Effects of Climate Change on World's Oceans – May 23, 2008, Gijon, Spain

Effects of climate-driven changes on coastal food webs: the role of precipitation patterns

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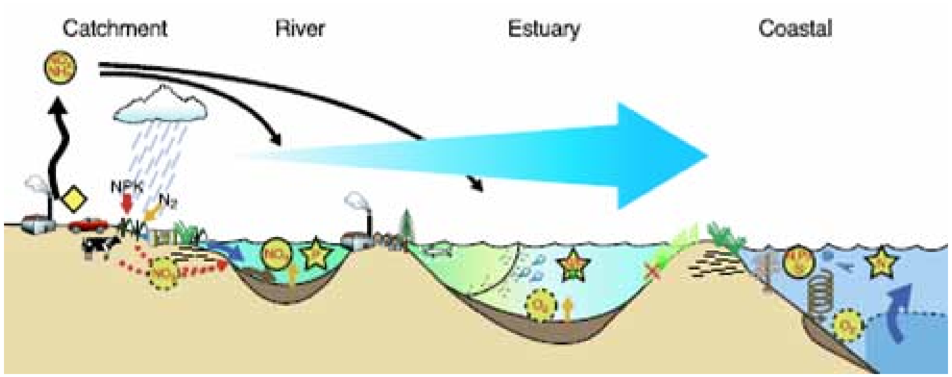
Effects of changes in precipitation patterns

Climate changes projections for 21st century are expected to cause a number of potential impacts (IPCC 2007).

While changes in sea level appears the most obvious threat to costal areas, **changes in precipitation patterns** and therefore in timing and volume of freshwater and nutrient delivery to coastal wetlands will also be critical

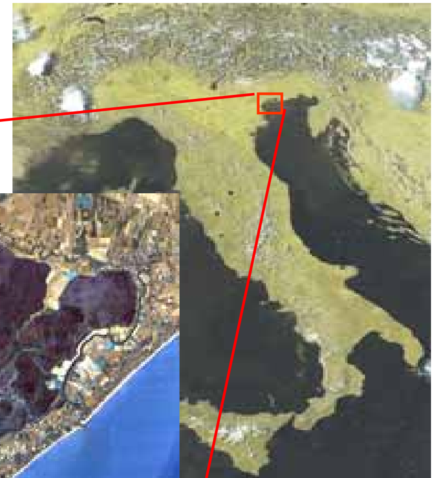
Scavia et al., 2003

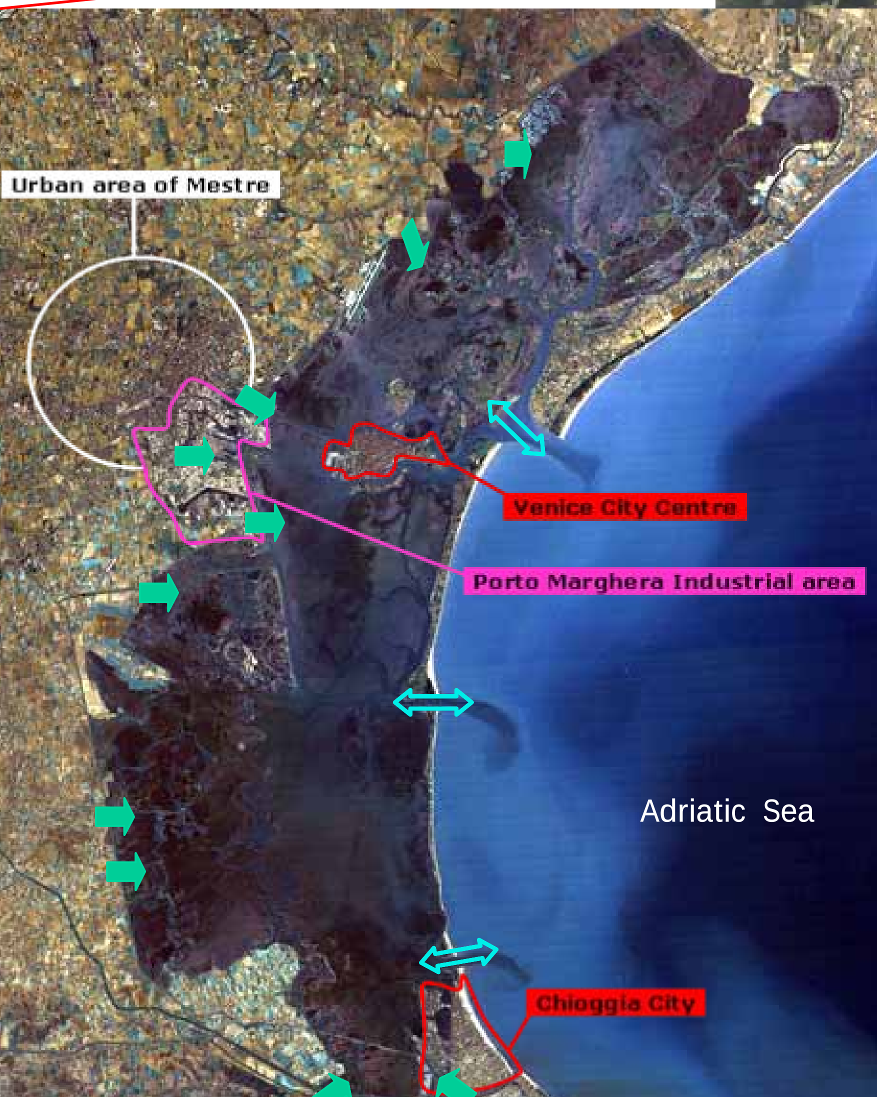


The ecosystem of the lagoon of Venice responses to TIMING & VOLUME of freshwater and NUTRIENT delivery

Aim: assessing the potential impact of changes on **seasonal precipitation patterns** on the biogeochemistry and on the food web of the lagoon of Venice

The study site: the Lagoon of Venice





LAGOON OF VENICE:

Total surface 550 km^2, average depth 1m;

11 rivers:

freshwater discharge ≈ $3x10^6$ m^3 day^{-1} (**loads: 4000tN/y, 200 tP/y**)

Venice, industrial area, 2 sewage treatment plants (**loads: 2000tN/y, 50tP/y**)

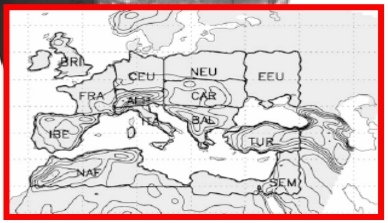
3 inlets:

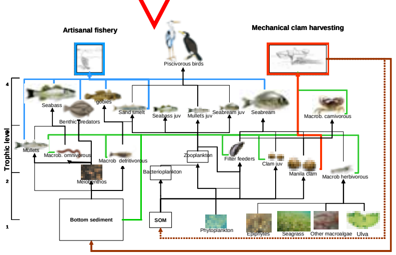
water exchanged through the inlets ≈ 1/3 of the total volume in a tidal cycle

