PREDICTION MODELING AND REFERENCE CONDITIONS FOR SPRAT AND TURBOT EXPLOITATION IN EU WATERS OF THE BLACK SEA

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ABSTRACT

Yield-per-Recruit analysis in absolute values was presented for sprat and turbot. For sprat, 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. 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. For the turbot, the 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 –173.8 tons; F_{max} = 0.27 - 182.6 tons.

Ten years projections of the turbot SSB/SSB_0 are presented. First panel (A) show 5 years exploitation at F = 0.2, then lowering at F = 0.1 and SSB/SSB_0 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.

Sprat relative yield (Y/F_0) at very low levels of the fishing mortality is high during the first projected year. At F = 0.8, in the second projected year fall of the relative yield was detected up to the levels of F = 0.5. After the fifth projected year, in all tested confidence intervals, plateau of the relation Y/F0 was observed. Similar is the case with the relative (SSB/SSB_0) and even slight increase at CI 97.5% and SSB/SSB_0 med, after change of fishing mortality (from F = 0.8 to F = 0.5) was detected. The model suggests that recruitment is stable, none influenced by the changes in fishing mortality. Fishable and total biomass, represented as relation with the biomass at unexploited state, show similar trends with those of relative SSB.
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.

KEY WORDS: Projections, modeling, sprat, turbot, EU waters

INTRODUCTION

Sprat (*Sprattus sprattus* L.,1758), is a marine pelagic species, usually inshore schooling, sometimes entering in the estuaries (especially the juveniles), and tolerating salinities as low as 4‰. In the daytime, it keeps to bigger depths and in the night comes to surface. It forms big schools and undertakes seasonal movements between foraging (inshore) and spawning (open sea) areas (Ivanov and Beverton 1985). Sprat is one of the most important fish species, being fished and consumed traditionally in the Black Sea countries. It is most abundant small pelagic fish species in the region, together with anchovy and horse mackerel and accounts for most of the landings in the north-western part of the Black Sea. Whiting is also taken as a by-catch in the sprat fishery, although there is no targeted fishery beyond this (Raykov, 2006).

The decreasing mean size and CPUE (2006-2007) in Bulgarian and Romanian fisheries are indicating that the fishing pressure might be too strong for the present level of exploited stock biomass, and further catch limitations may be needed. The analysis of the main population parameters (abundance, catch, fishing mortality) shows that the sprat stock has recovered from the depression in the 1990s due to good recruitment in 1999-2001 and the biomass and catches have gradually increased over the 1990s and early 2000s.

The stock estimates, however, confirm the cyclic nature the sprat population dynamics. The year with relatively strong recruitment were followed by years of low to medium recruitment which leads to a relative decrease of the Spawning Stock Biomass (SSB). High fishing mortalities (F_{1-3}) were observed in 1990-1994, 1998, and 2003. In the recent period SSB has again decreased due to lower recruitment and high fishing mortality. Landings have initially (in 2001-2005) reached levels comparable to the 1980s but dropped again in 2006-2007. According to the results of the production model the MSY is estimated to be in the range of 44,442 t. F_{msy} (ages 1-3) amounts to 0.53. Bmsy appears to be in the range of 128 000 t. Thus, the present level of fishing mortality is close to the equilibrium Fmsy but catches exceed the equilibrium level (Pilling et al., 2008; Daskalov et al, 2009).

Turbot (*Psetta maxima*) occurs all over the shelf area of all Black Sea coastal states at depths of about 100 m -140 m and makes grouped local shoals. Turbot inhabits sandy, mixed bottoms or mussel beds. In all Black Sea countries turbot is important target for the fisheries. Major fishing gear are gillnets, demersal trawls in Turkey and turbot also caught as a by-catch of sprat fisheries, long-lines and purse seines. In order to protect turbot stock in EU waters and improve the stock reproductive capacity, the mesh size of gillnets have been synchronised between Bulgaria and Romania (STECF SG BLACK SEA 2009).

Coefficient of commercial fishing mortality of turbot was assessed at F = 0.55-0.71 in 1990 – 1995, and from F = 0.41-0.44 in 1996 – 2000. Such coefficient of the commercial fishing mortality exceeds all the known assessments of $F_{0.1}$ for stocks of the Black Sea turbot and directly points to its overexploitation.The Black Sea STECF SG BLACK SEA 09-02 performed assessment of historic stock parameters for the period 1970 – 2008 using XSA (VPA 3.1, Lowestoft), based on landings at age data of turbot from Bulgaria, Romania, Ukraine and Turkey, which were agreed as representative for the total Black Sea area. Data for the period after 1988 processed by the 09-02 during the previous three meetings were combined with landings at age data from Prodanov et.al (1997). During the meeting the SG BLACK SEA discussed concerns that the official landings are misreported to an unknown extent, and decided to interpret the assessment results only as relative and indicative for the trends in the stock. Recent data from national statistics by countries for the period 1988 – 2008 were added to the historic catch at age data set compiled during the previous meetings from Prodanov et al. (1997) for the period 1970 – 1988. Both Romanian and Ukrainian series indicate that the recent estimates of the most important age groups 2-5 slightly increase in recent years and Bulgarian and Turkish – slightly decrease, respectively.

According to the analysis the recruitment has two peaks in 1971-1978 and 1988–1994 and increase of recruitment after 2001.

Correspondingly, SSB attained higher values up to 18,000 t during the period 1976–1983 and very low values after 2000. Since 2004 slight increase in SSB was observed. Fishing mortality F_{4-8} has a peak in 2000-2001. The STECF SG BLACK SEA 09-02 (Daskalov et al., 2009) consider these results as a useful and indicative of trends in turbot abundance in the Black Sea. Gradual increase of SSB is observed after the historic low in 2002 but biomass still remains quite low compared to the stock size in the 1970 and 1980s. The present results cannot be used for the aims of the management advice and prediction of stock size.

