obtained.

The calculations are repeated for a range of X-values (F-array) and final results are plotted in graphs. The formulas can be derived from those used in Jones' length - based cohort analysis:

$$C(L_1,L_2) = [N(L_1) - N(L_2)].\frac{F(L_1,L_2)}{Z(L_1,L_2)}$$

$$N(L_1) = \left[N(L_2).H(L_1,L_2) + \frac{N(L_1)-N(L_2)}{Z(L_1,L_2)}.F(L_1,L_2)\right].H(L_1,L_2)$$

where $H(L_1,L_2) = \left(\frac{L_\infty - L_1}{L_\infty - L_2}\right)^{M/2k}$

Solving this equation with respect to $N(L_2)$ gives:

$$N(L_2) = N(L_1).\frac{1/H(L_1,L_2) - F(L_1,L_2)/Z(L_1,L_2)}{H(L_1,L_2) - F(L_1,L_2)/Z(L_1,L_2)}$$

In order to calculate the yield (catch in weight) by length groups the catch, C (in numbers), has to be multiplied by the mean weight of the corresponding length group $(L1, L2)$:

$$\bar{W}(L_1,L_2) = q\left(\frac{L_1 + L_2}{2}\right)^b,$$

where q and b are parameters in the length-weight relationship.

The yield of this length group is given by:

$$Y(L_1,L_2) = C(L_1,L_2).\bar{W}(L_1,L_2)$$

During the time $\Delta t(L_1,L_2)$ that it takes a cohort to grow from L1 to L2 the number of survivors decreases from $N(L1)$ to $N(L2)$. The mean number of survivors of that length group is calculated as follows:

$$\bar{N}(L_1,L_2).\Delta t(L_1,L_2) = [N(L_1) - N(L_2)]/Z(L_1,L_2)$$

The corresponding mean biomass multiplied by Δt is:

$$\overline{B}(L_1,L_2).\Delta t(L_1,L_2) = \overline{N}(L_1,L_2).\Delta t(L_1,L_2).\overline{W}(L_1,L_2)$$

The annual yield in weight is the sum of the yield of all length groups:

$$Y=\Sigma Y_i$$

$$\overline{B} = \sum \overline{B}_i.\Delta t_i$$

is an estimate of the average biomass during the life span of a cohort or of all cohorts during a year.

4. Length-based Thomson and Bell model including X (F-factor)

Length interval is $i = (L_i, L_{i+1})$ - the index L_i is the lower limit of length interval, while the index L_{i+1} refers to the upper limit.

$$Z_i = M + X.F_i$$

$$N(L_{i+1}) = N(L_i).\frac{1/H_i - X.F_i/Z_i}{H_i - X.F_i/Z_i}$$

$$H_i = \left[\frac{L_\infty - L_i}{L_\infty - L_{i+1}}\right]^{M/2K}$$

where

$$C_i = [N(L_i) - N(L_{i+1})].X.F_i/Z_i$$

$$\overline{W}_i = q.[(L_i + L_{i+1})/2]^b$$

$$Y_i = C_i.\overline{W}_i$$

$$V_i = Y_i.\overline{v}_i$$

$$\overline{N}_i.\Delta t_i = [N(L_i) - N(L_{i+1})]/Z_i$$

$$\overline{B}_i.\Delta t_i = \overline{N}_i.\Delta t_i.\overline{W}_i$$

As an example of the practical application of the method we present the results of Turkish studies for the Black Sea anchovy (fishing seasons 1996/1997 and 1997/1998). Length structured cohort analysis (LCA) was used to obtain fishing mortalities per length class and to understand the impact of fishing on the anchovy stock as well as the MSY by the Thompson and Bell method (Sparre and Venema, 1992). In the length based Thomson and Bell analysis, the used some input parameters;

In 1996/97

$\overline{W}$ = 6.59 g, L_∞= 17.00 cm, K= 0.31, M= 0.56, t_o= -2.16, a= 0.0073, b=2.903

method $_{\text{(first length group)}}$=73277

In 1997/98

$\overline{W}$ = 7.89 g, L_∞= 15.57 cm, K= 0.417, M= 0.67, t_o= -1,826, a= 0.00055, b= 3.027

$N_{\text{(first length group)}}$=52155

Outputs;

In 1996/97

F-factor=1.32; MSY=155542 ton

F-factor=0.75; MSE=10,5 10^{12} TL

In 1997/98

F-factor=1.63; MSY=104920 ton

F-factor=0.75; MSE=18,5 10^{12} TL

The exploitation of *anchovy* along the South-eastern Black Sea coast had not reached the MSY. MSY was achieved at an F-factor of 1.32 taking present fishing level as 1.10 in 1996/97. But MSE was reached at F=0.75 and F=1.45 level in 1996/97 and 1997/98 respectively (Fig. 35). The present study shows that the current exploitation is well below the MSY level.

Since the length-based Thomson and Bell analysis is derived from Jones' length-based cohort analysis which in turn is based on Pope's age-based cohort analysis the length-based Thomson and Bell method has the same limitations as Pope's age-based cohort analysis.

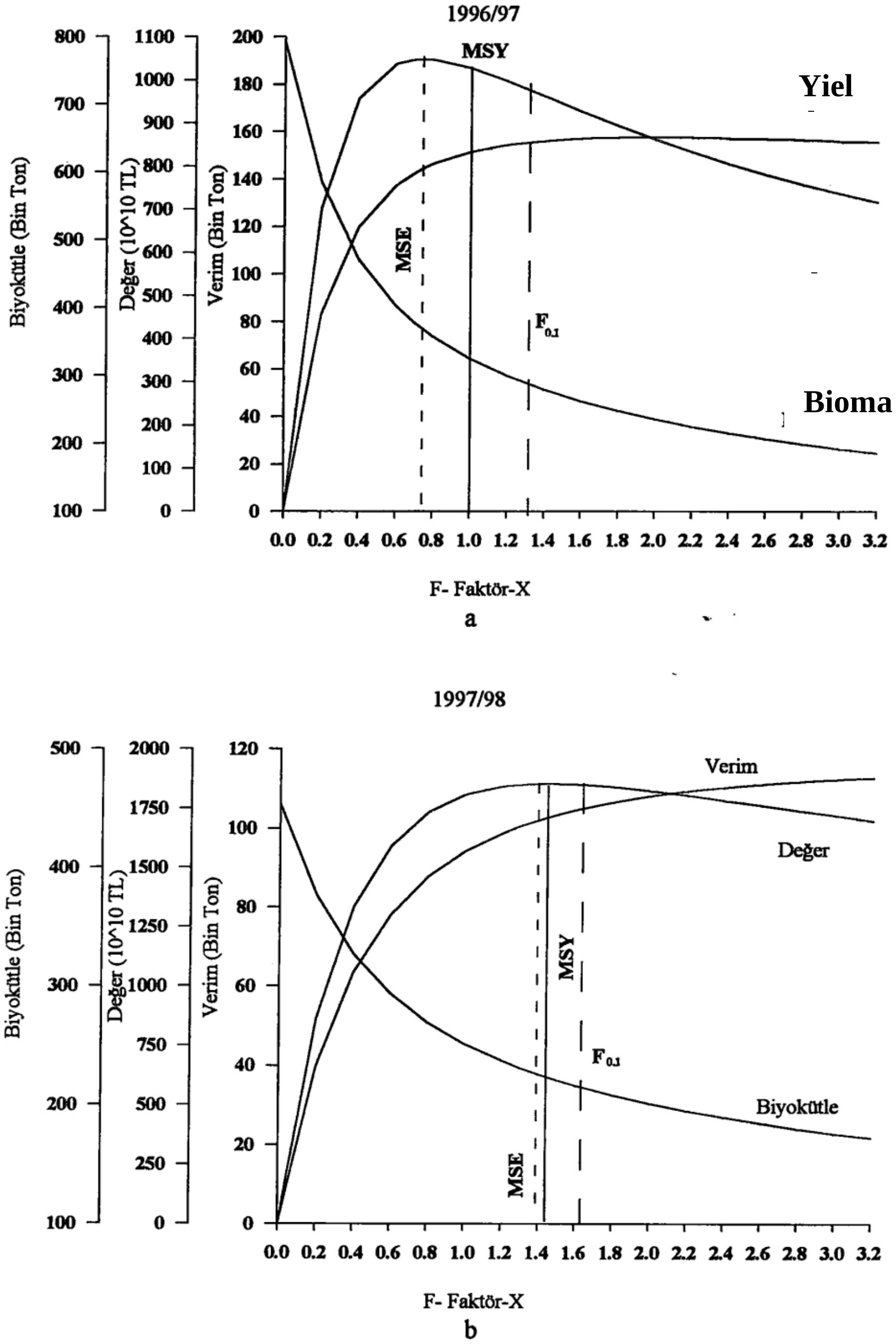


Fig 35 – Thomson and Bell prediction analysis for the Black Sea anchovy in Turkish waters.

The exploitation of *anchovy* along the South-eastern Black Sea coast had not reached the MSY. MSY was achieved at an F-factor of 1.32 taking present fishing level as 1.10 in 1996/97. But MSE was reached at F=0.75 and F=1.45 level in 1996/97 and

1997/98 respectively (Fig. 35). The present study shows that the current exploitation is well below the MSY level.