Residence time 1-25 days

High productive system for fisheries

Downscaling and linking





[1] high resolution regional climate model (RegCM)

rain

T, solar radiation, humidity

wind, pressure

rain

[2a] statistical model of nutrient input

[2b] statistical model of sea-lagoon boundaries

boundary conditions

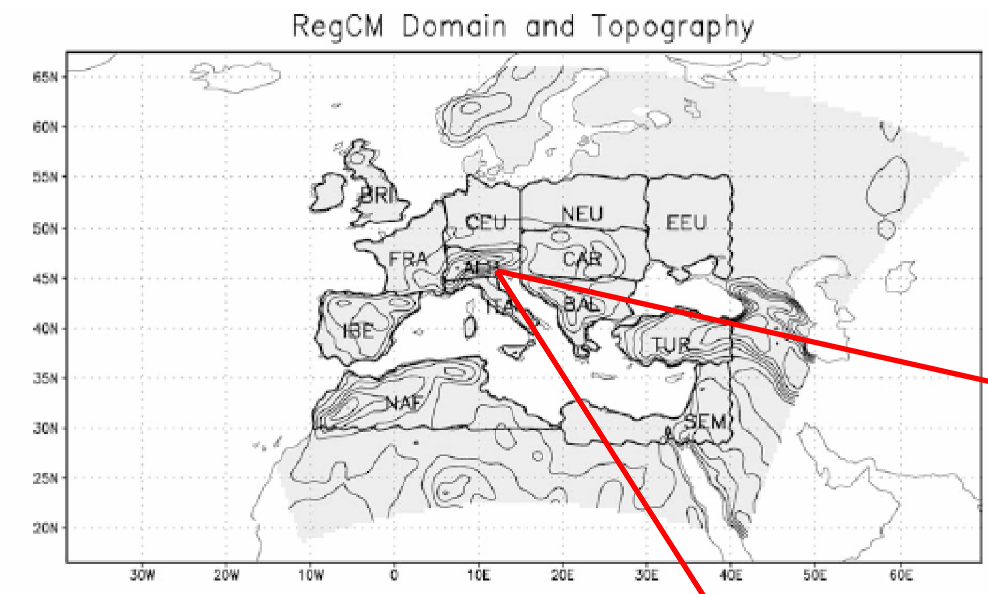
boundary conditions

[3] biogeochemical model of the lagoon of Venice

Nutrient forcing

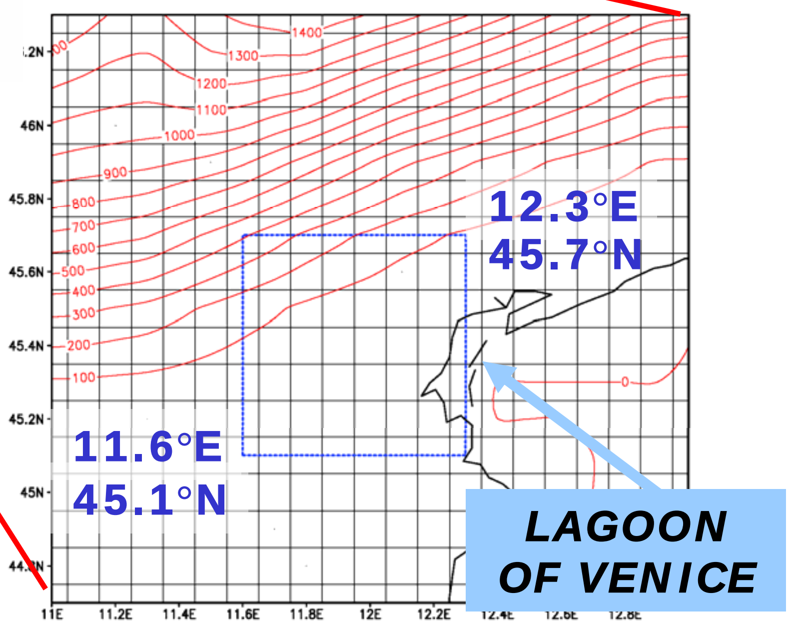
[4] Food web model of the lagoon

(1) High resolution Regional Climate Model (RegCM)



State of the art regional climate model, one way nested in HadAMH GCM model, resolution 20km

Giorgi et al. 2004a,b
Gao et al. 2006
ICTP (Trieste, ITALY)



We use results of rain, T, wind, humidity and pressure fields for the drainage basin

<u>3 runs</u>:

RF – reference condition 1961-1990

A2 - simulation of future condition 2071-2100 based on IPCC A2 scenario [CO_2 *~800ppm*]

B2 - simulation of future condition 2071-2100 based on IPCC B2 scenario [CO_2 *~600ppm*]

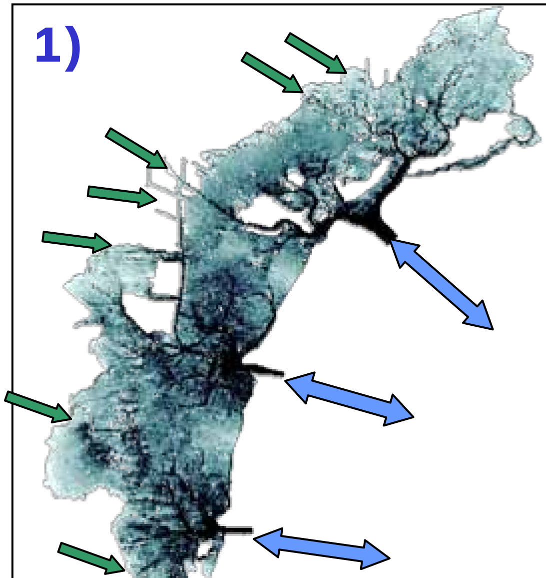
(Salon et al., *Clim. Res.*, accepted)

(3) The biogeochemical model (TDM)

Biogeochemical modelling: TDM

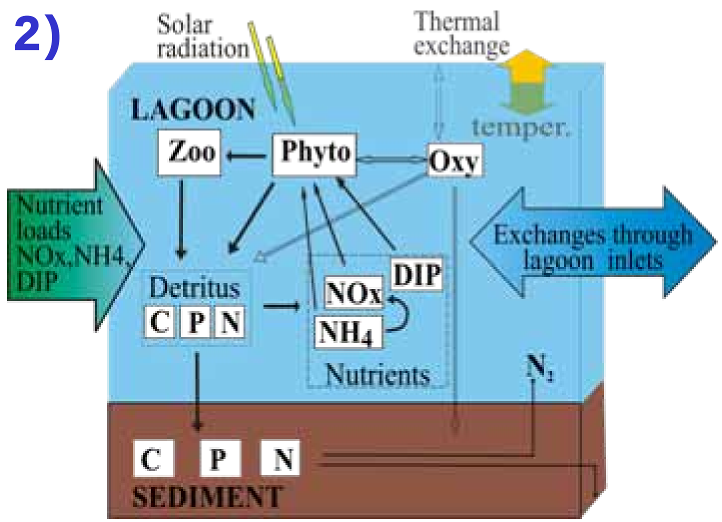
Trophic Diffusive Model – TDM: 3D fully coupled hydrodynamic and biological models

1)



Hydrodynamic model: Anysotropic diffusion and no advective term (residual currents negligible). Anysotropic and space varying diffusivity tensors

2)



