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

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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 coastal 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 responds 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 km², average depth 1m;

11 rivers:
freshwater discharge ≈ 3x10⁶ m³ day⁻¹
(load: 4000tN/y, 200 tP/y)

Venice, industrial area, 2 sewage treatment plants (load: 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
[1] high resolution regional climate model (RegCM)

[2a] statistical model of nutrient input

[2b] statistical model of sea-lagoon boundaries

[3] biogeochemical model of the lagoon of Venice

[4] Food web model of the lagoon

Nutrient forcing
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)

11.6°E 45.1°N

LAGOON OF VENICE

12.3°E 45.7°N

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

3 runs:

RF – reference condition 1961-1990

A2 - simulation of future condition 2071-2100 based on IPCC A2 scenario \([CO_2 \sim 800ppm]\)

B2 - simulation of future condition 2071-2100 based on IPCC B2 scenario \([CO_2 \sim 600ppm]\)

(Salon et al., Clim. Res., accepted)
Biogeochemical modelling: TDM

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

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

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

\[ \frac{\partial C_i}{\partial t} = \frac{\partial C_i}{\partial t}_{\text{biol}} + \frac{\partial C_i}{\partial t}_{\text{transp}} \]

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

\[
\frac{dB_i}{dt} = g_i \cdot \sum_{j=1}^{n} c_{ji} (B_i, B_j) - \sum_{j=1}^{n} c_{ij} (B_i, B_j) + I_i - (M_{oi} + F_i + e_i) \cdot B_i
\]

Production term  \hspace{1cm} \text{Predation}  \hspace{1cm} \text{Immigration}  \hspace{1cm} \text{Natural & fishing mortality, emigration}

(2a) **Statistical model of nutrient input**

1. Hysterical data of nutrient input

2. Logarithmic regression between rain and annual load using the REGCM rain of one year → annual total load

3. Daily nutrient discharges from annual loads
1 Hysterical 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 $\rightarrow$ mean seasonal value

3 Daily concentration values of one year from a climatological evolution
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
**Seasonal averages**

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**DIN [mg/l]**

Scenarios of the Venice Lagoon biogeochemical processes.
### Scenarios of the Venice Lagoon biogeochemical processes

**Seasonal averages & anomalies for state variables and fluxes**

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<tr>
<th>INPUT N</th>
<th>DIN</th>
<th>PHYTO ZOO</th>
<th>P. PRI.</th>
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<td>[mg/l]</td>
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#### BIO_RF

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**Export to the Sea**

-988 -1119 -806 -1325

### Seasonal averages & anomalies for state variables and fluxes

-988 -1119 -806 -1325

### Scenarios of the Venice Lagoon biogeochemical processes

-988 -1119 -806 -1325
- 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

DIN

Phytoplankton

NPZD model
ECOSIM

DIN (mgN/l)
Phytoplankton (mgN/l)

Time (months)

0 0.02 0.04 0.06 0.08 0.1 0.12 0.14 0.16 0.18

0 0.1 0.15 0.2 0.25 0.3 0.35 0.4 0.45 0.5

0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0 11.0 12.0 13.0 14.0

0 2 4 6 8 10 12 14

0 0.02 0.04 0.06 0.08 0.1 0.12 0.14 0.16 0.18
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.
Omnivory contribute to reduce direct effects of changes in PP.

Food web model allows for representing alternative pathways of energy flow.

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