Black Sea anchovy IBM and jellyfish modules

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MEECE
Marine Ecosystem Evolution in a Changing Environment

Talk outline:

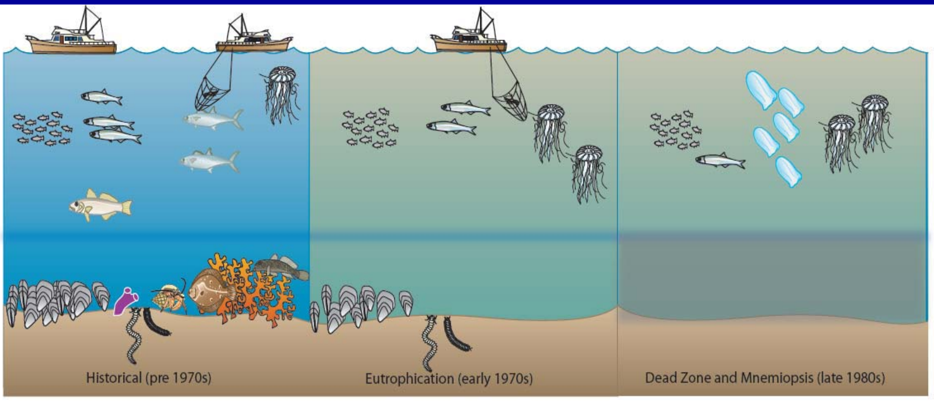
- Brief background on main drivers in the Black Sea
  - Anchovy Models
  - Ctenophore model
  - EwE (Ekin Akoğlu)

Research area: The *Black Sea*

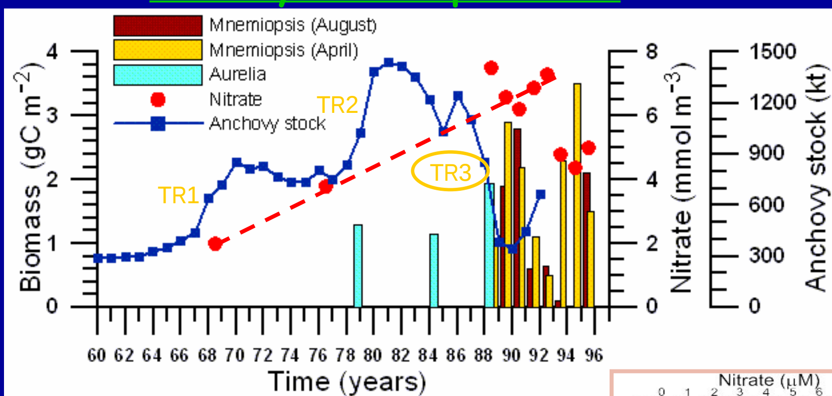
Research motivation (End-to-end controls)

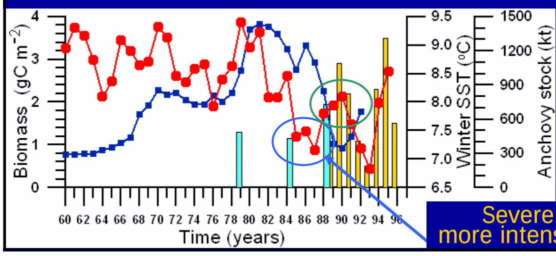
The Black Sea ecosystem was substantially modified due to concurrent effects of intense:

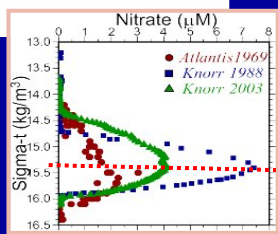
- Eutrophication,
- Overfishing (removal of piscivorous, heavy pressure on anchovy)
- Invasive species (outburst of gelatinous macrozooplankton *Mnemiopsis leidyi*),
- Decadal climatic variations.



Anchovy-Mnemiopsis shift





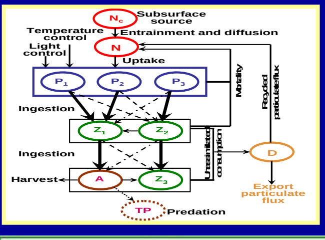


Severe winters (+ NAO)
more intense mixing, colder SST

Model structure

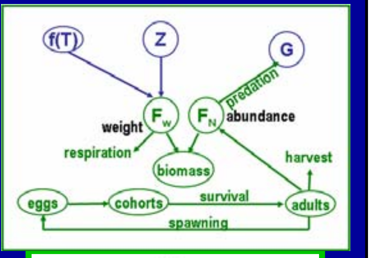
(Oguz, Salihoglu, Fach, 2008, *MEPS;*
Oguz, Fach, Salihoglu, 2008, JPR;
Salihoglu, Fach, Oguz, submitted)

- **NP3Z3 MODEL:**
  Nitrate +3 phytoplanton functional groups+ 3 zooplankton



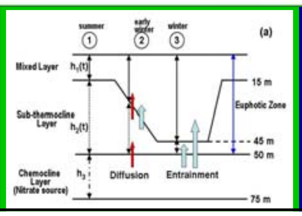
- **ANCHOVY life cycle model:**

  Bioenergetic based model with 90 cohorts: spawning June to August: (90 days)



- **Vertical model structure:**

  2 layer system:
  euphotic zone is divided to <u>mixed layer</u> and <u>sub thermocline,</u> chemocline (nitrate source)



Summary:

1) **Introducing a stage resolving anchovy model allowed to introduce a more realistic *Mnemiopsis* predation pressure on anchovy eggs and larvae population.**

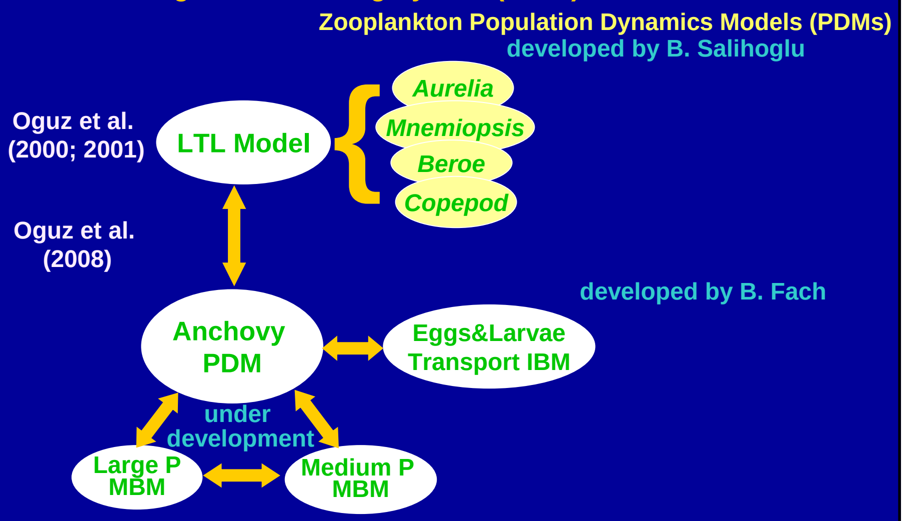
   The regime shift wouldn't be simulated without (holistic) resolving anchovy population and weight growth characteristrics.