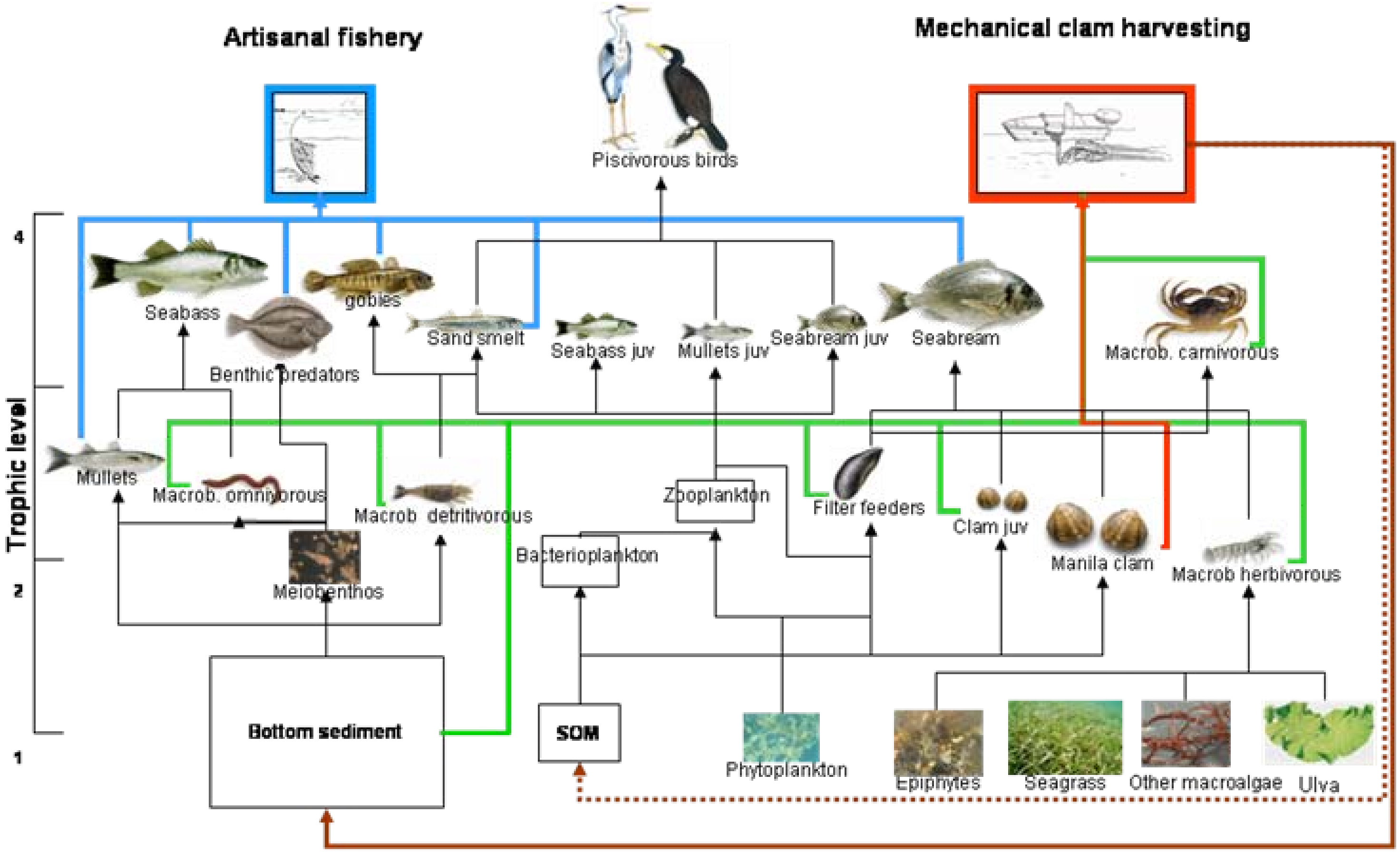
Biological model: Plankton – oxygen dynamic; DOM and sediment dynamics; Nutrients (CNP) cycles; 12 state variables; 28 parameters.

$$\frac{\partial C_i}{\partial t} = \left.\frac{\partial C_i}{\partial t}\right|_{biol} + \left.\frac{\partial C_i}{\partial t}\right|_{transp}$$

Horizontal resolution: 300m X 300m
Vertical resolution: 1m
Time step: 1h
Forcings: sun radiation, heat and oxygen exchanges at the air-sea interface
Boundaries: air-water interface, nutrient loads from drainage basin and exchanges at the inlets
Initial conditions: from measurements

(Dejak et al., 1998; [...] Solidoro et al., *Ecol Mod*, 2005)

(4) Food web model of the lagoon

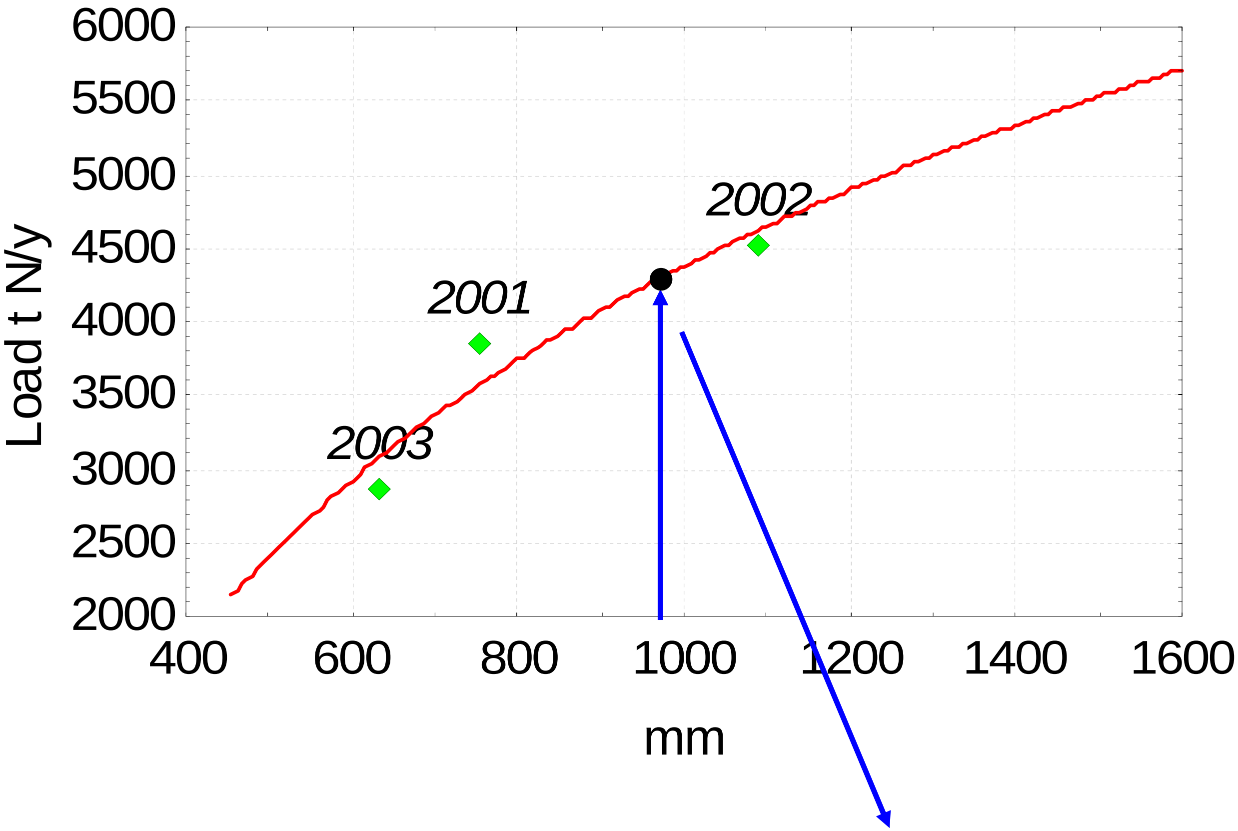


$$\frac{dB_i}{dt} = g_i \cdot \sum_{Pred\_j=1}^{n} c_{ji}(B_i, B_j) - \sum_{Pred\_j=1}^{n} c_{ij}(B_i, B_j) + I_i - (M0_i + F_i + e_i) \cdot B_i$$

Production term — Predation — Immigration — Natural & fishing mortality, emigration

(Libralato et al., *Mar Ecol PSZNI*, 2002; Pranovi et al., *Mar Biol*, 2003)

