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SYSTEM DYNAMICS MODEL OF SARDINE POPULATION (*SARDINA PILCHARDUS*) IN THE EASTERN ADRIATIC SEA

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INTRODUCTION

- fishery system is complex and difficult to manage or to operate
- application of system aproach to fisheries into decision making
- for investigation of behavior dynamics of fish population, different models exist
- the Schaefer production model is often applied for fishery purpose, particularly for efficient management of marine biological resources
- according to the System dynamics methodology, Schaefer production model for sardine population was presented
- comprehensive qualitative and quantitative models were made using available biological data
- several simulation scenarios were made in Powersim and Dynamo

SCHAEFER PRODUCTION MODEL

- production models are very simple but they can be good approximation for complex behavior dynamics of biological systems
- change of population biomass, which mathematically matches first derivation

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

- B (biomass)
- r (intrinsic rate) and CC (carrying capacity) are logistic growth parameters
- C (catch rate) is defined as product of biomass, catchability coefficient and fishing effort (C=qEB)

MENTAL – VERBAL MODEL OF SARDINE POPULATION

- all biological populations are regulated by the natural laws of birth and death

- the birth contribute to the increase of the existing biomass (positive (+) CCL)

- the mortality reduces biomass (negative (-) CCL)

- where there is no catch and without large fluctuations in environmental conditions, the population will grow to the state of natural balance

- natural balance (stady state) is determined by carrying capacity of the environment

- there will be no changes in biomass, but only the maintenance of equilibrium (zero growth)

MENTAL – VERBAL MODEL OF SARDINE POPULATION II

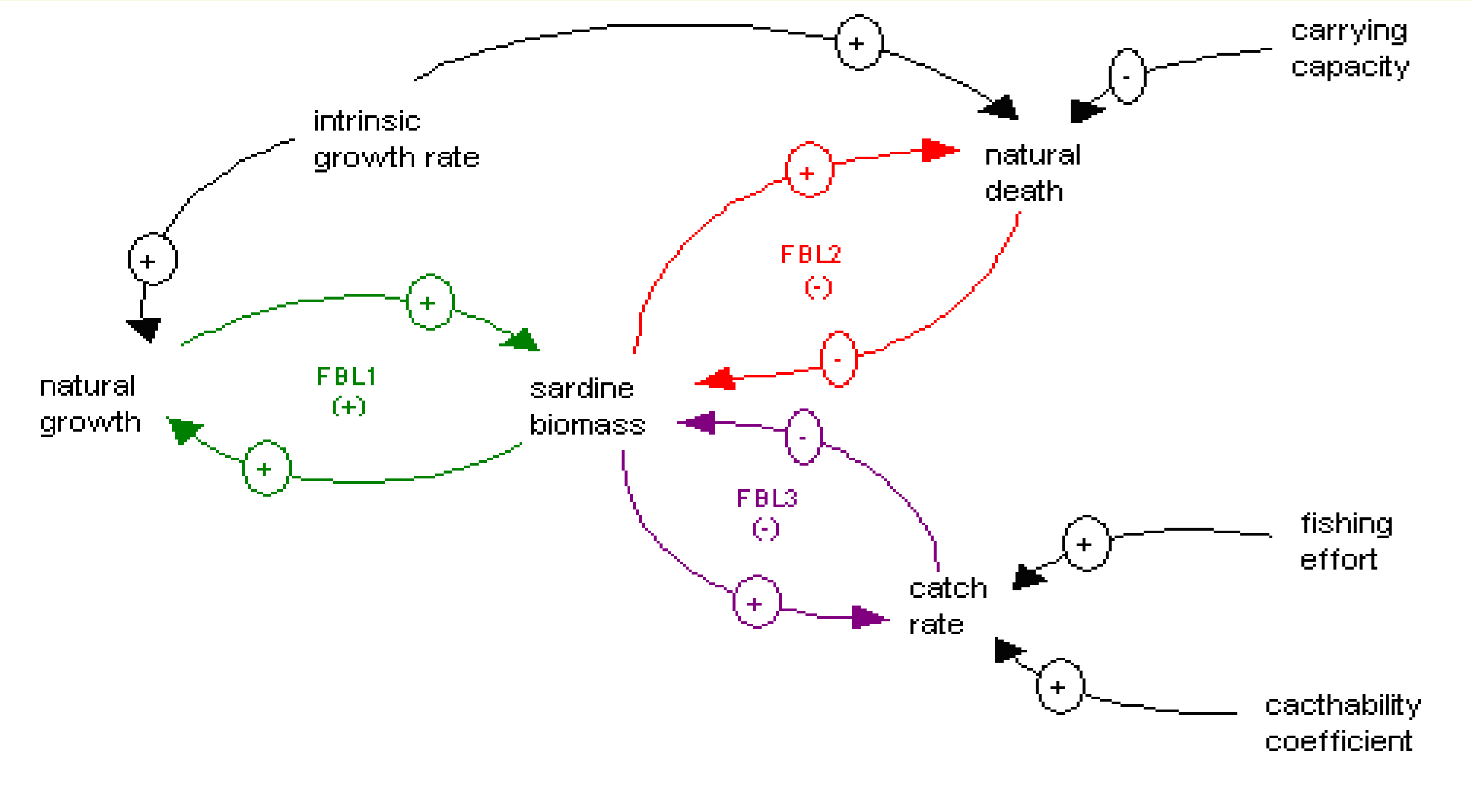
- sardine populations system is managed through the catch (negative FBL- a self-regulating loop), i.e. the size of the catch directly affects the value of sardine biomass

