Towards the integration of biogeochemical and food web models for a comprehensive description of marine ecosystem dynamics

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Biogeochemical processes and fish dynamics in food web models for end-to-end conceptualisation of marine ecosystems. Theory and use of Ecopath with Ecosim.

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IMBER (Integrated Marine Biogeochemistry adn Ecosystem Reserch)

GLOBEC (Global Ocean Ecosystem Dynamics)

LOICZ (Land Ocean Interaction Coastal Zone)

ISEM (International Society for Ecological Modelling, European Chapter)

End-to-End: why?

important drivers (stressors) of the marine ecosystems have many effects

Pollution

Nutrient input

- accumula
  living org
- effects o
  production

…position;
…a (Justic et al.,
…ecies

A comprehensive perspective of dynamics of marine ecosystems can be achieved by bridging studies regarding biogeochemistry and low trophic levels (plankton) and studies focussing on dynamics of high trophic ones

End-to-End

Biogeochemical/trophic relationships/spatial relationships

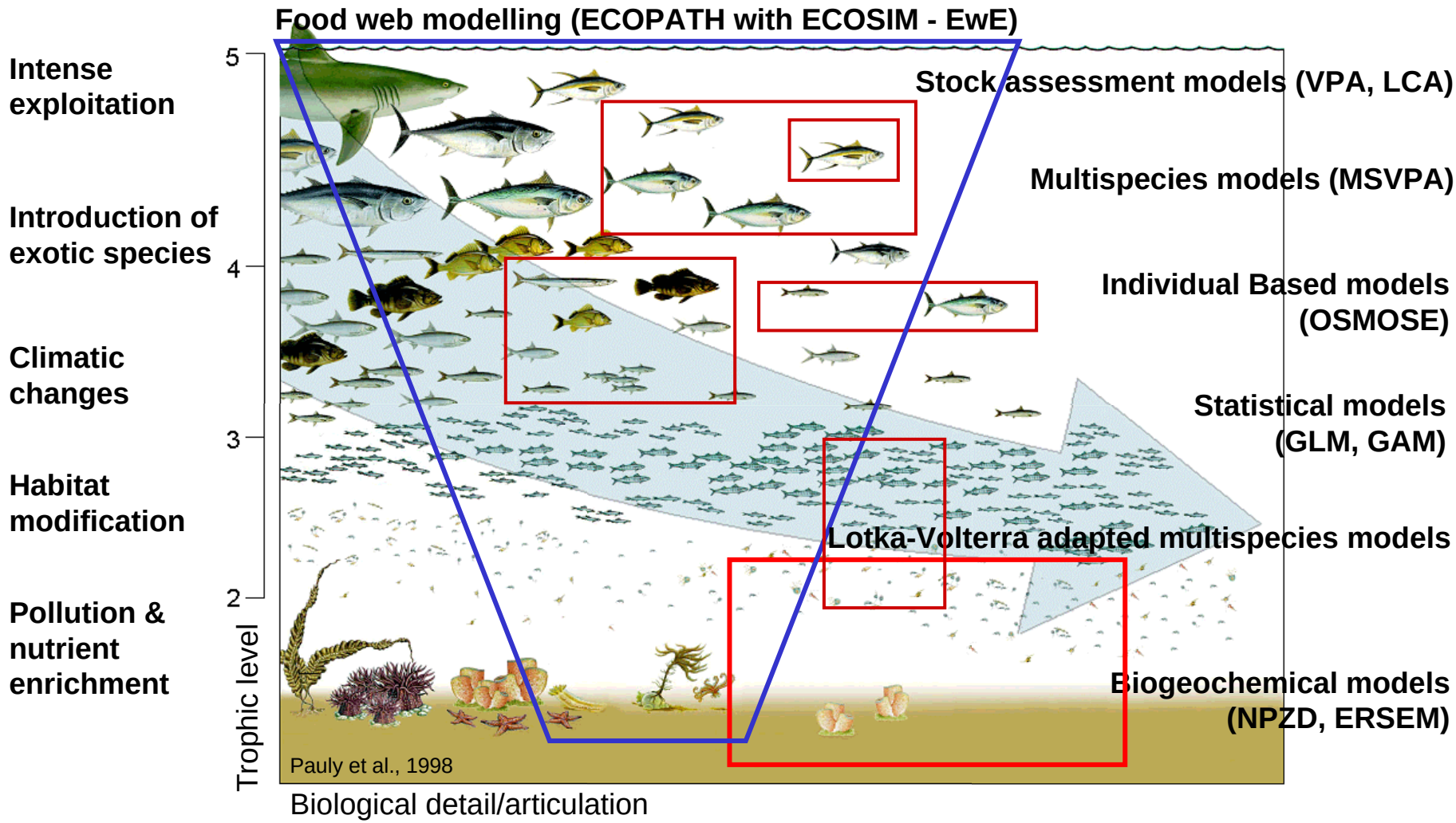
Fishe

Natural variability
Global warming

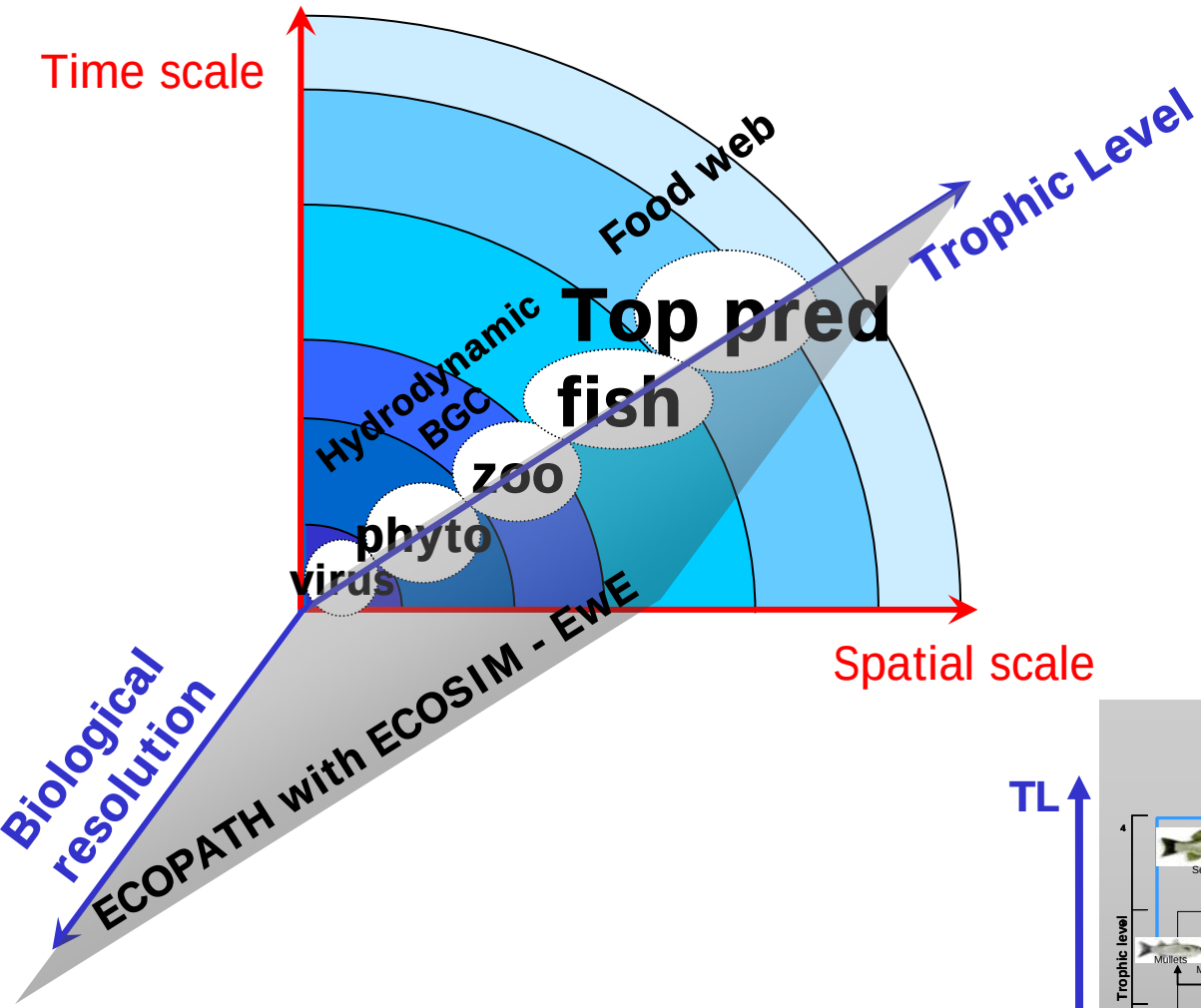
- depletion of target species (Myers & Worm, 2003);
- increase mortality of non-target species (by-catch);
- decrease in biodiversity (Robert et al., 2000);
- modification of habitats (Jennings & Kaiser, 1998);
- induced changes in the communities (Pauly et al., 1998);
- indirect effects of biological & physical changes (Yodzis, 2001);
- direct & indirect propagation of effects (Springer et al.,2003);

