# A holistic modeling approach for the analysis of long-term changes in sustainability of the Black Sea ecosystem


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## OUTLINE OF THE TALK

1) What is the marine ecosystem sustainability ?

2) Long-term, data-driven, holistic ecosystem assessment of the BS.

3) Early and modest scientific efforts toward the development of BS-EBM approach.

4) Major issues for building up a BS-EBM.

Sustainability implies provision of the ecosystem goods and services over the long-term at a certain level that maintains the ecosystem health and resilience.

The new paradigm to accomplish ecosystem sustainability is to implement a long-term science-based, adaptive holistic management approach that protects, maintains, and restores the functioning of an ecological system (at social, economic, ecological and institutional levels).

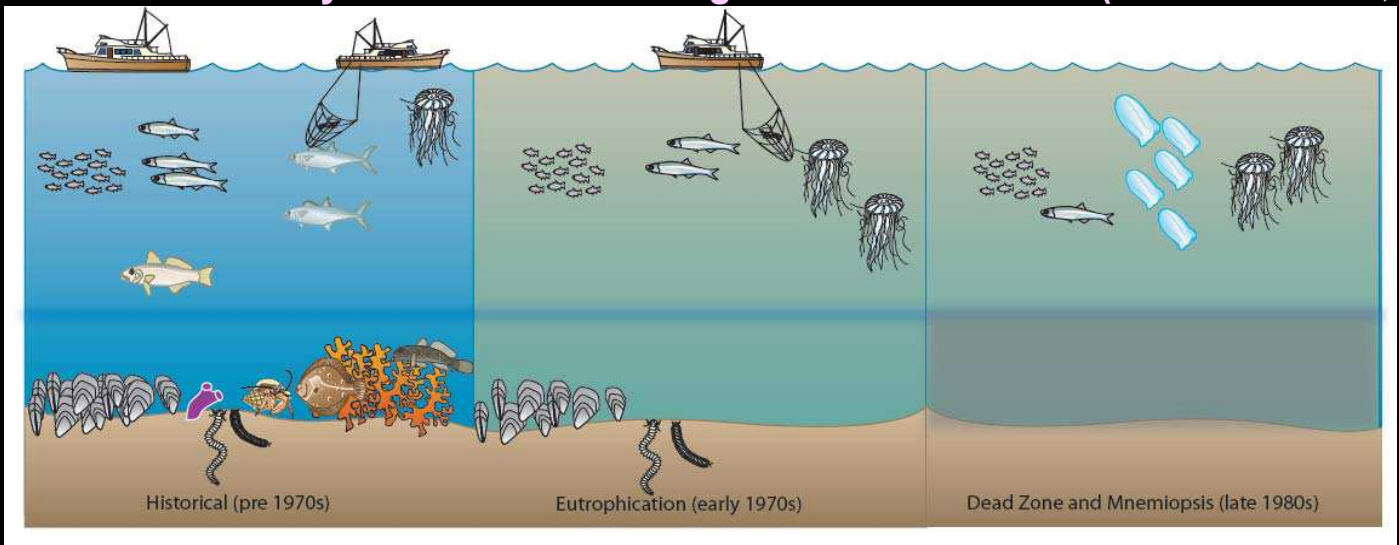
# Why do we need EBM for the ecological sustainability of the Black Sea?

The Black Sea has been one of the most heavily degraded and complex ecosystem in the world.

The BS in general, and its western coastal waters in particular, have been severely degraded in the 1970s and 1980s due to rapidly intensifying eutrophication, chemical pollution, decline in living resources (mostly fish stocks), alien species invasions, and climatic variations.

They introduced marked changes in functioning and structure of the ecosystem. Consequently, ecosystem services to the community have been diminished considerably, and their sustainability endangered seriously.

Transformation of the ecosystem structure along the western coast (Friedrich et al., 2006).