2) **The anchovy-Mnemiopsis <u>regime shift</u> took place mainly due to simultaneous effects of over-enrichment and over-fishing. Overenrichment was triggered by climate induced changes.**

Ongoing work:

Black Sea Ecosystem Modeling and Forecasting

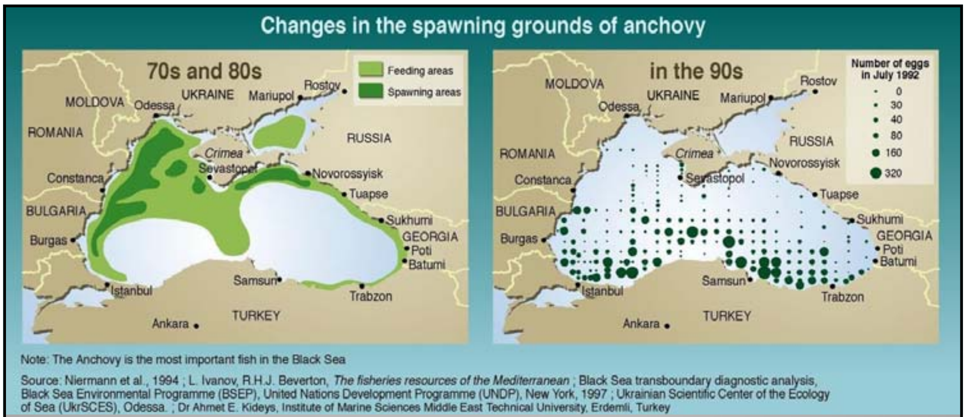
Black Sea Integrated Modelling System (BIMS)



Simple anchovy larvae IBM transport model

Bettina Fach, Baris Salihoglu and Temel Oguz

Marine Ecosystem Evolution in a Changing Environment



Changes in the spawning grounds of anchovy. (2001). In *UNEP/GRID-Arendal Maps and Graphics Library*. Retrieved 15:49, June 8, 2010 from http://maps.grida.no/go/graphic/changes_in_the_spawning_grounds_of_anchovy.

Objectives

1. Test influence of circulation patterns on connectivity patterns

2. Test the temperature effect on development and distribution of eggs

3. Test influence of food availability on larvae development and distribution

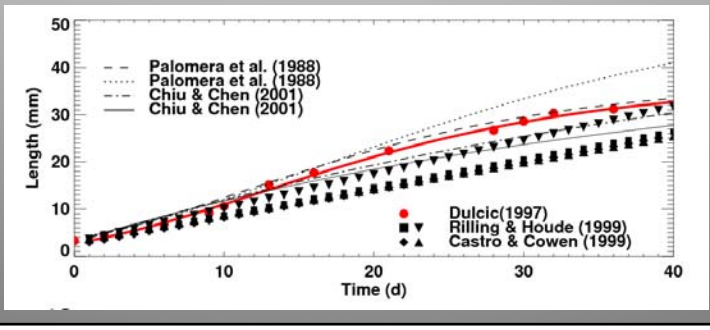
→ Compare warm (2001) and cold years (2003) and their consequences for anchovy distribution and development.

Simple Anchovy Larvae IBM

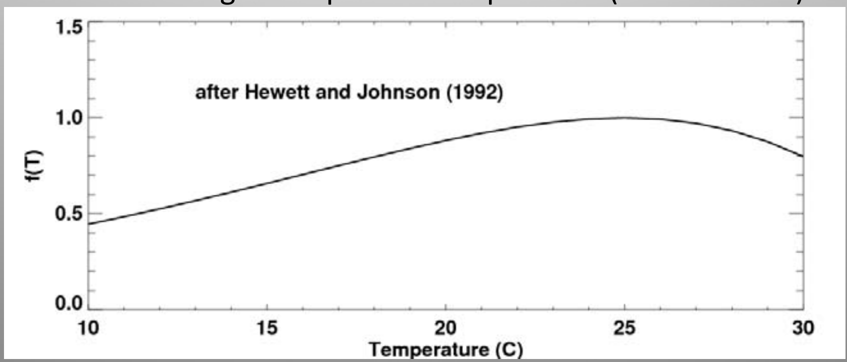
- IBM resolves growth of egg and larvae stages (total = 36 days)
- assumed these stages are not capable of directive swimming.
- Growth is defined after data from Dulcic (1997):

$$L_t = a\exp(-b\exp(-ct))$$

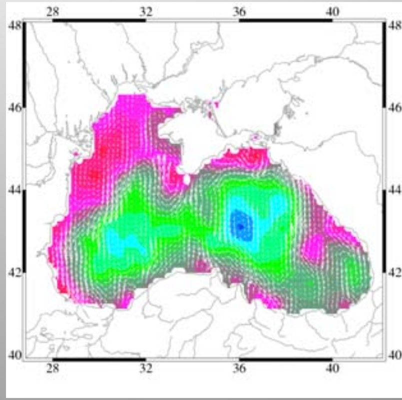
a Gompertz equation with a = 36.87 mm, b = 2.609 and c = 0.077



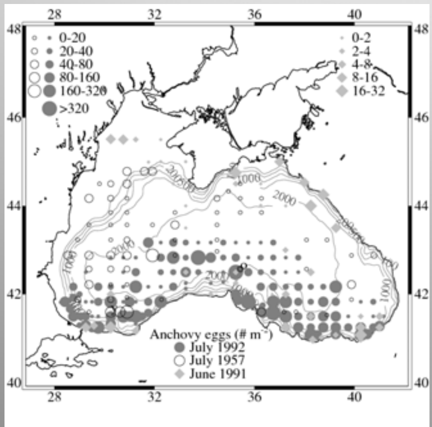
- Growth is temperature dependent: Spawning assumed only in areas above 20° C, a temperature limitation function after Hewett and Johnson (1992) is applied to above growth
- size at hatching is temperature dependent (2.9 – 3.3 mm)

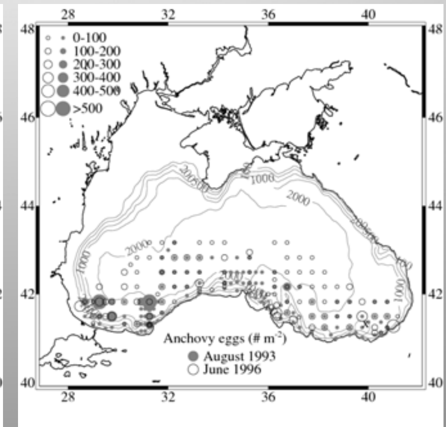


- Apply with hydrographic data available on Circulation (Altimeter data – AVISO) and Temperature (AVHRR)
- assumed that anchovy eggs and larvae stay mainly in surface waters.
- Eggs and Larvae are not capable of directive swimming
- Spawning occurs mid June-August in areas where water temp is > 20 ° C



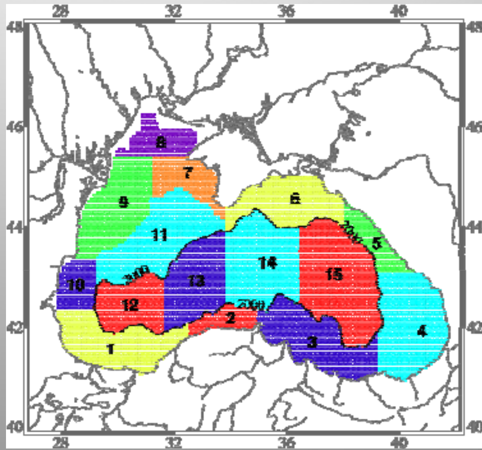
Turkish Data (eggs)



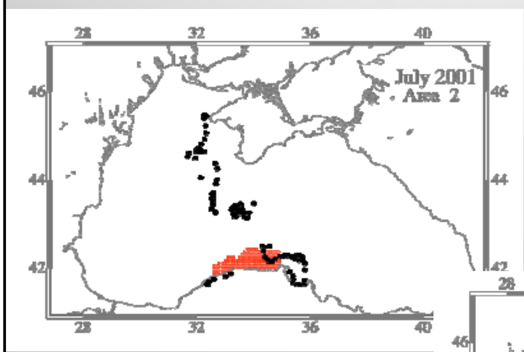


Spawning areas

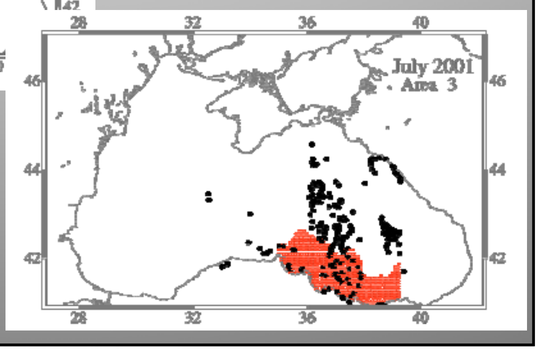
- Spawning areas defined after known spawning areas (e.g. 1 & 3 etc.), as well as prominent physical features (e.g. Batumi eddy, #4)
- Initially assumed only coastal regions as spawning grounds, but available data shows considerable egg biomass in open waters (hence area 12-15).
- The 2000m isobar was chosen as boundary between open and shelf waters because of the Rim Current.