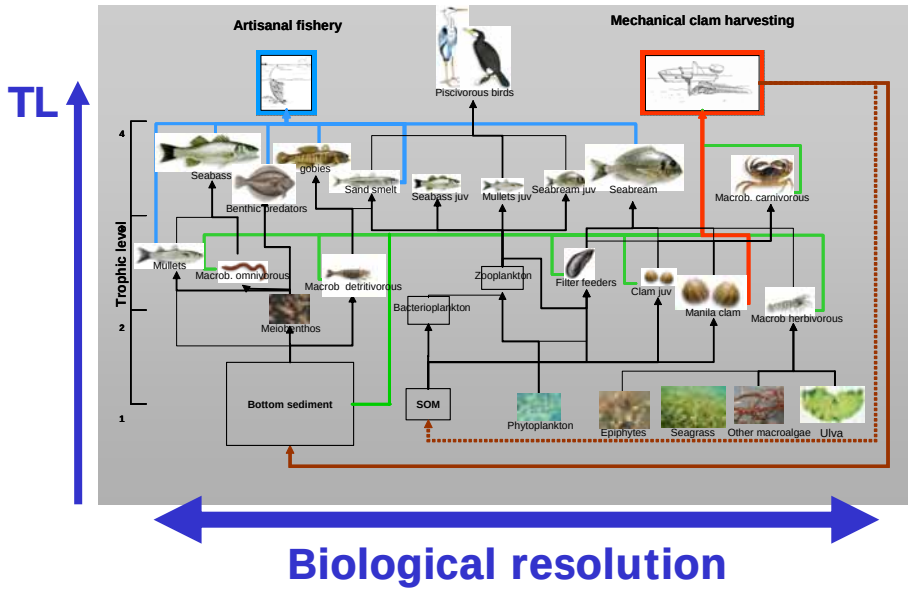
- modification of habitats;
- modification species distribution (Loukos et al., 2003);
- effects on physiology & behaviour (Maury & Lehodey, 2003);
- influences on recruitment (Stenseth et al., 2003);
- impacts on trophic interactions (Hunt et al., 2002);
- direct & indirect propagation of effects;

End-to-End: how?



