

Nutrients Cycling and the Trophic Status of Coastal Ecosystems – (EUROTROPH)

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Objectives

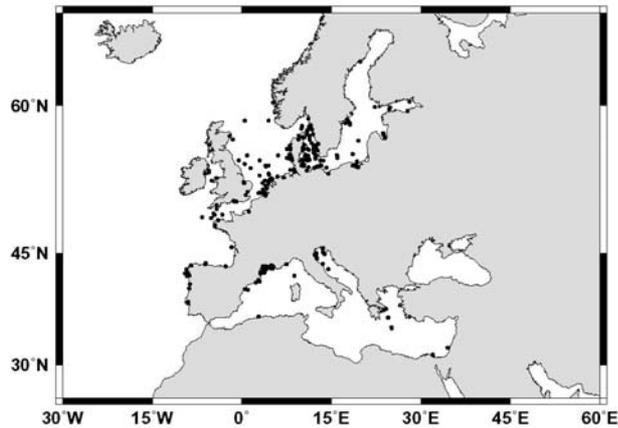
An ecosystem is net autotrophic when production of organic carbon is higher than consumption. Conversely, it is net heterotrophic when consumption exceeds production. Despite its fundamental aspect in terms of carbon and nutrients cycling, the net metabolic state of the coastal ocean is still a matter of debate. Riverine fluxes of nutrients and organic carbon have been significantly affected by human activities and have probably modified the autotrophic versus heterotrophic balance in estuaries and, locally, in the coastal ocean. Any change or improvement in anthropogenic carbon and nutrients loadings will affect the trophic status of coastal ecosystems in ways that still have to be understood. Specific objectives included:

- Quantification of the trophic status of coastal ecosystems using different approaches at various time scales.
- A breakdown, unraveling and understanding of the nutrient cycles in autotrophic and heterotrophic systems.
- Integration and dissemination of results to all appropriate user communities.

Results

Two main approaches were applied to study ecosystem metabolism during EUROTROPH: 1) compilation of available data-sets at the European regional level [1,2] and, 2) the collection of detailed field measurements in the three study sites (Randers Fjord; Scheldt estuary; Bay of Palma). As an example of the large number of scientific outcomes of the project, the Figure below shows the map of the sites from the bibliographic database on metabolic performances of European coastal waters (available at <http://www.obs-vlfr.fr/eurotroph/index.php>). The objectives of this part of the study were to compile published direct measurements on ecosystem function, essentially primary production and respiration and then to upscale these estimates, and to compare them with indirect estimates based on flux models in the coastal zone (Land-Ocean Interaction in the Coastal Zone).

By pinpointing several regions strongly impacted by human activities, this study should be useful for policy makers to decide where pollution reduction plans are strongly needed. Furthermore, this study pointed out a severe lack of knowledge in many European areas which precluded the satisfactory upscaling of estimates (for instance, Northern Baltic Sea and Eastern Mediterranean Sea). This paucity of results for certain regions can be used as a guideline for the selection of future scientific field work sites.



Potential exploitation by end users

The EUROTROPH project aimed to use the produced data/information to improve communication between scientists and policy-makers. It allowed to set the regulatory framework for the project and to collate the gained scientific research information in an administrative, legislative and socio-economic framework. Five individual reports produced during the project are described below:

(1) Ecological Impacts and Conceptual Models: Background nutrient levels at each study site (including data from the sampling campaigns) are described and sources of inputs identified. Generic conceptual models have been derived, and the biological impacts of eutrophication and associated system effects discussed. Signs and symptoms of eutrophication observed at each site are highlighted and examined.

(2) Ecological Modelling: Numerous models were reviewed and the MOHID model chosen as the most suitable for all sites. The model serves as a management tool for testing different scenarios which produce eutrophic symptoms and for developing Decision Support Systems (DSS). Importantly, it provides data for cost-benefit analysis by testing different nutrient inputs, the repercussion of this in the environment, and the quantification of benefits to each study area.

(3) Administration & Legislation: Each study area is reviewed in relation to the regulatory framework at a national, European and international level. The administration and implementation of relevant water quality legislation at each study site is reviewed and compared, with the information produced allowing the assessment of differing administration and implementation strategies.

(4) Socio-Economics: The costs and benefits associated with reducing nutrient inputs as a result of implementing recent water quality legislation are addressed. The benefits of improved water quality in the Randers Fjord were assessed using a contingent valuation approach. The analysis provides information and advice to water quality managers in order to determine the efficacy of existing and future treatment strategies on a catchment-wide basis.

(5) Monitoring and Management: This report collates the management and monitoring issues raised within the project and summarises these issues for use by legislators and administrators in a way which allows dissemination of the results to a wider audience.