The important role in TAC assessment plays the forecast of stock value in advance time 1-3 years. The most common approach to such a forecast is estimation of initial (terminal) stock size under the influence of natural and fishery mortality according to Baranov's equation [32] and its increase due to new generations entering the fishery. At the same time mortality coefficients and the size of recruitment are either given (for example, by «status quo» principle), or calculated (recruitment can be estimated according to the «stock-recruitment» dependence). Such calculation scheme is direct in contrast with the opposite one used in VPA; after the calculations according to the inverse scheme, the direct scheme algorithms are used applied.

The fish stock estimation system using holistic methods developed in YugNIRO helped to design analytical models of commercial populations, where only the direct calculation scheme is realized starting from the initial stock according to surveys data (trawl, lampara, hydroacoustic). In contrast with biostatic models they gave possibility of low exploited stock estimation and didn't depend on the distortion and incompleteness of statistic data. Some YugNIRO designs that allow estimated of exploited fish stocks, are given below.

5. Whiting fishery population model – Ricker's modified model (Shlyakhov et al, 1983).

Whiting population is referred to 1A type according to Ricker's classification (Ricker, 1975). Number of fish population ($N_{i,j}$) and possible catches ($C_{i,j}$) of each age, also recruitment rate ($N_{i,2} = R_i$) in year I, are calculated through:

$$N_{i+1,j+1} = N_{i,j} \cdot (1 - u_{i,j}) \cdot S_{i-1,j-1},$$

$$C_{i,j} = u_{i,j} \cdot N_{i,j} \,,$$

$$N_{i,2} = R_i = \alpha P_{i-3} \cdot \exp[-\delta P_{i-3} \cdot (1 - u_{i-3})] \,,$$

$$b_j = \sum_{J=2}^{n} N_{i,j} \cdot (1 - u_{i,j}) \,, \qquad [53]$$

Where – $u_{i,j}$ is exploitation coefficient (is usually given);
$\alpha = 8{,}55$ и $\delta = 1{,}21$ – Ricker's reproduction equation parameters,
$S_{i,j}$ –survival rate, which equals ($a_j - b_j \cdot P_{i-1}$), coefficients a_j and b_j are found for each age from the linear regression equations (survival of fish in age j and year i according to the trawl surveys on the stock abundance in the year $i - 1$ according to the trawl survey), their data is given in table 26.

Table 26 – Coefficients a_j and b_j, which characterized "stock-survival" dependence of whiting in Black Sea by age groups j (from Shlyakhov, 1986)

Survival coefficients	j, years					
	2	3	4	5	6	7
a_j	0,6107	0,5011	0,3886	0,6134	0,6632	0,7636
b_j	0,1029	0,0808	0,0752	0,1264	0,1174	0,1265

Average mass of individuals by age groups, assessed according to Bertalanffy equation, is used for transition to weight indices of a stock.

As input information, assessments of $N_{i,\,j}$ for three consecutive years according to the data of trawl surveys (theoretically, any assessments of generation size, for example, from VPA, can be used) are used, and also operation coefficients that can be permanent or variable for all ages and fishing years during the period, for which the calculation are done (direct calculation for 5 years forward from a terminal year). Modified Ricker model is implemented in the YugNIRO (program "MODEL" for IBM) and was used for whiting stock assessment to 2002 (Shlyakhov, Charova, 2003).

6. Model of commercial population of picked dogfish is a combination of Baranov model and empirical model of reproduction (Kirnosova, Shlyakhov, 1988).

In the model of isolated commercial population of picked dogfish attributed to 1B type by the Ricker classification (Ricker, 1975), natural mortality is set in the form of instantaneous coefficients M_j , which are invariable from one fishing year to another and differentiated by ages for males and females separately. Values M_j are calculated according to the data referring to the pre-fishing period, including the data of trawl surveys, and represent the values averaged for the period (Kirnosova, 1990). Constitutive model equations for each gender can be put down as follows

$$N_{i+1,j+1}= \varphi_j \cdot N_{i,j} \cdot \exp[-(M_j + F_{i,j})] + (1 - \varphi_j) \cdot N_{i,j} \cdot \exp\text{-}M_j,$$

$$C_{i,j} = N_{i-1,j} \cdot \varphi_j \cdot \{F_{i,j} \cdot [1 - \exp\text{-}(M_j + F_{i,j})]\} / (M_j + F_{i,j})$$

$$R_{i+1}= 0.5 \cdot 0.84 \cdot \sum_{j=10}^{j=19} 14 \cdot N_{i-1,j} \cdot \exp[(-0.75 \cdot (M_j + F_{i,j})] \cdot n_j, \qquad [54]$$

where i, j – the indices of fishing year and age (commercial part of a stock is formed by the fish aged from 10 to 19 years);

n_j – portion of mature females in the age j;

φ_j – partial fishing replenishment in the age j;

0.5 – portion of males/females in population;
0.75 – time interval from the start of the calendar year to the period of mass breeding season (September-October), years;
0.84 – the survival rate of juveniles from birth to the start of the next calendar year;
14 – average breeding power of females.

Average mass of individuals by age groups, assessed according to Bertalanffy equation, is used for transition to weight indices of a stock.

As input information, assessments of $N_{i, j}$ in terminal year according to the data of trawl surveys (theoretically, any assessments of generation size, for example, from VPA, can be used) are used, and also the coefficients of fishing mortality F. They can be permanent or variable for all ages and fishing years during the period, for which the calculation are done (direct calculation for 6-7 years forward from a terminal year). The model is implemented in the YugNIRO (program "KATRAN" for IBM) and was used for whiting stock assessment to 2009.

7. Stock assessment by the modified Baranov model.

The constitutive model equation for fish quantity assessment is of the form:

$$N_{i+1,j+1}= N_{i,j} \cdot (\exp\text{-}M_{i,j}) \cdot (1 - u_{i,j}), \qquad [55]$$

where $M_{i,j}$ and $u_{i,}$ are the coefficients of natural mortality and exploitation respectively (are set as constant variables).

As input information, assessments of $N_{i, j}$ in a terminal year according to the data of trawling surveys are used, and are re-established by means of division by the coefficient of partial replenishment for the ages represented incompletely. Average mass of individuals by age groups, assessed empirically or according to Bertalanffy equation, is used for transition to weight indices of a stock.

As input information, assessments of $N_{i, j}$ in a terminal year according to the data of trawling surveys (theoretically, any assessments of generation size, for example, from VPA, can be used) are used, and also the exploitation coefficients u. The simplicity of the method allows using Microsoft Excel aids. This method is used for the stock assessment of turbot and other fish species, usually for 2-3 years following a terminal year. As an example, a summary table of turbot stock assessment in 2006-2007 is given (Table 27).

Table 27 – Turbot stock assessments in the Ukrainian sector of the Black Sea in 2006-2007 according to the modified Baranov model

j, years	$W_{av.}$, kg	M	u	Terminal year			Fishing year, i			
				2005			2006		2007	
				$N_{i,j}$	$N_{i,j}$ reconstruct	$B_{i,j}$	$N_{i,j}$	$B_{i,j}$	$N_{i,j}$	$B_{i,j}$
3	1,0	0,15	-	0,0264	0,1759	0,004	0,1759	0,026	0,1759	0,0264
4	1,6	0,20	0,06	0,2370	0,7404	0,379	0,1423	0,073	0,1423	0,0729
5	2,8	0,25	0,06	1,1042	2,1077	3,092	0,5698	0,836	0,1042	0,2918
6	3,3	0,30	0,06	0,8713	0,8713	2,875	1,5430	5,092	0,3968	1,3095
7	4,0	0,35	0,06	0,4067	0,4067	1,627	0,6068	2,427	1,0745	4,2979
8	4,8	0,40	0,06	0,2836	0,2836	1,361	0,1879	0,902	0,4019	1,9292
9	5,9	0,45	0,06	0,0654	0,0654	0,386	0,1787	1,054	0,1184	0,6985
10	7,6	0,50	0,06	0,0861	0,0861	0,654	0,0392	0,298	0,1071	0,8141
11	9,0	0,55	0,06				0,0491	0,442	0,0223	0,2010
12	12,2		0,06						0,0266	0,3248
Σ_{3-11}	-	-	-	3,1		10,378		11,150		10,0

8. Two- species dynamic model of interacted population of whiting and picked dogfish (Shlyakhov et al, 1995).

Whiting and picked dogfish are closely connected by trophic relationships in the Black Sea. The analysis results of retrospective materials show that there exists an inverse relation between $M_{i,j}$ coefficient of picked dogfish and total stock B_i of whiting, that is approximated by the equation of the form $y = cx/(c+dx)$, where $y = M_{i,j}$; $x = B_i$.