End-to-End: issue of scales...not only

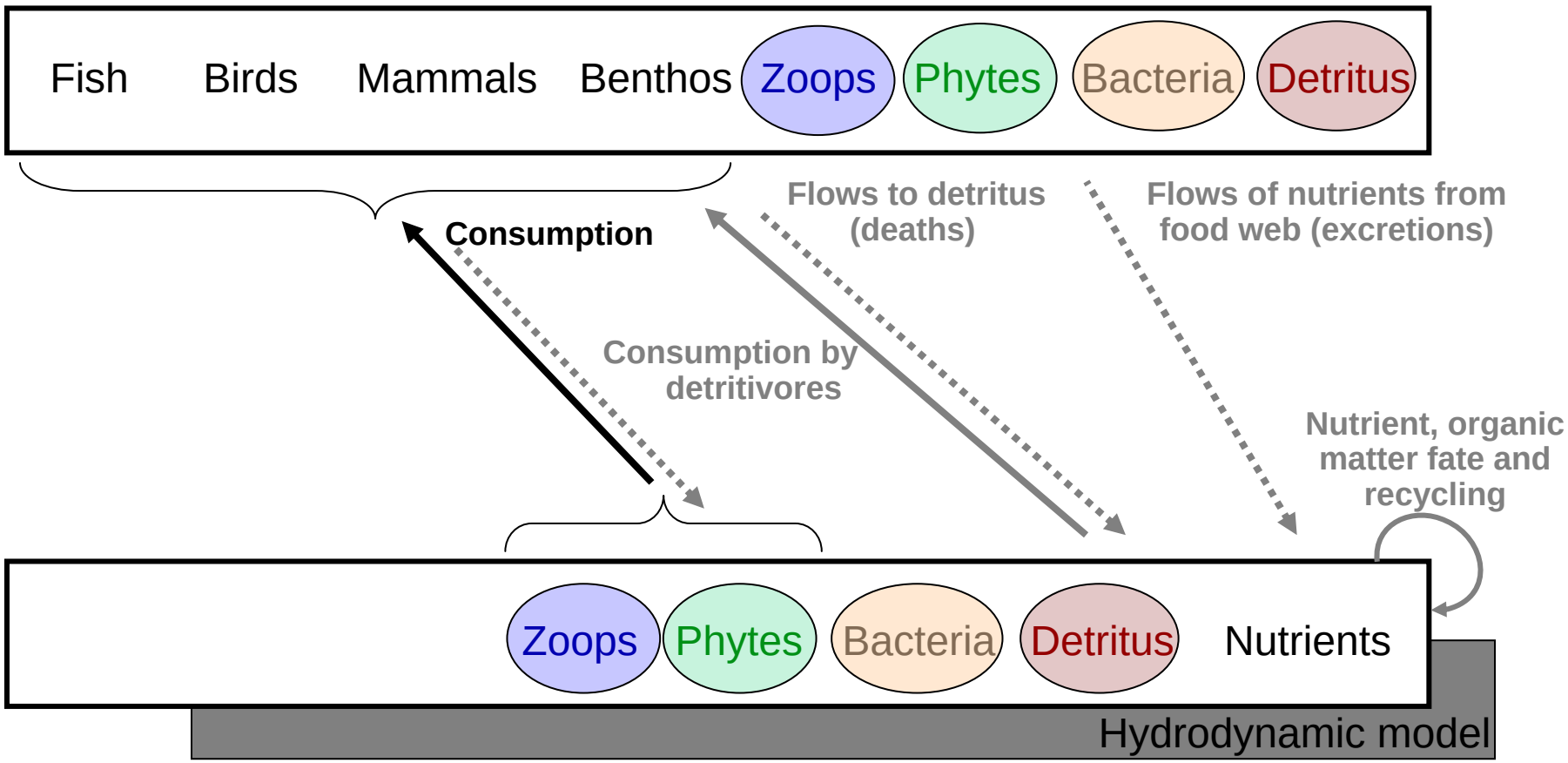




ECOPATH with ECOSIM - EwE

BGC model & food web model

High TL (HTL) Feeding and fishery interactions (EwE)



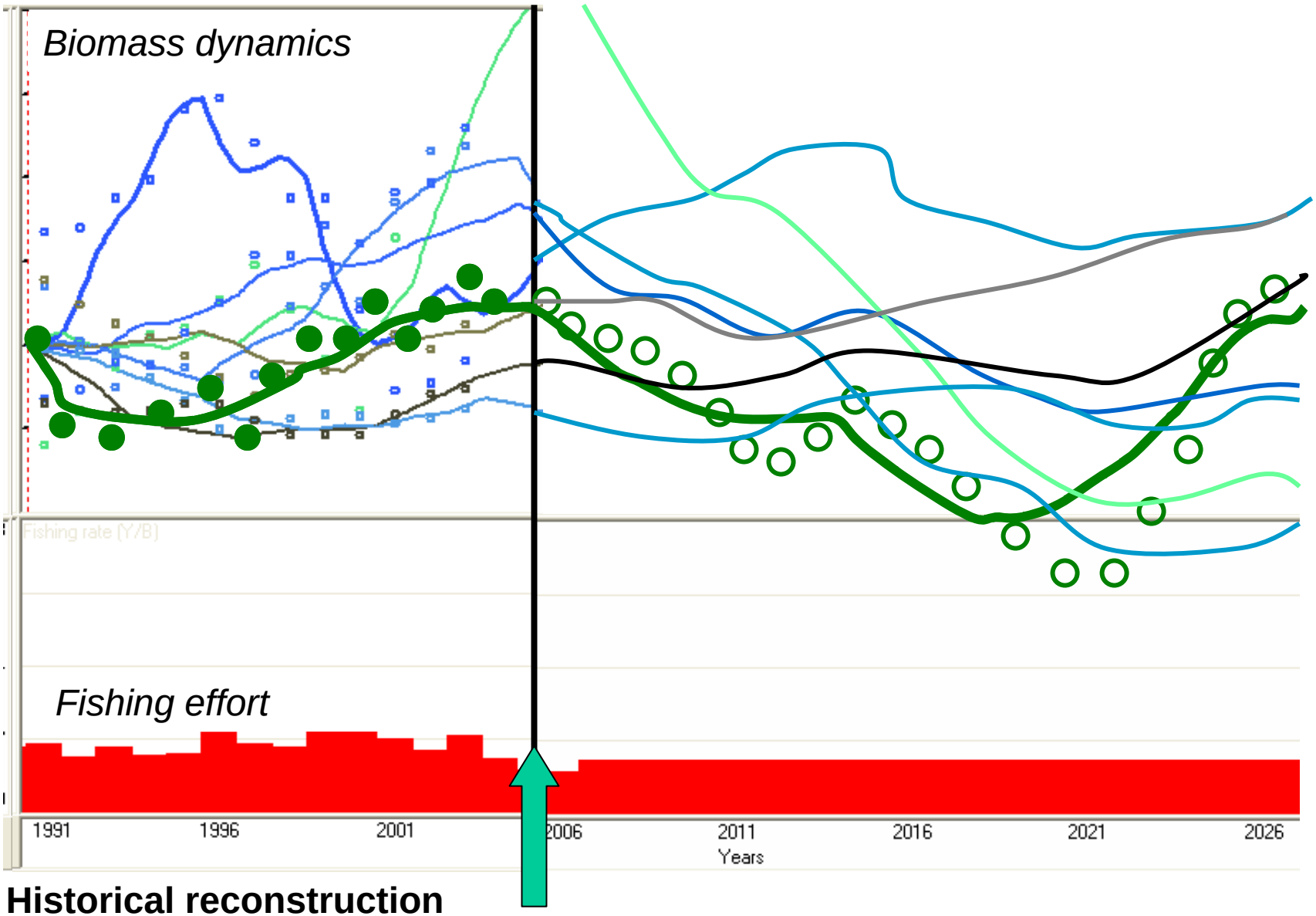
Low TL (LTL) Feeding interactions (Biogeochemical model, BGC)

Step 0 – Comparison, Reconciliation and 'validation' of state and rate parameters

- 'Functional groups' particularly zoobenthos
- Primary and secondary production and consumption rates
- Predation rates for common groups
- Time scale – annual basis?
- Currency issues – Carbon biomass vs Wet weight biomass? Conversion

(courtesy Steve Mackinson)