References

- [1] Gazeau, F, Gentili, B, Smith, SV, Frankignoulle, M, & Gattuso J-P (in press) Estuarine, Coastal and Shelf Science
- [2] Middelburg, JJ, Duarte, CM, & J-P Gattuso (in press) In: Respiration in aquatic ecosystem



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EUROTROPH

Partners

- Université de Liège, Belgium
- Université Libre de Bruxelles, Belgium
- Nederlands Instituut voor Oecologisch Onderzoek, Netherlands
- Observatoire Océanologique de Villefranche-sur-mer, France
- Aalborg Universitet, Denmark
- Instituto Mediterráneo de Estudios Avanzados, Spain
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Objectives

1. Quantification of the trophic status of three European coastal ecosystems using different approaches at various time scales. The three European coastal ecosystems are Randers Fjord (Kattegat) - Denmark; Scheldt estuary (North Sea) - Netherlands/Belgium; Bay of Palma (Mediterranean Sea) - Spain. A large range of techniques have been used to estimate the trophic status of coastal ecosystems. As a result, available estimates are difficult to compare and, even at local scale, the link to environmental quality/disturbance is not well established.
2. Breakdown, unravelling and understanding of the nutrients cycle in autotrophic and heterotrophic systems. In order to improve our knowledge of nutrient cycling and to assess its relationship with the metabolic state of the ecosystem, we proposed to quantify the uptake and turnover of dissolved inorganic and organic nitrogen and phosphorus, as well as to study the distribution, composition and turnover of particulate and dissolved organic matter (labile and refractory).
3. Integration and dissemination of results to all appropriate user communities. An important current issue is the translation and implementation of scientific research information into environmental management strategies. This transfer between intrinsically different fields is not straightforward but nevertheless essential. Biogeochemical and socio-economic models will be used to simulate future scenarios including better management options.

Results (1)

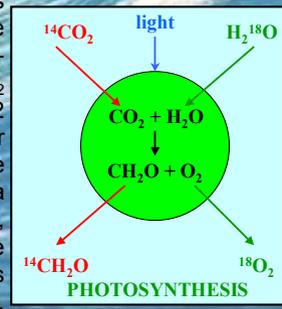
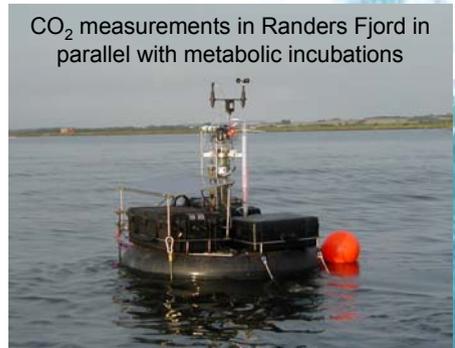
1 – Compilation of historical data

Workpackage 1 is aimed at synthesizing and interpreting data available for the selected sites. A database was built for the Randers Fjord (1962-2002) and Scheldt estuary (1940-2003), in collaboration with local environmental agencies. No historical data were found for the bay of Palma. These databases as well as descriptions of the data are downloadable on a website constructed during the course of the project (<http://www.obs-vlfr.fr/eurotroph/index.php>).

2 - Determination of the trophic status

The objective of Workpackage 2 is to evaluate the trophic level of coastal ecosystems including estuaries. Coastal ecosystems receive large amounts of terrestrial organic carbon as well as nutrients from riverine and atmospheric inputs. The coastal zone may thus be heterotrophic if the respiration of the organic matter of marine and terrestrial origin exceeds local phytoplankton production. In this situation, the coastal zone thus acts then as a source of CO₂ for the atmosphere and the water column may become more or less anoxic.

The reverse situation occurs under autotrophic conditions, when the production of organic matter due to the abundance of nutrients exceeds the respiration. In this case, the shelf becomes a sink of CO₂ from the atmosphere and exports organic matter to the sediments and to the open ocean. At present, there is much debate concerning the trophic status of the coastal systems in the world. One of the reasons that it is so difficult to achieve a consensus is that there are a variety of methods used to estimate the importance of primary production relative to respiration and this methodological variability itself can result in very different conclusions being drawn. In order to address this, three different approaches have been used during EUROTROPH to estimate primary production, during in-situ incubation experiments: 1 - precise measurements of the O₂ production (or consumption by respiration under dark condition) (OOV); 2 - ¹⁴C uptake and production of particulate and dissolved organic matter (ULB); 3 - addition of ¹⁸O labelled water and measurements of the production of ¹⁸O₂ (NIOO). The use of three different methods permits a better estimate of the gross production, the respiration and, by difference, the net production. The results are especially interesting in the estuarine zone where the processes are very complex and the measurements delicate. They confirm the strong heterotrophic character of estuaries, even those estuaries that are minimally disturbed by anthropogenic activities such as the Randers Fjord.