On the basis of models of commercial population of those fish species (see above), the main calculated expressions of two-species model are presented in the from of modification of the equations of basic models (Shlyakhov, Korshunova, Galuzo, 1983, Kirnosova, Shlyakhov, Pronenko, 1986), as:

$$N^*_{i+1,j+1} = N^*_{i,j} \cdot \exp[cB^{**}_i/(c + dB^{**}_i) + F^*_{i,j}];$$

$$R^*_{i,o} = \sum_{j=10}^{j=19} 14 \cdot N^*_{i-1,j} \cdot \exp\{-0.75 \cdot [cB^{**}_i / (c+dB^{**}_i)] + F^*_{i,j} \cdot n^*_j \cdot 0.8437];$$

$$N^{**}_{i+1,j+1} = N^{**}_{i,j} \cdot (1 - u^{**}_i) \cdot [a_j - (2 - A^*_i / A^*_o)];$$

$$R^{**}_{i,2} = a`P^{**}_{i-3} \cdot (1 - u^{**}_{i-3}) \exp[-b`P^{**}_{i-3} \cdot (1 - u^{**}_{i-3})] , \quad [56]$$

where F – instantaneous coefficient of fishing mortality;

A – SSB of picked dogfish

B – total stock biomass of whiting;

R – recruitment (in the age of fingerlings for picked dogfish, two-yearlings for whiting);

n – portion of mature females in the age j;

u – exploitation coefficient (coefficients of diminution);

a` and b`– Ricker stock-recruitment equation coefficients;

a, b, c, d – dimensionless coefficients;

* – the symbol indicating belonging of index to picked dogfish population;

** – the symbol of whiting indices;

i – fishing year index, j – age group index.

The tuning of the model consisted in determination of values u^{**}_i, by which the minimization of functional is achieved:

$$\sum_{i=1}^{k} [(A^*_i - A\hat{}^*_i)^2 + (P_w^{**}i - P\hat{}_w^{**}i)^2] , \qquad [57]$$

where P_w^{**} is a stock of whiting in weight (thousand tons); k is a number of observation years taken into account by tuning; ^ is the symbol for stock assessments done according to the assessment survey data.

As values $A\hat{}^*_i$ and $P\hat{}_w{}^{**}_i$ the published estimates according to the data of assessment trawl surveys (Shlyakhov, 1986; Kirnosova, Shlyakhov, 1988), and starting values u^{**}_i are set as ratio of Black Sea whiting catch according to FAO statistics to the respective direct assessments of its stock done according to the trawl survey data. Tuning was executed with the use of iteration method: corrected values of operation coefficient $u`^{**}_i$ were determined on each step by formula:

$$u`^{**}_i = u^{**}_i \cdot P\hat{}_w{}^{**}_i / P_w{}^{**}_i \ , \qquad [58]$$

The results in Table 28 estimates P_w^{**} and A^* were obtained on the basis of calculations of the input data of the status of stocks of whiting and dogfish in 1979, and in fact are predicted with a lead time from 1 year to 6 years

Stocks of whiting and picked dogfish were assessed with the use of this method on the Black Sea shelf from Batumi to the Danube mouth in 1986-1994 (Shlyakhov, 1997).

Table 28 – The dynamics of the Black Sea whiting and picked dogfish stocks according simulation on Two- species models, tons *

Species	The estimated characteristics of the stock and fishery diminution	Year					
		1980	1981	1982	1983	1984	1985
Whiting	$P_w{**}_i$ by simulation	47	37	50	122	158	114
	$P\^_w{**}_i$ by trawl surveys	25	24	66	92	105	77
	$u{**}_i$ (coefficient of diminution)	0.0037	0.0050	0.0455	0.0038	0.0039	0.0040
Dogfish	$A{*}_i$ by simulation	36.9	37.6	37.5	37.3	37.1	38.1
	$A\^{*}_i$ by trawl surveys	37.5	40.4	39.8	42.0	44.7	42.0

* Note: the terminal year were 1979; the value $A\^{*}_i$ are given to medium sized of survey area 44.2 square kilometers

11. THE TOTAL ALLOWABLE CATCH AND REFERENT POINTS

Total Allowable Catch (TAC) is generally accepted fishery regulation parameter. TAC is set for each of the major target species, and the amount of fish that may be taken in a fishing year is not exceeded in the year.

Effective strategies are in place to ensure that stocks of any depleted fish resources are being rebuilt. The catch of non-target species is reduced to a level that will allow stocks of the species to be maintained at ecologically-sustainable levels.

As overwhelming majority of the exploited populations of the Azov-Black Sea fishes are regarded as shared, i.e. inhabiting (or migrating) in the waters under the jurisdiction of more than one coastal state, it is extremely critical to take agreed among all the countries of the region actions for conservation and management of marine fish resources. However fisheries management at the regional level is still absent in the Black Sea, it is carried out independently by each riparian State on the basis of national legislation. That's why TAC is still not a tool of fisheries management in Turkey and

"STECF is unable to advise on a specific EU TAC for sprat, anchovy or whiting" (Daskalov et al, 2012).

In this section, we will touch upon the existing modern practices of establishing TAC in the Black Sea region, as well as the use in these practices the reference points.

Traditional approach to TAC assessment is based on equal intensity of stock exploitation in all its possible conditions. With this approach, the fishing intensity is calculated taking into account the long-term goals of stock usage and equilibrium dependence of the stock productivity on its exploitation level. В качестве целевого ориентира управления первоначально использовали значения промысловой смертности F_{max}, F_{MSY} (или соответствующие значения промыслового усилия f), которые соответствовали теоретически максимальной устойчивой продуктивности запаса. Позднее стали применять более щадящие критерии $F_{0.1}$ и $f_{0.1}$.

Precautionary approach as a management objective includes: "irreversible or long-term adverse effects on fisheries and the marine environment are avoided" (Garcia and Mace 1999). The philosophy of the precautionary approach includes four important principles (Babayan, 2000):

1. Prevention or minimization of the risk of damage to exploited stocks and aquatic ecosystem;
2. The immediate adoption of agreed measures in the event of a real threat to the state of the stock or environment;
3. Accounting for uncertainty as a mandatory factor for fisheries management
4. Recovery of exploited stocks (including stocks associated and dependent species) to high levels of productivity and their subsequent maintenance at this level.

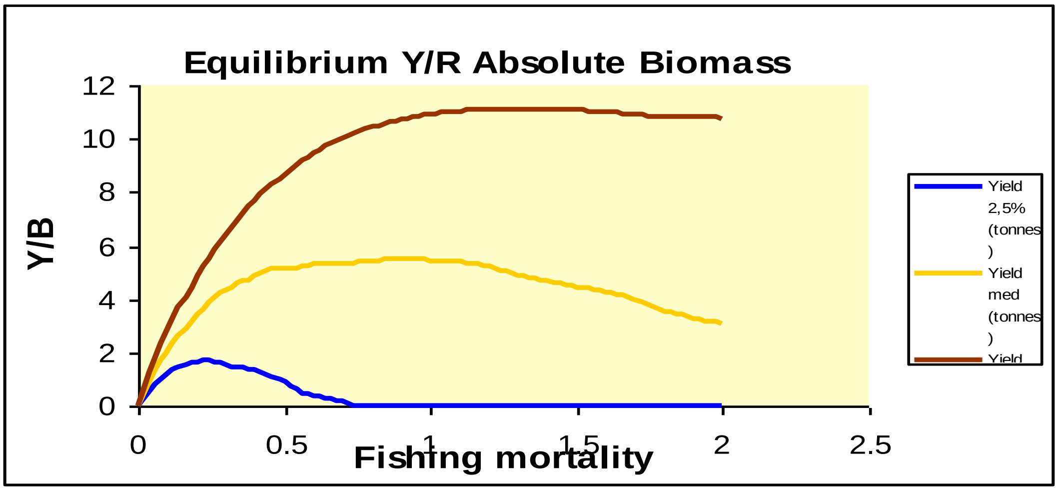
It is obvious that in the Black Sea in full view, this approach can be implemented only after the transition to the regional management of MLR. But some of its elements are already used as EWG STECF as well as at national levels.

Consider the current estimates of reference points for stock management sprat and turbot in the western part of the Black Sea by Bulgarian studies. Input parameters for Y/R analysis of sprat and turbot are given in the Table. 29.

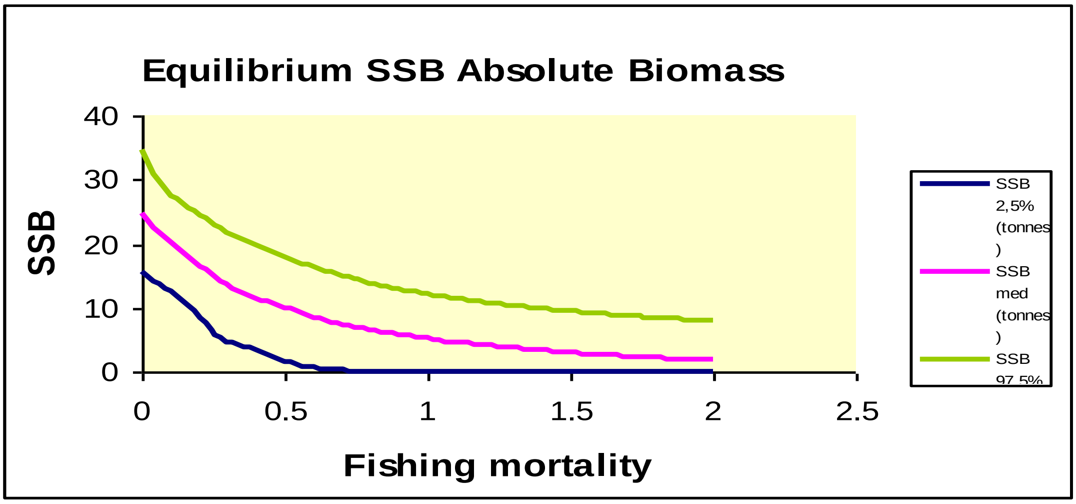
On Fig. 36, Yield-per-Recruit analysis in absolute values was presented. At present the level of fishing mortality (medium CI) is close to 1 and after this levels fraction Y/R continues to increase (medium and high CI) toward $F \geq 2$. The graphic show, that at mean values of the Y/R, reach its maximum or close to the $F_{med} = 1.02$ corresponding catch would be 5443.8 tons.