The turbot SSB during recent years is at low level compared to historical abundance. In 2002 and 2003 the SSB has been at the absolute minimum since 1970. Relative abundance estimates are confirmed by CPUE data. Catches have also dropped since 2002. A gradual recovery in the SSB and catches is observed since 2004. Recruitment was at minimum in 2000-2001 and started to increase since 2002. The increase in recruitment since 2002 has positively influenced the SSB but given that many small and immature turbots are caught by the fisheries such a positive influence may not propagate in the next years. Fishing mortality has peeked in 2000-2001 due to relatively high catches provided the low biomass of the stock.

Consistent with some international agreements, several authors justify that Fmsy should be treated as a limit rather than a target (Quinn and Collie, 2005, Mace, 2001). It is more economical to fish at F below Fmsy (Grafton et al., 2007).

Yield-per-recruit (Y/R) analyses using Beverton-Holt (Beverton and Holt, 1957) or Thompson-Bell (Thompson and Bell, 1934) formulation for growth in weight are a routine product of most assessments, and can be used to locate F_{max}, the abcissa where Y/R is maximum, or $F_{0.1}$ where the marginal gain is 10% of the gain at the origin (Gulland, 1968). However, many years ago, (ICES, 1977) has pointed out that Y/R is not a sufficient basis for the determination of Fmsy; the latter should also consider the effect of fishing on future recruitments: that is, Y/R should be combined with stock-recruitment relationships (SRR, which is tacitly embedded in production models).

Technically, this is not too difficult given a Y/R curve and a spawning stock-per-recruit (SSB/R) curve which is produced by the same piece of software. (Sissenwine and Shepherd, 1987) describe how the two pieces of information can be combined graphically. When the stock-recruitment relationship is of the Beverton-Holt or of the Ricker type, there are even explicit formula to derive the equilibrium yield for each F value and hence locate Fmsy. The real difficulty, however, is that one needs a reliable recruit-spawner plot.

The potential reference value that are provided by ICES for few stocks are F_{max} which is close to F_{MSY} but with the assumption of average recruitment, F_{mngt} (F according to management plan) or $F_{0.1}$ where slope of the yield curve is 0.1 that at the origin. Fmax is much too high and risky, and should be avoided as a proxy for F_{msy}. Simulations work has shown that acceptable proxies are either $F_{0.1}$ or the F where SSB/R is about 35-45% of SSBo, the SSB/R under no fishing (Clark, 1991, Mace, 1994, Quinn and Deriso, 1999).

MATERIAL AND METHODS

The Bulgarian and Romanian marine fishery is taking place in the Black Sea (GFCM Fishing Sub-area 37.4 (Division 37.4.2) and Geographical Sub-area (GSA) 29, Fig.1).

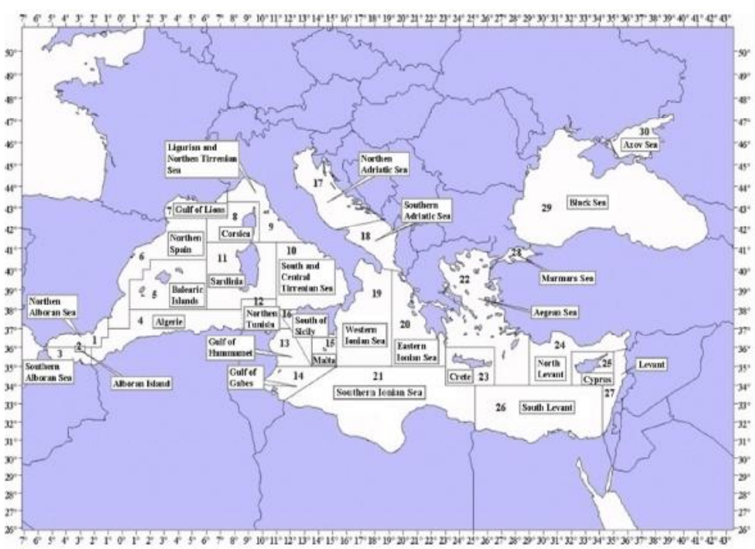


Fig. 1 - GFCM Statistical and Geographical Black Sea Sub –Area

The samples were collected from bottom trawl and mid-water otter trawl research surveys and in 2006-2009 in the corresponding area (Fig.2).

The input parameters for the reference point estimation were taken from direct length observations scientific surveys samples.

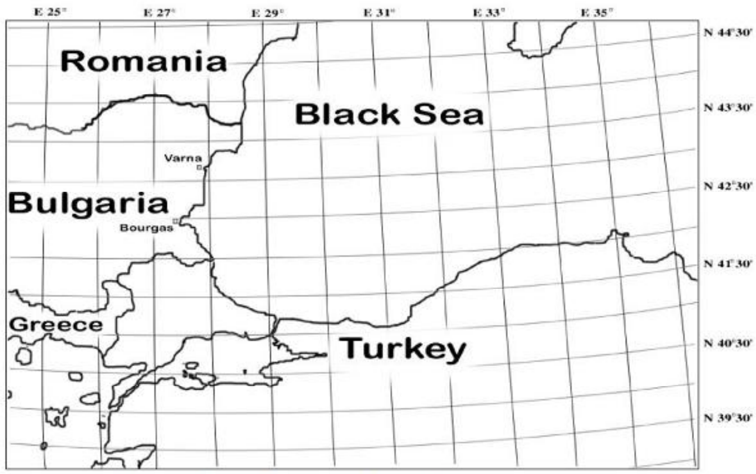


Fig. 2 - Sampling area for turbot and sprat

The catches of sprat in Bulgaria and Romania in 1990-2000 are almost uniform and kept the level below 4000t/year (Fig. 2). In 2002 some rise in Bulgarian trawl landings have been observed, since the Romanian sprat fishery decreased substantially (Fig. 3).

