Commercial Fishery Impact on the Modern Black Sea Ecosystem: a Review

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Abstract

During the last 30-40 years, the Black Sea ecosystem has been found subjected to diverse anthropogenic factors, one of which appears to be the fishing pressure. Till recently no common viewpoint is available regarding its influence on the ecosystem. The main objective of the study is to evaluate the role of commercial fishery in structural and functional alterations of the Black Sea ecosystem on the basis of a data-series relative to long-term dynamics of fisheries statistics and biological population indices.

Key words: fish stock, landing, fishing intensity and effectiveness, trawling, overfishing.

Introduction

The Black Sea appears to be one of the important fish basins influencing greatly the economy of all the Black Sea countries. Its fish productivity is assessed to be higher as compared to the other seas of the Mediterranean area except the Sea of Azov. Not incidentally, even ancient Greeks exported fish caught in the Black and Azov Seas. The main objects they concentrated on were tunas, sturgeons, red mullet, and shed as commercially most valuable. Presently, the volume of fish in total catches of the Black Sea living resources proved to be dominant constituting more than 85%. By different estimates, fish biomass evaluation is found in the range of less than 1 million tonne to almost 6 million tonnes; but more frequently, the registered values fluctuate within 1.5-3.0 million tonnes, which seem to be more realistic. Annual fish value of P/B coefficient is accepted to be equal to 0.5-0.65.

The last twenty-five years of the 20th century were marked by dramatic changes in the Black Sea fishery. Since 1970s, its history can be distinguished by three consequent time periods (Figure 1):

– gradual catch increase till 1988s with total landings attaining its maximum - almost 800 thousand tonnes;

– drastic catch decrease over three years (1989-1991) till 200 thousand tonnes approaching its minimum over the whole period under consideration;

– partial increase of fish landings dating back to 1992s.

Naturally, the prime attention is being given to a period of dramatic catch decline terminated to a great damage for economy of all the Black Sea countries. Its reasons imply the divergence of opinions. The most important is worthy to be mentioned as follows:

– significant structural and functional alterations in the Black Sea ecosystem as a result of technogenic activity wholly embracing water exchange disruption between the Sea of Azov, the Black and Marble Seas posed by reduction and regulation of river outflows, complex pollution of marine aquatories and eutrophication of waters (Rass, 1992, 2001);

– forage base depletion in fish-planktophagous caused by mass development of Atlantic invader ctenophora *Mnemiopsis leidyi* (Grishin *et al*., 1994; Arkhipov *et al.,*1995; Gubanov and Serobaba, 2005);

– mass consumption of pelagic eggs and fish larvae by *Mnemiopsis leidyi* (Kideys *et al*., 2000);

– highly intensive and insufficiently regulated fishery (Caddy, 1993; Gucu, 1997, 2002; Prodanov *et al*., 1997; Shiganova, 1997; Bilio and Niermann, 2004);

– unfavourable climatic changes (Niermann *et al*., 1999).

Results and Discussion

Each of the factors mentioned evidently has the adverse and different by scales impact. However, the priority of each is of importance to be determined. In our view, the most reasonable verified version is dramatic commercial fish stock decrease resulted from excessive long-term exploitation.

The present work attempts to specify the character and the extent of commercial fishery effect on a fish stock formation (since 70 till now) and define its role in structural and functional changes of the ecosystem. For the purpose of the investigation, the following fisheries statistics and biological

