An application of mass balance ecopath model to the trophic structure in the Black Sea "after anchovy collapse"

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Abstract-Especially after the collapse of the anchovy stocks in 1989 in the Black Sea, various scientists claimed that the ecosystem of the Black Sea was changed, even spoiled. Utilising the available data, a steady-state model - Ecological Pathways (ECOPATH) has been used to understand and interpret the changes occurred in the Black Sea during the period of the anchovy stock decrement (collapse). For analysing the Black Sea ecosystem 7 model scenario were developed and tested (run). In this connection, the compatibility were checked whether especially calculated fisheries mortalities and biomass are fitting to that of field measurements. For this propose the fish biomass and the catch (harvest) values entered into the model have been manipulated to obtain the closest and acceptable compatibility between field measurements and model calculations. According to the model results, fish groups used in the model were interacting each other, but not significantly affecting the lower trophic level groups neither negatively nor positively. Additionally model results were implying that the system is not sustaining the very high *Mnemiopsis* biomass, measured by various authors. Again, model results were implying that the commercial fisheries were not significantly affecting the fish stocks due to the high biomass of the lower trophics and structure of the energy flow. In parallel to the previous statement, model results imply that *Mnemiopsis* was also not affecting the fish stocks' fluctuation in the Black Sea, opposite to various claims made that the *Mnemiopsis* might be the causative factor of fish stocks fluctuations occurred recently.

Material and Method

In the "steady state" ECOPATH model energy input and output of all living groups must be balanced. According to Christensen and Pauly (1992) mass balance equations used in the model are as follows:

i: is a group or compartment in the model.
j: is a group or compartment in the model.

Production by (i) –all predation on (i)–non-predation losses on (i)–export of (i) = 0
Production by(ii)–all predation on (ii)–non-predation losses on (ii)–export of (ii)=0
Production by (n)–all predation on (n)–non-predation losses on (n)–export of (n)=0

ECOPATH database consists of the three parts. These are;
- Food matrix,
- Harvest (catch) and
- Biomass.

Modelling Approach

In this work, the whole Black Sea is included into the model. Any zonation or the subregion is not diferentiated. To analyse the Black Sea ecosystem four main model runs have been done by using different groups in each run (Table 1).

Table 1. Ecological groups, model parameters, data entered and calculated missing parameters used in fourth run. Bold characters are indicating the calculated values

Groups/Parameters	Biomass	P/B	Q/B	EE	GE	Harvest
1. Large pelagics	**0.051**	1	4.307	0.900	**0.232**	0.046
2. Large demersal	0.082	1.150	4.164	**0.127**	**0.276**	0.012
3. Merlangius	0.400	1.630	8.76	**0.995**	**0.186**	0.048
4. Mullus+Spicara	0.085	2.500	8.575	**0.900**	**0.292**	0.016
5. Small pelagic	1	2.500	9.802	**0.964**	**0.255**	0.577
6. Belone+Scomber	**0.015**	2.500	6.844	0.900	**0.365**	0.022
7. Zoobenthos	70	2.500	10	**0.012**	**0.250**	-
8. Meso-zoo	**7.455**	40	200	0.900	**0.200**	-
9. Ciliate	3	100	300	**0.016**	**0.333**	-
10. Chaetognaths	0.550	29	74	**0.061**	**0.392**	-
11. Jellies	315	0.500	2	**0.000**	**0.250**	-
12. Appendicular	0.065	29	73	**0.980**	**0.397**	-
13. Noctiluca	7.300	40	200	**0.933**	**0.200**	-
14. Bacteria	7.500	1022	**2044**	**0.160**	0.500	-
15. Phytoplankton	60	330	-	**0.153**	-	-
16. Detritus	-	-	-	**0.563**	-	-

First Run
Unmanipulated data
Without given biomass values of the fish groups
Given 75% decreased biomass values of the fish groups
Given 100% increased harvest values of the fish groups

Second Run
Including the Aurelia in addition to the groups used in first run.

Third Run
Both of the Aurelia and Mnemiopsis are combined under Jellies group in the third run and the other groups are kept same.

Fourth Run
The fish, and zooplankton groups are separated. The group number in the fourth run is higher than the other previous runs.

Fourth run performed to understand the lower and higher trophic interactions in the Black Sea ecosystem in the light of previous runs. This is thought to be more representatives for the Black Sea ecosystem. For this purpose, the previous "ecologic groups" used were sub-divided into relatively smaller components.