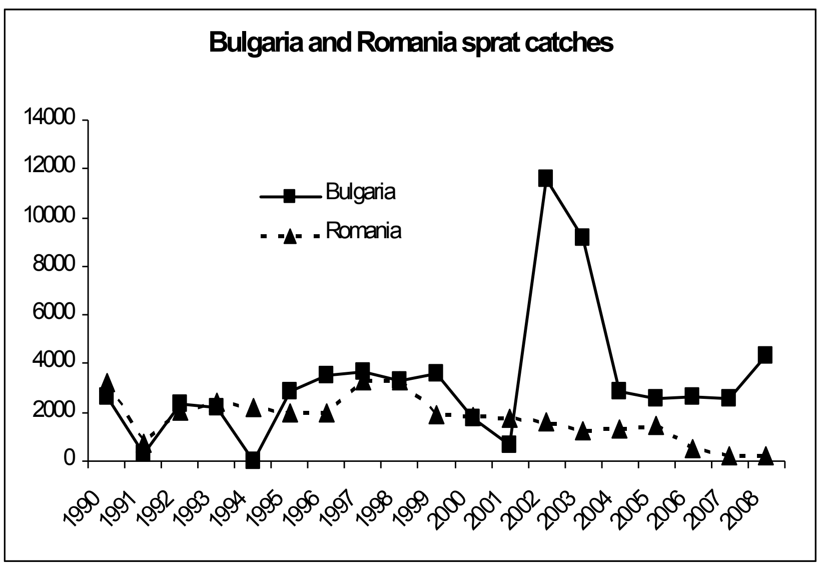


Fig. 3 - Sprat landings in the Bulgarian and Romanian Black Sea waters for 1990-2009

The established TAC for Bulgaria and Romania was 15 000 t for 2008. In 2009 and 2010 TAC has been reduced to 12 750 tones allocated for common EU Black Sea waters.

Reported turbot catches in both countries are highly underestimated (Fig. 4). In Romania some increase after 2002 are detected but the levels are below those reported in Bulgarian Black Sea zone (RADU et al., 2006). Since 2007 with EU Council Regulation TAC for turbot has been established as follows: 100 tons, allocated 50:50 in Bulgarian and Romanian waters, respectively.

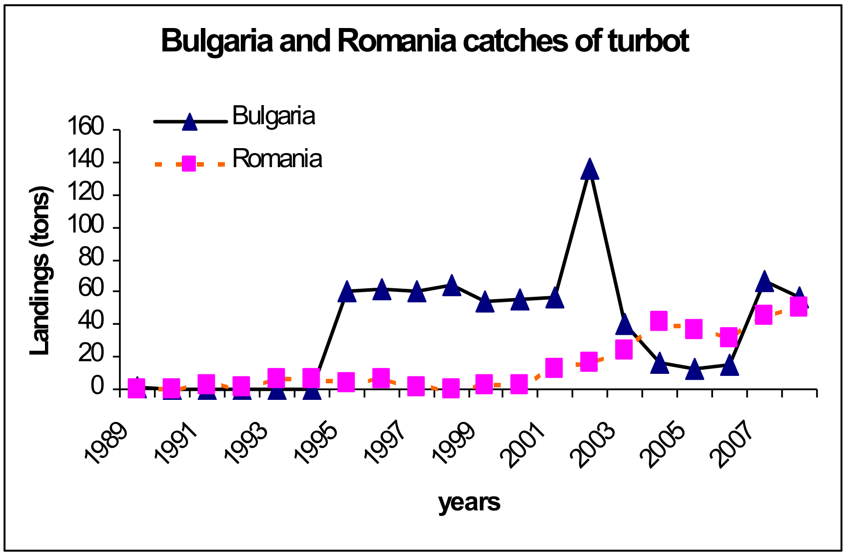


Fig. 4 - Turbot landings in the Bulgarian and Romanian Black Sea waters for 1990-2009

Yield-per-recruit (Y/R) analyses were performed using Beverton-Holt model (BEVERTON and HOLT, 1957) to set candidate reference points for turbot and sprat sustainable exploitation.

The model was used to locate F_{max}, the abscissa where Y/R is at maximum, or $F_{0.1}$ where the marginal gain is 10% of the gain at the origin (Gulland, 1968).We used “steepness” formulation of (BEVERTON and HOLT, 1957) model to generate candidate reference points. Parameter describes how steeply the Beverton and Holt SRR rises with increasing SSB at the origin. For there to be any sustainable yield at all, the SRR must lie above a straight line drawn between the origin and the point (S0, R0). At the other extreme, as the steepness increases, the SRR approaches the constant SRR.

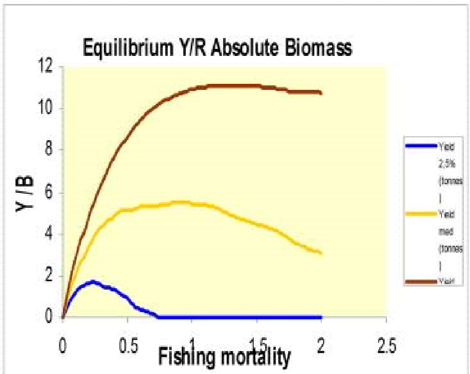
Accordingly, the steepness parameter (h) is defined as the recruitment (as a fraction of R0), that results when the SSB is 20% of S0. When h approaches 1, the Beverton-Holt SRR approaches the form of the Constant SRR; when h approaches 0.2, recruitment becomes linearly related to spawning stock biomass.