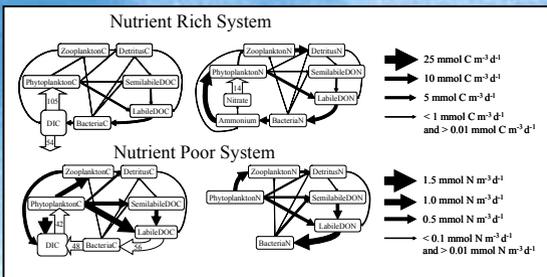


Results (2)

3 – Nutrient cycling in systems of various eutrophication levels (Workpackage 3)

The flows of carbon and nitrogen were studied using C and N isotope tracers during an experimental phytoplankton bloom in Randers Fjord. In the nutrient rich system, an algal bloom is observed, and carbon and nitrogen uptake occur at a constant ratio with little exudation of DOC.

In the nutrient-depleted system, carbon and nitrogen cycling are dominated by the microbial loop. Heterotrophic processes are the main source of dissolved organic nitrogen. Most of the carbon exudated by algae is respired by the bacteria and did not

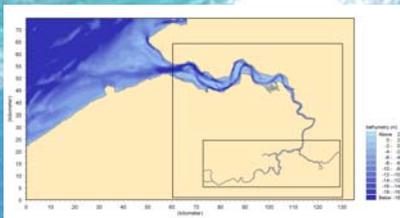


pass to higher trophic levels. A combined isotopic-modelling approach was adopted to obtain a more complete and consistent picture of carbon and nitrogen cycling and of ecosystem functioning. Moreover, it also allowed for the quantification of the links between algae and bacteria and between carbon and nitrogen dynamics and a sharpening of modelling tools that represent these processes.

4 - Biogeochemical modelling (Workpackage 4)

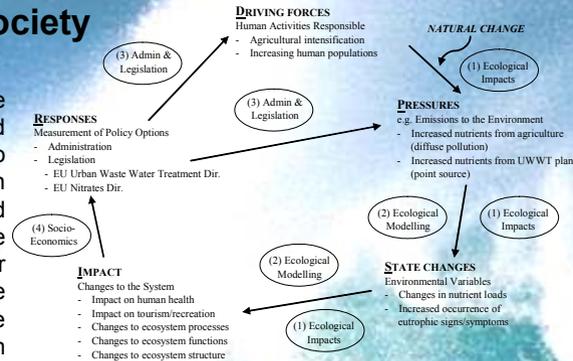
Reactive-transport models that integrate hydrodynamics with transport and transformation processes are particularly appropriate for estimating the fluxes of reactive species in areas characterized by complex hydrodynamic and biogeochemical behaviours, such as estuarine and coastal zones. In particular, they can be used to analyse and predict the shift between heterotrophic and autotrophic status within these systems, either in space (due to the existence of C and N gradients) or in time (due to the variability of the boundary conditions or to changes in the anthropogenic pressures).

In the case of the Scheldt estuary, we used a two-dimensional (depth-integrated) nested model (MIKE 21, DHI-Dk) together with its newly developed water quality module (ECOLAB). In addition to salinity and SPM, 6 variables are presently considered (degradable organic matter, O₂, NH₄, NO₃, Si, chlorophyll) which are involved in various processes (aerobic respiration, nitrification, denitrification, re-aeration, gross and net primary production).



Relevance for Society

WP5 aims to use the data/information produced throughout the project to improve communication between scientists and policy-makers. It sets the regulatory framework for the project and collates the deliverables gained in the other work packages in an administrative, legislative and socio-economic framework. WP5 comprises 5 individual reports described below. Figure indicates the links between these reports through the application of the DPSIR approach.



(1) Ecological Impacts and Conceptual Models: Background nutrient levels at each study site (including data from the EUROTROPH sampling campaigns) are described and sources of inputs identified. Generic conceptual models have been derived, and the biological impacts of eutrophication and associated system effects discussed. Signs and symptoms of eutrophication observed at each site are highlighted and examined.

(2) Ecological Modelling: Numerous models were reviewed & the MOHID model chosen as the most suitable for all sites. The model serves as a management tool for testing different scenarios which produce eutrophic symptoms & for developing Decision Support Systems (DSS).

(3) Administration & Legislation: Each study area is reviewed in relation to the regulatory framework at a national, European and international level.

(4) Socio-Economics: WP5 is addressing the costs and benefits associated with reducing nutrient inputs as a result of implementing recent water quality legislation. The benefits of improved water quality in the Randers Fjord were assessed using a contingent valuation approach. The analysis provides information and advice to water quality managers in order to determine the efficacy of existing and future treatment strategies on a catchment-wide basis.

(5) Monitoring and Management: This report collates the management and monitoring issues raised within WP5 and summarises these issues for use by legislators and administrators in a way which allows dissemination of the results to a wider audience.