Step 1: 1-way coupling of fundamental links



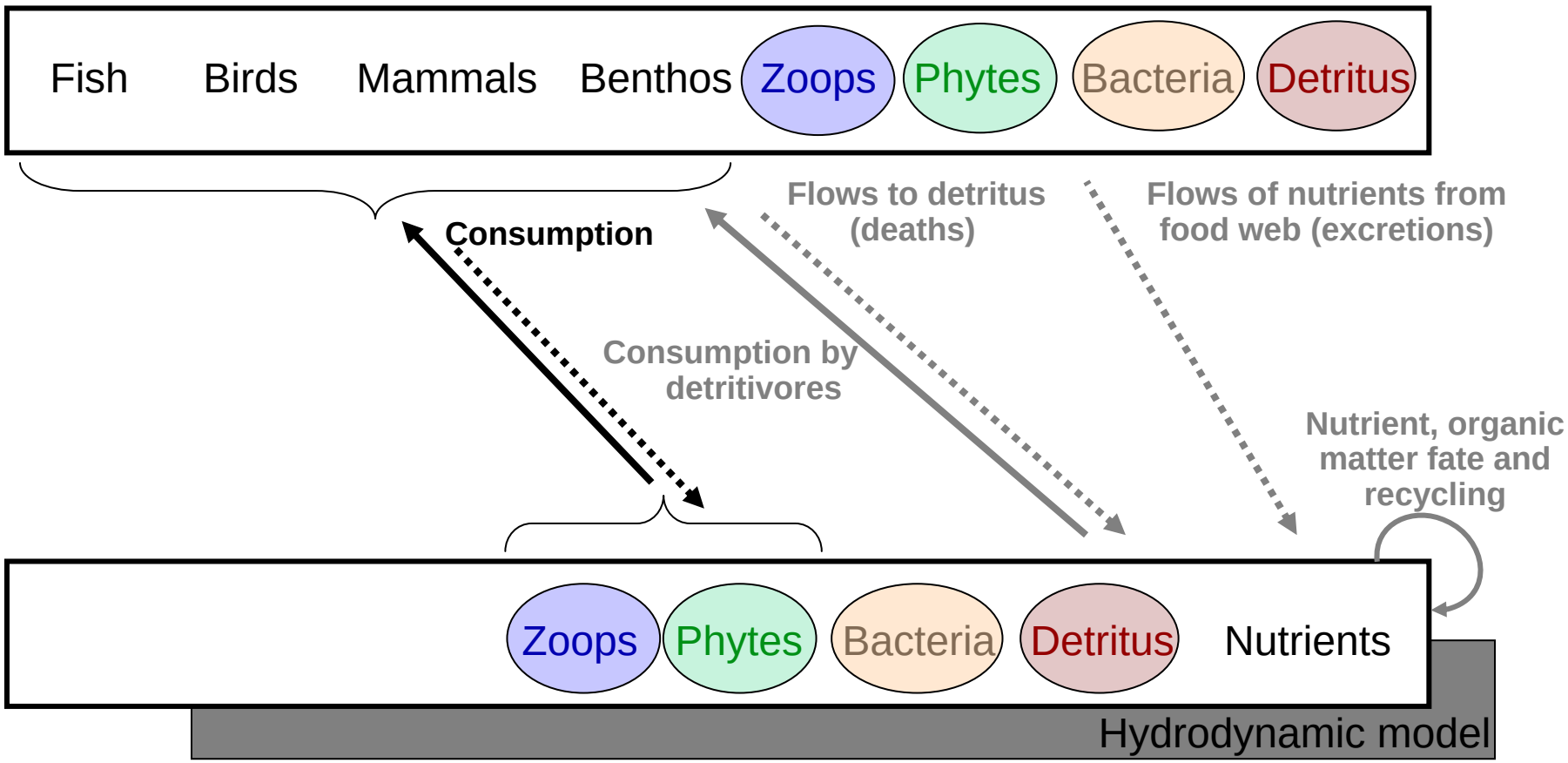
Historical reconstruction

BFM input

(courtesy Steve Mackinson)

Need for a 2-ways coupling

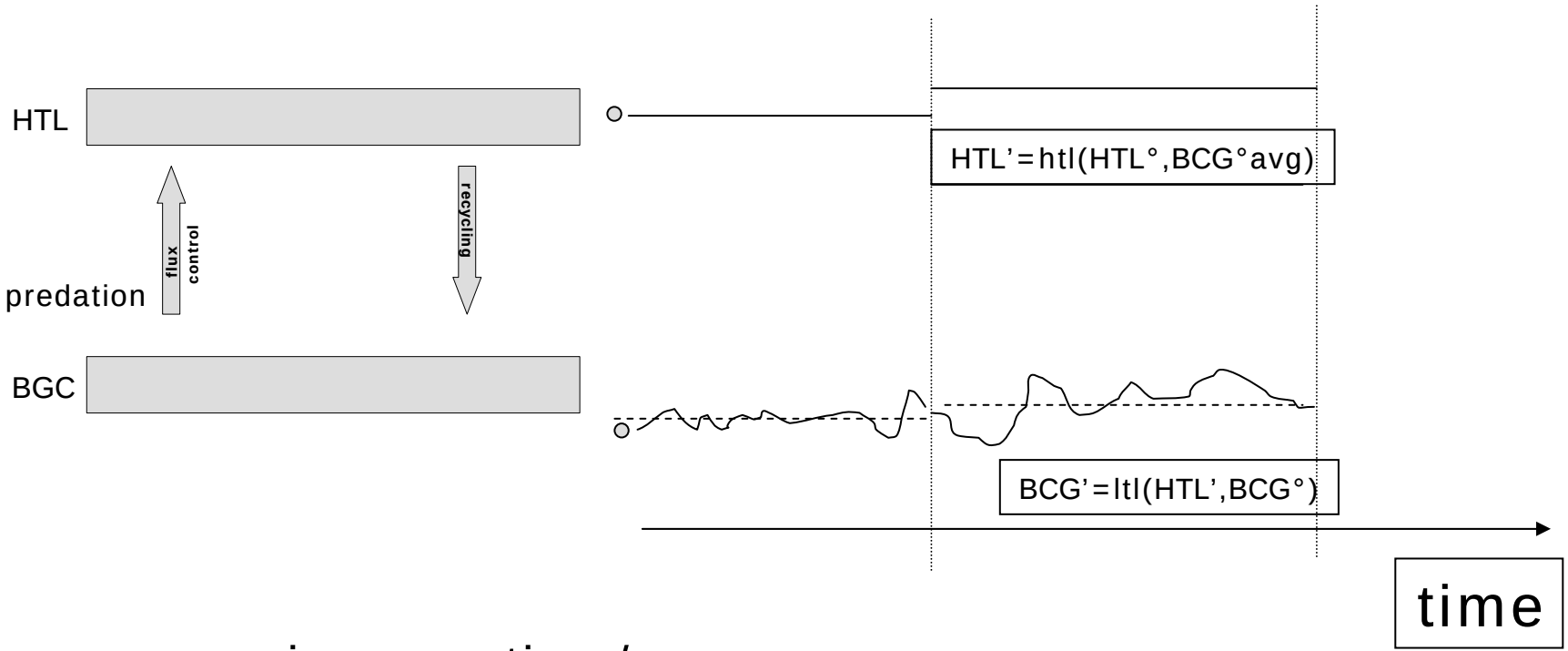
High TL (HTL) Feeding and fishery interactions (EwE)



Low TL (LTL) Feeding interactions (Biogeochemical model, BGC)

Step 2: “brute force” coupling

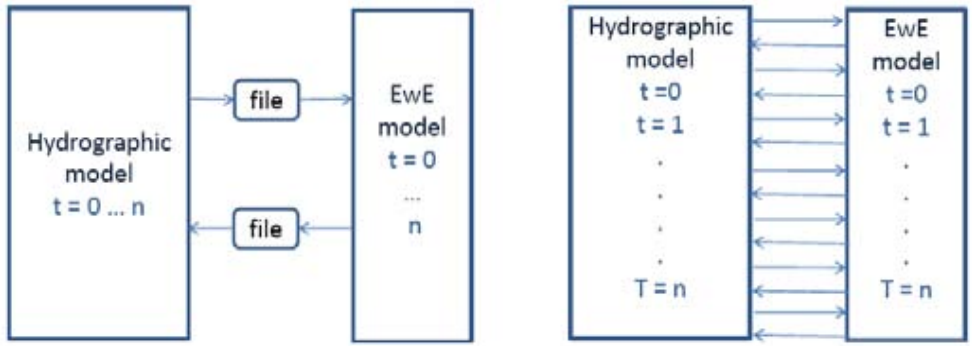
‘brute force’ home made coupling



averaging over time/space

To define averaging scale and what to held constant while integrating other components is to define the links among models (slow/fast dynamics)