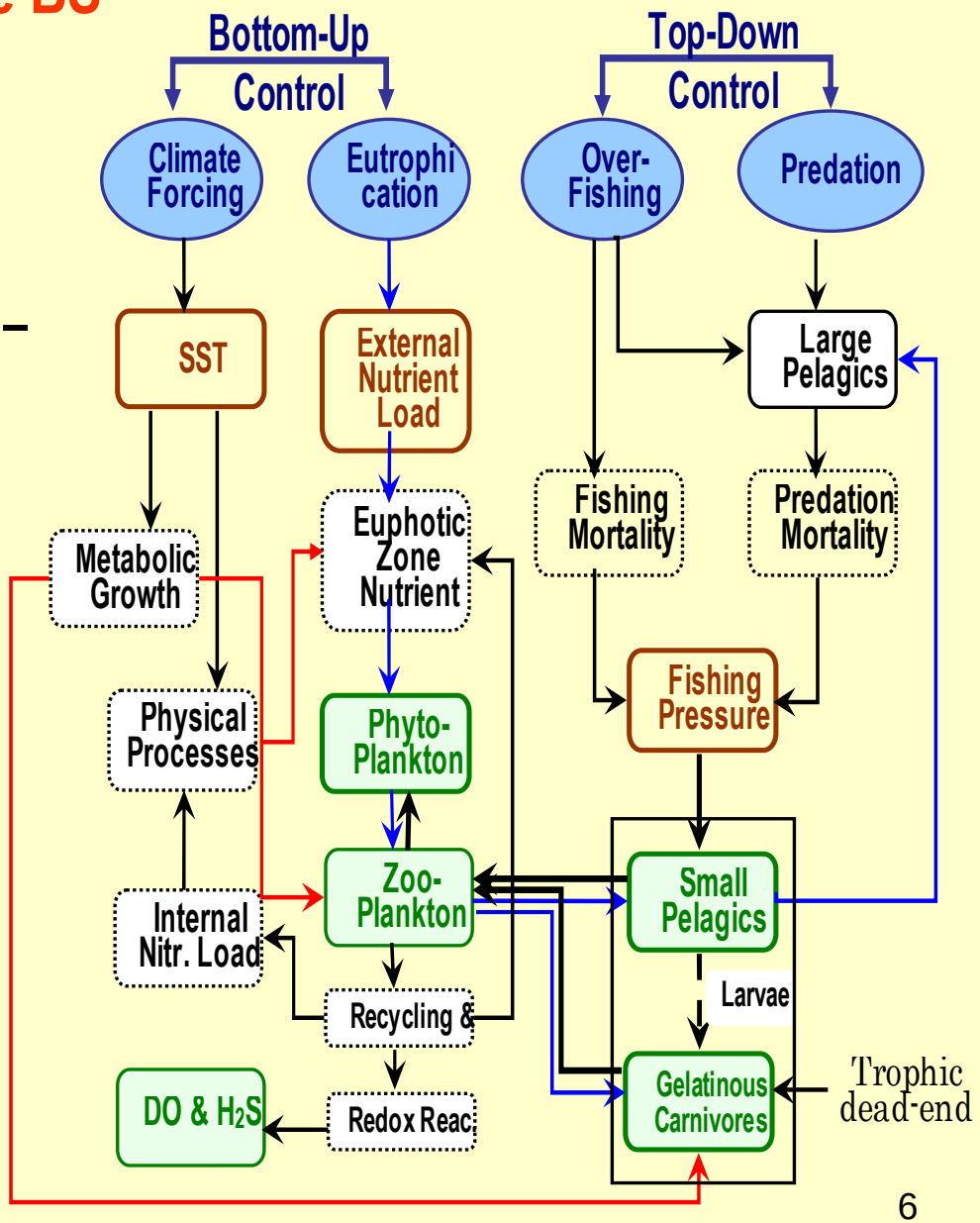


## How do we develop an EBM for the BS ?

- obtain a complete knowledge of the types of natural and anthropogenic exogenous and endogenous disturbances and drivers, and their impacts on the ecosystems,

# A simplified schematic representation of trophic controls and food web interactions in the BS

**The BS ecosystem is a complex adaptive nonlinear system governed by cumulative impacts of disturbances and drivers over long – (e.g. decadal) - time scales.**