Table 1 - Input parameters for Y/R analysis

Input parameters	**Turbot**	**Sprat**
L∞	120.4	13.45
k	0.076	0.45
to	-2.811	-0.68
q	0.0001	0.008
n	3.129	2.85
M	0.25	0.95

Input parameters for the above described model are presented on table 1.

RESULTS AND DISCUSSION



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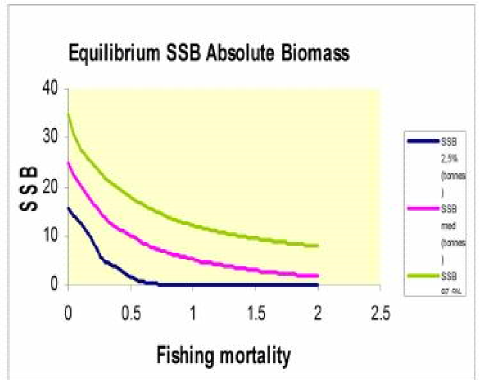

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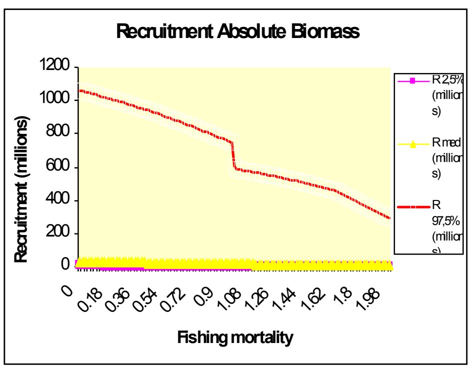

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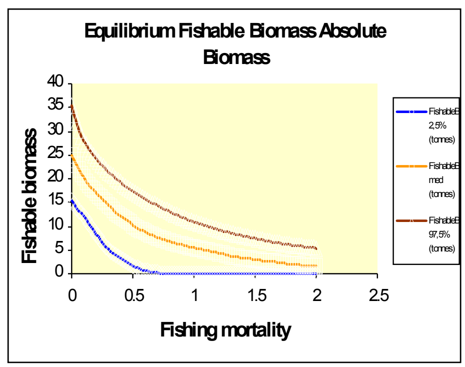

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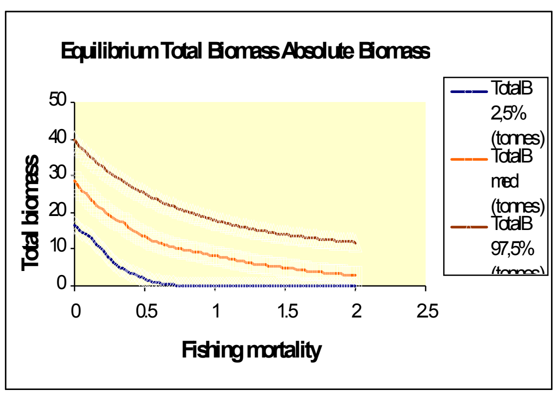

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Fig. 5 - Graphical representation of the equilibrium levels of exploitation with the corresponding CI

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 $F \geq 2$.

On Figure 5, Yield-per-Recruit analysis in absolute values was presented. 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. 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, 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. 5, 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. 5, 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. 5, 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);
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. 5, 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.

REFERENCE LEVELS OF EXPLOITATION

The candidate reference point for the sprat stock in the western part of the Black Sea $F_{0.1}$ and corresponding SSB, Yield, Fishable and Total Biomass per recruit was presented on Fig. 23 According to the analysis, $F_{0.1}$ criteria advice to keep the fishing mortality rates in the range of 0.75 to 1.0 with bell shaped histogram, after simulation run performed. The other tested variables (Fig. 6) show similar trends, as the taller bars are on the left side of the histograms. The values of $F_{0.x}$ reference point are lower and thus more restrictive than $F_{0.1}$ criteria. Two bars on $F_{0.x}$ candidate reference point panel are taller in the range of 0.5 to 0.6, referring to more restrictive character of possible sprat fishing mortality (Fig. 7).