Step 2: 2-ways coupling

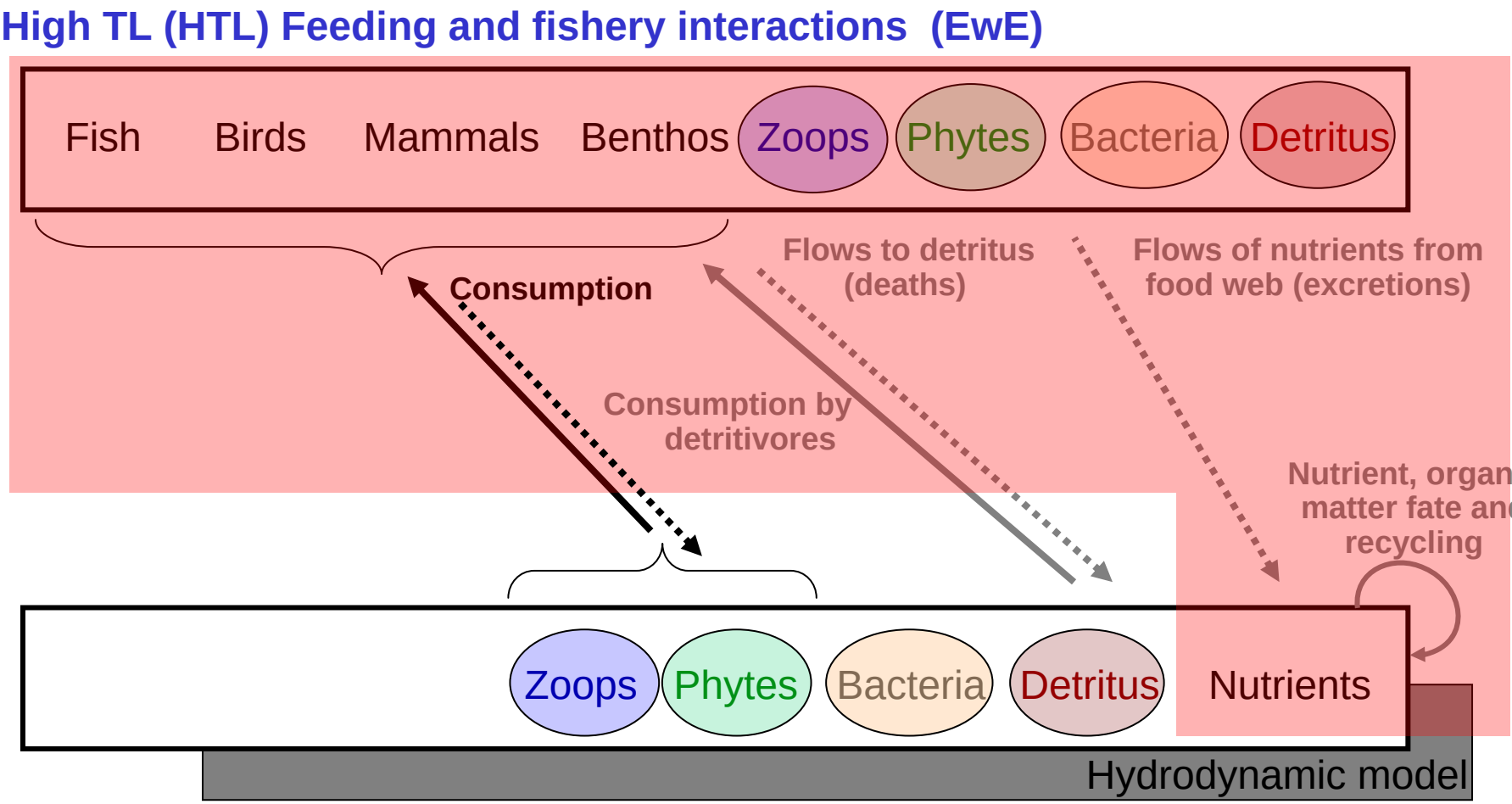


EwE-GCM-Climate linkages

- Salinity
- Temperature
- Nutrients
- Advection
- Detritus dynamics
- Primary producer dynamics
- First-order consumer dynamics
- Second-order consumer feedback

- Issues to tackle
  - Scale
  - Time

A step in between: 1.5-ways coupling



(modified from Steve Mackinson)

Application to the Venice Lagoon

Biogeochemical model: TDM

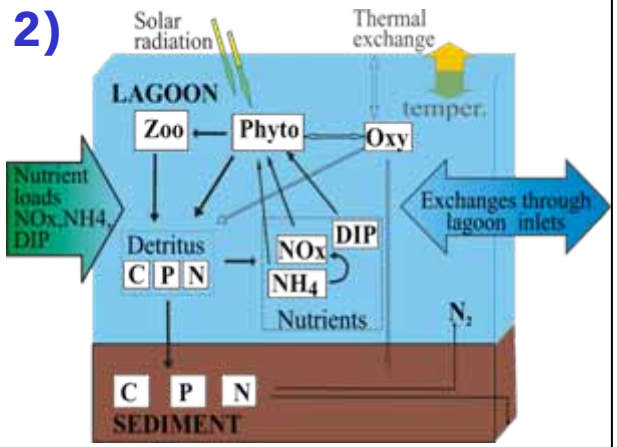
EwE fod web model

3D fully coupled hydrodynamic and biological models

1)

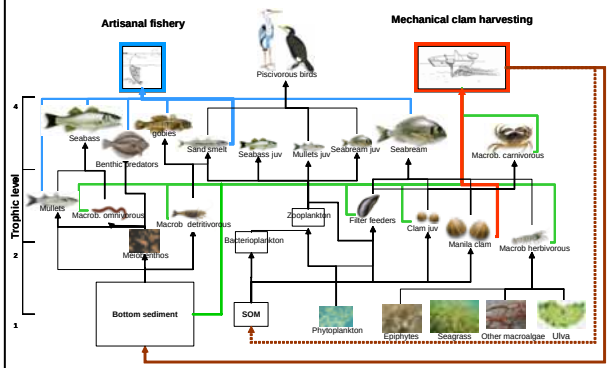
Hydrodynamic model:
Anysotropic diffusion and no advective term (residual currents negligible).
Anysotropic and space varying diffusivity tensors

2)



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

3)



Ecosystem model:
27 state variables (functional groups); from Phytoplankton to seabirds; 2 nonliving functional groups; 2 fishing activities