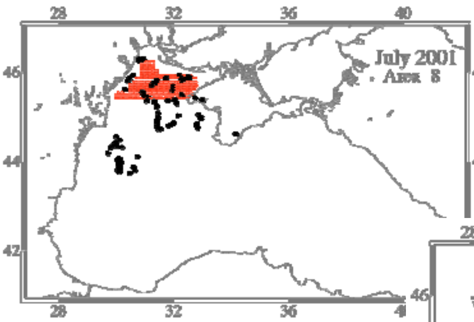
Late larvae distribution

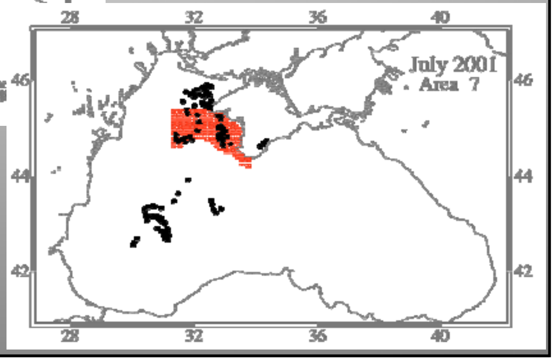


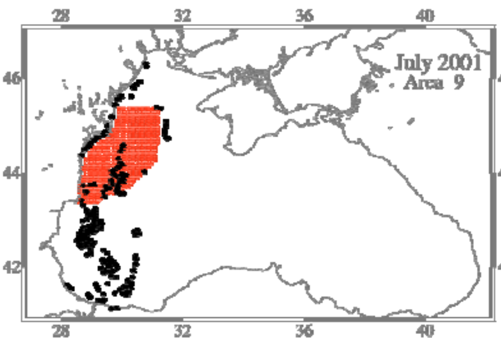
Turkish coast

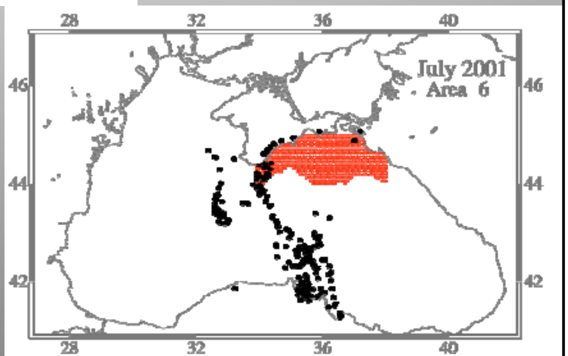


NW Shelf

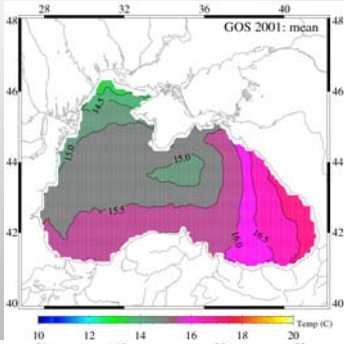

July 2001
Area 8


July 2001
Area 7

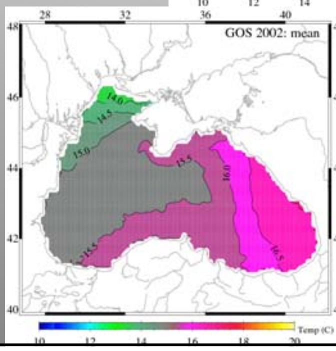

July 2001
Area 9

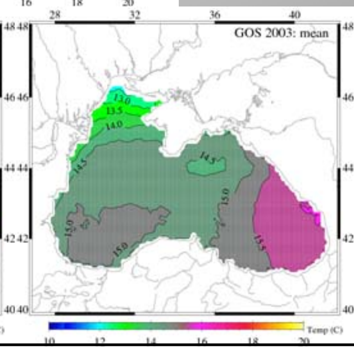

July 2001
Area 6

Mean Temperatures

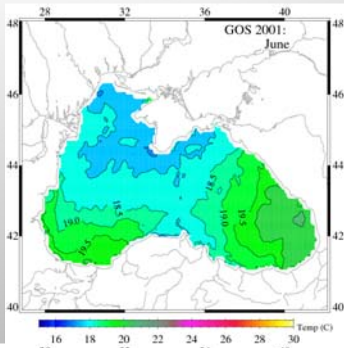


2001 mean temp = 15.6
2002 mean temp = 15.62
2003 mean temp = 14.91

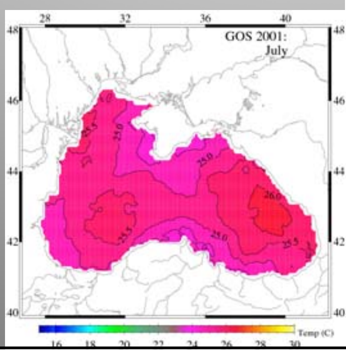


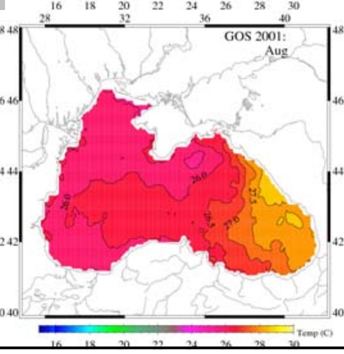


2001



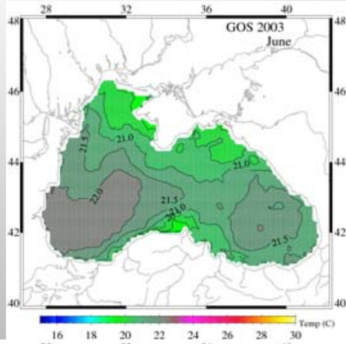
2001: mean Temp=15.6
June: 18.75
July: 25.24
August: 26.38