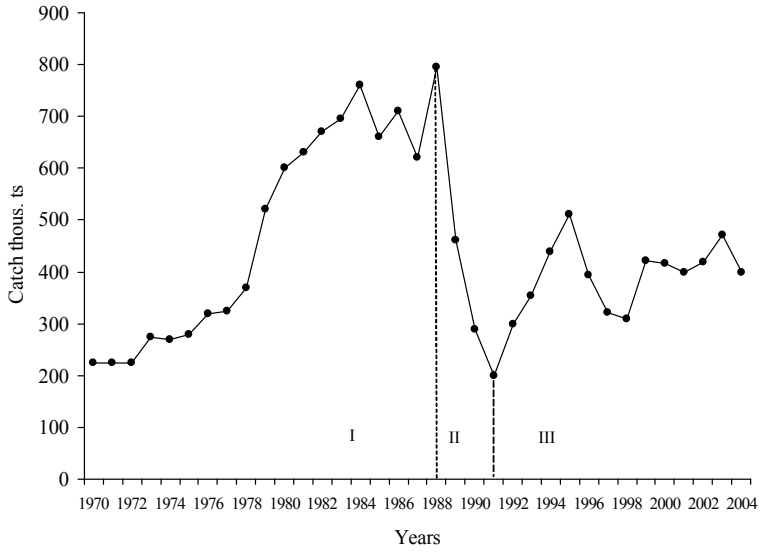

Figure 1. Basic periods of commercial fishery development in the Black Sea in 1970 – 2004ss. I. - Catch increase II. - Sharp catch decline III. - Catch restoration.

population indices were applied.

– commercial fish stock (biomass) (B);
– volumes of fish landings (Y);
– fishing intensity (fishing coefficient or exploitation ratio) (Y/B);
– effectiveness of fishing (*d*Y: *d*Y/B);
– composition of commercial species and ecological diversity of commercial ichthyophauna;
– structural and functional characteristics of commercial fish species.

Analyses in long-term dynamics of commercial fish stocks and fish landings in the Black Sea showed a stable tendency to rise for both indices till the end of 1970s (Figure 2). Average annual rates of growth were equal and constituted about 6% per each thus sustaining a quasi-stable condition in a "stock and catch" system. However, in the very late of 1970s, the balance in the system appeared to be disturbed as a result of oncoming stock reduction contrasting ever-increasing catches.

The onset of stock decrease that occurred simultaneously with the sharp increase of fishing intensity, enhanced more than two-fold over five years (1979-1983ss). During this time period, the heavy fishing in the Black Sea as well as the growth of fish landings happened to be directly related to the mounting pressure from expanded Turkish fishery (Figure 3). So, in the mid of 1980s, the annual volume of Turkish landings in the Black Sea increased more than four fold as compared to the previous period (Gucu, 1997; 2002).

The fishing coefficient for the period within 1979-1983ss increased from 0.16-0.20 till 0.40 that meant the annual rates of its growth exceeded 20% (Figure 4). In the following 5 years (1984-1988), the annual rates of fishing coefficient growth were found sharply declined to 7.5%. Nevertheless its absolute value in 1988s exceeded 0.55. Coefficient of correlation between stock (B) and fishing coefficient (Y/B) in 1979-1988ss constituted - 0.898 ($p < 0.01$) that indicates close negative connection between these parameters.

Consequently, growing fishing intensity involved decrease of fishing effectiveness. Since the beginning of 1980s, the catch growth rates (*d*Y) were lagging behind intensive fishing coefficient growth rates (*d*Y/B), which evidences, in our opinion, the beginning of stocks over-exploitation. In the following years (up to 1988s), the scales of this phenomenon continued to grow.

Variations found in quantitative indices for the Black Sea fishery proceeded simultaneously with significant changes in a species composition and fish landings. Except for many valuable species, the portion of which, at the beginning of 1970s, amounted up to 30%, the dominant (>90%) in catches, at the end of 1980s, was small short cycle species - anchovy, sprat, small horse mackerel and others (Table 1).

The reason for the changes is quite clear and there is no need for further discussion. By the mid of 1970s, such valuable fish as sturgeons were exploited rather intensively; and some species (turbot in particular) were close to over-fishing (Ivanov and Beverton, 1985). Heavy fishing in the second half of 1960s came to a complete halt for mackerel to be commercially important for all the Black Sea countries (Danilevsky *et al*., 1979). Thus over-exploitation of large-size predatory fish and dolphins along with water eutrophication were responsible for biomass increase in small plankton-feeding fish.