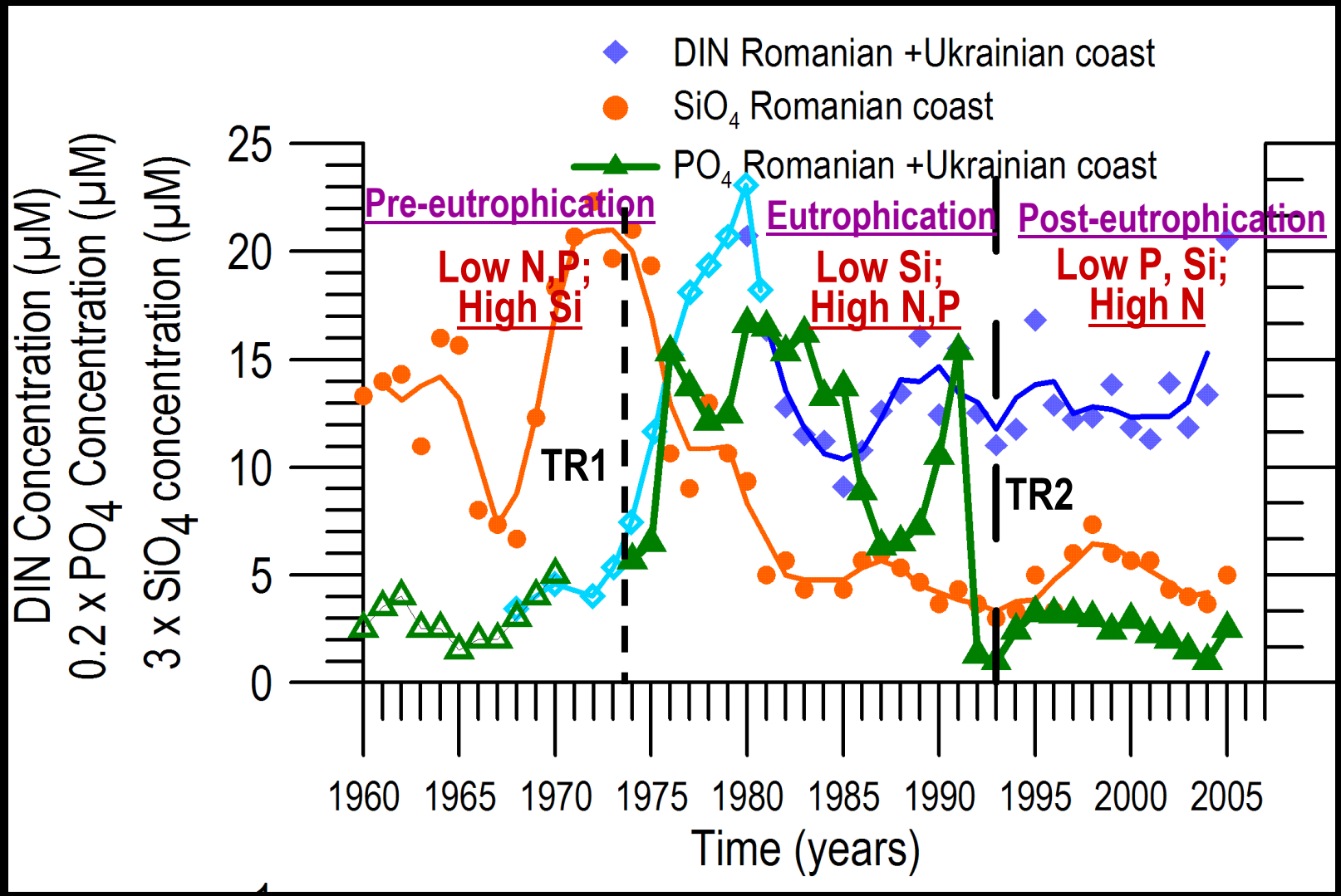



Oguz et al., 2006; JMS
Oguz and Gilbert. 2007; DSR

## How do we develop an EBM for the BS ?

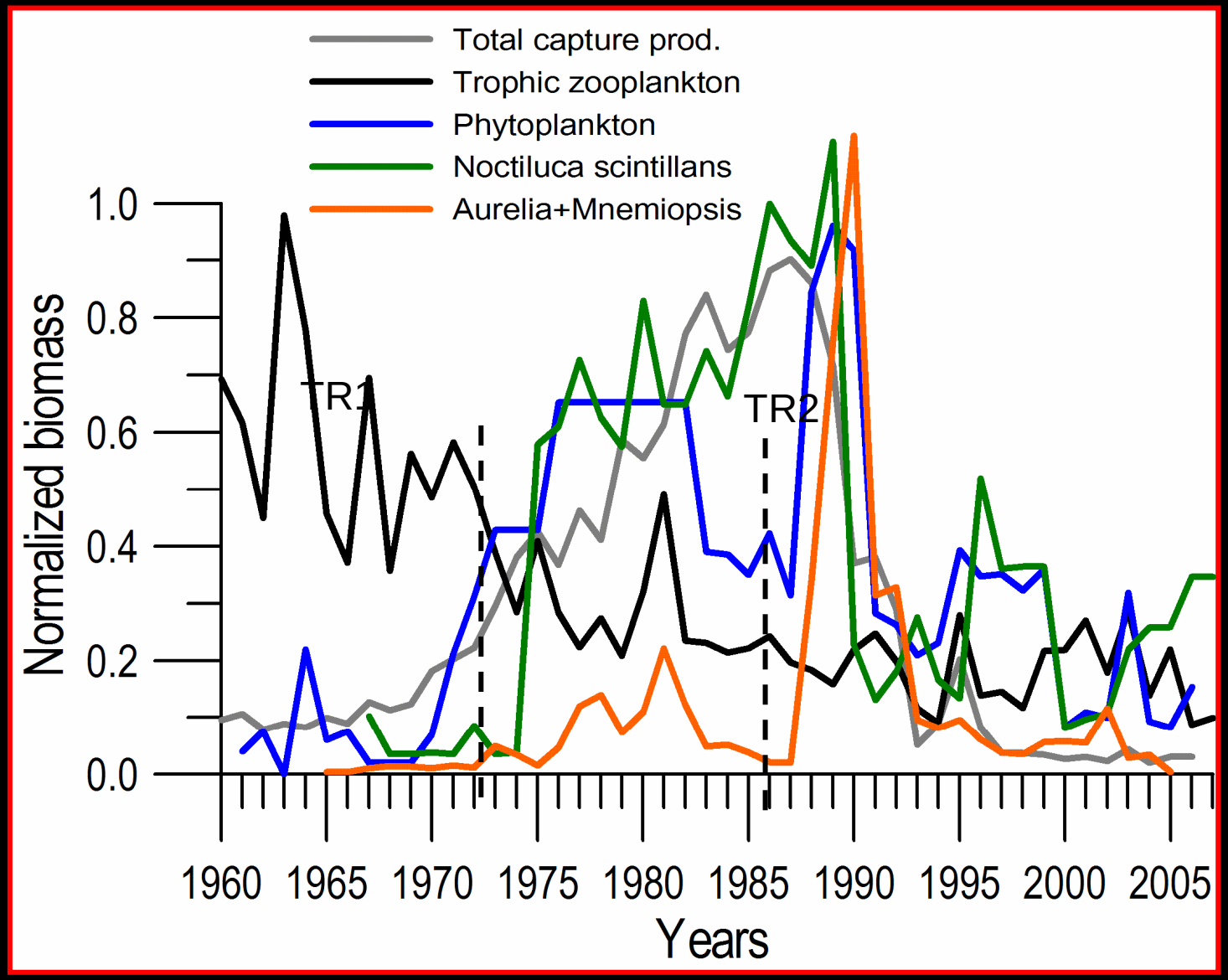
- obtain a complete knowledge of the types of natural and anthropogenic exogenous and endogenous disturbances and drivers, and their impacts on the ecosystems,
- obtain a full scale scientific assessment of the past and present ecosystem structures and trajectories of change,