Results and Discussion

In order to obtain a more realistic Fig. fitting to the field observations, the number of ecosystem compartments were increased to 16. The 5 fish compartments of the previous run, were rearranged as Large Pelagics, Small Pelagics, Large Demersals, Merlangius merlangus euxinus, *Mullus barbatus + Spicara spp.*, *Belone belone + Scomber spp.* In order to take different food requirement of the different zooplankton groups this box is divided into 5 subgroups, namely Mesozooplankton, Ciliate, Chaetognaths, Appendicularians, Noctiluca sp. Here, through bacteria → Ciliate → Appendicularian pathway a microbial loop is also included into the model.

Another important deficiency of the previous runs were the gelatinous organisms. By definition, production by a group should not be larger than the total consumption by that group. However, this statement is not valid, since the gelatinous organisms retain very high concentration of water in their bodies (more than 95% of their body). This feature hinders the utilisation of classical approaches to estimate food requirement of this group. Here Q/B and P/B ratios for this group were taken from DEASON (1982) and KREMER (1977), respectively. In this case, P/B became 20 times higher than Q/B. In the ECOPATH model, however, the respiration of the group is failed since this parameter is determined as the difference between consumption and the sum of production and the non-assimilated part of the diet. This approach is only valid if the carbon content of the organism and its prey is identical. However, for instance, carbon content of a unit-wet weight of Ctenophoran is about 45 times lower than the carbon content of a unit wet weight of its major prey, Calanus.

The result of the fourth run is not coinciding with the field data given in the material method. After the re-organisation and taking care to be close to that of the values obtained in the field observations data were fed and the resulting outcome was that the biomass was increased in meso-zooplankton.

Mixed trophic impact

Lower trophics have more interactions with the other groups than the higher trophics. However, the top predators can be considered as a control mechanisms in the systems but here the top predators have negligible biomass as compared to the lower trophics. Small pelagics is the only fish group, which influenced all other fish groups but it is not affecting any lower trophic organism groups. In previous runs, the system seen to be formed by two compartments and the results found here are now supporting the idea of the seperated compartments such as lower trophics and higher trophics in correct words - fish system that are acting nearly independently from each other. In natute, of course the system elements are tied to

each other through food web and lower trophics are supporting the upper trophic layers as food source. Model result imply only that the relative biomasses are mis-structured in a sence that at the bottom there is a huge biomass and at the top a low biomass (Fig. 1).

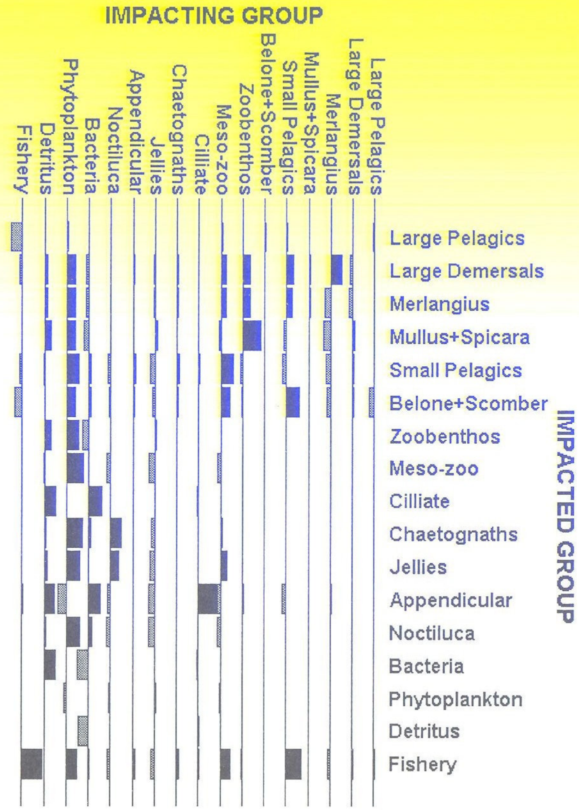

Fig. 1. Mixed trophic impact of the model groups.

The mean transfer efficiency is not varying here again. The result of the mean transfer efficiency is resulting in this wide based pyramid. The transfer efficiency between the groups is not equal and the very small parts of energy can rich higher trophic levels. This energy is trapped by the jellies. This phenomenon may address to the eutrophication in the Black Sea, which caused abnormal production values.