- the catch is determined by multiplying the catchability coefficient (part of the stock that is caught by one unit of fishing effort) by fishing effort

- other factors that affect biomass reduction of observed population (catastrophic environmental pollution, etc.) can be included in the model

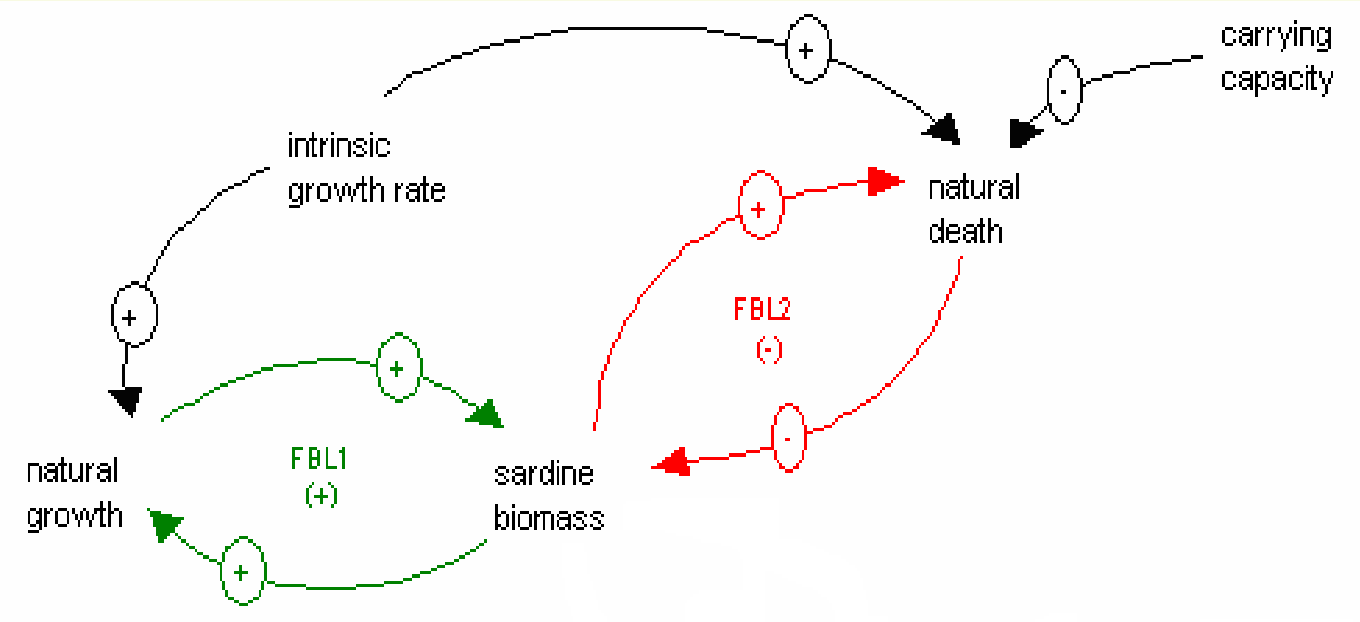
- the system of sardine populations identified three dominant feedback loops: a positive (FBL1 (+)) and two negative (FBL2 (-), FBL3 (-))