(2a) Statistical model of nutrient input



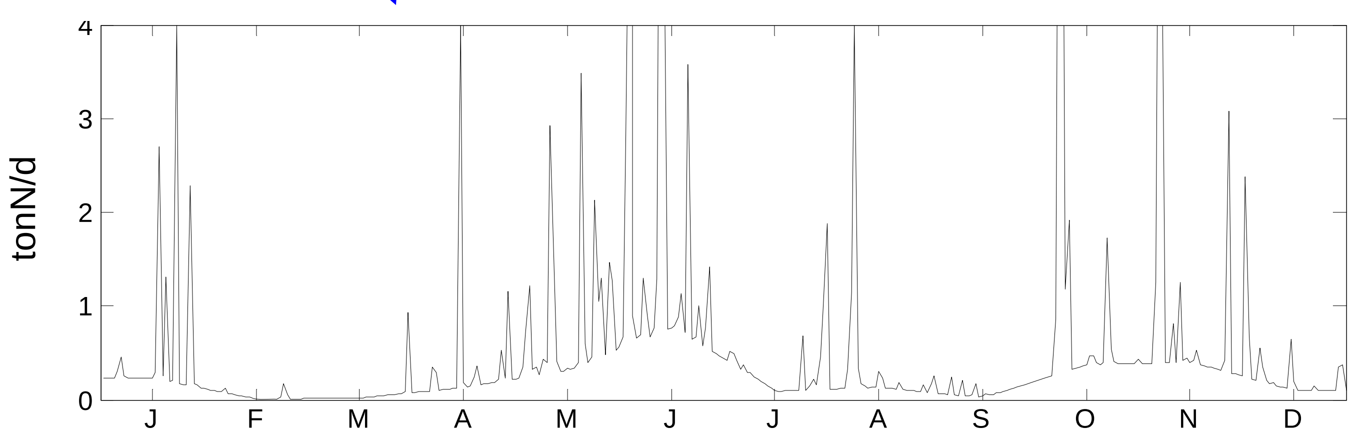
1 ◆ Hystorical data of nutrient input

Logaritmic regression between rain and annual load

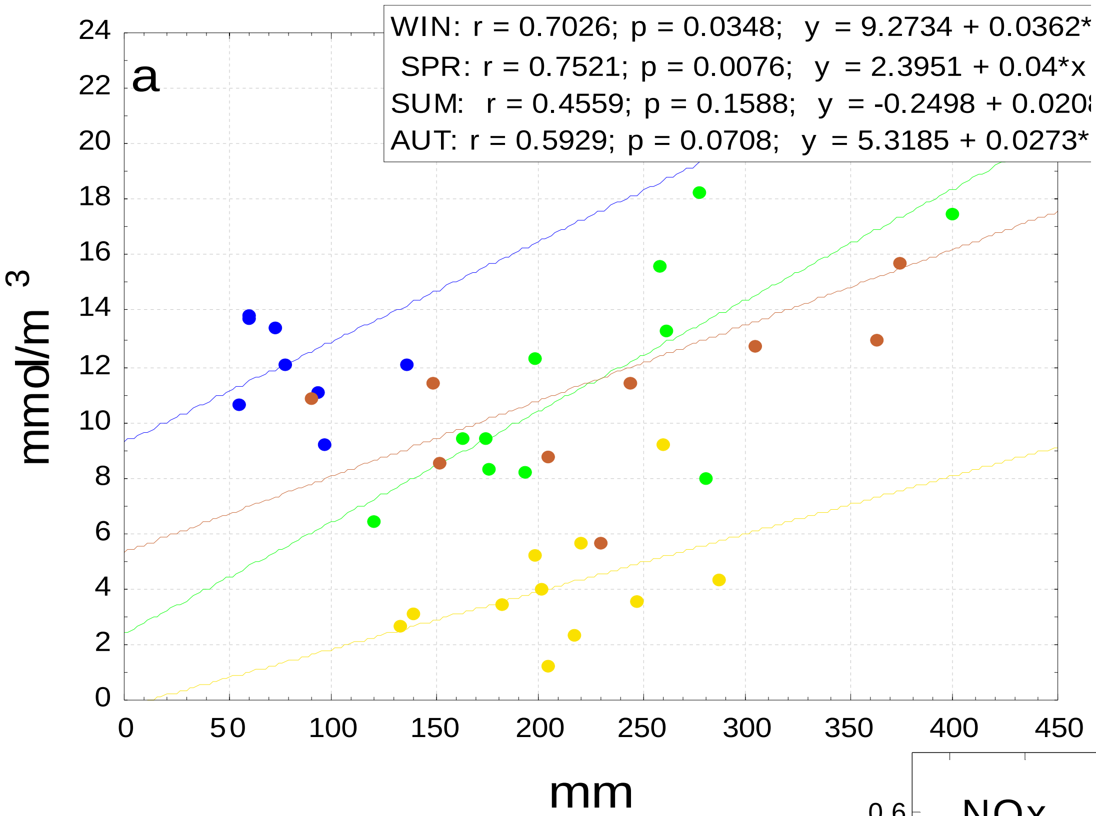
2 using the REGCM rain of one year → annual total load ●

3

Daily nutrient discharges from annual loads



(2b) Statistical model of boundary conditions



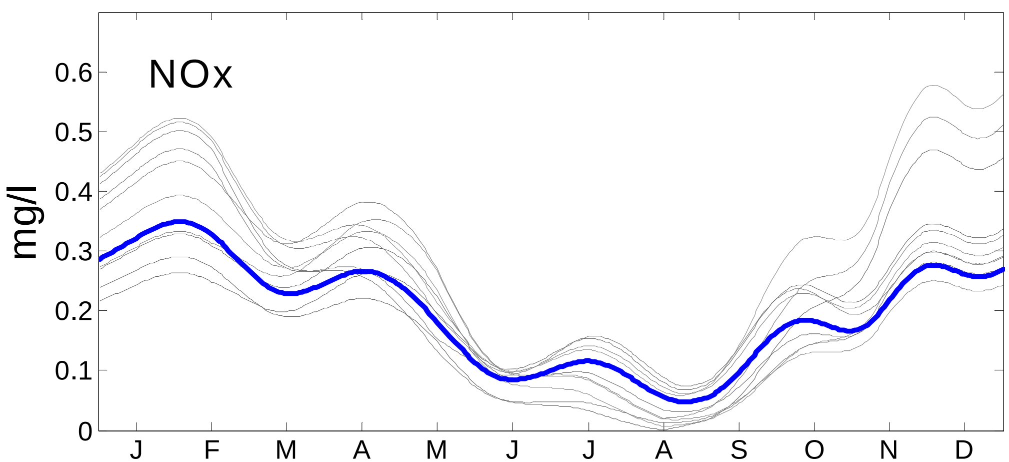
1 Hystorical data of DIN, DIP, PHYTO concentration in the coastal area