Horizontal resolution: 300m X 300m
Vertical resolution: 1m
Time step: 1800 s

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

One 1.5-way coupling

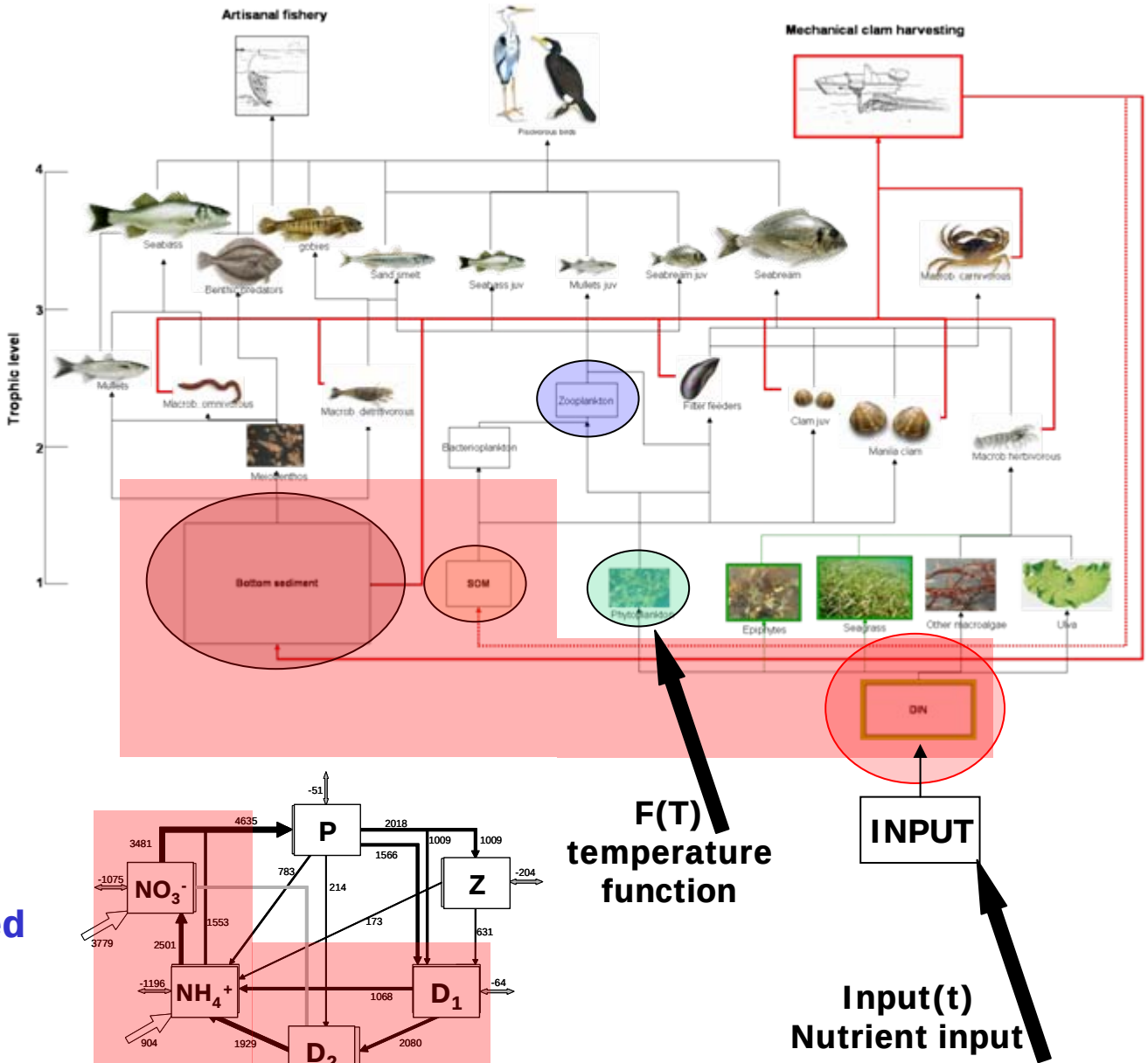
- Include DIN as a “non-living group”;

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

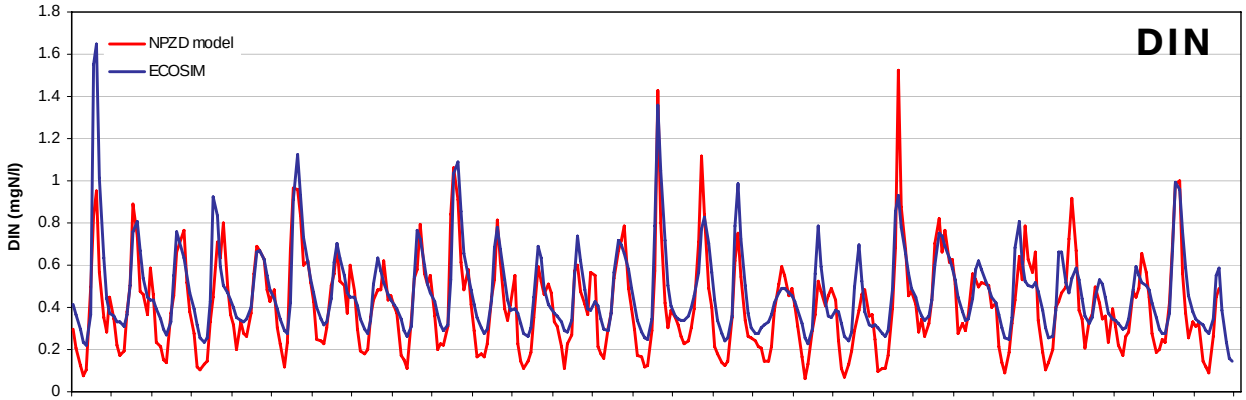
-“uptake” of DIN (“consumption” parametrized as in TDM);

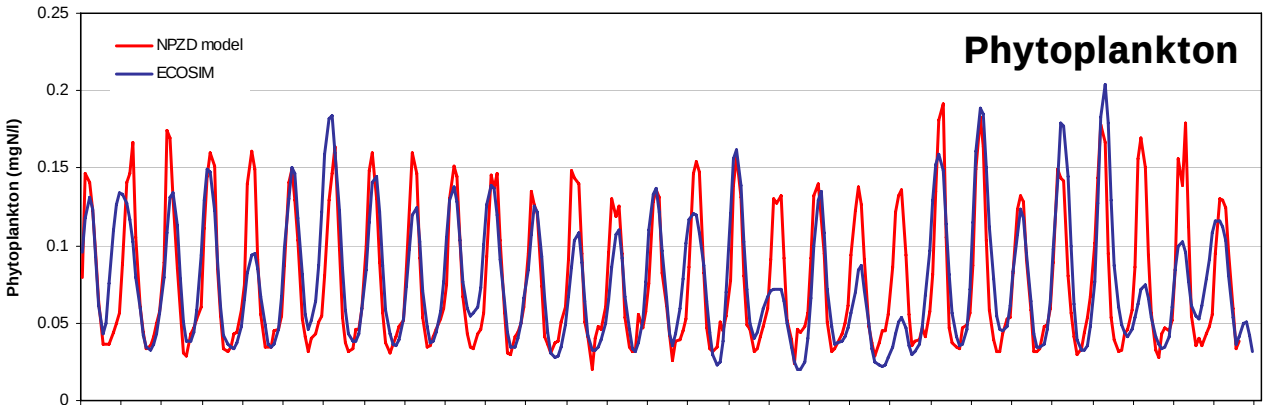
- setting “detritus fate” for HIGH TROPHIC LEVELS for representing flows from food web into OM and Nutrient compartments