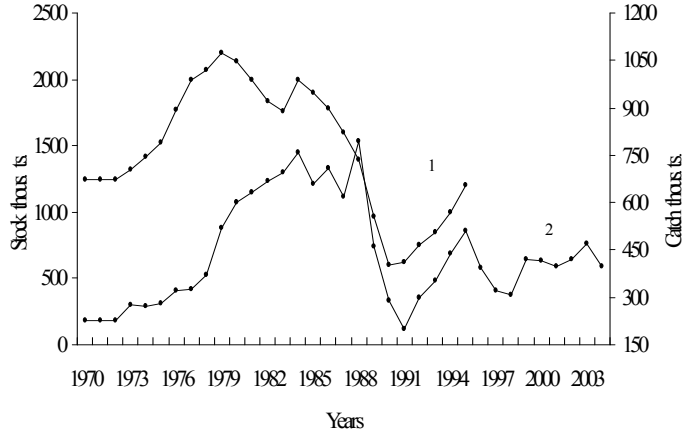

Figure 2. Dynamics of stock and fish catch in the Black Sea in 1970 – 2004ss (1 – stock, 2 – catch) (Prodanov *et al*., 1997).

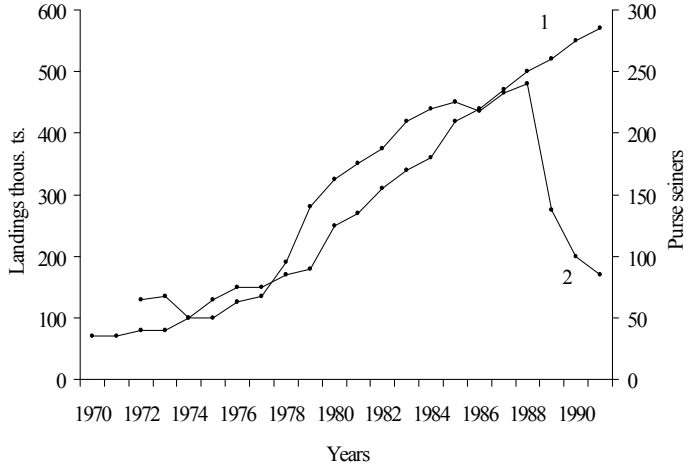

Figure 3. Dynamics of Turkish total landings and the number of Turkish purse seiners (1 – purse seiners, 2 – landings thous. ts.) (Gucu, 1997; 2002).

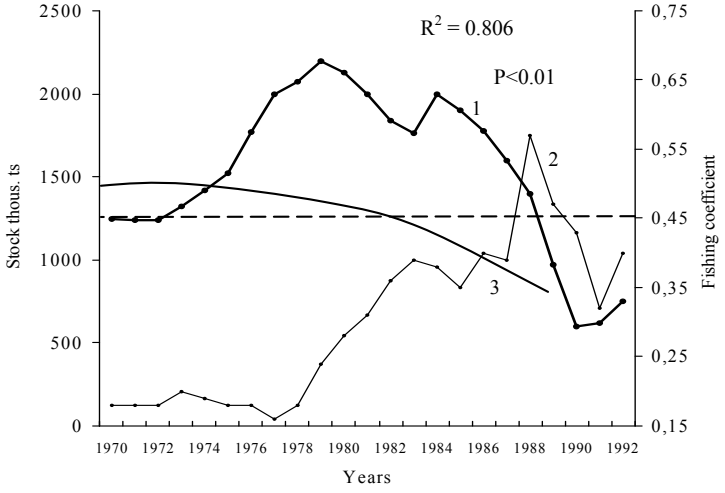

Figure 4. Dynamics of fish stocks, intensity and effectiveness of fishery in the Black Sea in 1970 – 1992ss (1– stock, 2 – fishing coefficient, 3 – effectiveness of fishing).

Table 1. Species composition of the Black Sea landings in the end of 1960s - beginning of 1970-s and in 1988s (%) (Ivanov and Beverton, 1985; FAO yearbook, 2004)

Species	1960 - 1970ss		1988s	
	Thousand tonnes	%	Thousand tonnes	%
Anchovy	53.6*	69.8	67.7*	93.4
Sprat	1.6*		8.6*	
Horse mackerel	12.5*		12.6*	
Whiting	2.1*		4.5*	
Atlantic bonito	16.1	30.2	1.7	6.6
Mackerel	1.2		1.5	
Bluefish	3.2		1.2	
Shad	0.8		0.2	
Turbot	2.0		0.2	
Picked dogfish	1.5		0.7	
Thornback ray	0.9		0.2	
Mugils	2.6		0.3	
Red mullet	1.7		0.5	
Sturgeons	0.2		~ 0.01	
Total	182.8	100	783.8	100

* Small short cycle fish species

Another proof of the Black Sea fish over-exploitation evidences the decrease of anchovy of mid size and mid age in the end of 1980s testifying thereby "rejuvenation" of the population. On the contrary, weakening of fishing pressure on its population in the following years challenged a reverse effect, namely, the size- age structure rehabilitation and its catch increase (Figure 5). Thus drastic fall of total catches in 1989s might have been predicted beforehand and only the emergence of two highly productive generations of horse mackerel in 1983s and 1984s arrested it for some years.