regression between rain and seasonal means + noise

2 using the RegCM rain of one year → mean seasonal value

3

daily concentration values of one year from a climatological evolution



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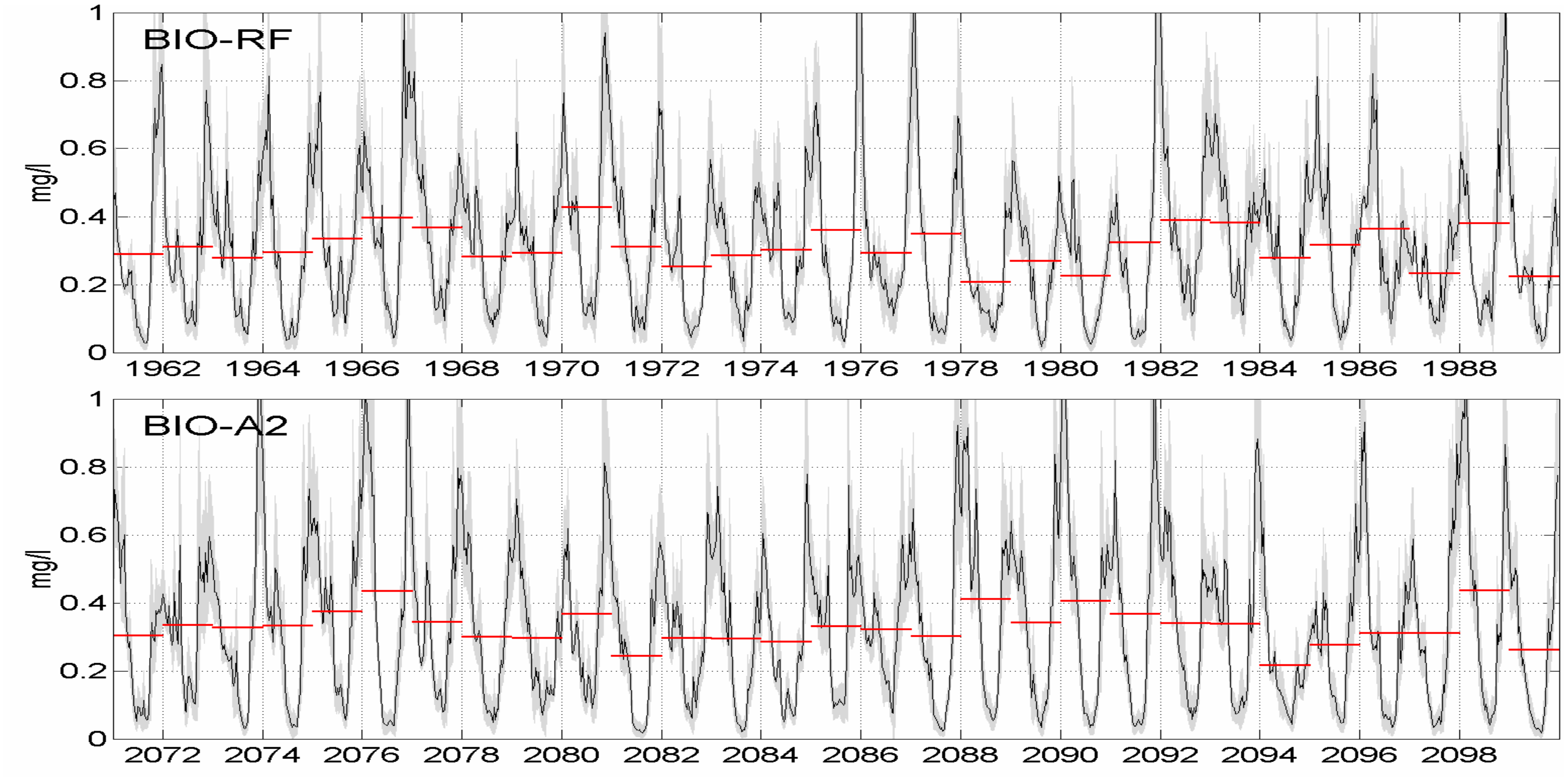
Scenarios of the Venice Lagoon biogeochemical processes

mean evolution of DIN on the lagoon under 3 scenarios (30 YEARS):

BIO-RF: reference run 1961-1990
BIO-A2: future scenario 2071-2100 based on A2
BIO-B2: future scenario 2071-2100 based on B2

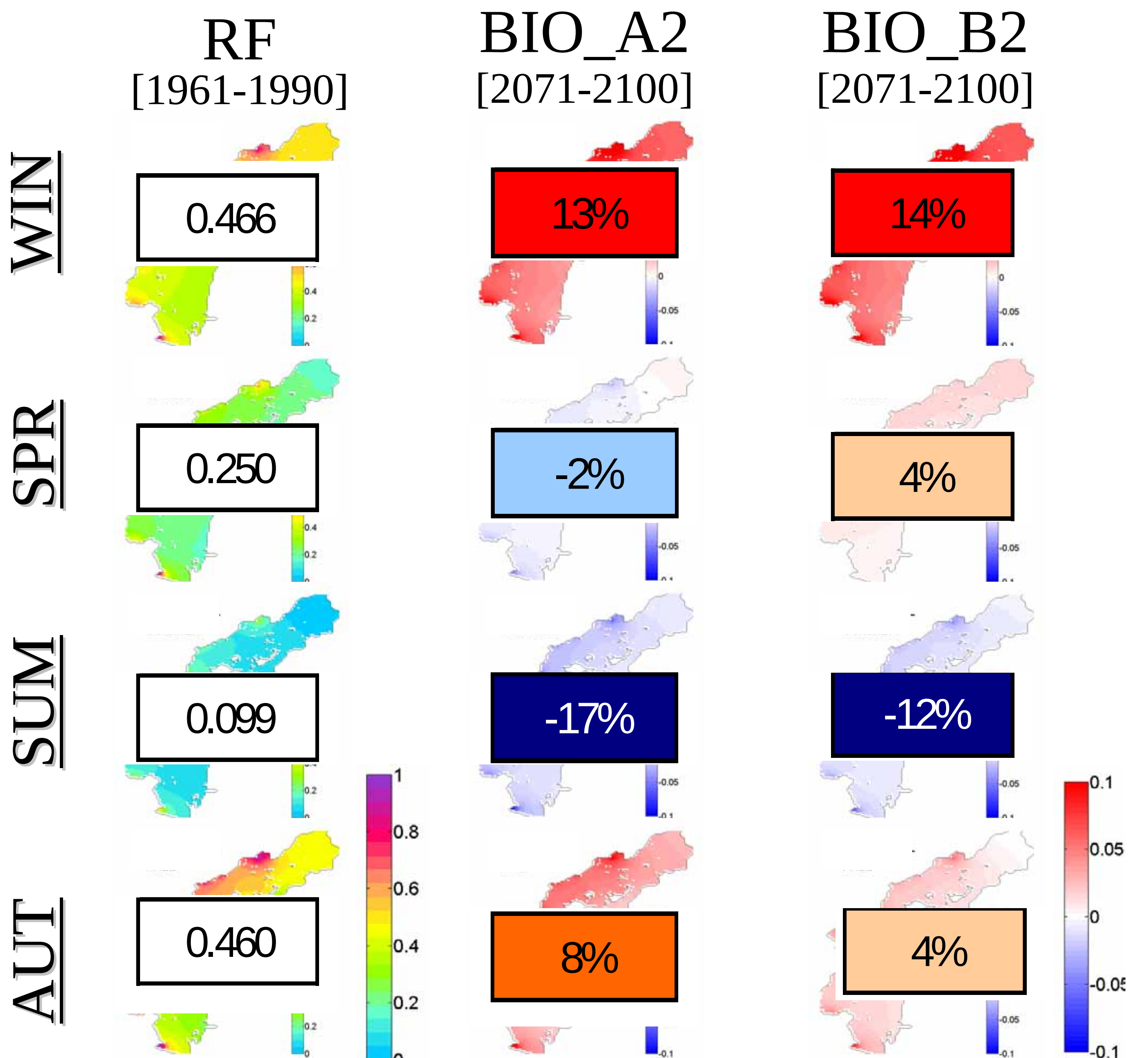


Strong seasonal cycles, strong interannual variability

Scenarios of the Venice Lagoon biogeochemical processes

Seasonal averages

DIN
[mg/l]



Seasonal averages & anomalies for state variables and fluxes

		INPUT N [tN/y]	DIN [mg/l]	PHYTO [mg/l]	ZOO [mg/l]	P. PRI. [tN/y]	P. SEC. [tN/y]	EXPORT TO THE SEA [tN/y]
BIO_RF	win	1304	0.466	0.290	0.259	1352	499	-988
	spr	1629	0.250	0.702	0.459	4412	1295	-1119
	sum	1290	0.099	0.924	0.348	4712	1135	-806
	aut	1710	0.460	0.292	0.269	1507	509	-1325
BIO_A2	win	12%	13%	-2%	0%	-2%	0%	13%
	spr	-4%	-2%	-1%	2%	0%	1%	1%
	sum	-9%	-17%	-3%	-13%	-6%	-13%	-11%
	aut	8%	8%	1%	2%	2%	3%	7%
BIO_B2	win	15%	14%	0%	3%	0%	2%	14%
	spr	-1%	4%	0%	6%	3%	5%	7%
	sum	-6%	-12%	0%	-11%	-3%	-10%	-5%
	aut	6%	4%	0%	2%	1%	2%	0%