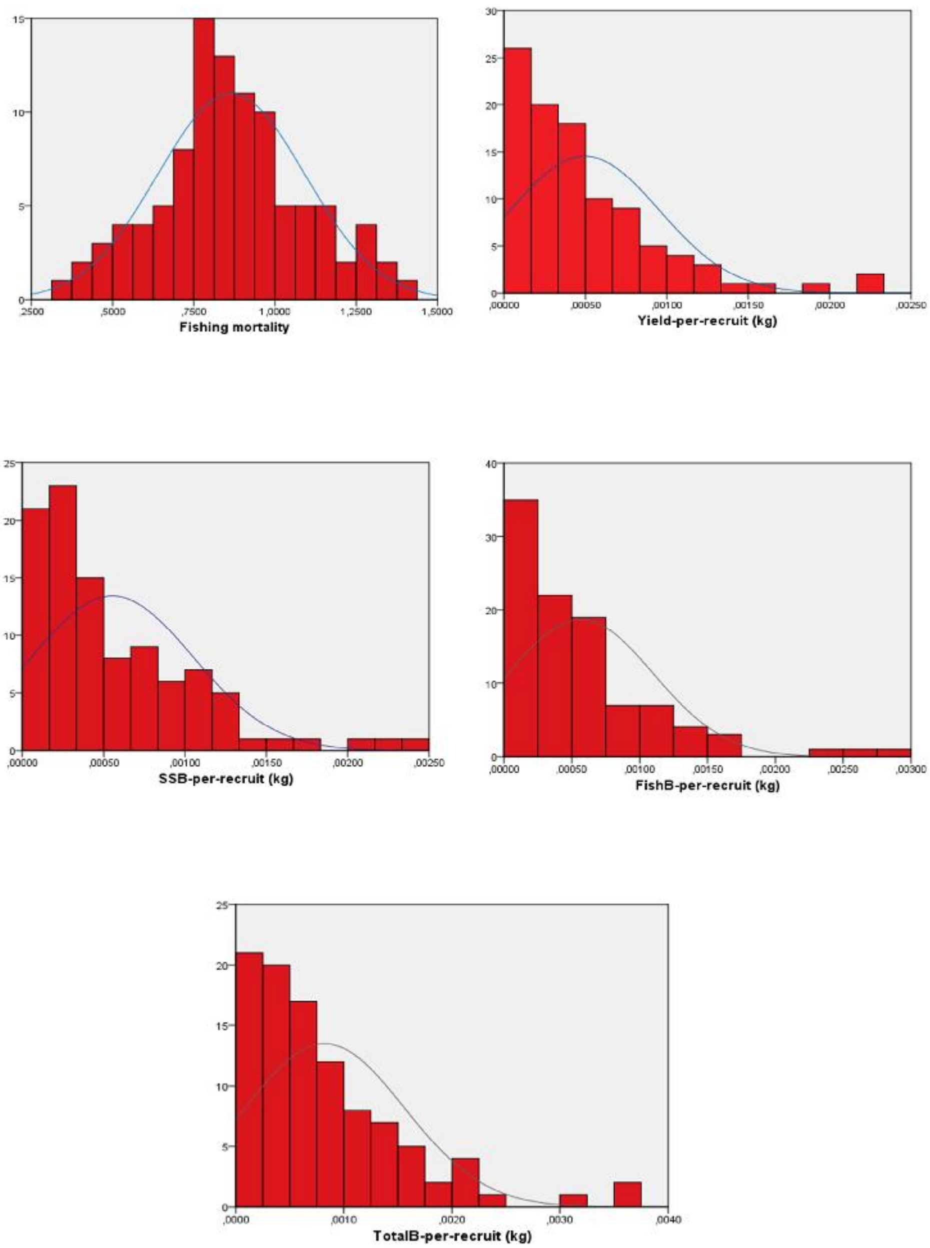


Fig. 6 - $F_{0.1}$ candidate reference points for the sprat

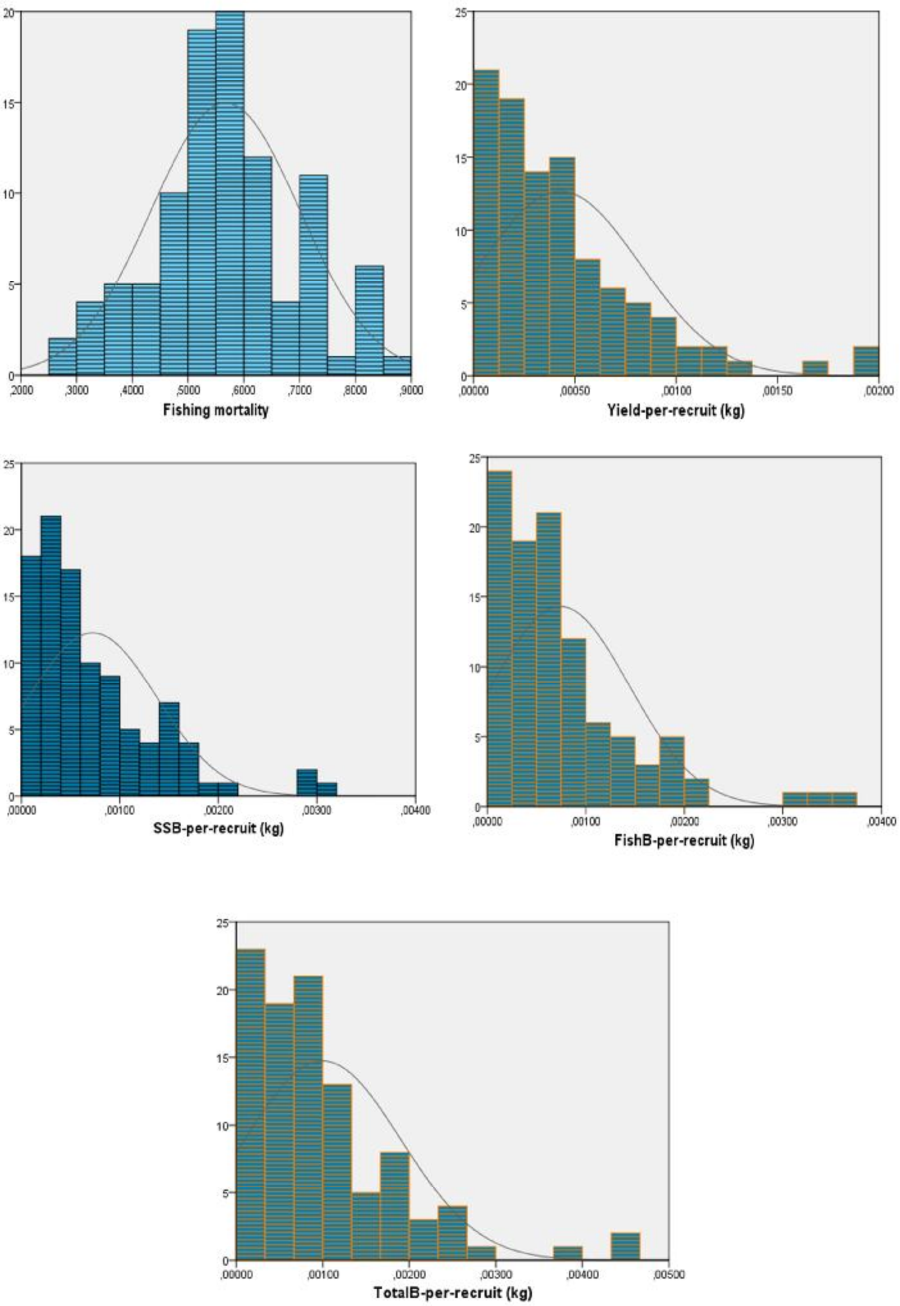


Fig. 7 - $F_{0.x}$ candidate reference points for sprat

Relationship between fishing mortality, catch and recruitment in the frame of MSY scenario in absolute biomass option was presented on Fig. 8. It is evident from this figure that for the levels of fishing mortality up to 1.0 (F_{opt} = 0.8 -1.00) yield in the range of 4–8 thousand tons can be realized. Respectively, the highest recruitment is within these catch range, as at 12 thousand tons possible catch the recruitment decreases substantially (Fig. 8).