# Eutrophication effect:
# Nutrients at the northwestern shelf



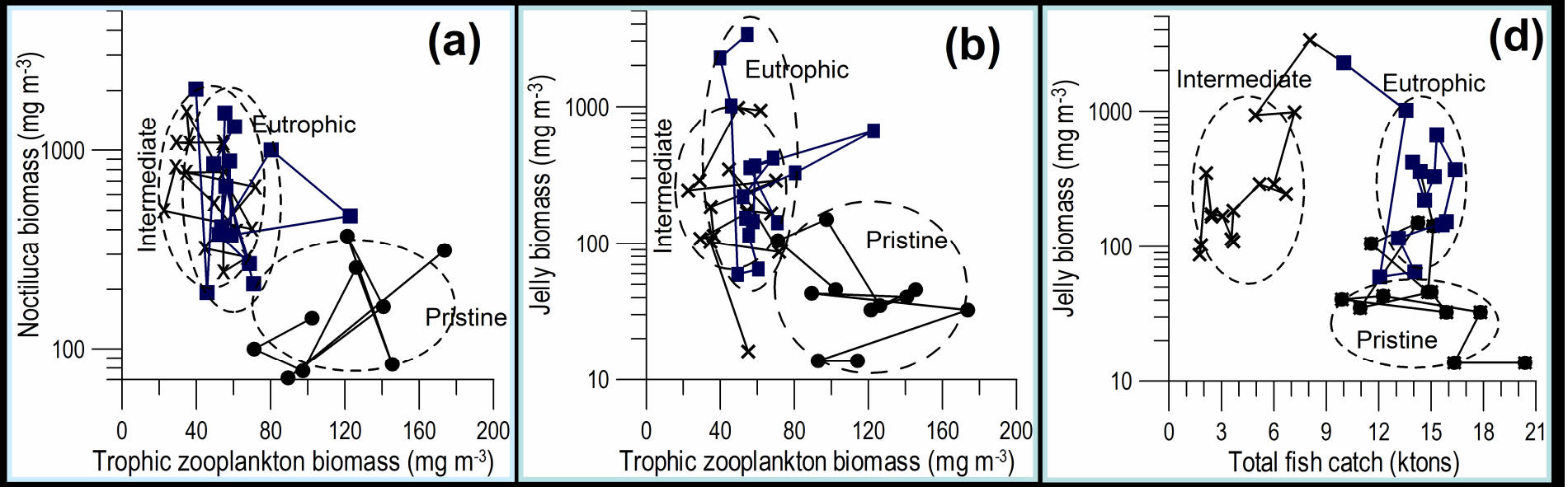

Oguz and Velikova; MEPS, 2010

# Plankton biomass in the northwestern shelf




Oguz and Velikova; MEPS 2010

# The pristine and intermediate ecosystem phases are two alternative states of the low-eutrophic system.



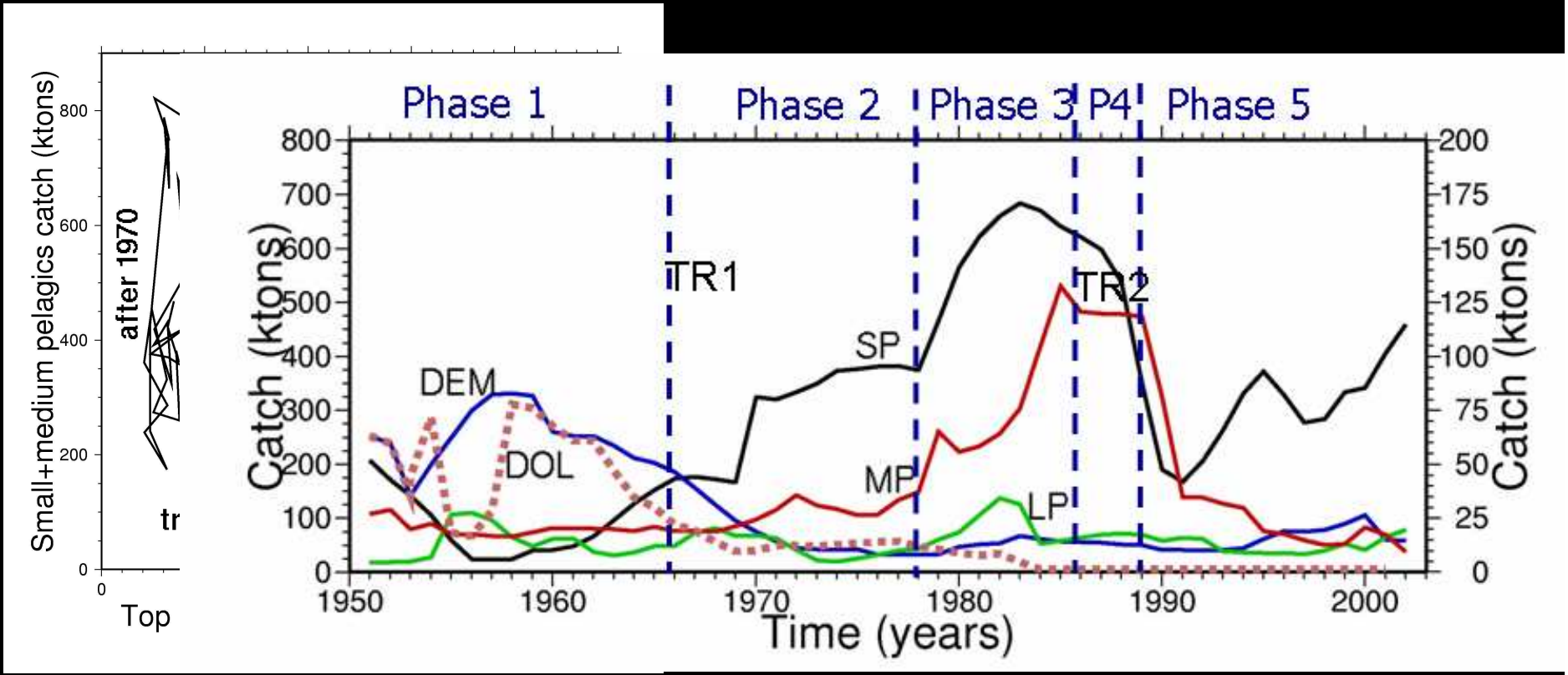

**Pristine= pre-eutrophication (>1970)**
**Eutrophic (1970-1992)**
**Intermediate=Post-eutrophication (>1992)**

**Oguz and Velikova; MEPS 2010**

The implication is revival of communities that have changed states can be very slow or even impossible. It is not certain that the system will move into a state that is similar or comparable with the pristine state.