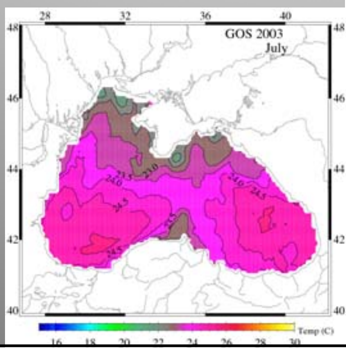


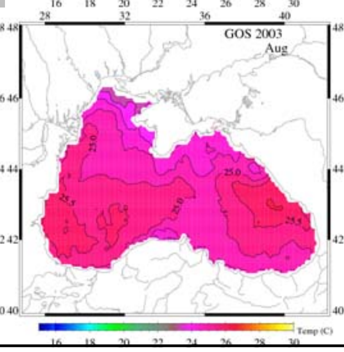


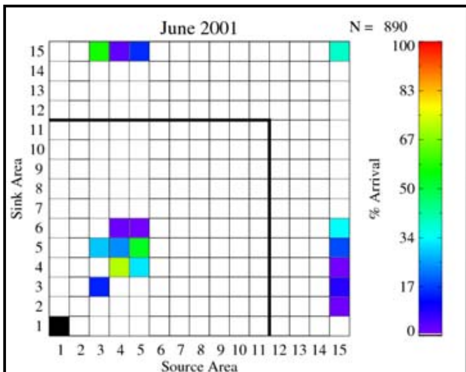
2003

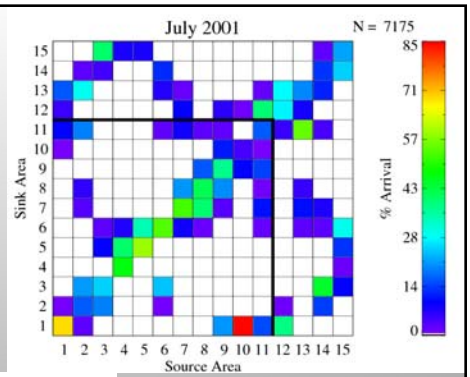
2003 mean temp = 14.91
June: 21.34
July: 23.92
August: 24.99





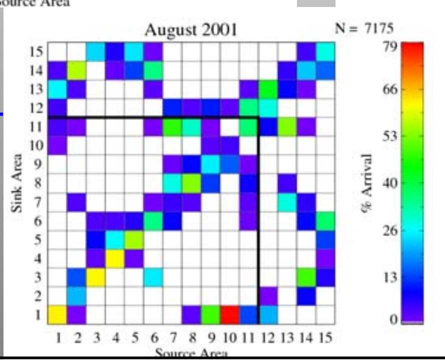


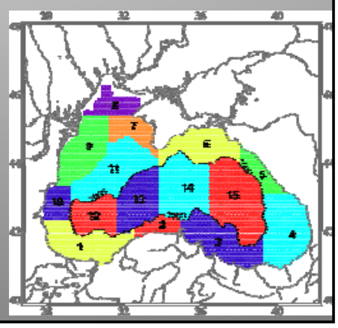


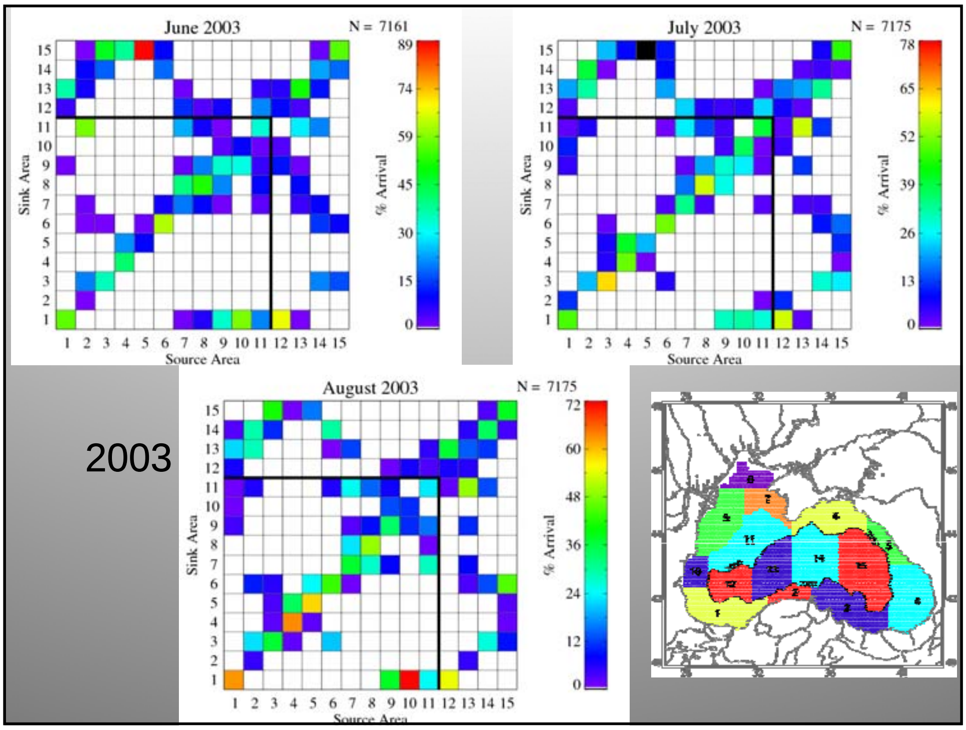


cold June!

2001







Conclusions

- Larval dispersal is strongly controlled by advection through the Rim Current circulation around the periphery of the basin and the two basin-wide gyres. Locally controlled by mesoscale eddies spinning off this rim current.
- NW-shelf is connected to the south-western shelf off the Bosphorus, while the spawning area on the southern shelf off Samsun (Turkey) is connected to the north-east spawning region off the Azov Sea.
- However, the southern shelf and the north-east spawning areas are much more isolated.
- Interannual variability in the dispersal of late larvae is considerable, but mainly depending on circulation patterns, not temperature. In both cold and warm years temperatures were sufficient for >95% of the eggs to develop into late larvae – except in June 2001 (very cool temps in an otherwise anomalously warm year)
- Now need to test food availability!

work in progress:

Anchovy Larvae IBM

- IBM resolves **physiology** of egg and larvae stages (36 days)
- assumed these stages are not capable of directive swimming.

Growth: $\frac{dW}{dt} = (eC - R) \cdot W$

Consumption:

$$C = c_1 \cdot W^{-c_2} \cdot f(T) \cdot f(Z)$$

Respiration:

$$R = r_1 \cdot W^{-r_2} \cdot f(T) \cdot A_F$$

Temperature limitation function after Hewett and Johnson (2992)

$$f(Z) = \frac{s Z^2}{K_z^2 + sZ^2}$$

Feeding preference

Running offline coupled with BIMS-ECO, where food in form of micro- and mesozooplankton is available.

Invasive Ctenophore Model Structure (Salihoglu et al., JMS, accepted)

Bioenergetics-based anchovy model (Oguz et al 2008)

⬆

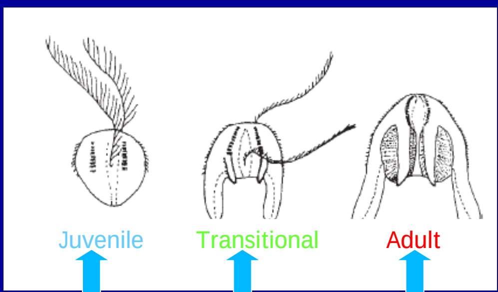
Stage resolving Mnemiopsis Leidyi biomass model (Fennel 2001, Stegert et al., 2007)

+

Egg Juvenile Transitional Adult stages (Rapoza et al. 2005)

+

Growth dynamics (e.g. Kremer 1976, Kremer and Reeve 1989)