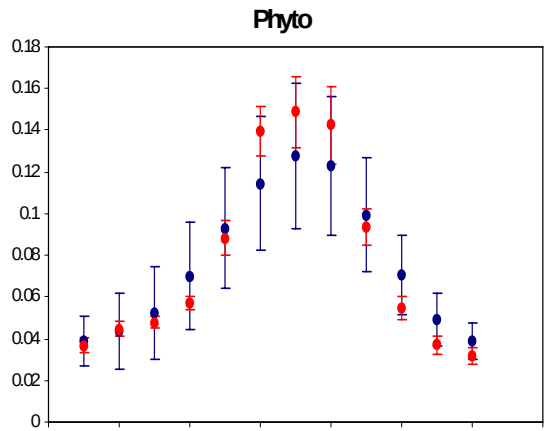
- annual averages of OM degradation flows estimated from TDM used in the “detritus fate” between OM & nutrient compartments

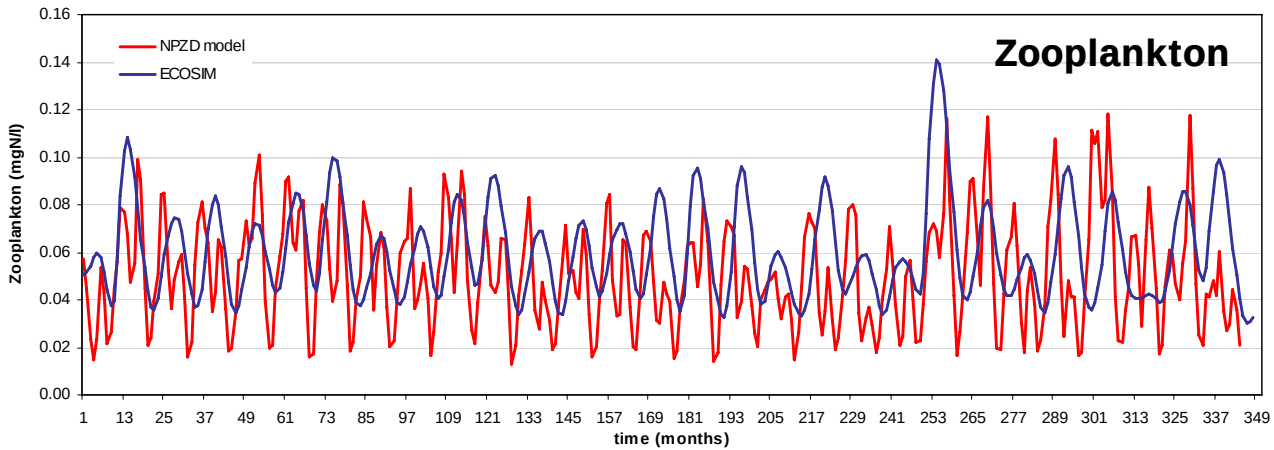


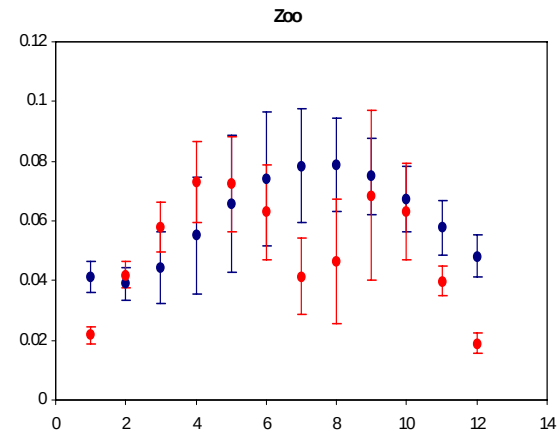
0D: BGC averaged in space





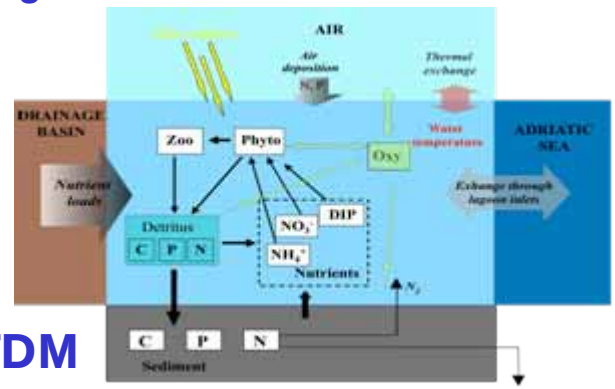






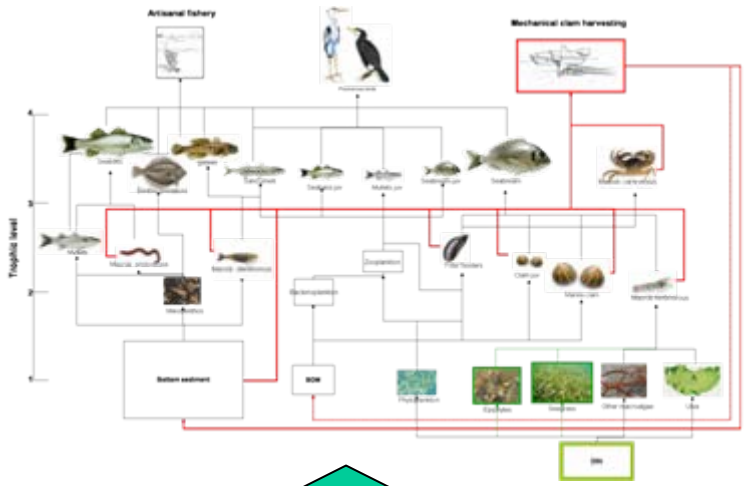
2D: BGC averaged in time

Biogeochemical 3D-NPZD calibrated model

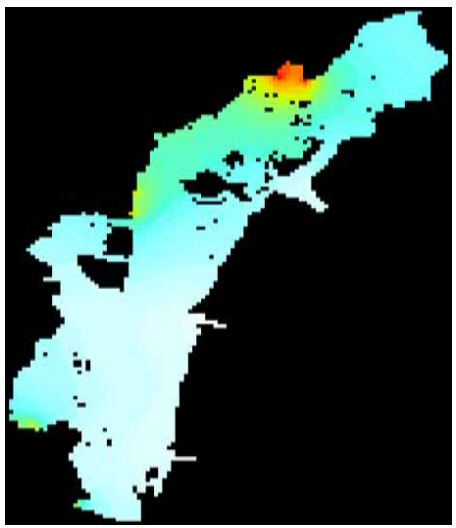


TDM

Ecopath with Ecosim food web



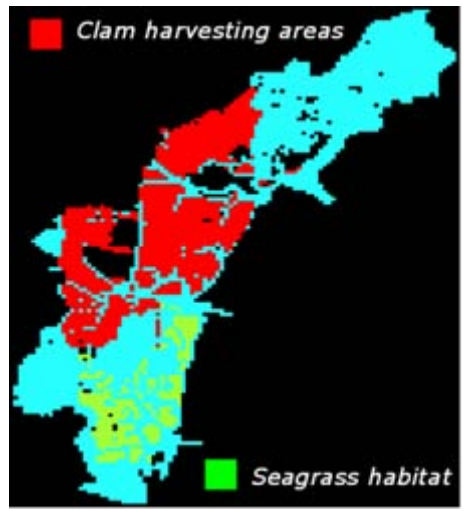
Yearly average DIN field from TDM (year 2001)