# Fishery exploitation

Oguz, MEPS; 2007




**Long-term catch variations of dolphins (DOL), demersals (DEM), large pelagics (LP), medium pelagics (MP), and small pelagics (SP).**

**The abscissa on the left shows catch values for the small pelagic group, and on the right for the other groups.**

# Key assessments for the present state of BS ecosystem:

1) The western coastal waters are still subject to high nitrogen enrichment, but limited by phosphorus. On the contrary, the interior system is limited by nitrogen.

2) The pelagic ecosystem has achieved a moderate improvement in respect to the intense eutrophication period of the 1980s, but not to the pristine conditions of the 1960s.

3) Climatic variations (cooling in the 1980s and warming in the 1990s) have played strong role on both biomass and species levels.

4) The recovery of benthic ecosystem was not encouraging so far, and is expected to take much longer time. Shallower regions (<30-40 m depths) continue to be controlled by opportunistic species. But there are signs of improvement. Benthic habitat have begun to revive, but it is unclear whether they will regain their dominance.

5) Multispecies fishery is unsustainable. The system is in an undesirable state in terms of fish biomass. It is dominated by anvhovy and sprat, that are fish species of low commercial value. No recovery of medium pelagics, demersal and predatory fish species.

Some ongoing threats are:

- ✓illegal fishing and destructive harvest techniques,
- ✓lack of regional cooperative fishery management,
- ✓eutrophication-induced instability of the food web structure.

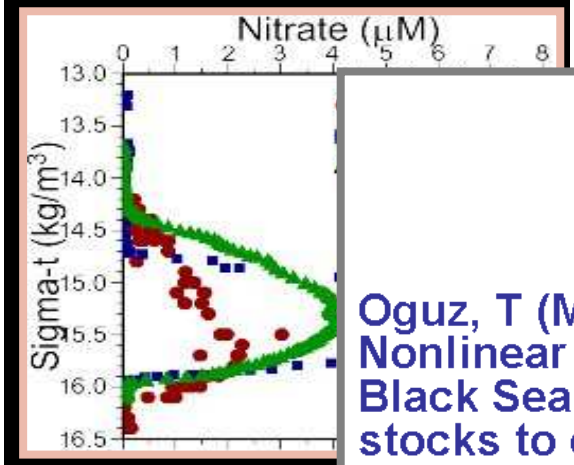
Ecological conditions are still fragile in the Black Sea.

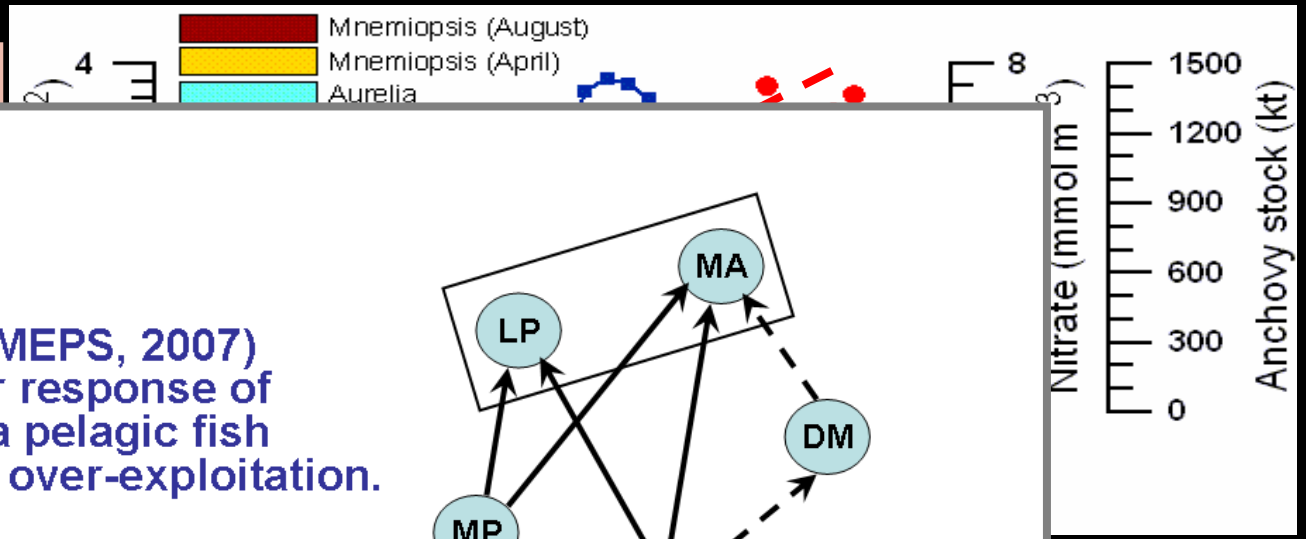
## How do we develop an EBM for the BS ?

- obtain a complete knowledge of the types of natural and anthropogenic exogenous and endogenous disturbances and drivers, and their impacts on the ecosystems,
- obtain full scale scientific assessment of the past and present ecosystem structures and trajectories of change,
- develop a modelling system that comprises the main characteristics of nonlinear ecosystem dynamics and food web interactions as well socio-economic and management options.

# A simplified dynamic higher trophic level model that

- simulates how the fish community responds to the changes in fishing intensity and
- assesses ecologically sustainable yield (ESY); that is a yield an ecosystem can sustain without shifting to an undesirable state.




Oguz, T (MEPS, 2007)
Nonlinear response of Black Sea pelagic fish stocks to over-exploitation.