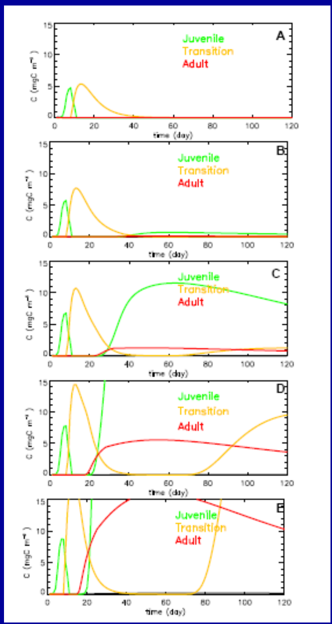


Protistan

Mix:
protists
copepods
fish egg

Metozoan:
copepods
fish egg
larvae

Influence of temperature on ctenophore (Mnemiopsis) growth



10° C

15° C

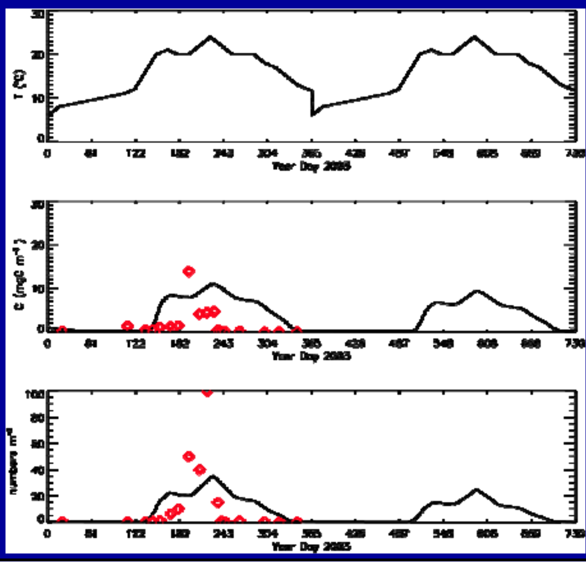
20° C

25° C

30° C

Constant food conditions of 25 mg C m^{-3} mesozooplankton and 90 mg C m^{-3}, and microplankton.

Time distribution of (A) observed temperature for year 2003 repeated in two cycles, (B) simulated Mnemiopsis biomass,(C) simulated Mnemiopsis abundance. Symbols indicate observations obtained from Finenko et al., (2006) for year 2003 in the Sevastopol Bay.



SUMMARY

•The model is used to analyse the influence of temperature and food variability on Mnemiopsis leidyi reproduction and outburst.

•A decrease of 5◦C can result in considerable decrease in biomass of all stages, whereas at a temperature of 25◦C a 40% decrease in food concentrations could result in termination of transfer between stages.

•Model results demonstrate the strong role of mesozooplankton in controlling the adult ctenophore biomass capable of reproduction and that different nutritional requirement of each stage can be critical for population growth.

•The high overall population growth rates may occur only when growth conditions are favorable for both larval and lobate stages.

•Current model allows the flexibility to assess the effect of changing temperature and food conditions on different ctenophore stages.

Modeling Black Sea Ecosystem with Ecopath with Ecosim*

Ekin Akoğlu and Barış Salihoğlu

*www.ecopath.org

COMPARISON OF COASTAL VERSUS MID-BASIN BLACK SEA ECOSYSTEM PROCESSES

Barış Salihoğlu

Colleagues: Bettina A. Fach[1], Heather Cannaby[1], Temel Oğuz[1], Viktor Dorofeev[2], Alexander Kubriyakov[2], Ekin Akoğlu[1]

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Sevastopol, Ukraine 2

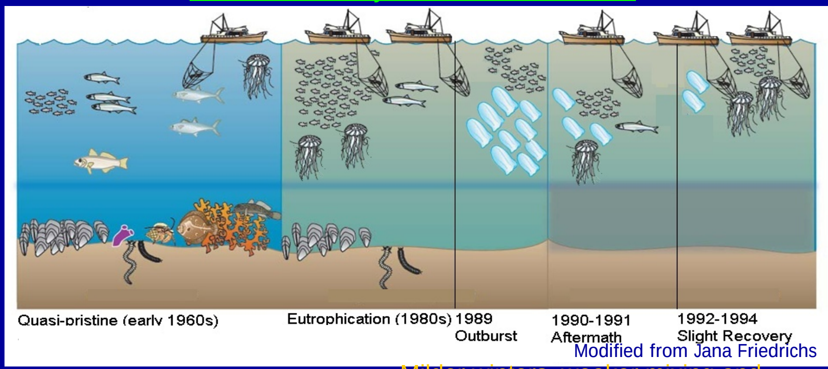
This research is supported by EU 6th FP SESAME and 7th FP MEECE projects

Talk outline:

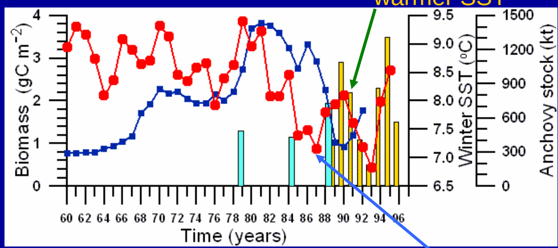
- **Background on the status of the Black Sea**
- **Research motivation**
- **Model**
- **Results (**Northwestern Shelf vs Eastern Black Sea)
- **Summary and outlook**

Research area: The *Black Sea*

Black Sea ecosystem transformations



Milder winters, weaker mixing and warmer SST



Severe winters (+ NAO)
more intense mixing, colder SST

Black Sea as a case study

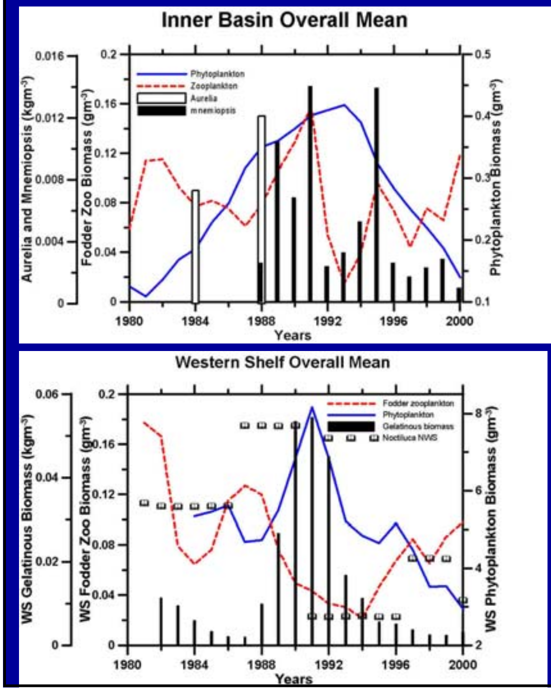
The Black Sea has been over exploited for decades…
- Over fishing, eutrophication, and invasion by alien invasive species have resulted in dramatic shifts in ecosystem structure and severe environmental degradation.

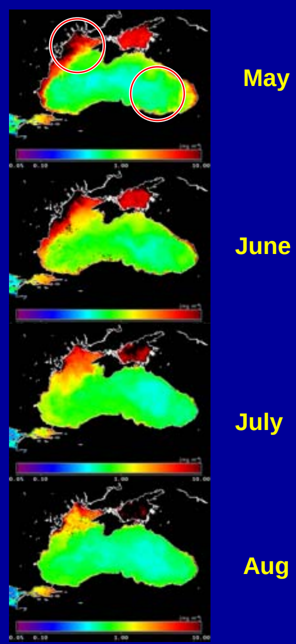
Opportunity now to assess modelling capacity with regard to each of these environmental pressures, in combination with changing climatic forcing.

Property	Pristine (<1970)	Eutrophication (1975-1992)	Post -eutrophication (1993-2005)
DIN	1 μM	8 μM	7 μM
SiO_4	35-45 μM	20-25 μM	20-25 μM
PO_4	< 2 μM	3-8 μM	< 2 μM
Phytoplankton	< 3.0 g m^{-3}	10-20 g m^{-3}	~5 g m^{-3}
Trophic zooplankton	250 mg m^{-3}	75-150 mg m^{-3}	50-100 mg m^{-3}
Aurelia+Mnemiopsis	50 mg m^{-3}	up to 3000 mg m^{-3}	< 500 mg m^{-3}
Total fish catch	15 x 10^3 tons	5-15 x 10^3 tons	2 x 10^3 tons
% share of piscivores fish	40-50	30-15	< 10

Table: Approximate values of major ecosystem properties during three different regimes of the north-western Black Sea.