Table 29 – Input parameters for Y/R analysis of sprat and turbot (western part of the Black Sea)

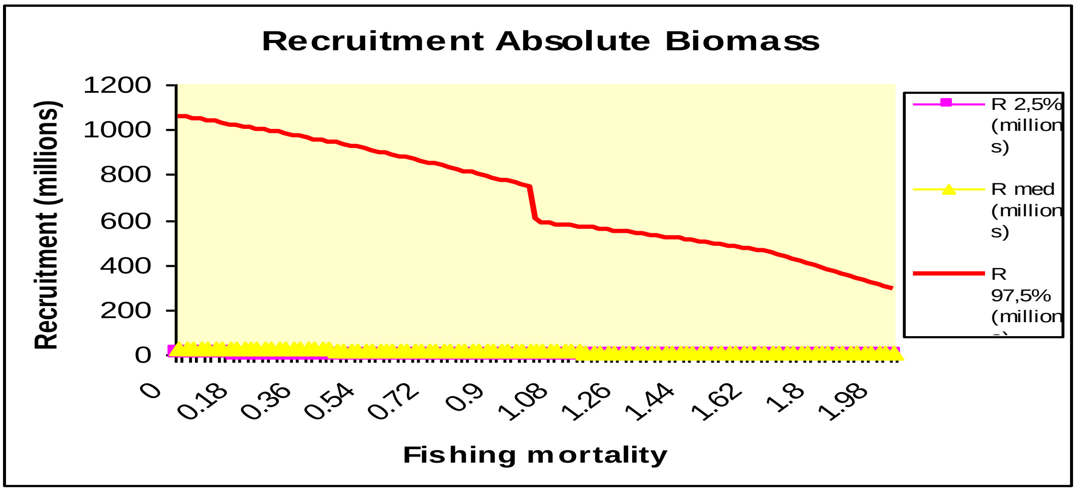
Input parameters	Species	
	Turbot	Sprat
L_∞	120.4	13.45
K	0.076	0.45
t_0	-2.811	-0.68
q (***A***)	0.00001	0.008
n (***B***)	3.129	2.85
M	0.25	0.95



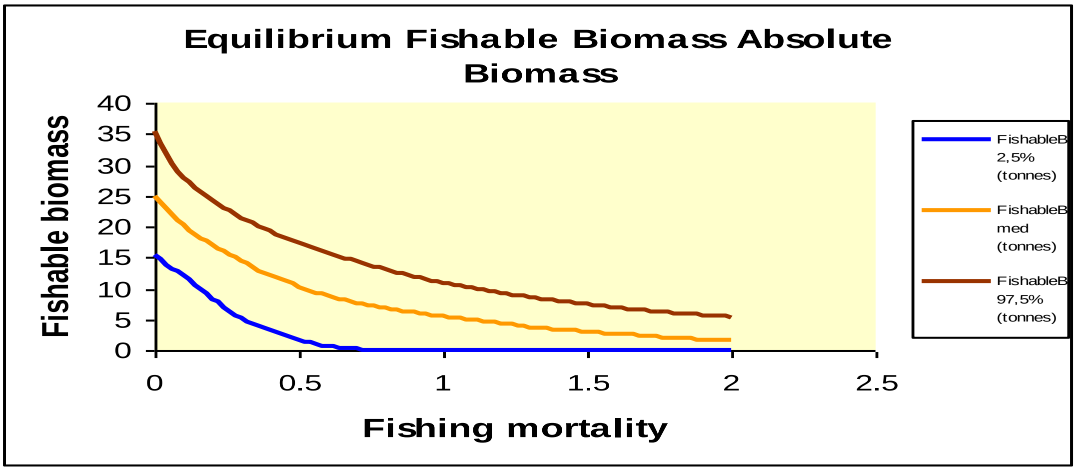
A



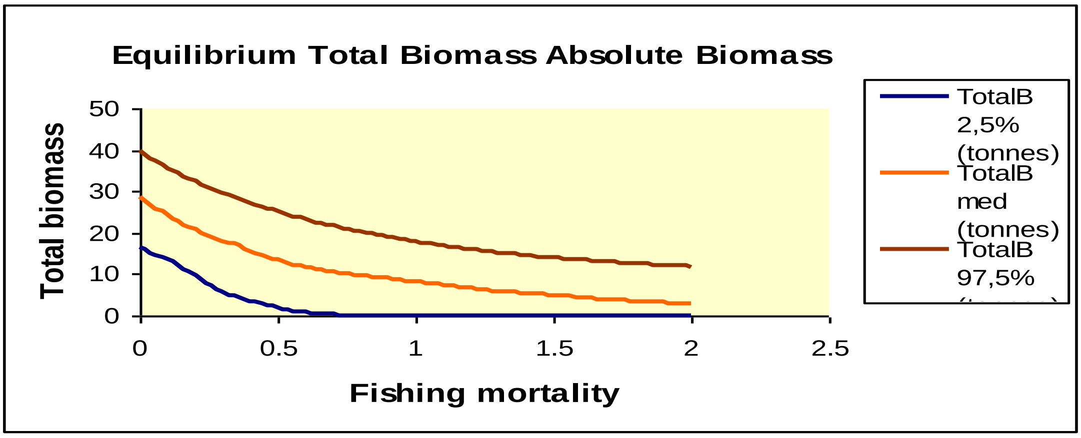
B



C



D



E

Fig 36 – Graphical representation of the equilibrium levels of exploitation with the corresponding CI.

The value of fishing mortality is very close to the value of the natural mortality coefficient – $M = 0.95$, which means that the stock is underexploited. Upper limit (CI 97.5%) for Y/R is still increasing to $F = 2.0$, since lower CI 2.5% could reach F maximum around 0.26. In this case, as it was shown on the graphic, the model suggest, that after this value (CI = 2.5%) the stock will collapse (Fig. 36, A). Mean levels of CI show that at F levels equal to 1.02 the relation between yield and fishable biomass at non-exploited state is around 0.25.

The increase of the fishing mortality after the 0.8 – 1.0 decrease the absolute yield (at mean values of the CI – med) and at $F \geq 0.5$, could lead to serious stock degradation (CI = 2.5%). From the Y/R analysis is evident that the levels of F which ensure yield per recruit at maximum (or close to the maximum) will decrease spawning stock biomass (Fig. 36, B) to the levels representing very tiny proportion from the non-exploited biomass (in the lack of any fishery).

The Y/R analysis show that the recruitment at CI 97.5% decreases, as some serious fall over the levels of $F = 1$ was observed (Fig.36, C).The absolute yield values at the corresponding CI and fishing mortality are as follows:

1. At (97.5% CI) $F_{opt} = 1.08$ possible catch: **11 017.4** (plateau follows and F_{max} determination is impossible);
2. At **med** CI $F_{opt} = 1.02$ possible catch would be **5 443.8** tons (yield decreasing follows under the levels of 4 thousand tons and in condition that F is increasing above 1.0);
3. At CI 2.5% $F_{opt} = 0.26$, possible catch is **1 654.4** tons. The trend of fishable and the total biomass are similar (Fig. 36, D). In all of the observed cases biomass decrease were observed connected with increasing the fishing mortality levels. In most of the cases the relation between SSB and recruitment, corresponding to $F_{0.1}$, exceeds 20% of its virgin state.

On Fig. 37, analysis of the optimum and maximum possible levels of fishing mortality levels turbot are presented. It is evident that range between F_{opt} and F_{max} are very close. This clearly speaks that exploitation patterns could easily lower the stock. The model does not accounts further stock decrease, but fishing mortality over 0.4 are undesirable at the present stock biomass. Yield per recruit at F_{opt} = 0.2 –173.67 tons; F_{max} = 0.27 - 182.581 tons.