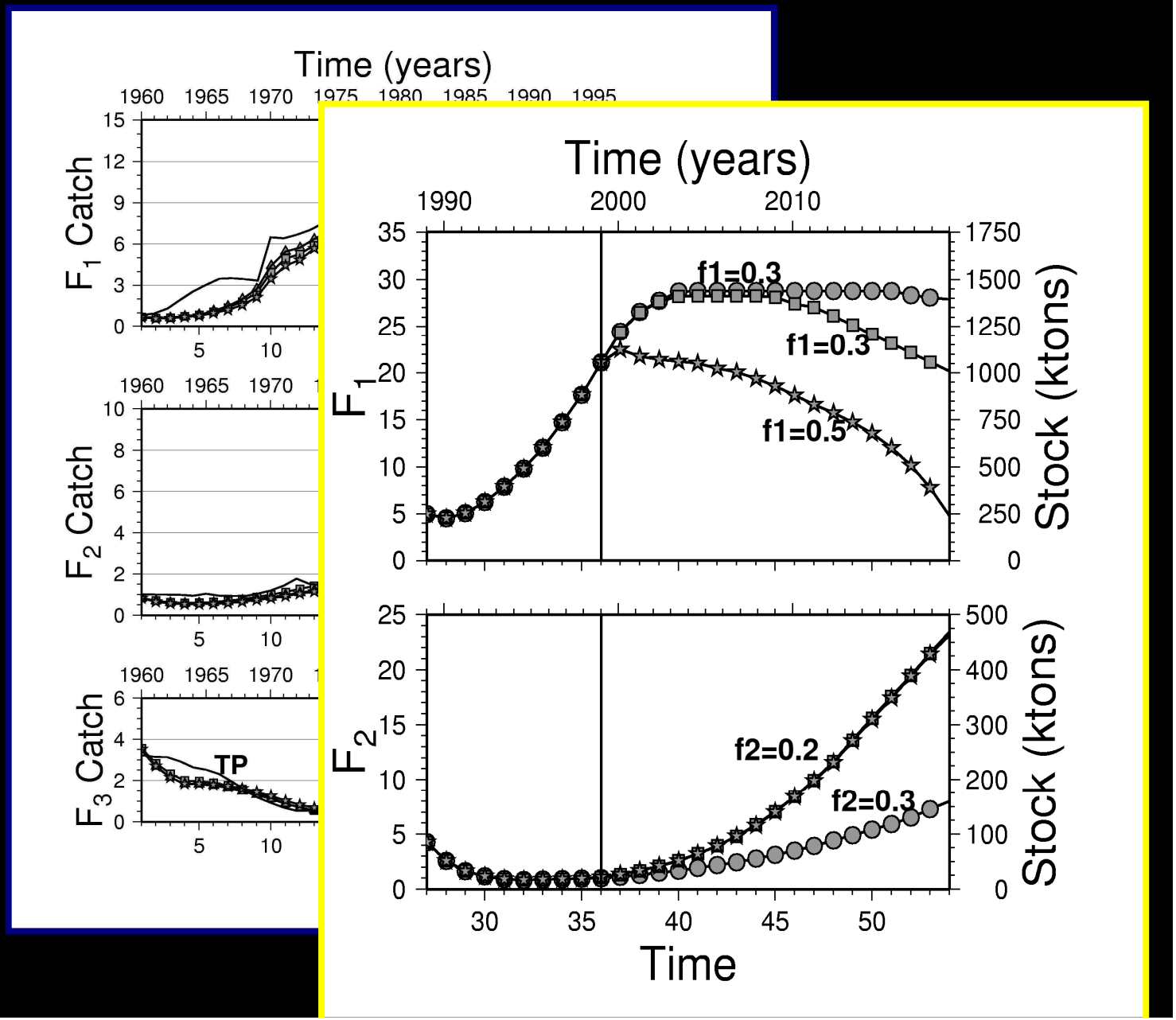



$$\frac{dS_1}{dt^*} = R_1 S_1 \left(1 - \frac{S_1}{K_1}\right) - R_2 S_2 \frac{S_1^2}{K_2^2 + S_1^2} - R_3 S_3 \frac{a_1 S_1^2}{K_3^2 + a_1 S_1^2 + a_2 S_2^2} - f_1^* S_1$$