Inner basin vs Nortwestern shelf





Research motivation:

The Black Sea ecosystem was substantially modified due to concurrent effects of intense:

- Eutrophication,
- Overfishing,
- Invasive species (outburst of gelatinous macrozooplankton *Mnemiopsis leidyi*),
- Climatic variations.

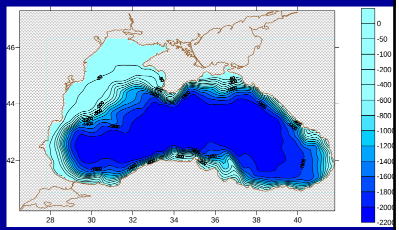
Main focus:

- Interactions between lower and higher trophic levels after the end of 1980s.
- How these interactions control coastal and open basin ecosystems?
- Impact on the seasonal cycle, PP and export.

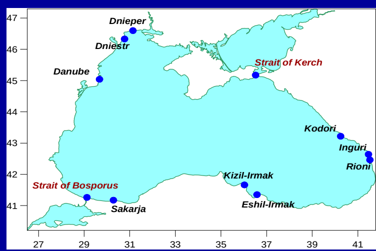
Technical details of physical model

Princeton Ocean Model (pom2k)

- **Horizontal grid ~ 5km regular array**
- **Vertical grid: 26 sigma levels, compressed towards upper 200 m**
- **Initialisation: Spun up from climatology using atmospheric climatological forcing**
- **Forcing:**
  - Atmospheric forcing (6-hours data) (ERA40 or SXG)
  - Climatic river input (9 in total)
  - Straits discharges (Bosporus/Kerch)
- **Data assimilation:**
  - Optimal Interpolation of temperature and salinity deviations from climatic mean onto model grid at monthly time scales (1971-1992)
  - Altimetry SSH anomalies assimilated into model as temperature and salinity (1992-2001)



Black Sea model domain



Rivers and straits included in model

Technical details of ecosystem model

BIMS_ECO, BIMS_CIR (Oguz et al, 2001)

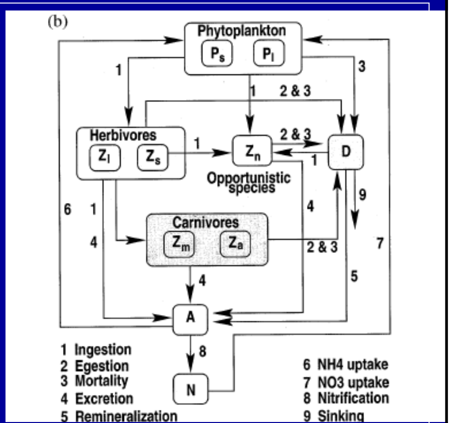
- Pelagic food web model
- Nutrient cycling
- Vertical grid extends to 200 m (26 z-levels with 2 m resolution near the surface and 20 m near the lower boundary).
- Horizontal grid as in Circulation model.

Model compartments

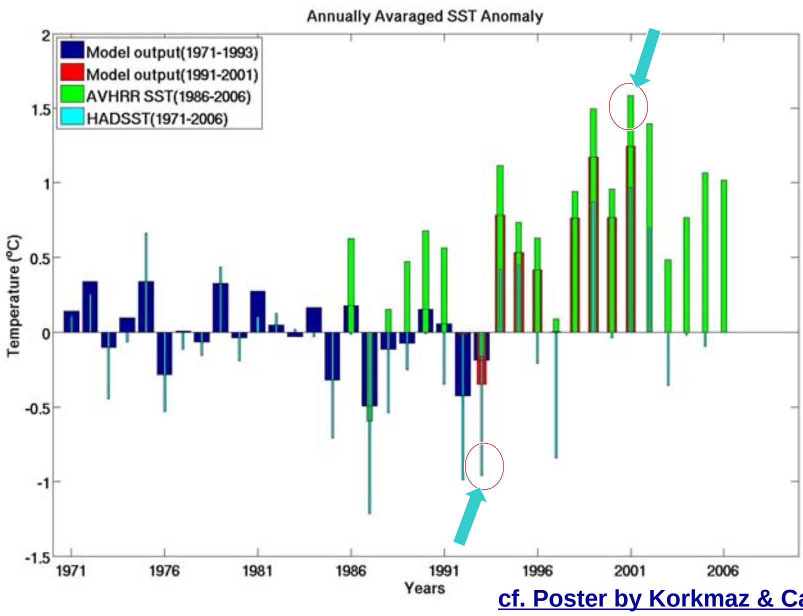
Tropic level-0
- N - nitrate
- A – ammonium
- DON- Dissolved inorganic nitrogen
- D - Labile pelagic detritus

Tropic level-1
- Ps - small (<10 μ m) phytoplankton
- Pl – large (> 10 μ m) phytoplankton

Tropic level-2
- Zs – microzooplankton
- Zl – mesozooplankton
- Zn - opportunistic heterotrophic dinoflagellate *Noctiluca scintillans*
- Za - gelatinous carnivore *Aurelia aurita*
- Zm- gelatinous carnivore *Mnemiopsis leidyi*

