Influence of variable catch factors on sardine population level in eastern Adriatic tested by System Dynamics

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Abstract:
System perspective can be applied to the fishery management. Therefore investigation of sardine population behaviour dynamics by system dynamics methodology is presented in this paper. The model is based on Schaefer production model and available biological data was used for sardine in the Adriatic Sea. The Schaefer production model is often applied in order to submit behavior dynamics of fish population and particularly to manage marine natural resources efficiently. Alegria-Hernandez (1983) used Schaefer and Fox production models for sardine population in Eastern Adriatic. Initial value for catchability coefficient of 3,99E-5 is taken from Alegria-Hernandez (1983). According to the same author value of the optimal fishing effort is between 4115 and 5292 effective fishing days in one year for the sardine in the Eastern Adriatic. Those values are tested using developed model. Simulation scenarios were made in Powersim and DYNAMO. Although model can be applied for all other species and many of different regions, sardine population was chosen due to its great importance to Croatian fishing.

Keywords: sardine population, catch factors, Schaefer production model, eastern Adriatic

Introduction:
Many factors contribute to the complexity of the fishery system. It is difficult to manage, or to operate, within this highly uncertain, complex system. One of the solutions can be application of system approach to fisheries into decision making. Viewing the fisheries as a system leads to recognition of the variety of closely interacting, dynamically varying components involved. Different models for investigation behavior dynamics of fish population exist. The Schaefer production model is often applied for fishery purpose, particularly for efficient management, of marine biological resources including their protection. Alegria-Hernandez (1983) used Schaefer and Fox production models for sardine population in eastern Adriatic. In this paper, Schaefer production model was used due to

lack of appropriate biological data for any other model. According to the System dynamics methodology Schaefer production model for sardine population was presented.

Production models are very simple but they can be good approximation for complex behavior dynamics of biological systems. Change of population biomass (Dudley, 2003), which mathematically matches first derivation, is:

$$\frac{dB}{dt} = \left[(r * B) - (r * \frac{B^2}{CC}) \right] - C$$

where:
dB/dt - rate of biomass change
r – intrinsic growth rate
CC – carrying capacity
C – catch rate
B – sardine biomass.

In the model catch is defined as product of fishing effort (f), catchability coefficient (q) and sardine biomass (B) (Ussif, 2003). It is common practice to assume catch is proportional to fishing effort and stock size, although this is only the case if the catcahability coefficient doses not vary through time or with stock size (Haddon, 2001).

Any system is a set of interrelated components. In a fishery system, one of the primaries, most dynamic components of the system are people and their behaviors (Orbach, 1980). This paper deals with the influence of variable catch factors on sardine population level in tested by system dynamics i.e. dynamics of sardine population when fishing effort change its value. Total fishing effort in relation to stock under exploitation is an essential parameter in the policy of sustainable marine resources management (Alegria-Hernandez, 1983). In sardine catch the unit of fishing effort should be calculate as the effective fishing effort of a purse-seine day or night. For example it is suggested to use effective boat days for fishing effort calculated in purse-seine for haring fishery (Alegria-Hernandez, 1983). According to Alegria-Hrenandez (1983) value of the optimal fishing effort for the sardine is between 4115 and 5292 effective fishing days in one year in the Eastern Adriatic. Simulation scenario at the beginning tests dynamic behavior of sardine biomass when fishing effort is lower and fishing effort increases through simulation and all other variables are given according to Alegria-Hrenandez (1983).

1. System dynamics structural flow diagram of sardine population

System dynamics structural flow diagram of sardine population is presented in Powersim language. It comprises all variables included in the model, together with existing causes-consequences links and feedback loops in sardine population system.

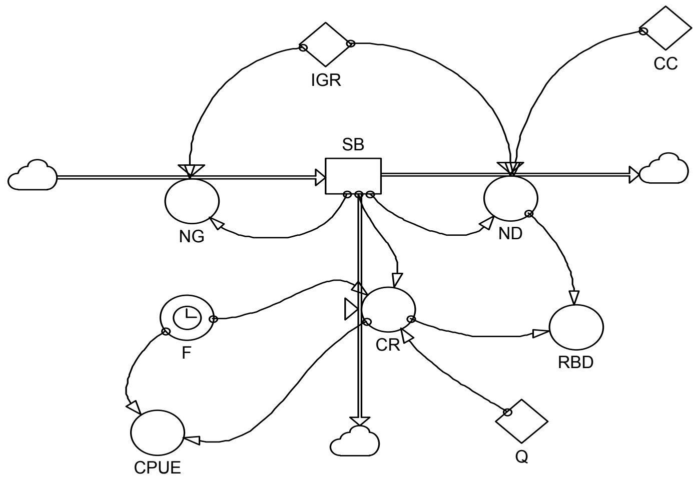

Figure 1. System dynamics flow diagram of sardine population in Powersim language (Sliskovic, 2007)

Where symbols in Powersim were:
NG – natural growth
SB – sardine biomass
IGR – intrinsic growth rate
CC – carrying capacity
ND – natural death
CR – catch rate
Q – catchability coefficient
F – fishing effort
RBD – rate of biomass decrease
CPUE – catch per unit effort.