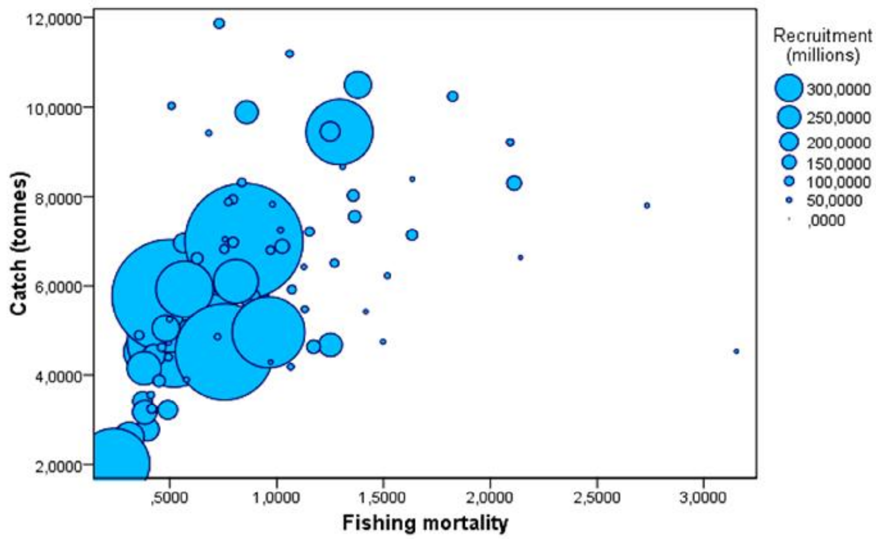
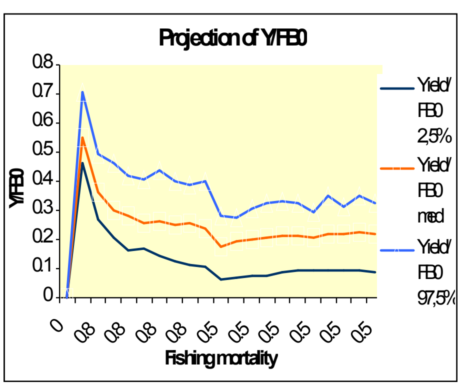


Fig. 8 - Modeled catch vs. fishing mortality relation and changes of recruitment

Prediction model of the stock parameters in relation with fishing mortality variation for 10 years



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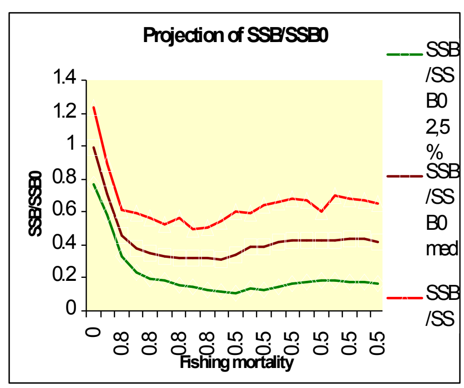

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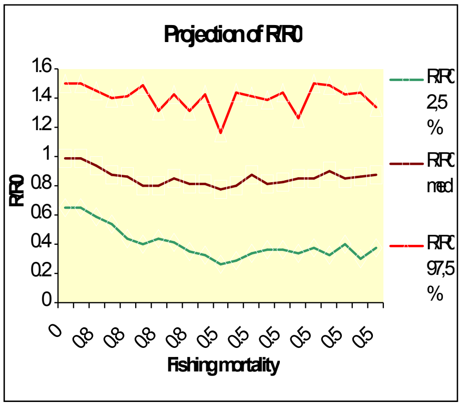

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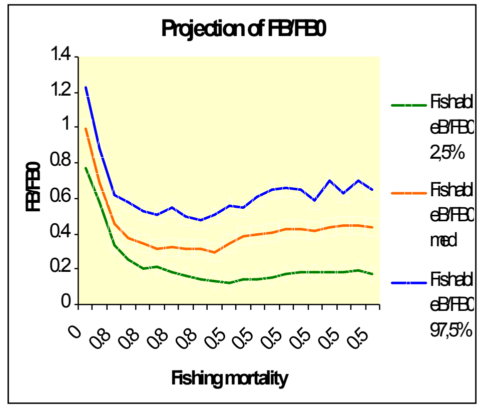

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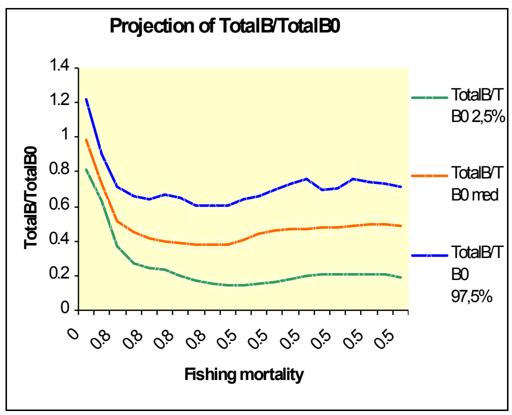

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Fig. 9 - 10 years predictions of the stock parameters of sprat related to fishing mortality variations

The relative yield (Y/F_0) at very low levels of the fishing mortality is high during the first projected year (Fig. 9, A). At F = 0.8, in the second projected year fall of the relative yield was detected up to the levels of F = 0.5 (Fig. 9, A). After the fifth projected year, in all tested confidence intervals, plateau of the relation Y/F0 was observed. Similar is the case with the relative (SSB/SSB_0) (Fig. 9, B), and even slight increase at CI 97.5% and SSB/SSB_0 med, after change of fishing mortality (from F = 0.8 to F = 0.5). Recruitment (Fig. 9, C) is stable, none influenced by the changes in fishing mortality.