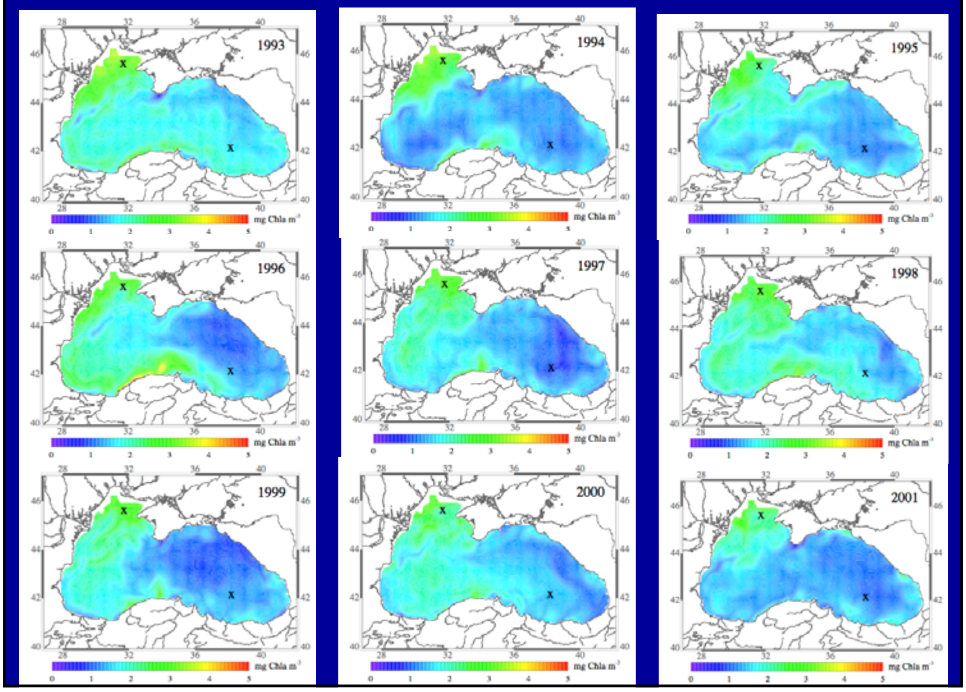


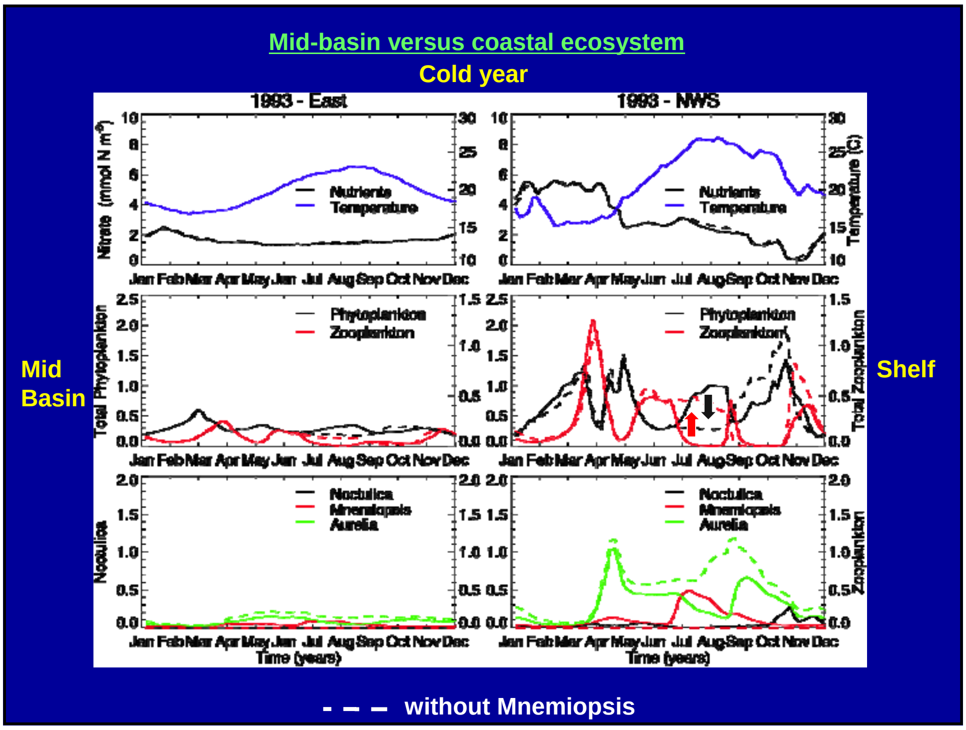
Temperature variability

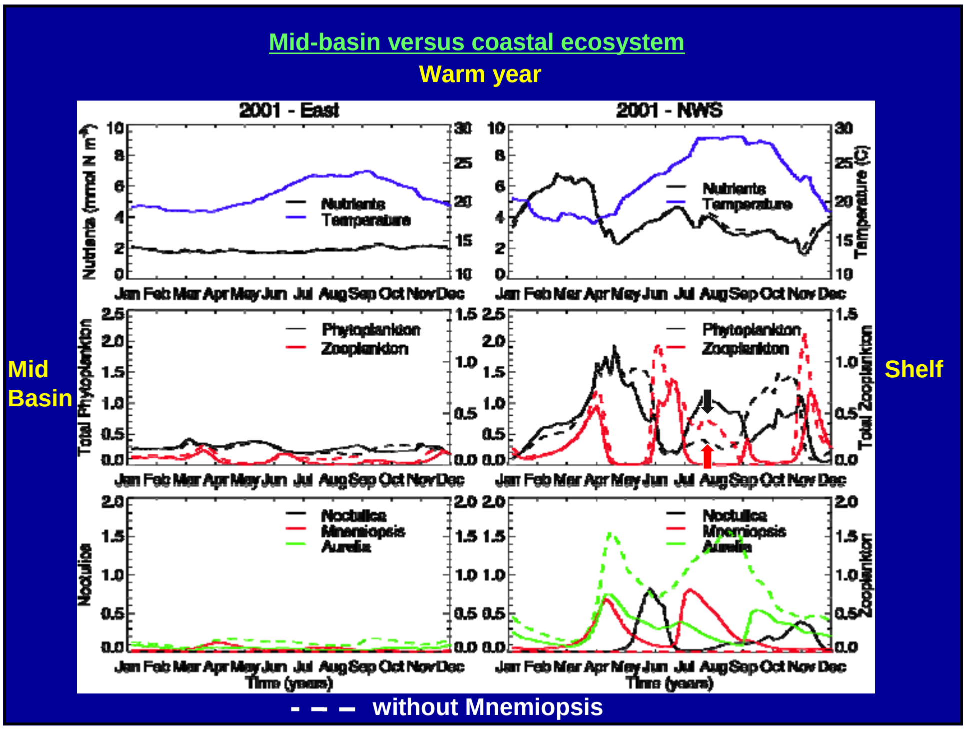


cf. Poster by Korkmaz & Cannaby

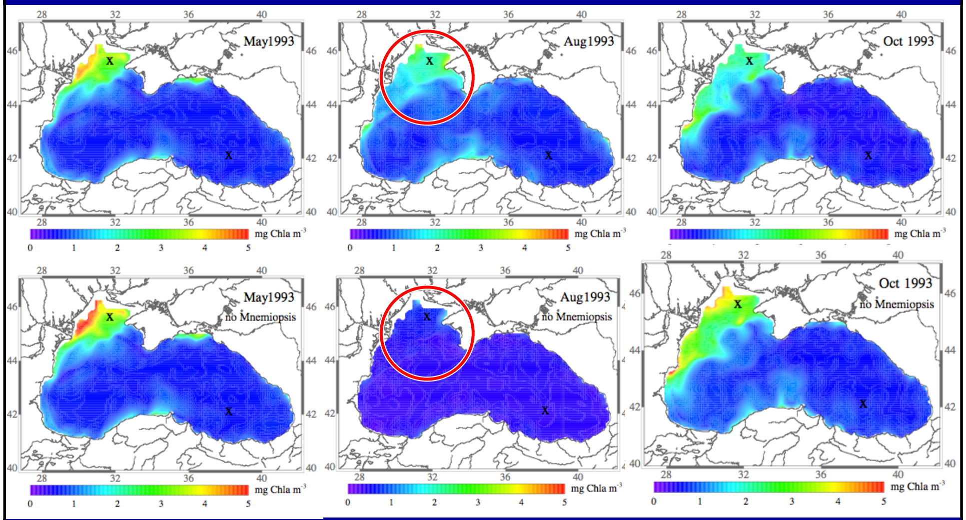
Model results



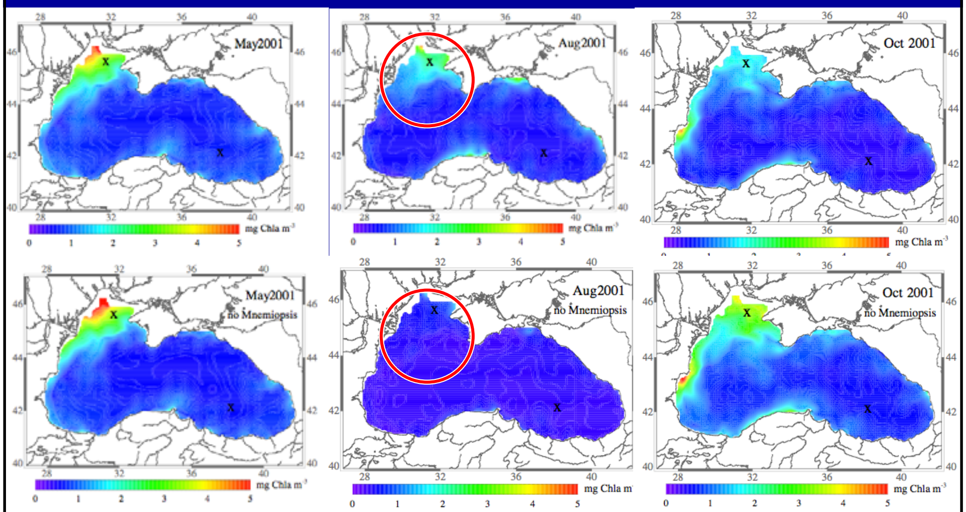

Mid-basin versus coastal ecosystem
Cold year
1993 - East
1993 - NWS
Nitrate (mmol N m-3)
Temperature (C)
Nutrients
Temperature
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Total Phytoplankton
Total Zooplankton
Phytoplankton
Zooplankton
Noctulica
Zooplankton
Noctulica
Mnemiopsis
Aurelia
Time (years)
Mid
Basin
Shelf
- - - without Mnemiopsis