Flow diagram of the model

Flow diagram of the system is shown in flow diagram Fig. 2 is the result of the model, which is shown the Black Sea ecosystem in steady state. It is clearly visualise the dominancy of the lower trophics in the system. The results are implying that the fish biomass in the system is negligible beside the huge jelly and other lower trophics. The important amount of the flowing energy is flowing through the lower trophics. Consumption here is shown by "Q" and is equal to the total inflow into the concerned group. The energy flows are originated from the lower trophics, as it is known. Normally the energy is transferring from the first trophic level to the top predators.

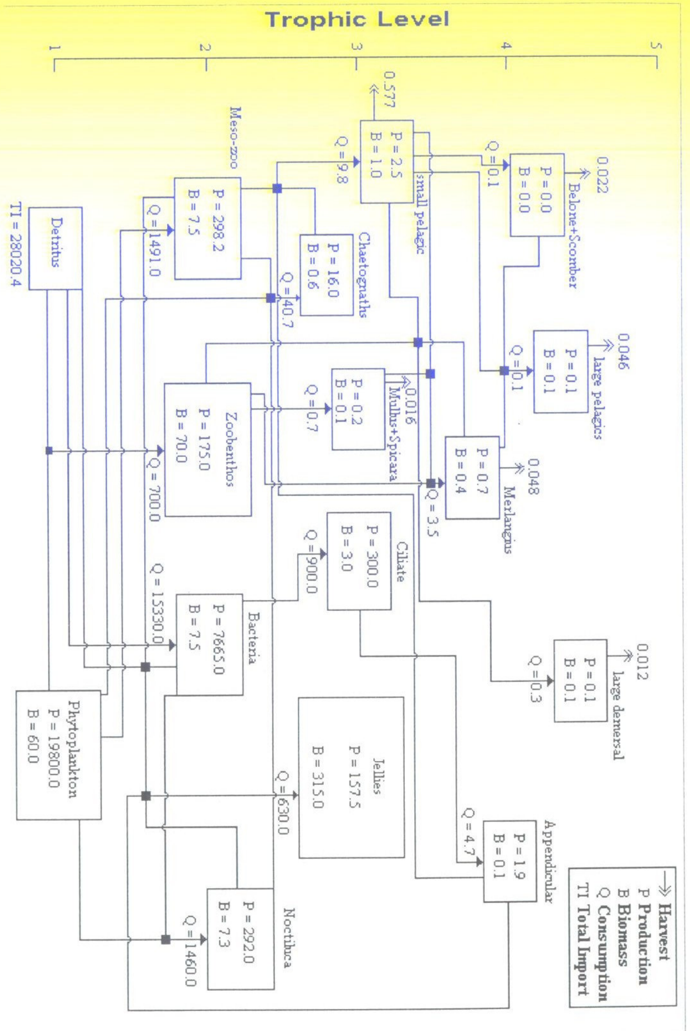

Fig. 2. Trophic flow diagram of the model results (all values are given in ton/km^2)

Concluding Remarks

Higher trophic levels of the Black Sea ecosystem is not controlling or playing a vital role. Fish groups with their low biomass are not significantly affecting the huge biomass of lower trophics. The catch statistics probably are not reflecting the real situation. To balance the model even a 100% change in harvest (catch) did not influenced the mortalities as expected. For the ECOPATH approach, it is impossible to get logical result with the original non-manipulated *Mnemiopsis* data. If there is any negative link between the *Mnemiopsis* and the fish stocks, then the fish stock should fluctuate in relation with the *Mnemiopsis*. However, the catch data of the major species in the Black Sea are not following this rule (Figs. 3 & 4).

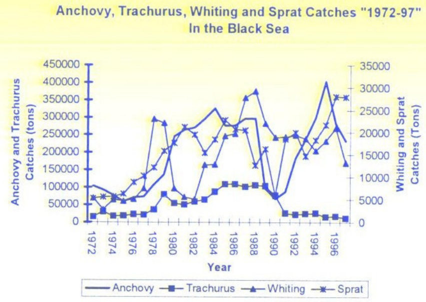

Fig. 3. Trends in catches of some major fish species in the Black Sea between 1972-1997 (FAO, 1998).

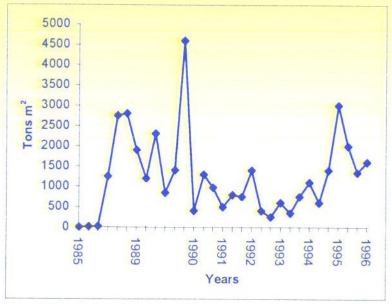

Fig. 4. Developmental trend in Mnemiopsis (Shiganova 1998).

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