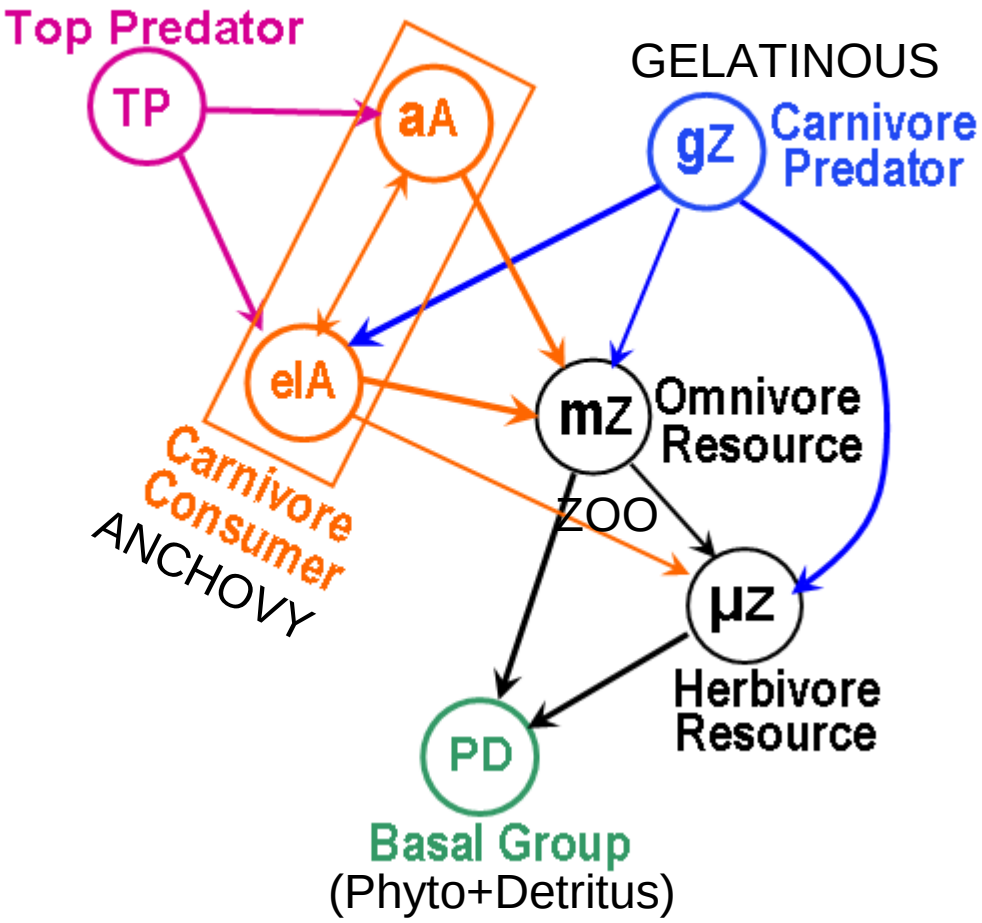
$$\frac{dS_2}{dt^*} = \varepsilon_2 R_2 S_2 \frac{S_1^2}{K_2^2 + S_1^2} - R_3 S_3 \frac{a_2 S_2^2}{K_3^2 + a_1 S_1^2 + a_2 S_2^2} - D_2 S_2^2 - f_2^* S_2$$

$$\frac{dS_3}{dt^*} = \varepsilon_3 R_3 S_3 \frac{a_1 S_1^2 + a_2 S_2^2}{K_3^2 + a_1 S_1^2 + a_2 S_2^2} - D_3 S_3^2 - f_3^* S_3$$

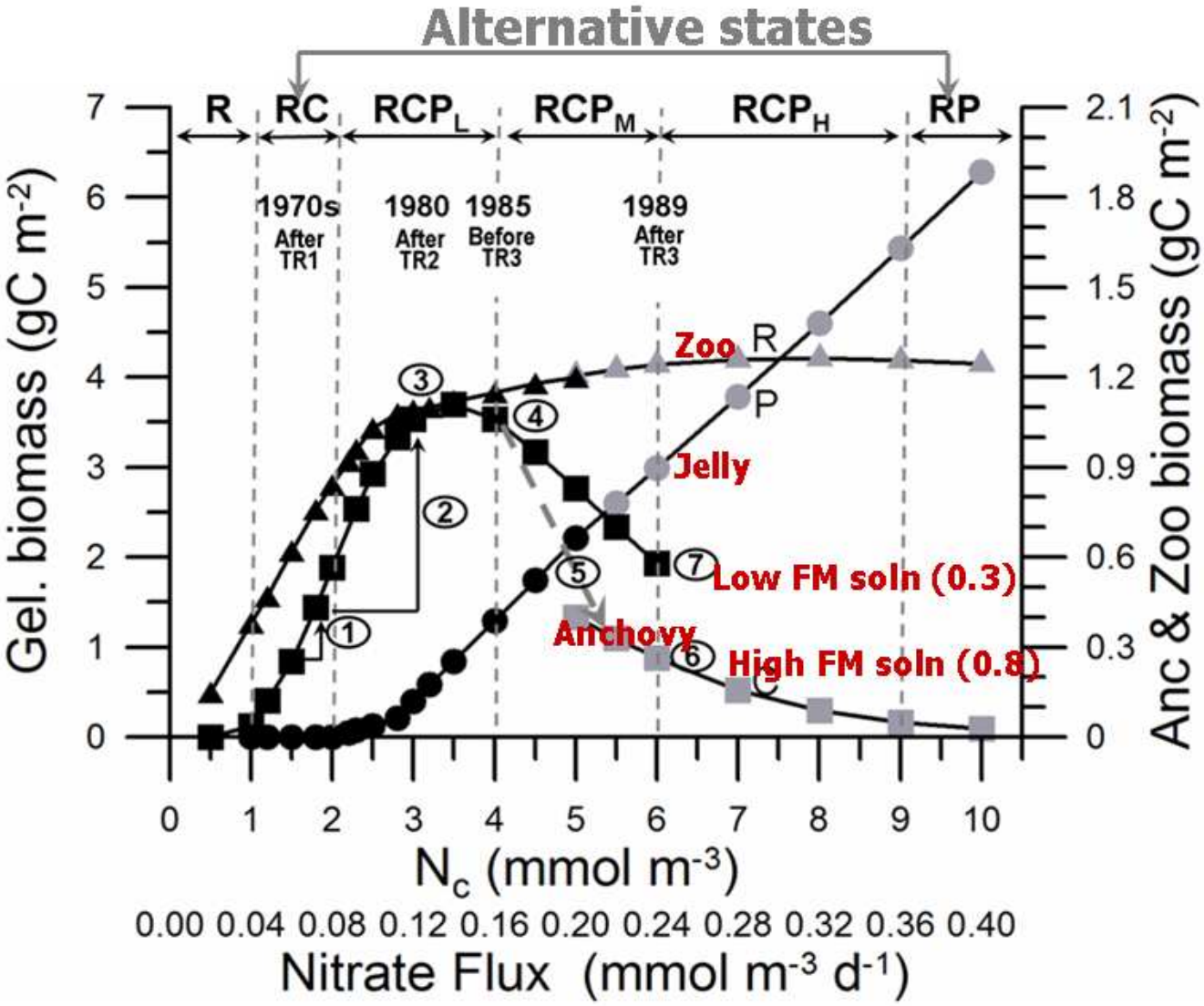
# A simplified dynamic higher trophic level model