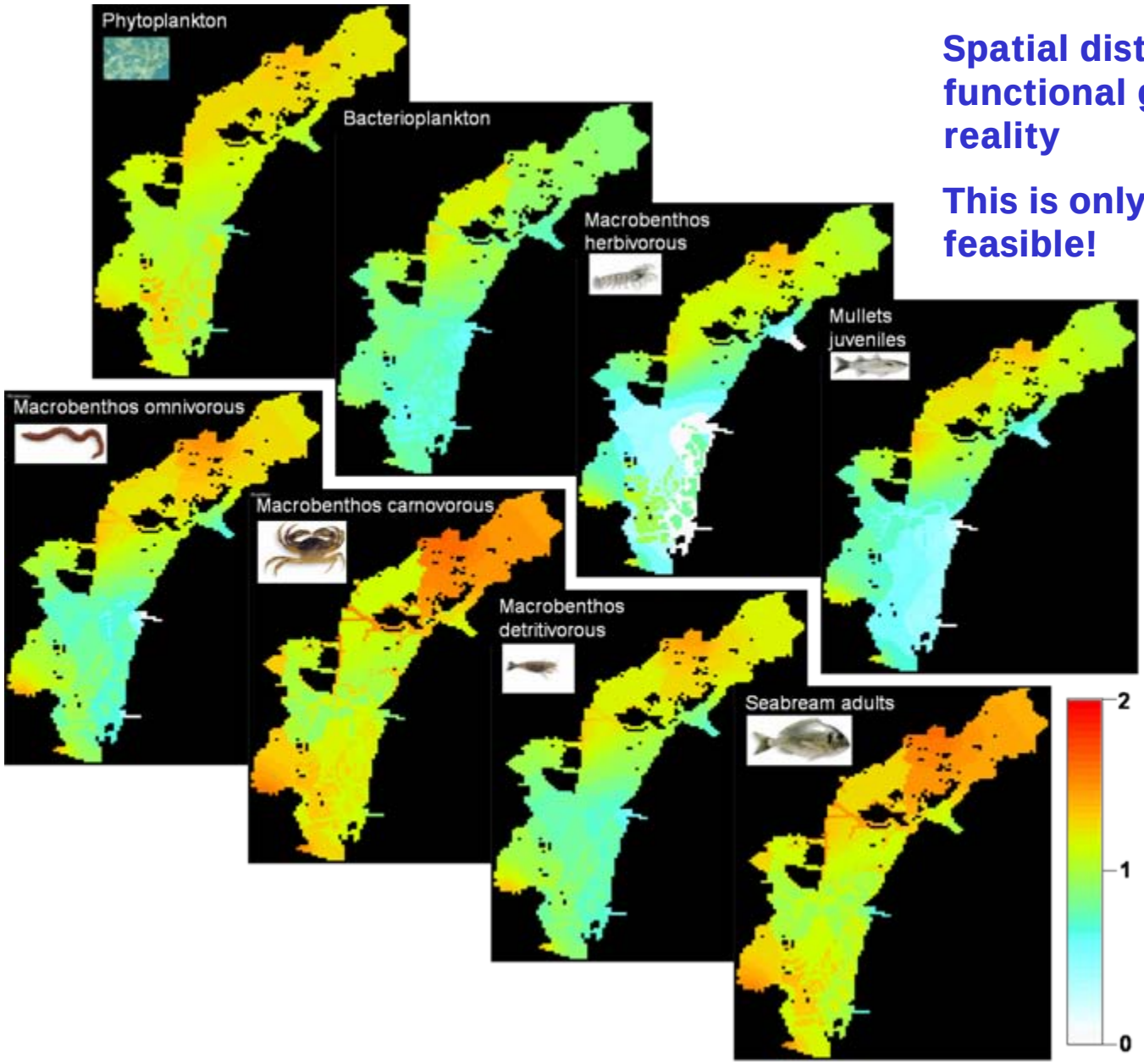
The yearly average field of Dissolved Inorganic Nitrogen (DIN) for a representative year (2001) was obtained from TDM

used as input forcing parameter in the spatio-dynamic routine of the Ecopath model (ECOSPACE)

2 major habitats were defined and food web components apply to opportune cells



2- results from 2D one-way coupling



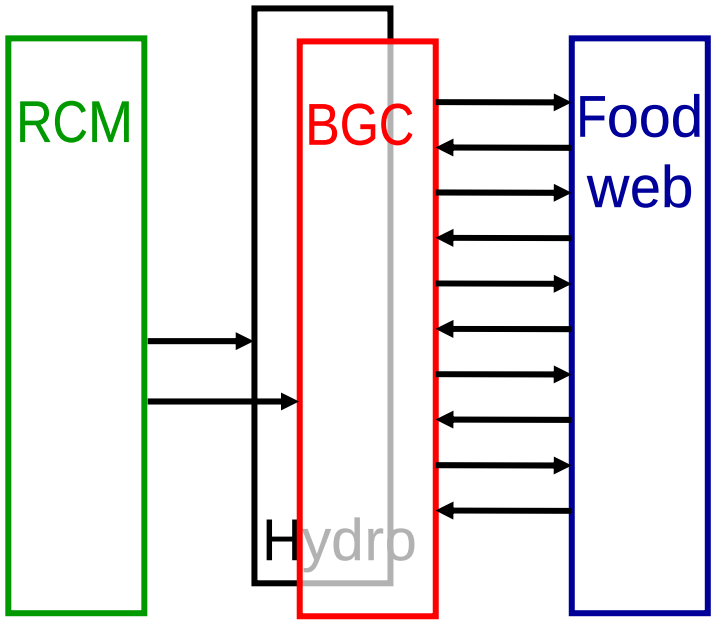
Spatial distribution of most functional groups resembled reality

This is only preliminary… But feasible!

Conclusions

One-way coupling implied a time and/or space aggregation

EwE (v5) allows for including biodiversity scale and had enough flexibility for representing biogeochemical processes



Linking available (and tested) models seems the solution: we don't want to go into a big model (3D+hydro+BGC+food web+....)

However, we need to have the complete feedbacks from food web models to the BGC ones too: need for two-way coupling.

COUPLERS? DATA ASSIMILATION?

....EwE (v6) .... Two way coupling is possible...

In the future!!

Thanks

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