In addition, the imbalance in a "stock and catch" relationship in 1980s is exhibited in peculiarities of the long-term "stock and catch" dynamics indices. As it is seen in the figure, the catch curve is equal in form to that of the stock retarding for 4-5 years (Figure 6). Thus the peak for the stock in 1979s was accompanied by peak for the catch in 1984s, minimum of the stock in 1983s was attended with that of the catch in 1987s. And again the peak for the stock in 1984s was followed by the catch peak in 1988s. It could hardly be regarded as incidental coincidence. Present temporal intervals correspond to the life span of one generation of the main commercial species - anchovy and horse mackerel constituted in the end of 1970s more than 75% of total landings. Correlation coefficient value between stock within 1979-1987ss and catch within 1983-1991ss was equal to 0.748 ($p < 0.02$). In this connection, the position of a number of scientists holding to the idea of "the fatal" role of *Mnemiopsis leidyi* in sharp decline of Black Sea catches doesn't seem to be rather convincing.

Phenomenon of *Mnemiopsis* "outburst" attaining its high point in 1989s suggests the direct consequence of biomass decrease in small fish planktophagous (anchovy, horse mackerel and others) resulted from overfishing (Figure 7). Only due to small numbers of these fish, *Mnemiopsis leidyi* turned out to be competitive to these planktophagous in a given ecological niche. In 1988s as compared to 1979s, the commercial fish stocks reduced more than one and a half-fold: from 2200 thousand tonnes to 1400 thousand tonnes. Finally, the ecological niche occupied by fish planktophagous appeared to be partly empty and correspondingly, according to the general ecological rule *"nature abhoret vacuum"*, was occupied by *Mnemiopsis.*

Along with *Mnemiopsis,* the crucial role in structural and functional alterations of the ecosystem in the north-west of the Black Sea played the extensive commercial bottom sprat trawlings commenced in 1970s of the 20th century. Since 1979s till 1986s, more than 120 thousand operations were performed in the NW shelf of the Black Sea. As compared to the previous period, the volume of sprat catch appeared to be increased as much as 15-20 times during some years. Bottom trawling affected directly the sea ecosystem by mechanic destruction of bottom biotops by trawlboard and low headline, respectively damaging or completely destroying benthic communities.

Much more deleterious influence on the ecosystem was exerted by bottom sediments (pelitic fractions) raised into the pelagic layer. It induced secondary eutrophication and water pollution, decline of its transparency, depression of photosynthesis processes. However, the main negative factor of bottom trawlings was recognized silting of vast bottom areas. Thus pelitic particles from Tarkhancut Cape of the Crimea peninsula spread with the current for the distance of 150-200 km (Figure 8). Totally, more than 5 thousand square km of the shelf were silted as an outcome: at larger parts, the silt layer thickness varied from 2 till 5 cm, attaining up to 40-50 cm in spots. In a period of 1976-1984ss, some silt depositions raised into the water layer constituting