<-10%	-10%<x<-5%	-5%<x<-1%	-1%<x<1%	1%<x<5%	5%<x<10%	x>10%

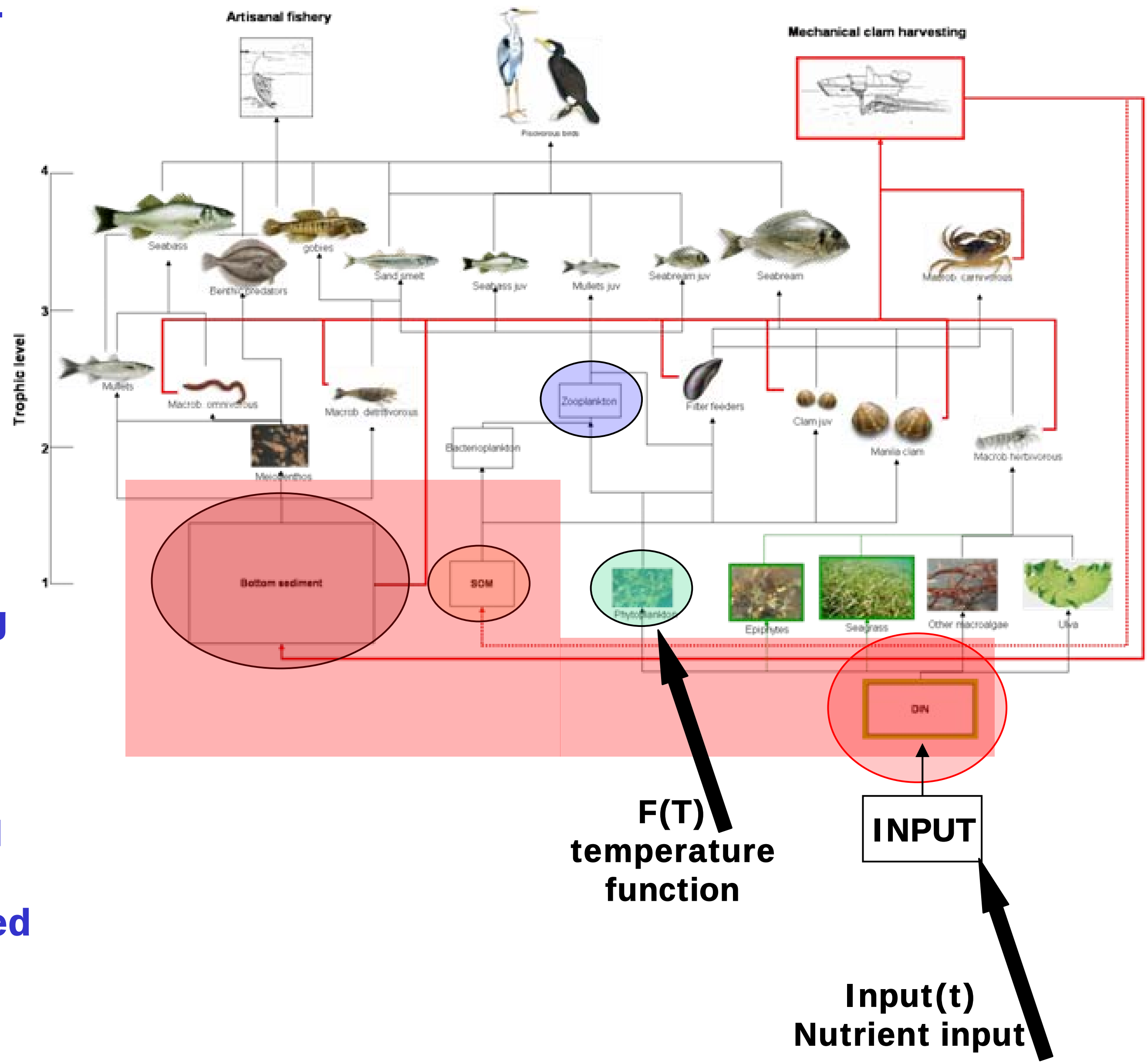
- Include DIN as a “non-living group”;

- phytoplankton (and other PP) become “predator” of DIN;

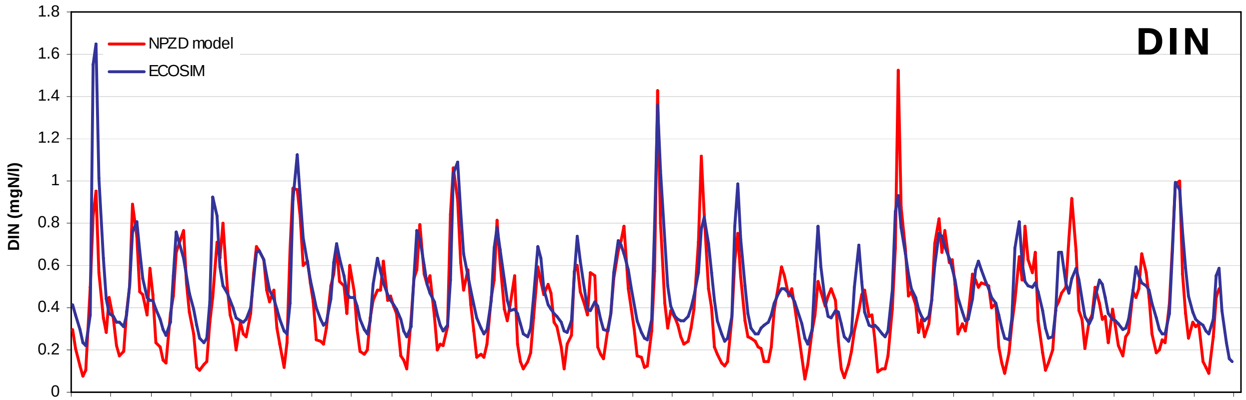
-“uptake” of DIN (“consumption” parametrized as in TDM);

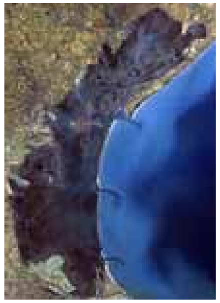
- setting “detritus fate” for HIGH TROPHIC LEVELS for representing flows from food web into OM and Nutrient compartments

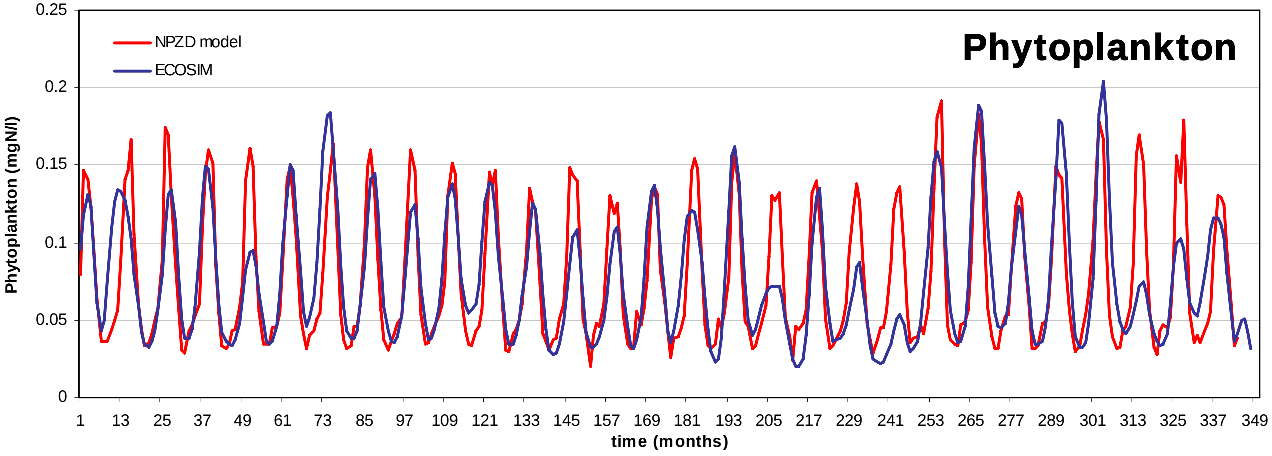
- annual averages of OM degradation flows estimated from TDM used in the “detritus fate” between OM & nutrient compartments