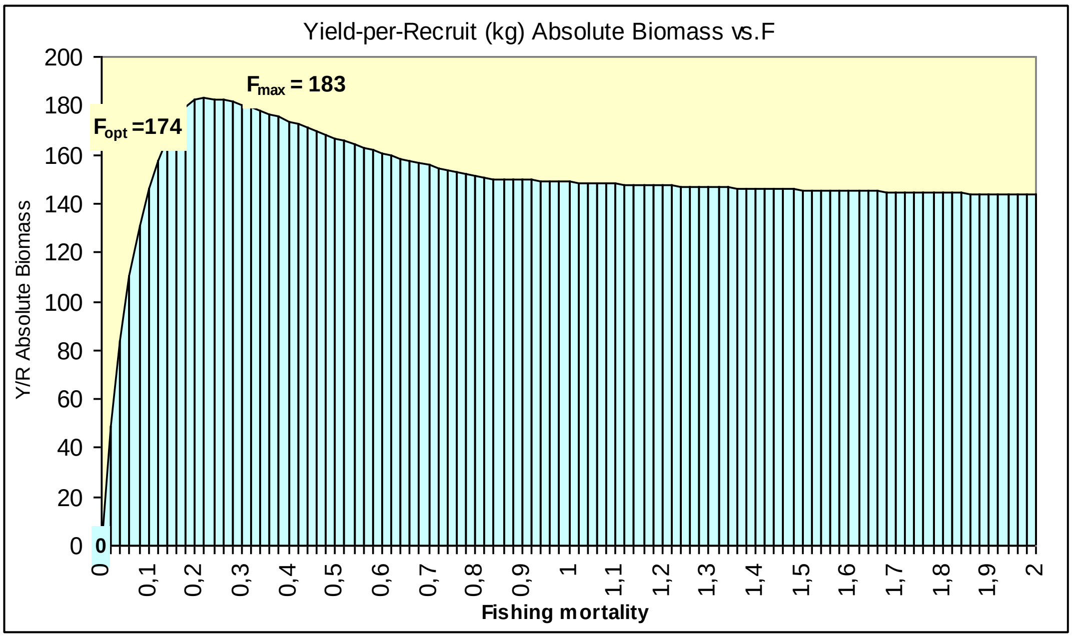
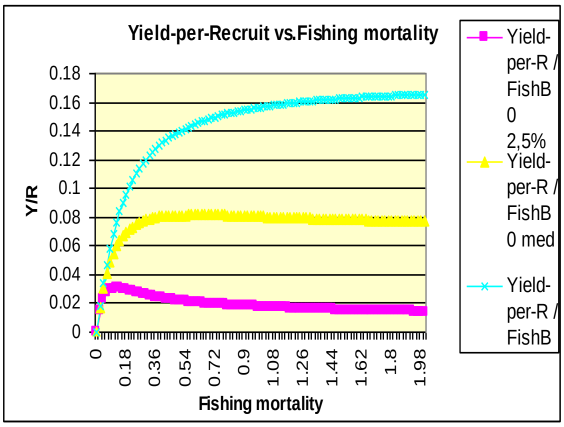
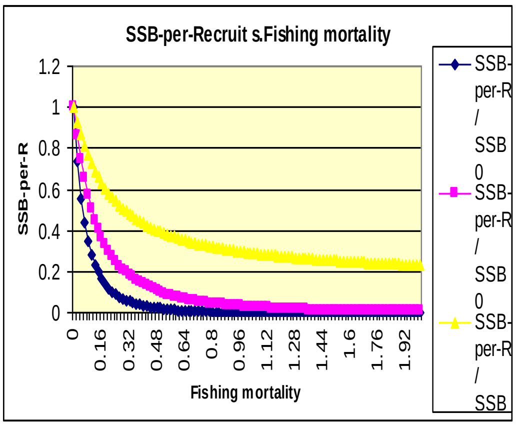


Fig 37 – Reference levels of turbot fishing mortality

On Figure 38 analysis of the equilibrium Yield-per-Recruit presented as fraction of unexploited biomass. The plot on fig.1 shows that the median Y/R, as a fraction of unexploited fishable biomass, reaches a maximum or close to one values of F above about 1.3. The value of F is at 4 times (M = 0.25), which is quite high value. The upper 97.5% confidence band for relative Y/R is still rising as F reaches 2.0, while the lower 2.5% confidence band may have reached a maximum for F somewhere around 1.1.From the Y/R analysis (Fig 38) it is clear that levels of F that produce Y/R at or near the maximum will also reduce the SSB to levels that are a tiny fraction of its unexploited level.





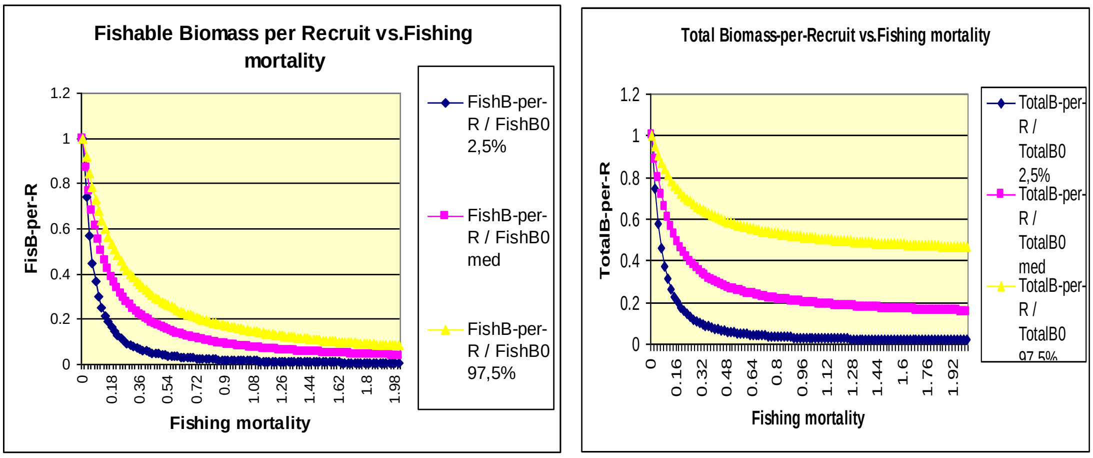


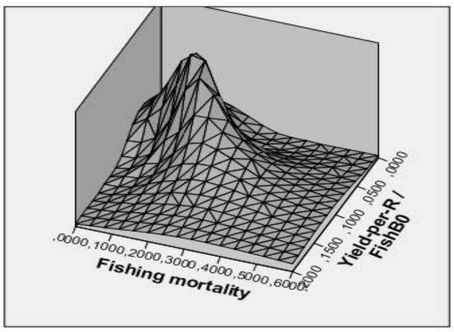
Fig 38 – Equilibrium state of the Yield per Recruit and other characteristics related from fishing mortality

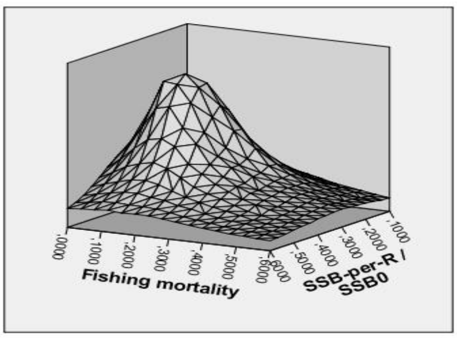
The Y/R analysis, assume that recruitment is unaffected regardless of how low SSB falls.

$F_{0.1}$ was used to set the optimum and maximum values for the fishing mortality rates. $F_{0.1}$ compared with the mean $M = 0.25$ is more sensible values of F.

In majority of cases SSB-per-Recruit corresponding to $F_{0.1}$ exceeds 20% of its unexploited level, a proportion often treated as one below which one would prefer not to fall. Determination values of F that produce a equilibrium SSB-per-Recruit that is 20% of its unexploited level.

On Figure 39 some important relations between Fishing mortality and Yield – per-Recruit/Fishable biomass at virgin state, SSB-per-recruit/SSS biomass at virgin state Fishable and Total biomass-per-Recruit/Fishable, respectively Total Biomass at virgin state are presented. It is evident that F_{opt}, according proposed candidate reference point is around 0.20, corresponding to the relatively low levels of the presented stock parameters, presented in relative terms (Fig.39).





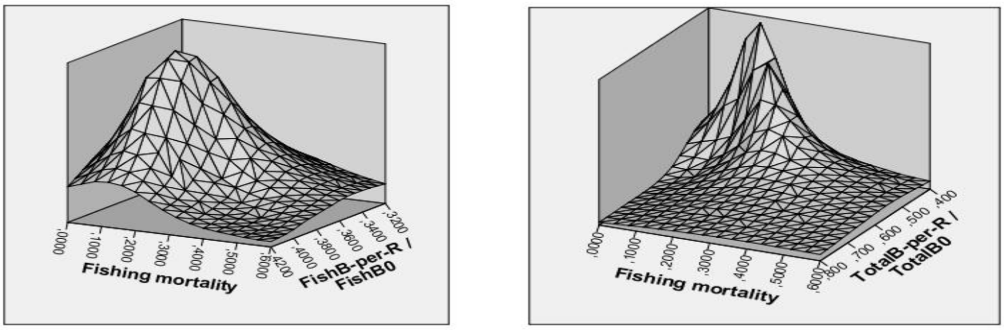


Fig 39 – $F_{0.1}$ criterion estimation related to parameters of the stock in relative terms

Another candidate reference point, which appears more restrictive, as regards exploitation over examined stock is $F_{0.x}$ ($F_{0.2}$). According it (Fig.40) , the fishing mortality should be lowered at levels between 0.10-0.15 regarding of Yield-per-Recruit/FishB0 and SSB-per-Recruit/SSB0 sustainability. For FishB-per-Recruit/FishB0 and TotalB-per-recruit/TotalB0 the simulation evokes even lower levels of fishing mortality.