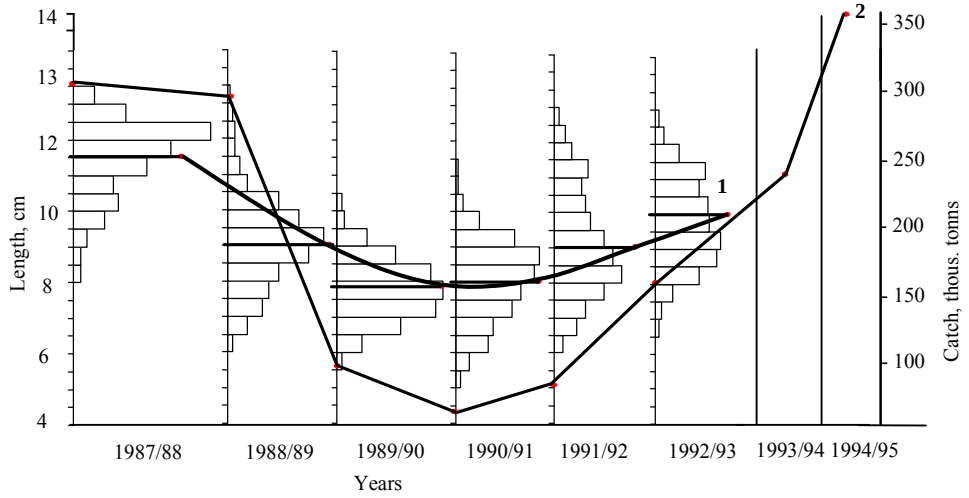

Figure 5. Dynamics of size composition in the Black Sea anchovy in 1987 - 1993ss (1 - mid length cm, 2 - catch, thous. ts.) (Gucu, 1997).

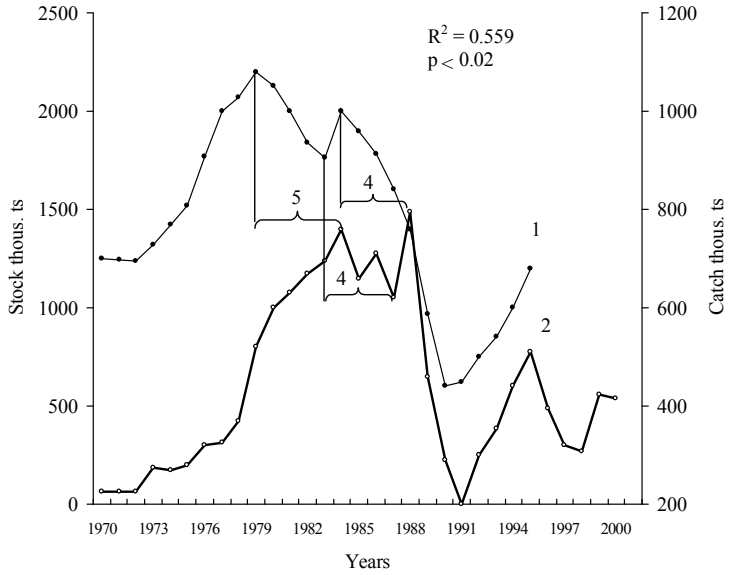

Figure 6. Dynamics of stock and catch in the Black Sea in 1970 - 2004s (1- stock, 2 - catch); 4, 4, 5 - explaination in the text.

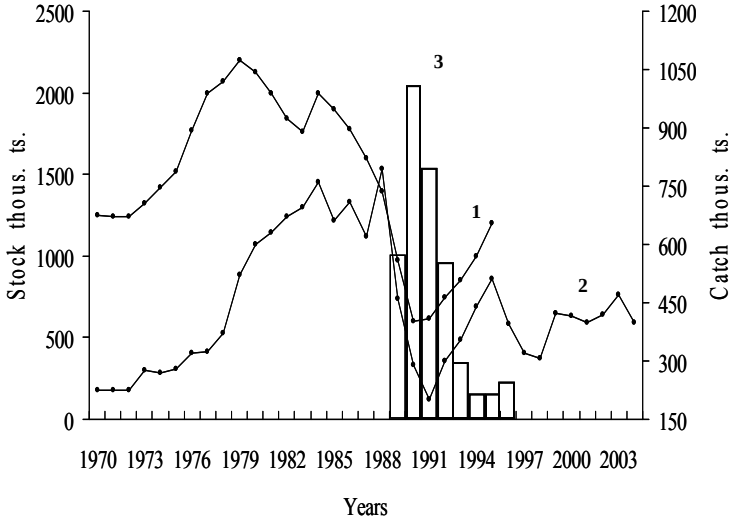

Figure 7. Dynamics of stock and fish catch in the Black Sea in 1970 – 2004ss. and *Mnemiopsis* biomass in 1988 – 1996 ss (1- stock, 2 - catch, 3 - *Mnemiopsis*) (Prodanov *et al*., 1997, Bilio and Niermann, 2004).