2. Scenario and results

Related to the fact that total fishing effort is an essential parameter in the policy of sustainable marine resources management, the influence of two value of fishing effort is tested. According to Alegria-Hrenandez (1983) value of the optimal fishing effort for the sardine in the Eastern Adriatic are between 4115 and 5292 effective fishing days in one year. Developed Scenario tested the dynamics of sardine biomass under two different level of fishing effort. At the beginning fishing effort has value of 4115 fishing days and after some time it raises to value of 5292 fishing days.

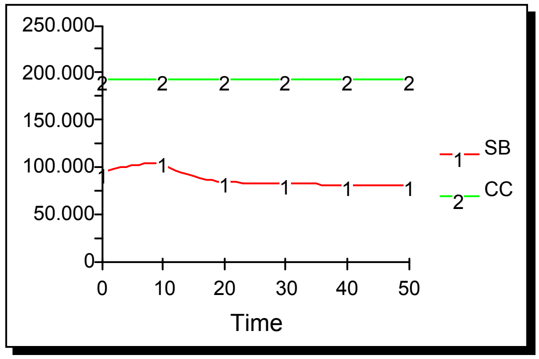

Figure 2. Dynamic behavior of sardine biomass (SB) and carrying capacity (CC)

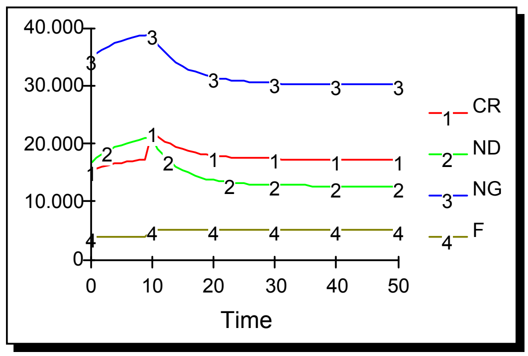

Figure 3. Dynamic behaviors of catch rate (CR), natural death (ND), natural growth (NG) and fishing effort (F)

Small increase of biomass is observed at the beginning of simulation (Fig. 2), which results from the fact that natural growth has higher value than rate of biomass decrease is. Comparative analysis of natural growth and catch shows that natural growth is higher than catch as provided this way. When higher value of fishing effort is introduced, the dynamics of sardine biomass starts to decrease (Fig. 2). After some time of adjusting, biomass reaches steady state as the response to changed value of fishing effort. Higher value of fishing effort results in greater catch i.e. “step” in the catch rate is evident immediately after fishing effort shifts its value (Fig. 3). In this case, comparing the values of catch and natural death, it can be noted that portion of catch in total death is larger than portion of natural death. Although, the value of natural growth increases at the beginning of simulation, it follows the same path as natural death. When fishing effort steps to higher value both of these variables decline sharply at first and, after some time stabilize their values. Sardine biomass is directly influenced by different value of fishing effort. Lower values of fishing effort cause increase in sardine biomass, while higher values of fishing effort decrease sardine biomass regarding to initial biomass. However, in this scenario, biomass reaches steady state which is far below carrying capacity.

3. Conclusion

Many management systems are based upon the size of fishing effort which can be applied on some fish stock in order to obtain desired catch level (Rothschild, 1977). Fishing effort is measured in units appropriate for the observed fishery (Clark, 1990). For sardine population in the Eastern Adriatic, the appropriate unit for fishing effort is effective fishing days in one year. Although, this Scenario is relatively simple, it shows that by system dynamics modeling different values of the fishing effort can be tested. Thus the optimal catch can be determined and sustainable development of observed population achieved. Applying the data for optimal fishing effort for the sardine population in the Eastern Adriatic (between 4115 and 5292 effective fishing days in one year), given by Alegria Hernandez (1983), on designed SD model, it is obvious that sardine biomass reaches steady state under these values of fishing effort, and that state of equilibrium is far below carrying capacity, i.e. it is possible to make fishing effort more intense. Populations that are harvested when they are near their maximum population size have more resilience to perturbations (such as fishing pressure) than population harvested when at lower population sizes (Haddon, 2001). System dynamics modeling can serve as a tool for fishery management, i.e. some management polices can be tested on adequate model without endangering real population.

4. References

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