SYSTEM DYNAMICS STRUCTURAL MODEL OF SARDINE POPULATION

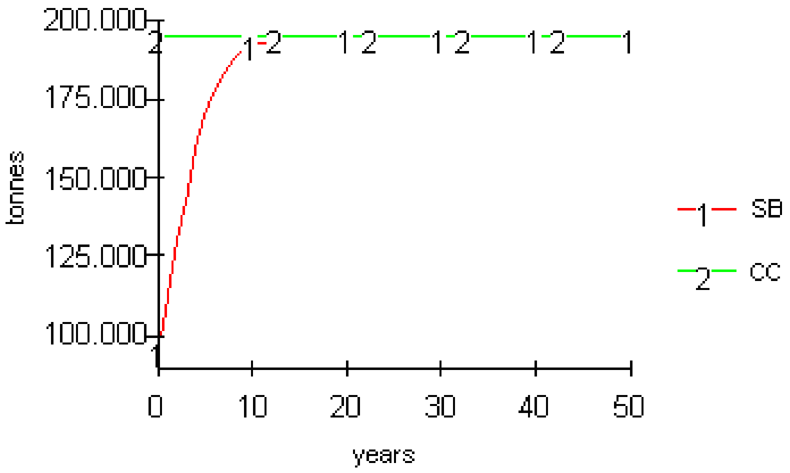


SCENARIO 0

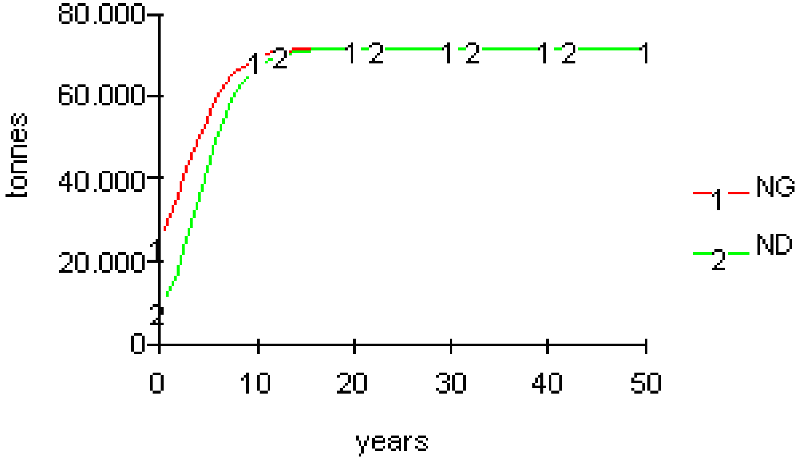
- behavior dynamics of sardine population without anthropogenic influence on the population i.e. fishing
- sardine biomass increased due to natural growth and decreased due to natural death



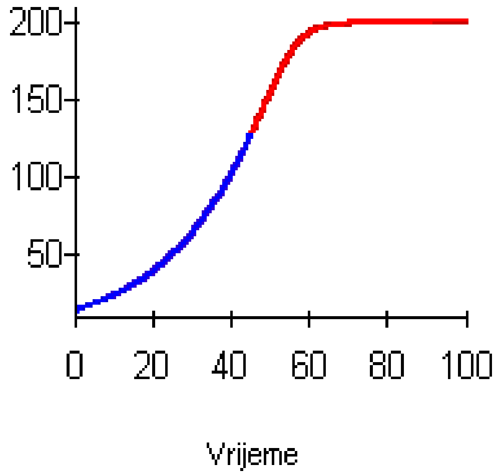
RESULTS OF SCENARIO 0

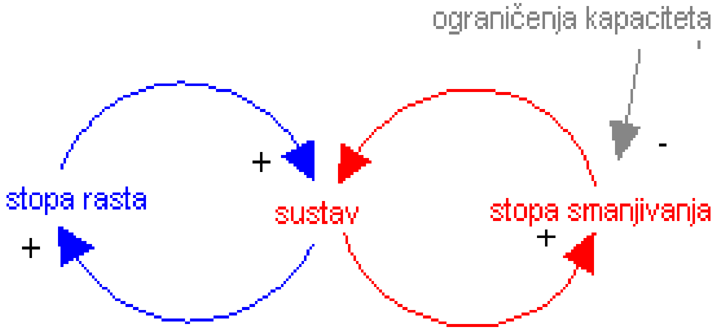


SB – sardine biomass
CC – carrying capacity



NG – natural growth
ND – natural death



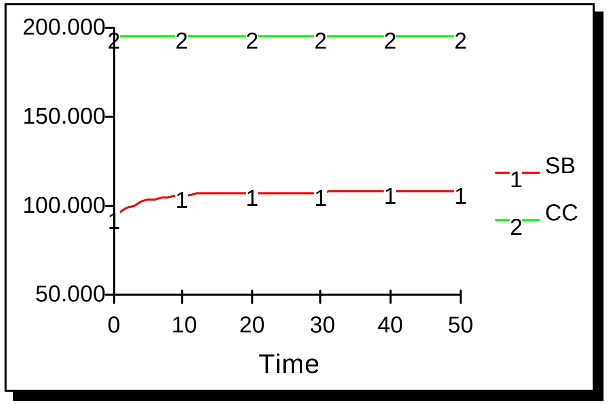


- nonlinear interaction between positive and negative feedback loop was key aspect of the structure that generated S-shape
- bending point in S-shape was point where shift in loop dominance occurred
- system asymptomatically approached its balance