Projections of the SSB/SSB0 are presented on Fig.41. First panel (A) show 10 years exploitation at $F = 0.2$, then lowering at $F = 0.1$ and SSB/SSB0 at 97.5% CI after pronounced decrease, a clear trend of increasing the relative SSB was observed.

On second panel (B), at CI 97.5%, the relative SSB decrease at $F = 0.2$; Exploitation at levels of $F = 0.3$ for 10 years lead to steep decrease in the relation SSB/SSB_0.

Following the method proposed by (Prodanov and Kolarov, 1983) suggested that at present stock biomass level 1502.04 t, $F_{opt} = 0.2$ will result 133.152 tons yield and at F_{max} will result 173.098 tons yield.

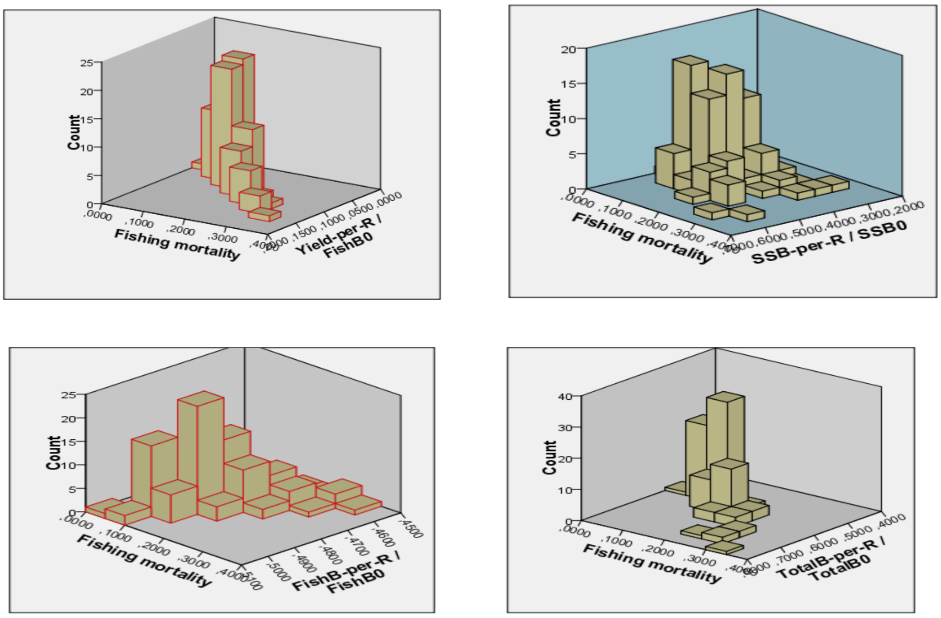
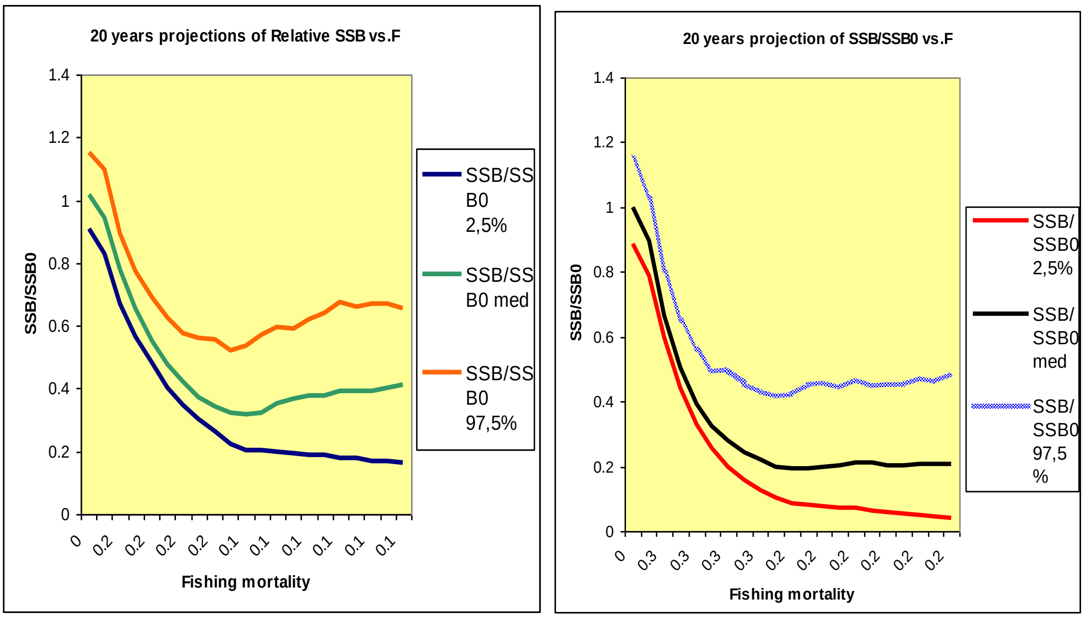


Fig 40 – Candidate $F_{0.x}$ criterion estimation related to parameters of the stock in relative terms



A. B.

Fig 41 – Projections scenario for turbot

In YugNIRO for two species: Azov anchovy (that is harvested by Ukraine mainly in the Black Sea) and turbot, we use precautionary approach for the TAC assessment. Azov anchovy is a species with major fluctuations of population. Such species do not fit the standard scheme of precautionary approach directed at the fishing stabilization on the specific target level reasoned beforehand. By the assessment of the TAC for Azov anchovy, we use VNIRO approach (Babayan, 2000) directed at the conservation of reproductive capacity of a stock. The presence of two pairs of the reference points - F_{tr1} and B_{tr2}, F_{tr2} and B_{tr1} is the special feature of this approach. Reference point B_{lim} is selected as the smallest value of biomass during entire fishery history. In case of Azov anchovy stock decrease to level B_{lim} or below this level, its commercial fishing is not recommended.

In so doing, the target reference points on anchovy biomass are used (assessed according the data of lampara surveys (Fig. 42):

B_{lim} = 10000 t; B_{tr1} = 48000 t; B_{tr2} = 208000 t (when $B_{av.}$ = 160000 t)
F_{tr1} = 0.9; F_{tr2} = 0.5 (when M = 0.8÷1.0).

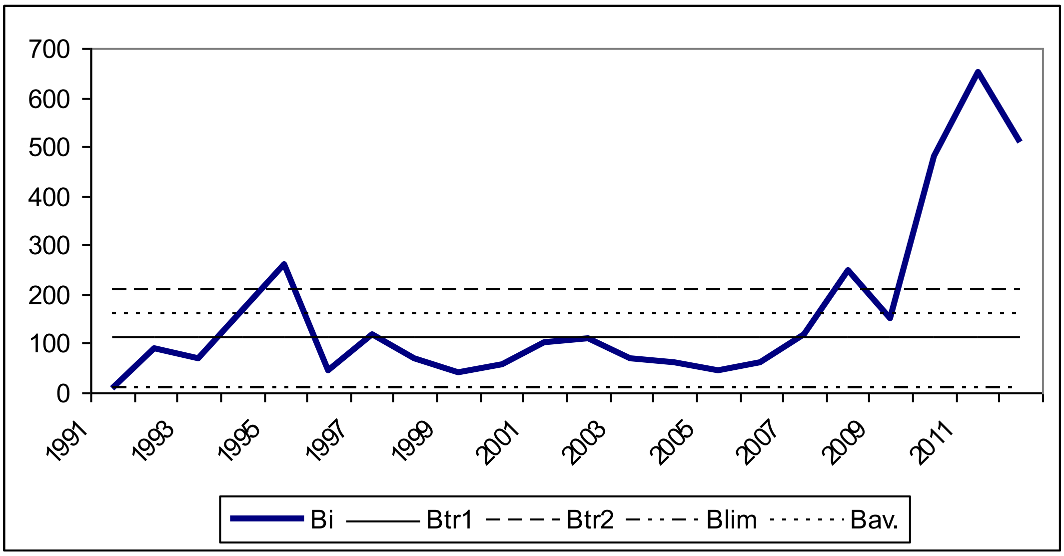


Fig 42 – Reference points (in Biomass) for management of the Azov anchovy

Azov anchovy stock management is carried out as follows. If a stock decreases to the point below B_{tr1}, fishing intensity is recommended to be not more than F_{tr2} = 0.5 for TAC assessment. The rate of fishing mortality is recommended to be F_{tr1} = 0.9, if stocks are above B_{tr2}. It should be noted that the capacity of Ukrainian and Russian fisheries fleet is not sufficient to ensure fishing intensity at the level F_{tr1}, if Azov anchovy stocks are high. Therefore only the reference point F_{tr2} is used in practice.

The strategy of establishment of the TAC level, developed in the YugNIRO, that will facilitate the reproduction of the turbot stock is used when regulating turbot fishing. The reference points used for this aim are:

$F_{0.1} = 0,14$; $F_{spa} = 0,2 \cdot F_{0.1}$, where F_{spa} – recommended fishing mortality level ("spare") at which stock recovery is provided.