Mid-basin versus coastal ecosystem
Warm year
2001 - East
2001 - NWS
Nutrients (mmol N m-3)
Temperature (C)
Nutrients
Temperature
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Total Phytoplankton
Total Zooplankton
Phytoplankton
Zooplankton
Noctulica
Zooplankton
Noctulica
Mnemiopsis
Aurelia
Time (years)
Mid
Basin
Shelf
- - - without Mnemiopsis

Mid-basin versus coastal ecosystem
Cold year

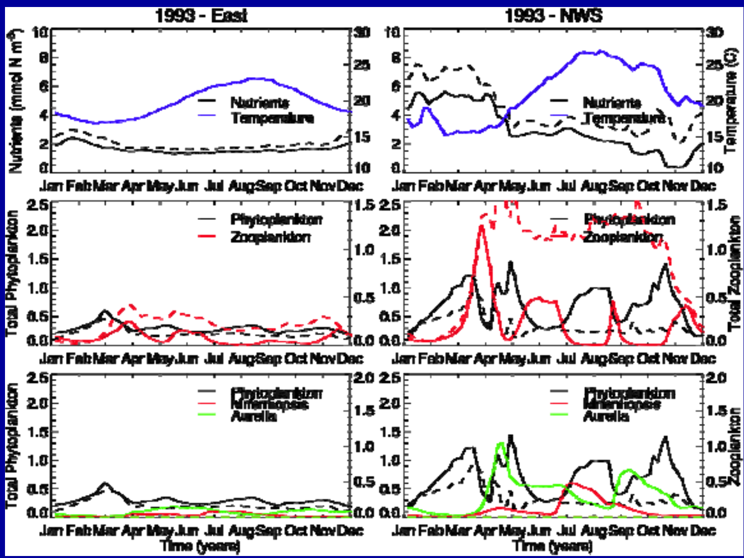


Mid-basin versus coastal ecosystem
Warm year



Mid-basin versus coastal ecosystem

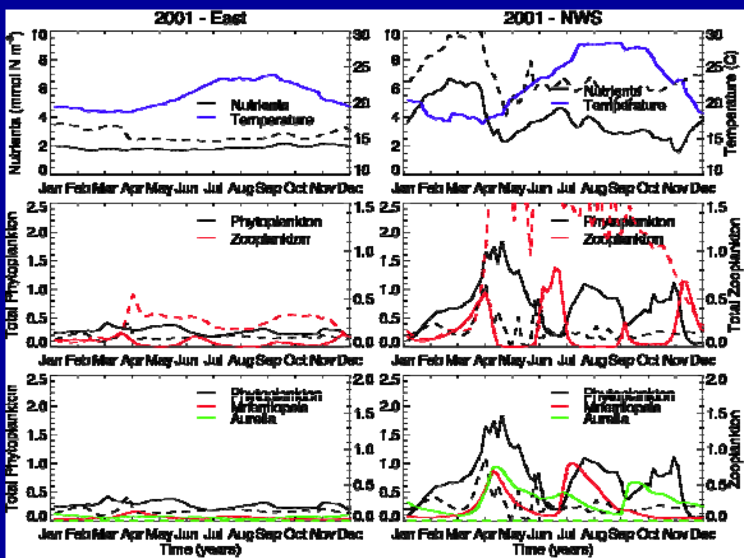
Cold year



- - - without Mnemiopsis and Aurelia

Mid-basin versus coastal ecosystem

Warm year



- - - without Mnemiopsis and Aurelia

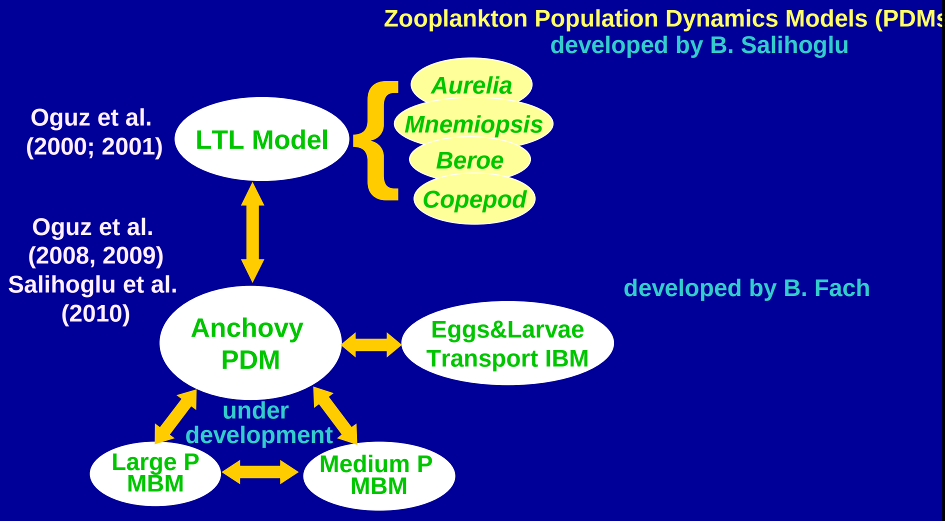
Conclusions

- Because of high biomass of the invasive ctenophore *Mnemiopsis leidyi*, longer periods of phytoplankton blooms occur in the coastal areas compared to the open basin.
- Severe regulation of the ecosystem by the upper levels of the food chain.
- Three consecutive maxima of phytoplankton biomass (spring, summer, autumn) occur in the coastal waters.
- The summer phytoplankton increase is a new element in the annual cycle of the ecosystem.
- Carbon export decreases 5-6% when *Mnemiopsis* is removed and up to 35-40% when all jellyfish are removed from the system.

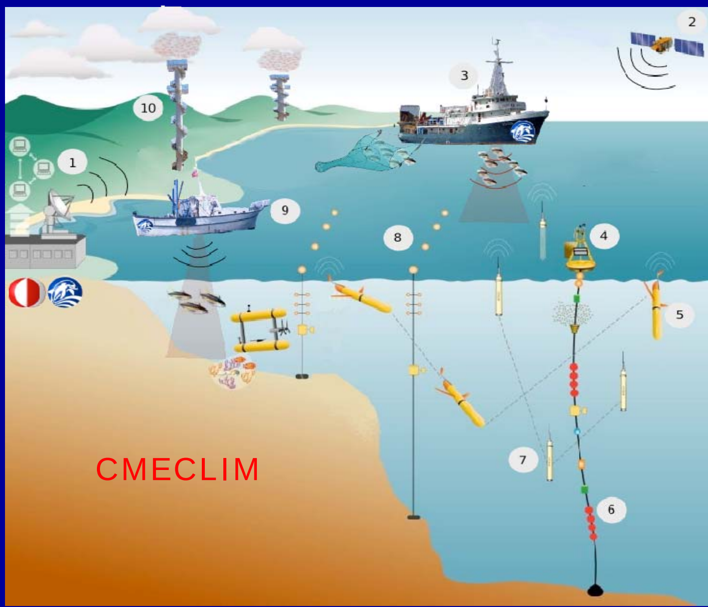
Outlook:

Black Sea Ecosystem Modeling and Forecasting

Black Sea Integrated Modelling System (BIMS)



CENTER FOR MARINE ECOSYSTEMS AND CLIMATE RESEARCH



Better monitoring of the Black Sea

Institute of Marine Sciences, Middle East Technical University, Turkey

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THANK YOU!