Stock assessment and modelling of commercially important fish species in the Black Sea as a basis of the ecosystem approach for marine bioresourses management

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Summary of PhD Thesis

Species in aquatic ecosystems do not exist in isolation, but are connected via complex trophodynamic relationships. A necessary condition for the description of the functional groups within the ecosystems is the investigation of their population (age-size structure, sex structure, mortality rates, etc.) and ecological characteristics (diet, trophic relationships, position of the species in the complex ecosystem structure). The aim of the present study is to investigate the state of three important commercial fish species - bluefish, horse mackerel and sprat - in the Black Sea, by analysing their age-size structure, growth rate, diet, and catch per unit of effort, as well as to assess the state of the Black Sea ecosystem and its marine bioresources using a mass-balanced model - Ecopath with Ecosim.

A comparative analysis of bluefish growth parameters between the past (1950s-1970s - historical data from the literature) and modern periods (2013-2015 - results from this study), revealed that nowadays, the sexually mature specimens (age 2 and 3) have significantly lower size and growth rate than those reported in historical studies. During the investigated period, bluefish showed poor feeding intensity - 75 % of all examined stomachs were empty. Small pelagic fishes such as horse mackerel and sprat were its preferred food, while in the historical period its preferred prey was the mackerel. The slower growth rate in the modern period might be due to a combination of factors: a shift in the bluefish diet as a result of the disappearance of larger fish like mackerel and bonito, and intensive fishing as evidenced by the predominance of young individuals of age 0 and 1 in the bluefish landings in 2013-2015.

In 2013-2015, the preferred prey groups for the horse mackerel along the Bulgarian Black Sea coast were Polychaeta, Crustacea and Pisces. The horse mackerel's feeding intensity tended to decrease with the cooling of the seawater and the increase in fish body size. The horse mackerel stomachs contained a large number of prey taxa, but most were classified as rare food (generalised diet). The feeding strategy indicated a relative specialisation on only a few prey items such as polychaetes, Decapoda larvae and fish. The horse mackerel's feeding strategy differed between seasons. In the spring, the horse mackerel was mostly benthivorous, in the autumn it tended to prefer fish prey, whereas in the summer it fed on a mixed diet of zooplankton, benthos and fish. These dissimilarities between seasons were probably due to differences in prey availability and accessibility, depth allocation of the predator, and varying nutritional needs of the horse mackerel during different seasons.

The EwE modelling (1990-2010) showed that the small pelagic fish (sprat, anchovy and horse mackerel) have the highest contribution to the total Black Sea fish biomass and catches. The mussels, the small pelagics and the demersal fish have the highest total mortality rates (Z) in the ecosystem. The Black Sea fishery has a strong negative effect on the exploited fish species. According to the model, representatives of the lower trophic levels such as benthic

crustaceans, zooplankton and small pelagic fish are keystone species for the Black Sea ecosystem, and exert bottom-up control on the ecosystem.

The Black Sea trophic diagram consists of four trophic levels, with the highest biomass contribution and energy flows originating from the lower trophic levels due to a high primary productivity. In the Black Sea ecosystem, 73% of the total system throughput (TST) originate from detritus and primary producers (trophic level one, TrL 1); 23% originate from TrL 2 (benthic crustaceans, zooplankton, Protozoa, Noctiluca); 2.3% - from TrL 3 (jellyfish, small pelagics, demersal fish, *Alosa*, *Sagitta*, *Rapana*; and 1% - from TrL 4 (predatory fish, marine mammals). The highest fishery catch - 71% - comes from TrL 3 (small pelagics), followed by 28% from TrL 4 (predatory fish). The Black Sea ecosystem is in an early stage of maturation, indicated by the high values of the indices TPP/TR (total primary production/total respiration), NSP (net system production), and TPP/TB (total primary production/total biomass), and the low values of the indices TST, FCI (Fin cycling index), and SOI (system omnivory index). The average system transfer efficiency (%TE) is 7.7%, where 10% is the typical value for the marine ecosystems, which suggests that the trophic flows in the Black Sea system are slow and a significant part of the system energy is stored in the detritus pool.

The time-dynamic simulations (Ecosim) showed that the changes in the fishing mortality (F) for small pelagics would have the most pronounced effect on the biomass of the functional groups included in the model. This phenomenon could be explained by the fact that the small pelagics have the highest biomass in the system. In addition, they occupy the middle trophic positions in the Black Sea ecosystem, and exert bottom-up and top-down effect on their prey and predators (the so-called wasp-waist control).

The CPUE indices of two commercial fishing vessels trawling for sprat along the Bulgarian Black Sea coast showed significant daily differences. The average CPUEs decreased from 2006 to 2015. Since the sprat stock is considered to be sustainably exploited by the Black Sea fishery, the decreasing trend in CPUEs might be due to the typical biomass fluctuations of the sprat between the years, but could also be a result of the lower demand for sprat by the fishery contracting companies.

The results of this complex study demonstrate the need for multiple indices and indicators, as well as multi-species models, when analysing the status of the marine ecosystems and their fishery resources. In addition to the conventional methods for fish stock assessments such as age-size structure, mortality, etc., the investigation of the trophic structure of the ecosystems – the transfer of energy and matter between the various trophic levels – is an essential element of ecological modelling. The detailed investigation of all these different aspects of the structure and elements of the ecosystems forms the basis of the ecosystem approach to fisheries (EAF).