Fishable and total biomass, represented as relation with the biomass at unexploited state, show similar trends with those of relative SSB (Fig.9, D, E).

On Figure 10, analysis of the optimum and maximum possible levels of fishing mortality levels 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.

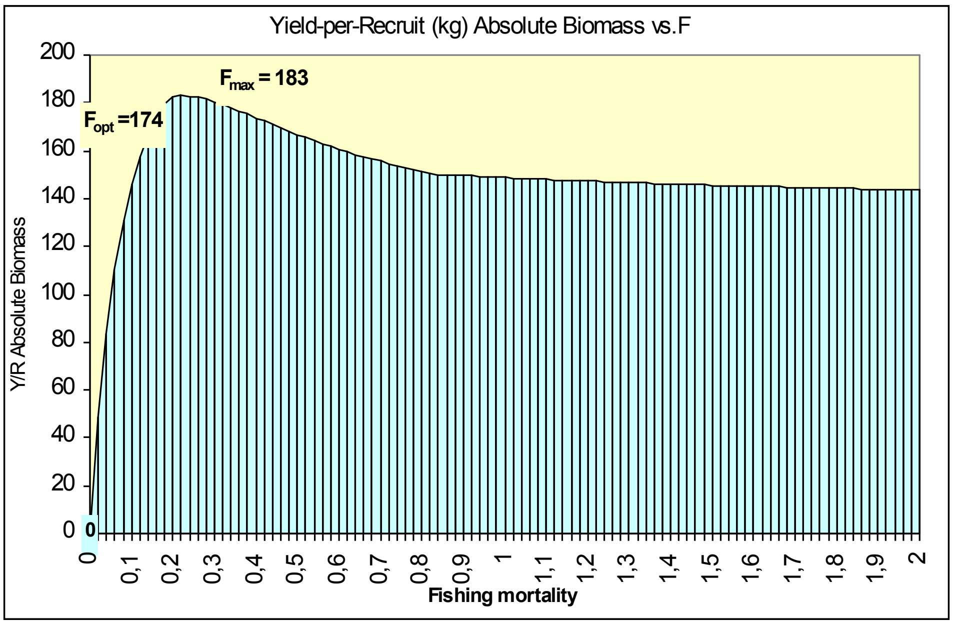


Fig.10 - Reference levels of turbot fishing mortality

On Figure 11 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 (Fig11) 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.

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.

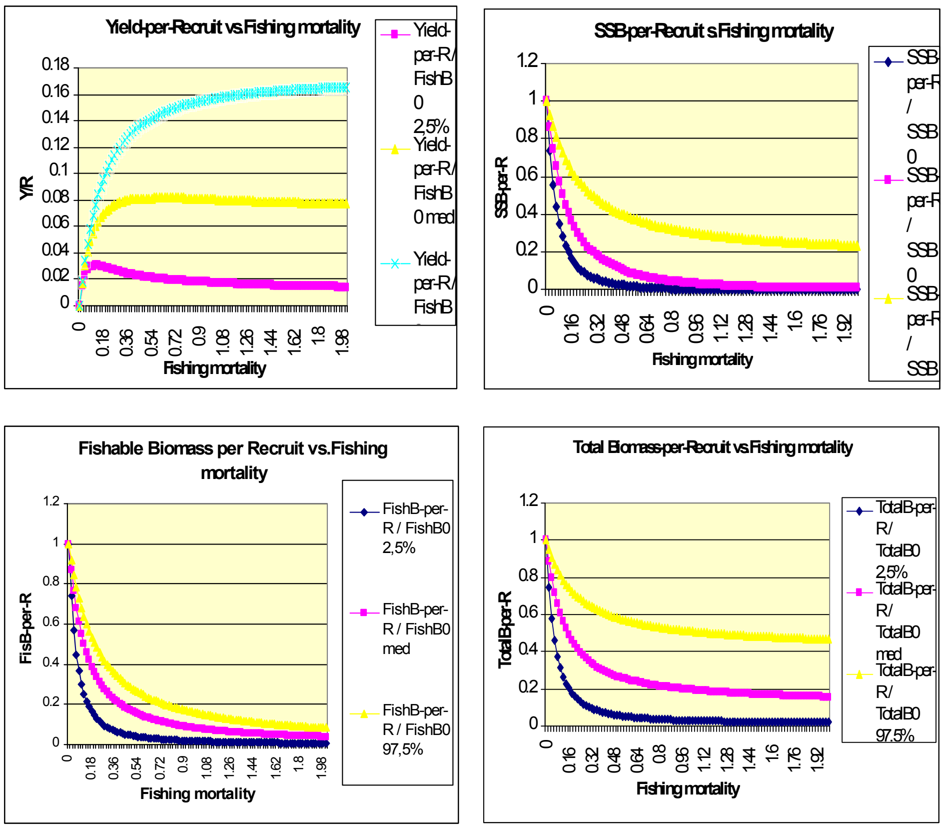


Fig. 11 - Equilibrium state of the Yield per Recruit and other characteristics related from fishing mortality

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 12 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.12).