SCENARIO 1

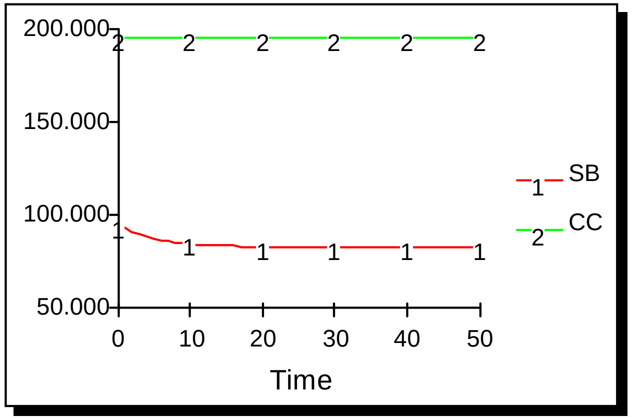
- scenario 1a tested dynamic behavior of sardine biomass with lower fishing effort values (f=4115 effective fishing days in one year)
- scenario 1b with higher fishing effort values (f=5292 effective fishing days in one year)
- all other variable were constant

RESULTS OF SCENARIO 1



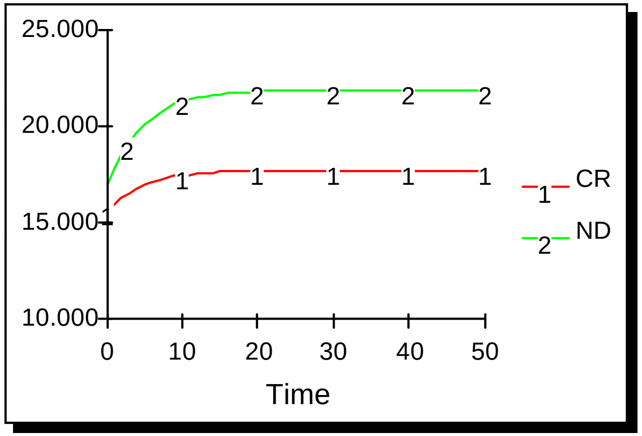
Scenario 1a f=4115

SB – sardine biomass
CC – carrying capacity

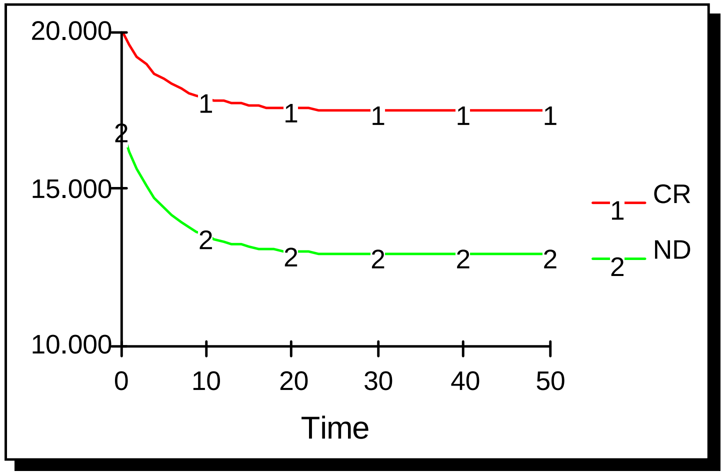


Scenario 1b f=5292

RESULTS OF SCENARIO 1 - II



Scenario 1a f=4115



Scenario 1b f=5292

CR – catch rate
ND – natural death

CONCLUSION

- modeling and simulation enabled testing of different scenarios without endangering sardine real population
- qualitative and quantitative models of Schaefer production model were developed using available biological data as initial values of the variables
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- Schaefer production model is commonly used in fishery management
- in Scenario 0, when fishing was not included, sardine population exhibited almost ideal S-shape behavior - one of the most common behaviors in dynamics population system
- very useful as teaching tool - testing the different values of fishing effort

Thank You!