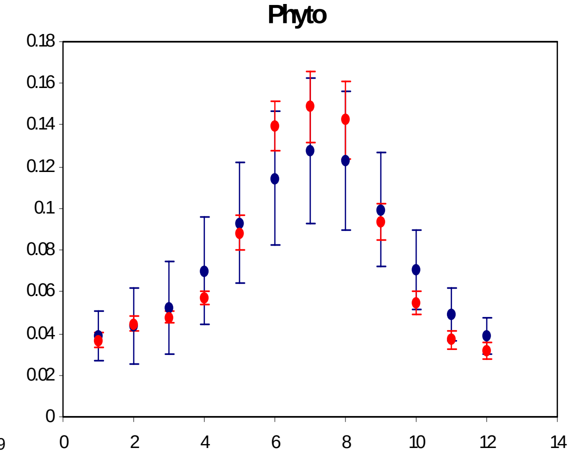


The Food web model including nutrient cycling

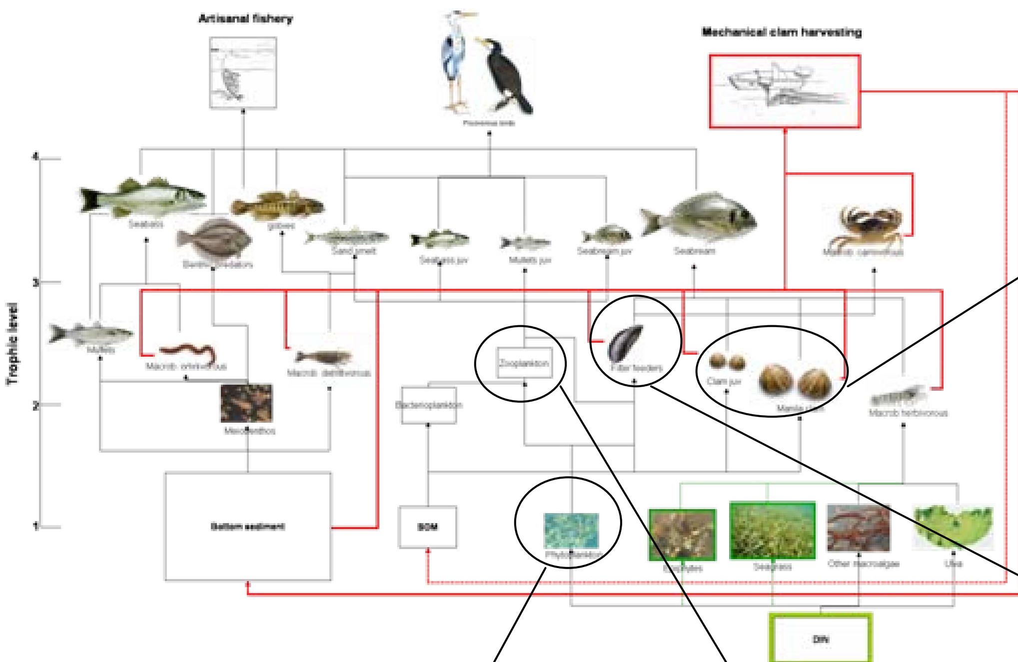


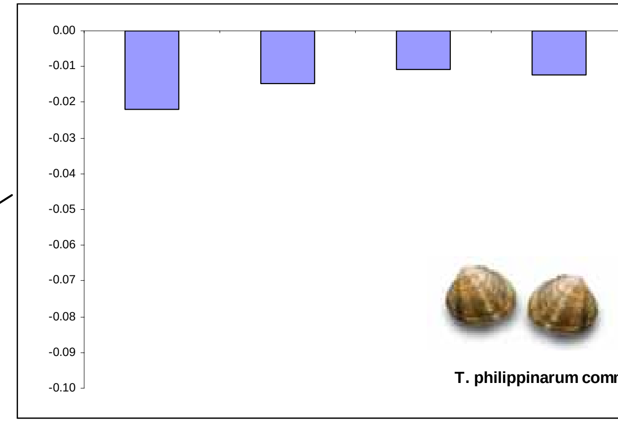


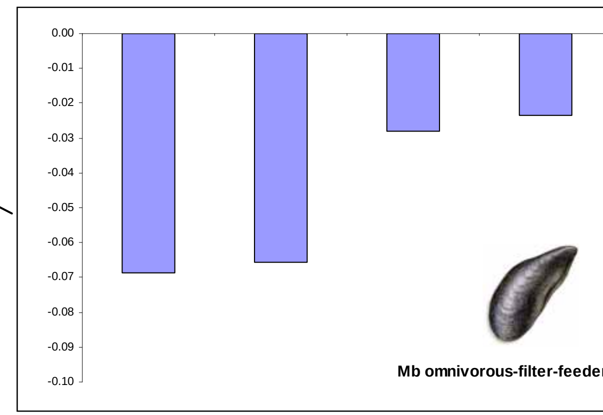


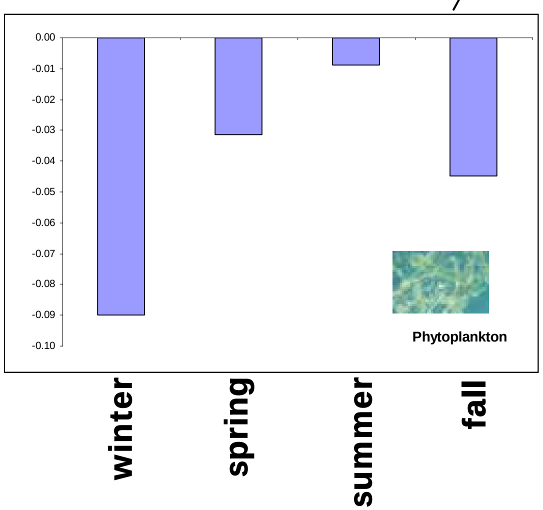


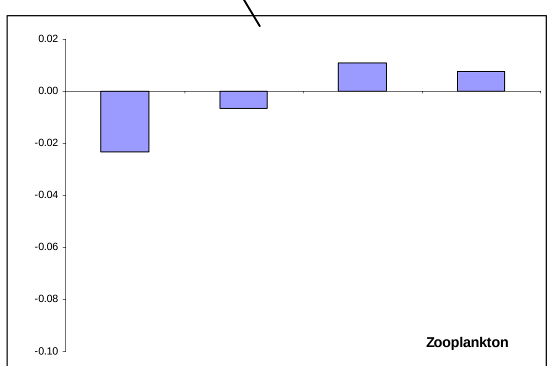
Seasonal anomalies B2 Scenario







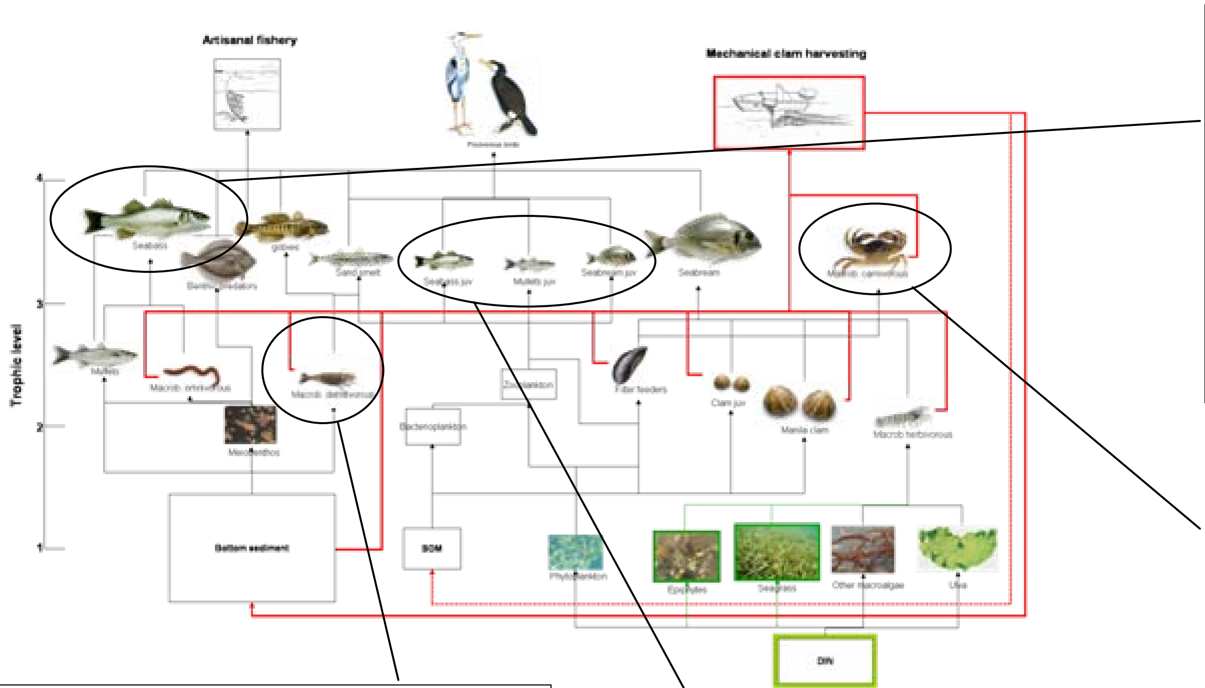


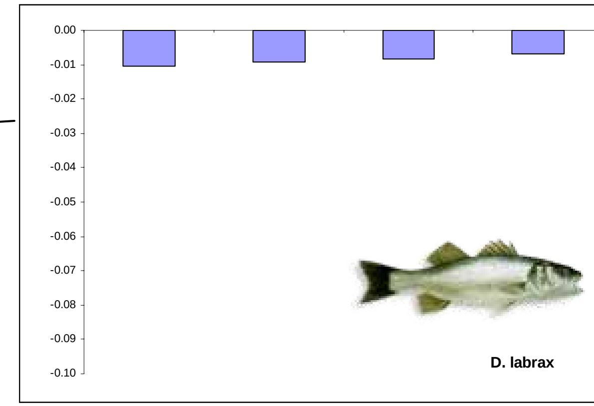


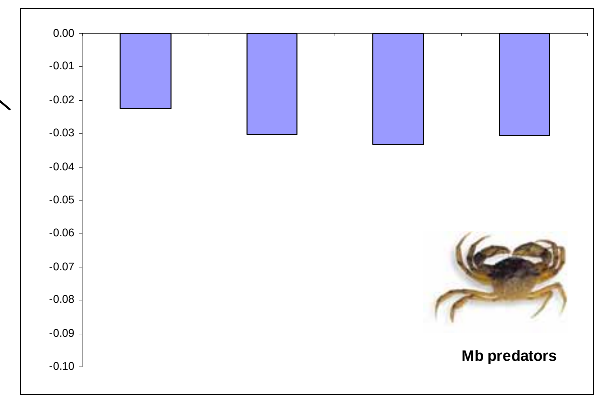
These should be considered indicative of changes in suitability in terms of trophic conditions (not changes in densities).

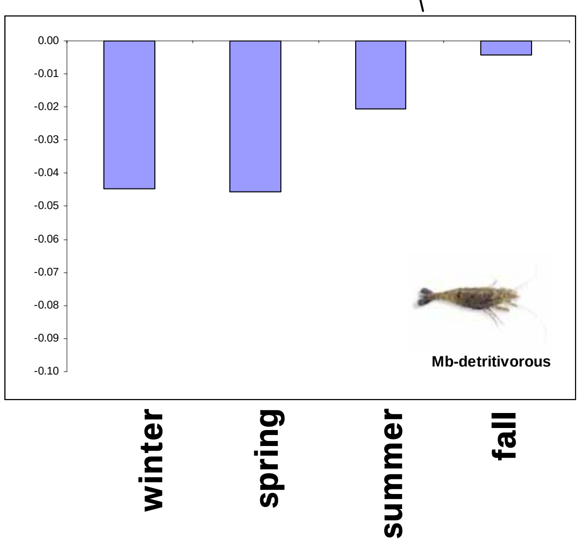
Ontogeny and recruitment are not considered and match-mismatch can produce additional effects.

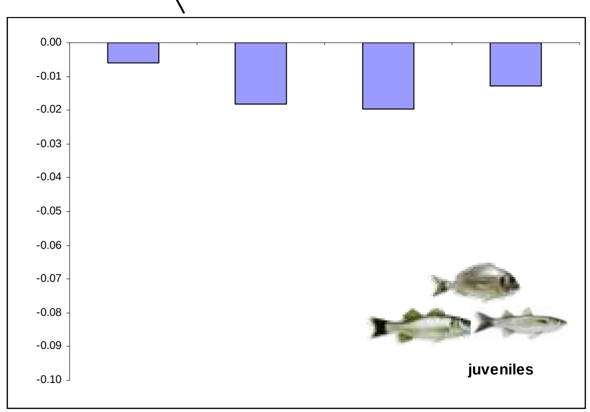
Seasonal anomalies B2 Scenario









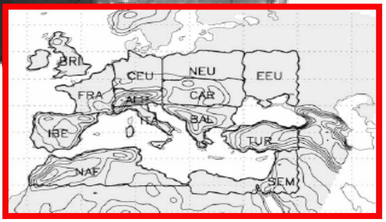


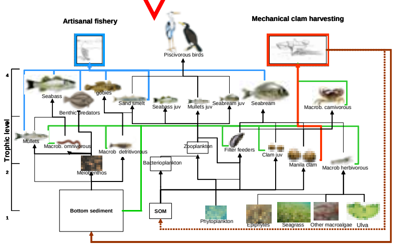
Omnivory contribute to reduce direct effects of changes in PP.

Food web model allows for representing alternative patchways of energy flow

The recruitment of some species (often occurring in fall) might be severely impacted

Conclusions





Future climate projections suggest that annual mean rain will not change much but the seasonal patterns will likely change: summer & spring more dry and winter & autumn more rainy

The increase in frequency of long drought during spring and summer will have a potentially high impact on primary productivity of the ecosystem

Increase of winter and autumn nutrient loads will potentially increase nutrient concentrations but with lower effects on primary and secondary productions (system is T, light-limited), then the nutrient surplus will be exported to the Adriatic Sea

The impacts on higher trophic levels will not always be more intense than those on lower trophic levels due to effects of alternative energy patchways and role of omnivory

Preliminary application: **there is LOT to do still** (include population dynamics)
Need for a complete **2-ways coupling**.
Need for BGC models for capturing spatial and high frequency dynamics
Future: other systems with longer **time series**, i.e. Adriatic Sea

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