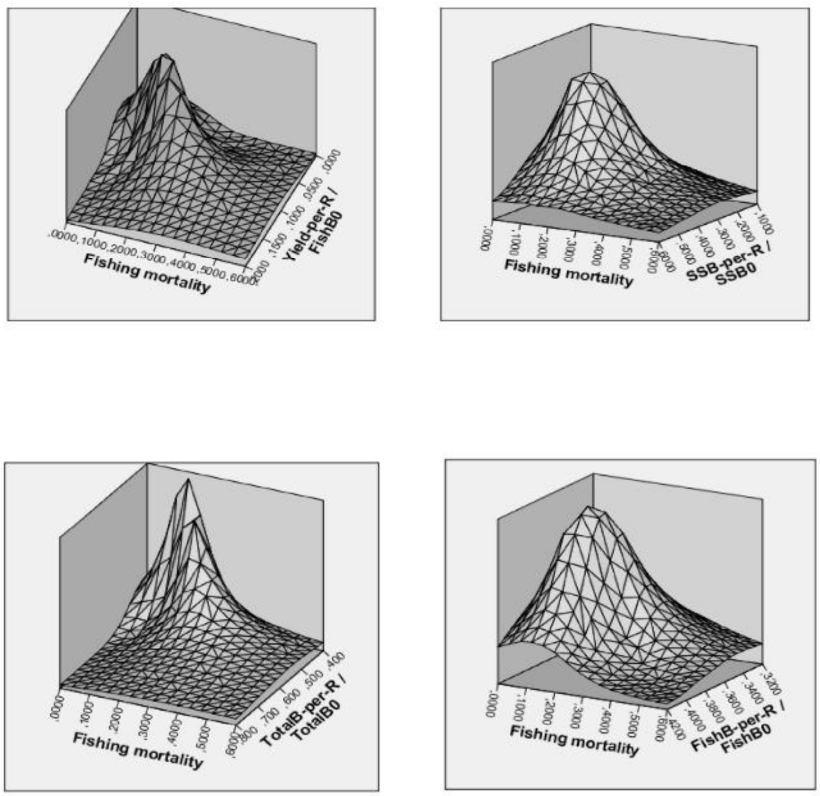


Fig.12 - $F_{0.1}$ criterion estimation related to parameters of the stock in relative terms

Another candidate reference point, which appears more restrictive, as regards exploitation over examined stock is $F_{0.x}$ ($F_{0.2}$).According it (Fig. 13), 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.

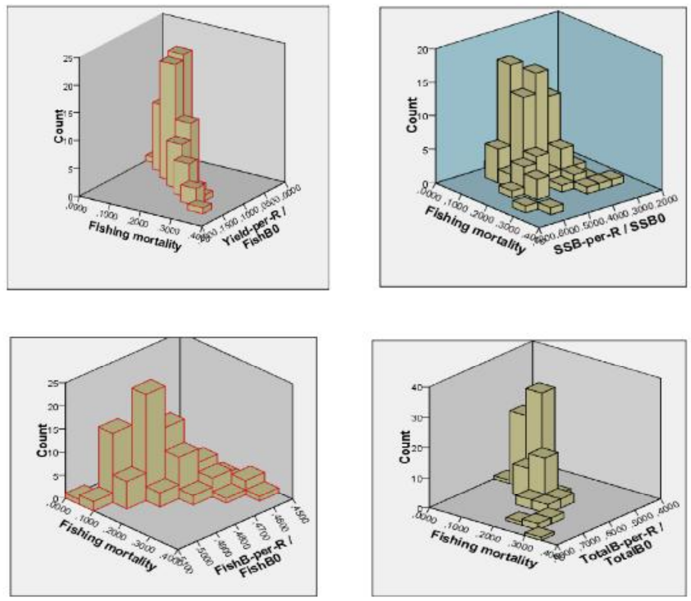
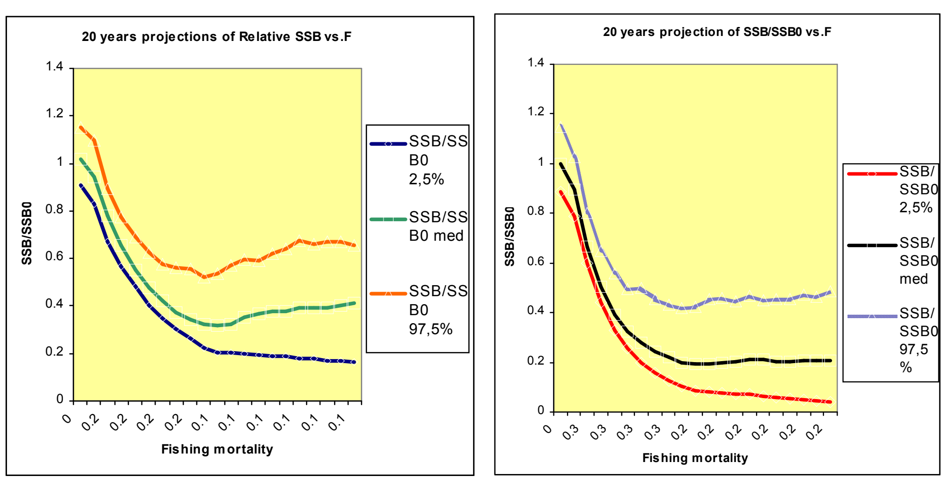


Fig. 13 - Candidate $F_{0.x}$ criterion estimation related to parameters of the stock in relative terms.

Projections of the SSB/SSB0 are presented on Fig. 14. 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.



A B

Fig. 14 - Projections scenario for turbot

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.

CONCLUSIONS

Both species 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.

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