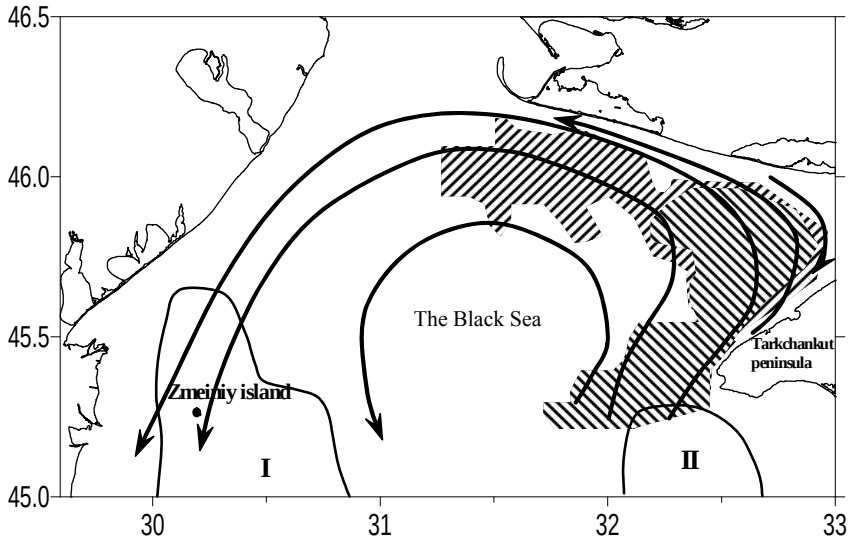

Figure 8. Region of silting pellite particles in the north-western part of the Black Sea. I, II - the main regions of sprat bottom trawling. Arrows show the main directions of the current (Zaitsev *et al*., 1992).

about 60 million tonnes (Samyshev *et al*., 1986).

Consequently, serious biological transformations occurred in communities as a result of silting. Thus the number of macrobenthos species in silty areas reduced 3.5 fold, their abundance 2.5 and biomass more than 20 fold (Zaitsev *et al*., 1992). In Karkinitsky Bay macrobenthos biomass losses, mainly mussels exceeded 800 thousand tonnes. Generally, in north-western shelf of the Black Sea since 60s, the total mussels stock has declined from 10-12 to 0.4 million tonnes (Gubanov, 2005). At the same time vast reproductive and feeding areas for most bottom-living and demersal fish species including sturgeons, turbot, gobies and others appeared to be lost as a result of silting.

Worsening of water transparency is considered to be one of the main reasons for "*Zernov's Phyllophora* field" biocenosis degradation. By most estimates, *Phyllophora* stock, numbered 9-10 million tonnes in 1960s does not exceed 0.5-0.8 million tonnes at present (Gubanov, 2005).

Variation of sprat fishing operations in 1990s from bottom to pelagic trawlings has not practically changed the situation since sprat forms benthic assemblages in the near bottom layer. Besides, effective fishing control regulation is lacking.

Bottom sprat trawling appears to be also detrimental for the Black Seas turbot population as a result of biotop destruction. During the last years the sharp decline of fish landings, deterioration of productivity and biological state of turbot in western shelf of the Crimea peninsula are observed. Thus in 2003s as compared to 1998s mid, mass of individuals diminished almost two fold - from 4.8 to 2.5 kg. The turbot mid age dropped from 7.8 till 6.5 years, that is, rejuvenation of the population took place. In this particular case the situation is rather similar to that as it was with anchovy in the end of 1980s. Simultaneously, the turbot catches reduced more than two fold (Figure 9).

At present the real evaluation of commercial fish stocks in the Black Sea is hampered due to the curtailment of fishery investigations. As a direct consequence, the current fishery can be considered as spontaneous and non-regulated. It can be exemplified by Black Sea sprat, that is, nowadays the main commercial species in the Ukraine. Anyhow, in 2003 and 2004s sprat catches in Ukraine appeared to be twice as low as it had been predicted despite the increase of sprat fishing effectiveness (Zuev *et al*., 2004; Eremeev and Zuev, 2005). The main reason for low fishing is explained by extremely high catches in previous two years (2001, 2002ss) reaching by official data 49.0 and 45.5 thousand tonnes, respectively. At the same time there is an opinion that in 1989-2003ss the fishery intensity (fishing exploitation ratio) was at a level of 1.8-6.5% (allowing fishing intensity more than 30%). However, this fact is greatly doubted.