If that strategy is used, TAC in a year i is assessed as follows:

1. The stock B_i is assessed;
2. The recommended value of TAC is assessed as

$$Y_{TACi} = B_i \cdot F_{spa} \cdot [1 - \exp - (M + F_{spa})] / (M + F_{spa}) \qquad [59]$$

It should be noted, that such strategy has allowed avoiding turbot overfishing in the waters of Ukraine and has facilitated some growth of the stock increase rate. However, the pace of such increase is very low due to large scale of IUU turbot fishing in Ukrainian waters.

At the end of this section, we touch on the adequacy of the methods EWG Black Sea, based on the analysis of bio-fisheries data, by results of which are given regional stock assessment MLR Black Sea and the STECF advice. Analysis of the catch of sprat, Black Sea anchovy, horse mackerel and whiting made by modifications VPA - ICA and XSA. When analyzing the input data for each of these species, the stock considered as one unit. Therefore, the matrix of catch of each country, structured by age, combined into one matrix for the whole sea. That is the method of VPA practically ignores the geography of the distribution of the stock.

Country's contribution to the final assessment of the stock is proportional to its share of the total catch. Thus each country is fishing only in the geographically separate area. It follows that the most plausible stock assessment will be obtained if the catch of each country is proportional to the exploited (by that country) part of the stock. How is performed this requirement?

If we assume the proportionate share of SSB (from the total SSB) in the waters of each country and area fraction exploited the country concentrations $S_{school\%}$ (from the total area concentrations), the most plausible stock assessment will be obtained by the sum of the deviations of zero share of catch $Y_{\%}$ (from the total catch) from relative area of the concentrations:

$$(S_{school\%} - Y_{\%})_{BG} + (S_{school\%} - Y_{\%})_{GEO} + (S_{school\%} - Y_{\%})_{RO} + (S_{school\%} - Y_{\%})_{RF} + (S_{school\%} - Y_{\%})_{TR} + (S_{school\%} - Y_{\%})_{UKR} = 0,$$

where BG, GEO ... - symbols of the Black Sea countries.

A measure of the adequacy of the method VPA for each fish species may become the standard deviation Sd, as counted as

$$Sd = \pm\sqrt{\sum (S_{school\%} - Y_{\%})^2}$$

In our case, adopted following gradation the adequacy: Sd when less than 20% - good, 21-30% - the average, 31-50% - low, 51-100% - very low, and more than 100% - absent.

Sprat and whiting. The main fishing produced in seasons when these species are distributed throughout the continental shelf. Hydroacoustic and trawl surveys indicate that biomass and fishing area agglomerations proportional to the area of the shelf (S_{csh}). In our case use only the relative performance, so the relative size of agglomerations sprat or whiting can be calculated (eg, Bulgaria) as

$$(S_{school\%})_{BG} = (S_{csh})_{BG} \cdot 100 / (S_{csh})_{BS} \qquad [60]$$

Black Sea anchovy and horse mackerel. Their main fishing done on the wintering grounds or during migration to wintering grounds. Anchovy winters and harvested in the waters of Georgia, Turkey and Ukraine (not every year). In addition, in the waters of Bulgaria, Romania and Ukraine fishing (short-term) is done during migration to wintering grounds. Based on hydroacoustic surveys and other studies, the relative size of agglomerations Black Sea anchovy can be expertly assessed as:

$$(S_{school\%})_{BG} = 0.001 \cdot (S_{csh})_{BG} \cdot 100 / (S_{csh})_{BS}$$
$$(S_{school\%})_{GEO} = (S_{csh})_{GEO} \cdot 100 / (S_{csh})_{BS}$$
$$(S_{school\%})_{RO} = 0.0005 \cdot (S_{csh})_{RO} \cdot 100 / (S_{csh})_{BS}$$
$$(S_{school\%})_{RF} = 0$$
$$(S_{school\%})_{TR} = 0.75 \cdot (S_{csh})_{TR} \cdot 100 / (S_{csh})_{BS}$$
$$(S_{school\%})_{UKR} = 0{,}005 \cdot (S_{csh})_{UKR} \cdot 100 / (S_{csh})_{BS}$$

Для ставриды, которая зимует также и в водах Российской Федерации, относительная площадь промысловых агломераций может быть экспертно оценена как:

$$(S_{school\%})_{BG} = 0.001 \cdot (S_{csh})_{BG} \cdot 100 / (S_{csh})_{BS}$$
$$(S_{school\%})_{GEO} = (S_{csh})_{GEO} \cdot 100 / (S_{csh})_{BS}$$
$$(S_{school\%})_{RO} = 0.0005 \cdot (S_{csh})_{RO} \cdot 100 / (S_{csh})_{BS}$$
$$(S_{school\%})_{RF} = = 0.01 \cdot (S_{csh})_{RF} \cdot 100 / (S_{csh})_{BS}$$
$$(S_{school\%})_{TR} = 0.75 \cdot (S_{csh})_{TR} \cdot 100 / (S_{csh})_{BS}$$
$$(S_{school\%})_{UKR} = 0{,}005 \cdot (S_{csh})_{UKR} \cdot 100 / (S_{csh})_{BS}$$

Table. 30 shows the baseline data and the results of the counting Sd, which indicate low adequacy (or lack thereof) applied EWG Black Sea ICA and XSA methods for regional assessment of stocks of sprat and whiting, average and good - for the Black

Sea anchovy and horse mackerel. Obviously, these results are preliminary and may be revised in a more rigorous analysis.

Table 30 – The adequacy of the methods of ICA and XSA for regional assessment of stocks of sprat, anchovy, horse mackerel and whiting in the Black Sea taking into account geography of distribution of stocks*

Country	S_{csh}, км²	$S_{school\%}$	Y, tons	$Y_{\%}$	$S_{school\%}-Y_{\%}$	$(S_{school\%}-Y_{\%})^2$	Sd%	The adequacy
Sprat								
BG	6664	6,3	3883	4,6	1,7	3,0		
GEO	638	0,6	139	0,2	0,4	0,2		
RO	13377	12,7	141	1,1	11,6	134,7		
RF	15791	15,0	6714	8,0	7,0	49,5		
TR	4704	4,5	49835	59,3	54,8	3003,0		
UKR	63922	60,8	22552	26,8	34,0	1155,7		
∑	105096	100,0	83264	100,0	109,6	4346,2	65,9	very low
Black Sea Anchovy								
BG	6664	0,1	43	0,0	0,1	0,0		
GEO	638	14,2	21832	8,3	5,8	34,2		
RO	13377	0,1	32	0,0	0,1	0,0		
RF	15791	0,0	0	0,0	0,0	0,0		
TR	4704	78,4	235260	89,8	-11,4	130,0		
UKR	63922	7,1	4752	1,8	5,3	28,0		
∑	105096	100	261919	100,0	0,0	192,2	13,9	good
Horse mackerel								
BG	6664	0	207	1,2	-1,0	1,1		
GEO	638	14	23	0,1	13,6	184,1		
RO	13377	0	14	0,1	0,1	0,0		
RF	15791	3	108	0,6	2,8	7,7		
TR	4704	76	16827	96,5	-20,7	430,3		
UKR	63922	7	258	1,5	5,4	29,0		
∑	105096	100	17436	100,0	0,0	652,1	25,5	average
Whiting								
BG	6664	6,3	7	0,1	6,3	39,4		
GEO	638	0,6	22	0,2	0,4	0,2		
RO	13377	12,7	55	0,5	12,2	148,9		
RF	15791	15,0	43	0,4	14,6	213,6		
TR	4704	4,5	10243	98,5	-94,0	8841,6		
UKR	63922	60,8	29	0,3	60,5	3666,0		
∑	105096	100,0	10398	100,0	0,0	12909,6	113,6	absent

*areas of the continental shelf of the country were taken from the Project "BlackSeaSCENE"; Y is the average catch for 2007-2011

Analysis of the adequacy of regional stock assessments Black Sea turbot of various modifications VPA was not produced for the reason that the question of the number of units of the stock and their geographical localization is unclear.

12. KNOWLEDGE GAPS AND RECOMMENDATIONS TO FILL

Effective use of analytical methods for the stock assessment MLR the Black Sea at a regional level impede many gaps in our knowledge. It is logical to classify them according to the following scheme: theoretical - practical - promotional. Below are the only major gaps in our knowledge.

1. Theoretical

1.1. The lack of rigorous analysis of the adequacy of the modifications VPA used for regional assessments of the status of stocks, fishing mortality MLR, in particular, sprat, turbot and whiting.

1.2. The lack of analysis of the choice reference points in the context of the application of the precautionary approach to regional estimates of the TAC.

1.3. The lack of methodology for application of the ecosystem approach to management MLR Black Sea.

2. Practical

2.1. There is incomplete and gaps in the historical data series of the length and age composition of MLR catches.

2.2. The absence of agreed by all six riparian countries of a regional methodology for the collection and processing of biological data that can be used in analytical methods of stock estimating.

2.3. The EWG 12-16 sensed that age reading in various species (incl. turbot, anchovy, whiting and others) may have important differences between countries that deteriorate the quality of catch-at-age data. There is also no harmonization regarding the sampling size and timing, that lead to inconsistencies in aggregating national catches to international figures.