# A more complex ecosystem-based model



# Anchovy - Jellies interaction along the productivity gradient

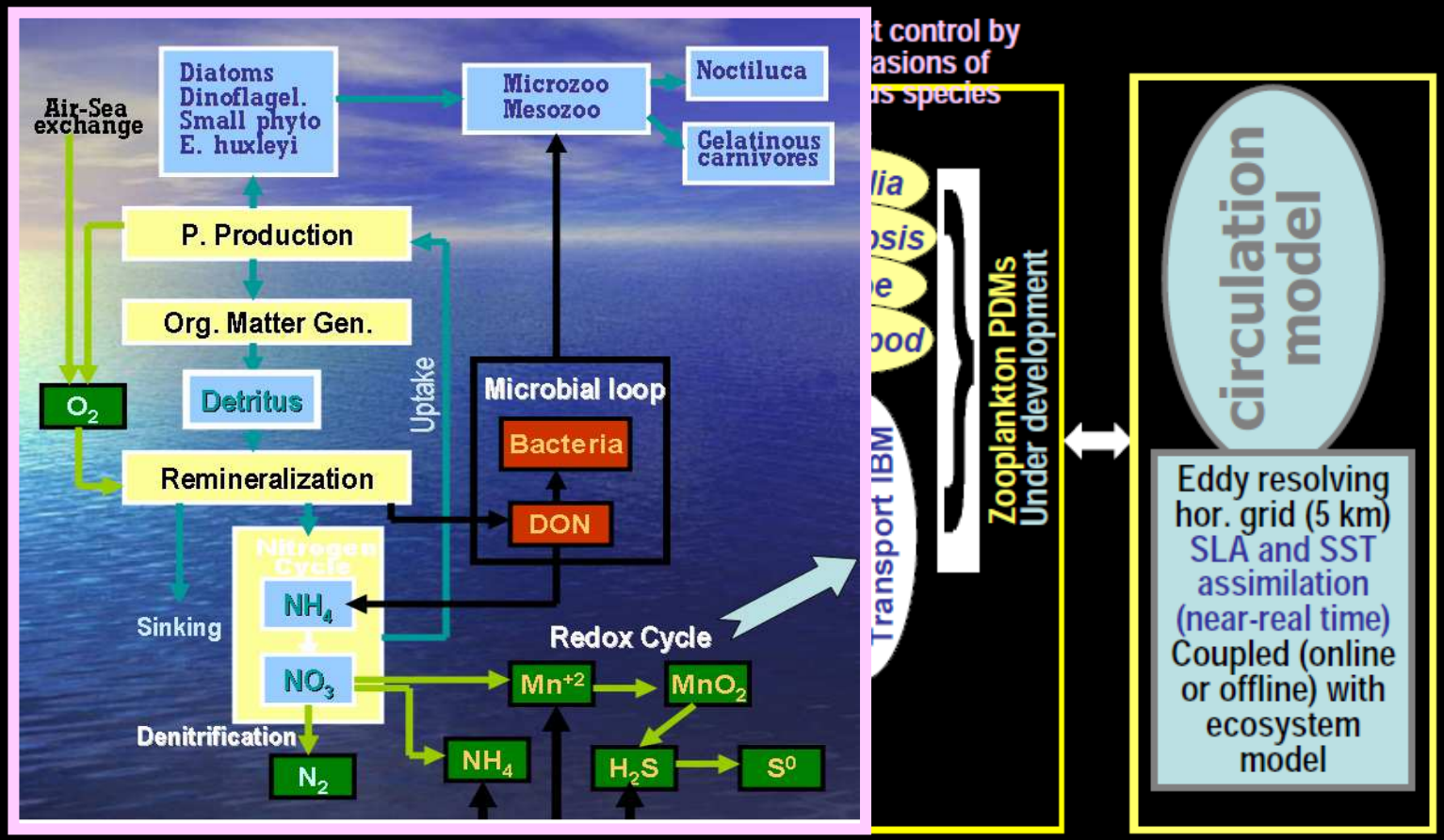



Oguz et al., 2008a; MEPS
Oguz et al., 2008b; JPR

# Black Sea Integrated Modeling System (BIMS)

Black Sea is an ideal system to model because it is relatively simple and well-studied.

Development of a model of "optimal complexity"




**However, BIMS currently does not explicitely consider management issues such as changes in exploitation strategies**

**TO CONCLUDE:** We have currently developed a fairly comprehensive understanding of the functioning of the BS ecosystem. The development of BIMS is underway.

## Some Major issues for building up a BS-EBM

1) A comprehensive observation strategy for a full suite of ecological, economic, and social indicators. It is currently not feasible under present economical capabilities of the riparean countries.
2) Development of a holistic modeling (ecological + socio-economic models) approach. It is an enormous task due to lack of observed data to model physiological features and to parameterize major ecological processes.
3) A management-oriented modeling study implies scenario-based simulations for the future ecosystem state. Therefore, How reliable the model results and How much complexity is necessary to be included into the model are important issues to study seriously.

## Some Major issues for building up a BS-EBM (cont'ed)

5) Communication among natural and social sciences for building up a holistic modeling system.

6) No strong political incentive and support by the countries.

7) Sufficient number of trained personnel to form a dedicated modeling group.

8) Uncertainties for a long-term funding to keep the group together.

Thank you for your attention