The history pattern of the Black Sea fishery over the last decades accurately recurs that of the World fishing. As it is known up to 60s of the 20th century the living resources of the World Ocean were considered by most specialists as an inexhaustible source of protein (Moiseev, 1969). Anyhow, it required not more than two dozen years to unravel the myth. Already in the mid of 1980s, owing to further intensive development of fisheries industry, the total world fish catches as well as other sea food yields practically ceased to grow. For the first time, previously numerous, large-size, commercially valuable fishes were found vanishing being replaced by small sized, commercially less important species.

According to recent data (Duda and Sherman, 2002) the current state of marine ecosystems in different regions of the world including biological

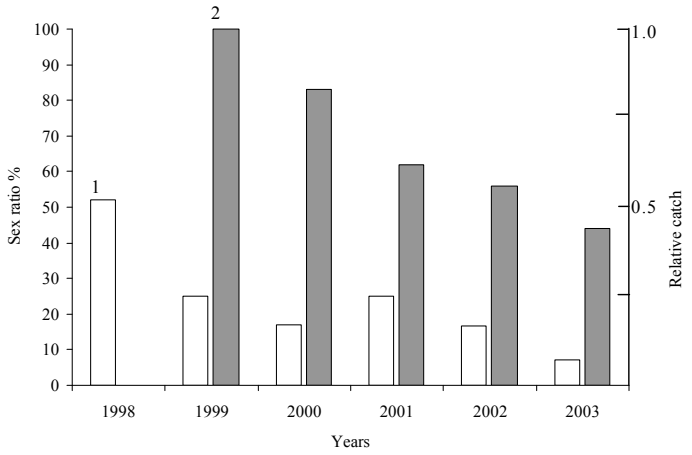

Figure 9. Sex ratio in turbot spawning population and the turbot relative catch near the south-western coast of the Crimea in 1998 - 2003ss (1 - Portion of females, 2 - Relative catch).

diversity and the levels of commercial productivity proved to be worse as it had been expected. The main reason is considered to be related to global over fishing. Revision of long-term world catches presented by FAO testifies a sharp decline of their volumes since 1980s of the 20th century. Just only due to the development of mariculture contributing almost 1/3 of fish landings, the total volume of World catches remains rather high.

To avoid the threat of foremost over catch and unpredictable transformations for the Black Sea ecosystem, large-scale monitoring on the environmental condition, dynamics numbers and biological state of the main commercial fish species should be renewed using regular trawler, ichthyoplankton, hydrological and hydroacoustical surveys.

Conclusions

– Intensive Black Sea fishery in the 1970 - 1980s being one of the main and important spheres of economic activity for coastal countries involved substantial qualitative and quantitative alterations in the ecosystem.

– Initially, these changes affected ichthyophauna taxonomic diversity and its structure. From the mid of 1960s a gradual reduction of species composition among the representatives of large-size, food valuable fishes such as turbot, bluefish, mackerel, Atlantic bonito, sturgeons and shed has occurred. They are replaced by numerous small anchovy, sprat, whiting, horse mackerel and others.

– Since the end of 1970s variations in ichthyophauna taxonomic diversity have accompanied by gradual decrease of total fish biomass (stock). Finally, it led to four-fold reduction of the Black Sea landings in 1991s.

– In its turn, the reduction of total fish biomass in the Black Sea in the end of 1980s more than one and a half as compared to its maximum value in 1979s led to a partial emptiness of the occupied ecological niche that according to the general rule «*natura abhoret vacuum*» was occupied by invader planktophagous *Mnemiopsis leidy.*

– Chaotic exploitation of living resources determines the urgent need to develop the general concept of the international regulation and environmental control as an important condition of their current protection and rational use. It implies coordination of scientific investigations and exchange of the information obtained, regulation of fishery as well as any types of nature conservation.

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