2.4. The generally low quality of the input data for assessments (in terms age and size composition, fishing effort, CPUE and research surveys). This low quality is due to a shortage of surveys of both commercial fisheries as well as independent scientific surveys to cover the entire stock areas of distribution.

2.5. Incompleteness and low quality of national statistics on fisheries in the Black Sea.

2.6. The lack of knowledge, evaluations and monitoring programs for assessing the IUU and discards.

2.7. The lack of reliable frameworks of assessing and standardizing of the commercial fleets fishing effort and CPUE

2.8. The lack of quality survey information deteriorates the estimates of the current population parameters (abundance and mortality) in stock assessments and decreases the reliability of the short term predictions and management advice.

2.9. Insufficient level of the experts riparian countries in stock assessment methods commit to run the models and perform assessments.

2.10. The absence of a complete regional database for fisheries.

3. Promotional

3.1. The lack of legal grounds and mechanisms for the development of regional management the Black Sea MLR advice and their implementation by all six coastal states.

3.2. The lack of funds for research on the state of stocks and their habitat.

We can not give comprehensive recommendations on how to fill the above gaps and provide some of the recommendations prepared by the Project SRCSSMBSF participants, EWG 12-16 and The Second meeting of the Working Group on the Black Sea.

1. Bulgaria recommendation (IO BAS)

Sprat and turbot are with high importance for Black Sea fishery. The level of exploitation varies in the years, as the fishing effort and fishing mortality have been changed during different periods with regards the changes in ecosystem and economic reasons, mainly. Nowadays, the sprat stock considered not-overexploited. Turbot in the Black Sea and in the western part, particularly considered as overexploted. The real levels of catches and effort are unknown.

For F_{opt} levels, till clarification of the stock-recruitment relationship, it is recommended to use levels two times less than accepted for assessment natural mortality coefficient M.

Being important key species in the Black Sea ecosystem, the measures for sustainable sprat and turbot utilization must include wider ecosystem considerations. Sprat and turbot stocks are dependant not only by fishing effort but on conditions of the environment, trophic base and etc.

In this view, measures that advice incorporation of ecosystem approach and rules and guidelines provided by “precautionary approach” (FAO, 1995) have to be taken into account in proper management of the key fish populations. Reasonable exploitation patterns, resulted from projections performed could be taken as a management advice for sprat. In case of turbot, the model could give some relative trends and catch statistics and control improvement is needed.

It is not advisable to cross these reference points for the present and next year with respect the need of reproductive capacity and spawning stock biomass stability. We propose investigations on population parameters and exploitation stock biomass of these commercially and ecologically valuable species in continuous base in order to create database. Stock assessment of sprat and turbot is in straight correlation with it rational exploitation, species and biodiversity conservation.

It can be summarized that concerning the period 1979-2004 the Black Sea sprat and anchovy are the main pelagic target for the Bulgarian fishery. The abundance and biomass of their stocks vary in wide range in different years in relation to the environmental conditions and fishery activity. In the period considered assessments of their stocks have been conducted by different methods and the last ones refer to the period 1995-2000. The results obtained demonstrate that in the Bulgarian Black Sea area the stocks of the fish species mentioned are moderately exploited. The fishing effort is not high for different reasons some of them referring to redirected commercial interests toward other living marine resources. In conclusion it can be noticed that in order to overcome some discrepancies in fish stock assessment, concerning however not only these fish species, it is necessary:

- standardization and harmonization of used equipment and methodology for pelagic and demersal fish species;
- joint research is needed with the effort of all 6 riparian countries and covering considerable parts of the fish species habitats. This would enable the applying of the classic methods as well as the use of fishery independent methods for stock assessments that will allow checking the compatibility and usefulness of particular methods for certain species and areas and thus enhancing the accuracy of the estimates carried out.
- introduction of quotas for most exploited migratory and shared fish species;
- establishment of statistical database for fish resources in the Black Sea. Most essential statistical data have to be concerning catch, fish effort, population size-age structure, mortality, etc. of commercially exploited fish species in the Black Sea and data for fish biodiversity and endangered species.

2. Turkey recommendation

The major problem in the application of VPA or LCA is the lack of historical time series. VPA needs historical data for the analysis based on data from short-term cohort. Instead of the true cohort analysis, pseudo-cohort was used.

VPA or LCA is one of the most efficient and most frequently used indirect methods for stock assessment. However, this method is based on fishery-dependent data (such as catch and effort statistics), age structure of the catch and “guesstimates” of mortality rates (Sparre and Venema, 1992; Lleonart, 2002).

In addition to differences caused by use of different fishing gears, such as pelagic trawls and purse seines, there are also huge differences in CPUE between same type fishing gears used on the Black Sea Furthermore, biomass estimate (yield by VPA) is very sensitive to variables such as natural mortality, a parameter that cannot be directly measured but only estimated (Sparre and Venema, 1992).

The acoustic survey of small pelagic fish is probably the best method. The VPA estimate was the least reliable, and that the acoustic estimate was superior to both estimates based on larval sampling (Bailey and Simmonds, 1990).

3. Ukraine recommendation

We recommend to revise the existing national historic data on the length and age composition MLR to improve the quality of the input data for the analytical methods of stock assessment. In cases when there is no possibility of improving the quality of data on the age composition (eg, spiny dogfish, brine), we recommend the use of production models and LCA. Целесообразно изучить опыт GFCM по их применению на региональном уровне.

At a meeting in Trabzon in January 2013 under the project SRCSSMBSF recommended the development of a regional methodology of converting the data on the length composition of fish in uniform arrays. Such a methodology is developed YugNIRO after the completion will be available for all the Black Sea countries.

4. EWG 12-16 recommendation

Two new scientific surveys (demersal and hydro-acoustic) have started in 2010 in EU water (Bulgaria and Romania) funded under the DCF, but results from them do not seem yet to improve the quality of the assessments. Under the DCF, EU members (Bulgaria and Romania) are obliged to survey commercial fisheries in order to collect input data for stock assessments (in terms age and size composition, fishing effort, CPUE), but such surveys are not funded till now. Instead, research institutes try to use project funding in order to collect data for the most important fisheries.

The EWG 12-16 recommends that a training course in population dynamics, stock assessment methods and using of the specialized software is organized to answer the needs of the majority of the scientists in the region.

The EWG 12-16 recommends to organize the workshop(s) for inter-calibration of age readings between different laboratories and scientists in the region and harmonization of the frameworks and methods of sampling of commercial fisheries and scientific surveys.

5. The Second meeting of the Working Group on the Black Sea recommendations and proposals

- The most updated and detailed data to improve the assessments of main stocks in the Black Sea shall be made available to the GFCM Sub-regional Group on stock assessment for the Black Sea.

- Implement the roadmap to fight IUU fishing in the Black Sea on the basis of the comments and priorities provided by the WGBS (Appendix C). Extracts from Appendix C, related to research IUU:

- Promote scientific research in the Black Sea through FAO Regional Projects (e.g. BlackSeaFish), the GFCM Framework Programme and any other relevant project

- Scientific studies on selectivity should be collected. On the basis of gaps identified in the studies, further papers should be drafted

Perform joint stock assessments of priority species

- *The first Working Group on stock assessment for the black sea will be organized in Oct-Nov 2013 together with some training sessions. It is suggested that this first exercise will be for shared stocks. An effort has to be done to collate information from different countries on a limited number of priority species (turbot, sprat, anchovy and whiting) and to be prepared in advance to perform this joint assessment exercise.*

Carry out joint surveys at sea (demersal and small pelagic species)

- *Prepare a cooperation programme for extending the current survey protocols being carried out at present to the other countries.*

- Collaborate with the BSC/AG FOMLR, including *inter alia* by i) elaborating a list of preliminary fishery indicators and targets to be included in the fishery component of the new Black Sea Integrated Monitoring and Assessment Programme (BSIMAP) that should be reported by riparian states, ii) updating of the template of the BSC/AG FOMLR national report on the status of fisheries and other living marine resources and iii) establishment of the biological safety limit for the selected fish stocks. With these objectives, a work program could be incorporated in the current GFCM/BSC MoU

- Advance towards the design of fisheries independent surveys that cover the whole area of distribution for the main demersal and small pelagics in the Black Sea.

- Compile the existing information on data collection systems for all riparian States.

- Facilitate, at national level, that scientific surveys incorporated in different ongoing projects and related to WGBS objectives could cover national waters of the different riparian States in accordance with applicable international and national laws.

- Update the available information on fisheries in the Black Sea, including i) fleet and effort information, ii) catch information,iii) biological data and iv) ongoing research, and contribute to the GFCM bi-annual report on the status of Mediterranean and Black Sea fisheries.
- The following meetings were scheduled:

Title	Date / Venue
Workshop for the definition of common protocols and methods for surveys in the Black Sea.	January-February 2014 / TBD
Third meeting of the WGBS	Before SAC 16/ Trabzon, Turkey

- The sub-regional group on stock assessment for the Black Sea (organized back-to-back with training on direct and indirect stock assessment methodologies), already scheduled to be held in Bucharest, Romania, was recalled to the meeting who decided to hold it from 14 to 18 October 2013.

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