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COMBINED EFFECT OF CHANGING HYDROCLIMATE AND HUMAN ACTIVITY ON COASTAL ECOSYSTEM HEALTH "AMORE III"

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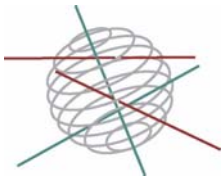

North Sea

FINAL REPORT PHASE 1
SUMMARY

COMBINED EFFECT OF CHANGING HYDROCLIMATE AND HUMAN ACTIVITY ON COASTAL ECOSYSTEM HEALTH "AMORE III"

SD/NS/03A

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Lancelot C , Rousseau V, Lacroix G, Denis K, Gypens N, Grosjean P, Van Nieuwenhove K, Parent J-Y, Ruddick K and D Delbare. ***Combined effect of changing hydroclimate and human activity on coastal ecosystem health. "AMORE III"*** (Advanced MOdeling and Research on eutrophication) project. Final Report Phase 1 Summary. Brussels : Belgian Science Policy 2009 – 6 p. (Research Programme Science for a Sustainable Development).

AMORE (Advanced Modeling and Research on Eutrophication) is an interdisciplinary consortium composed of biologists, bioengineers, biostatisticians and physical and ecological modelers aiming to the development of Sustainability Science for the management of coastal zones in the Channel and the Southern Bight of the North Sea with a focus on the Belgian coastal zone (BCZ).

Previous achievements since 1997 by the AMORE consortium demonstrated that the BCZ is a key pilot area for addressing causes of natural variability and effects of human activity on coastal eutrophication and the sustainable use of economic activity. The BCZ is indeed submitted to local (Scheldt, Ijzer) and transboundary (Seine, Somme, Rhine/Meuse) river inputs of anthropogenic nutrients that modify the N:P:Si nutrient balance and the ecosystem structure of the coastal area, favoring the blooming of undesirable *Phaeocystis* colonies over diatoms. However the actual contribution of local river inputs to the BCZ eutrophication and the related geographical spreading of *Phaeocystis* are largely determined by large-scale climatic phenomena such as the NAO (North Atlantic Oscillation) that determines the weather conditions over Northwestern Europe.

The research project AMORE III addresses the dual control of changing human activity and climate on eutrophication processes in the BCZ and the feedback effect of eutrophication on goods and services provided by the BCZ. As service, AMORE III focus on the atmospheric CO_2 absorption capacity of the BCZ while the newly-deployed offshore mussel farming is considered as a good. Mussel farming is a recent economic activity in the BCZ planned in three offshore areas (Nieuwpoort, Oostdijck and Westhinder) with varying proliferation of *Phaeocystis* colonies. While some negative effect of *Phaeocystis* colonies has been reported for mussel beds, their impact on mussel farming in floating cages is unknown but probably depends on *Phaeocystis* magnitude (colony size and number).

As a scientific contribution towards the sustainable use of the BCZ, AMORE III provides new ecological knowledge, technological developments and ecological modeling to:

- Assess the dual role of changing hydro-climate (wind strength and direction, temperature) and nutrient river loads in determining the geographical spreading and the magnitude of *Phaeocystis* blooms in the BCZ as well as the role of the coastal area as buffer of increased atmospheric CO_2; predict how these might change in the near future (2015) based on realistic scenarios of changing climate and river nutrient loads;

- Assess the impact of *Phaeocystis* colony spreading on offshore mussel farming and make recommendations for an optimized management;

- Define ecological quality criteria for measuring ecosystem changes and the effectiveness of management and policy applications.

The research methodology involves and combines (i) laboratory-controlled process-level experiments, (ii) the collection of historical and new field data, (iii) the set up of (near) real-time monitoring of phytoplankton distributions and (iv) numerical tools (statistical and dynamic models). In this methodology, the existing MIRO&CO-3D ecological model plays a central role as integrator of new knowledge gained from experimental studies and

as tool for eutrophication assessment and prediction as well as decision support. Complementary the (near) real-time phytoplankton monitoring is expected to provide a quasi synoptic view of phytoplankton biodiversity in the BCZ and adjacent waters and a powerful tool for model validation in areas where monitoring stations are absent as well as for identification of regions affected by undesirable *Phaeocystis* colony blooms. Application of multivariate statistical methods to this new data set is expected to support the model-sensitivity-based formulation of ecological quality criteria and provide early warning of ecosystem shifts. Progress achieved on all these items is detailed in the present report.

Phytoplankton ecology

Phytoplankton eco-physiological studies were focused on the mechanisms controlling *Phaeocystis* colony formation, a weakly constrained parameterization in the existing MIRO&CO-3D although crucial for determining their occurrence. Results suggest that *P. globosa* colony formation is related to the growth dynamics of the haploid population present in the water column. In particular, a light threshold of about 50 µmol m^{-2} s^{-1} and nutrient enrichment are necessary for the occurrence of syngamy and colony formation. Besides light and nutrients, a possible role of *Chaetoceros* spp. in triggering colony formation cannot be excluded.

Possible factors controlling the recurrent diatom/*Phaeocystis*/diatom succession in the BCZ were approached based on a statistically analysis of the 13-yr existing phytoplankton record at St 330 in the central BCZ. Disappointing the statistical analysis of phytoplankton records did not provide strong support to the regulation of the observed recurrent seasonal succession of diatom communities and *Phaeocystis* by temperature, nutrients and ambient light conditions. The small neretic diatoms and *Chaetoceros* seem however better adapted than *Guinardia* to lower temperature in late winter-early spring. Different resistance of the diatom communities and *Phaeocystis* colonies to grazing has been hypothesized as a factor shaping the phytoplankton succession.

Phytoplankton monitoring

AMORE III acquired a new instrument combining the technology of flow-cytometry (FlowCAM) and image analysis (PhytoImage). Laboratory experiments with pure cultures of phytoplankton species allowed defining specific conditions under which the combination of the FlowCAM and PhytoImage is a useful tool for monitoring phytoplankton in the North Sea. First we showed that a 800µm cell with a 2x magnification, or a 300µm cell with a 4x magnification, used both with a fluorescence triggering mode, are the most appropriate settings for the FlowCAM. Second, specific training sets and recognitions algorithms were designed in PhytoImage, not only for a given geographical area, but also for each season. Third our system can be presently used only for detecting relative abundances within the digitized sample. Absolute abundances, biomasses, etc. still need a careful calibration of the number of colonies or particles counted by the FlowCAM/PhytoImage in function of the density of these particles in the samples and the flow rate in the measurement cell.

Finally, the actual combination of the FlowCAM and PhytoImage has been successfully tested on sea (up to 4-5 Beaufort), and can provide (near-)real time data with a quick, but

simplified process. If needed, the series can still be reanalyzed with the full process back to the laboratory.

Detrimental (or beneficial) effect of *Phaeocystis* colonies on mussel feeding

The potential effect of *Phaeocystis* colonies on the production of offshore mussel (*Mytilus edulis*) farming was assessed based on laboratory bio-assays involving mussels fed with different concentrations and sizes of *Phaeocystis* colonies and on the field measurement of indicators of physiological state before, during and after *Phaeocystis* blooms. The physiology status of offshore mussels defined by its biochemical composition (protein, glycogen and lipid) showed seasonal variation in spring-summer that could be possibly attributed either to a negative effect of *Phaeocystis* colonies or mussel spawning or their combination. The combined use of laboratory feeding experiments and additional field observations in late summer – early fall when a secondary *Phaeocystis* blooms is sometimes observed will allow concluding on the effect of *Phaeocystis*.

First feeding experiments with *Isochrysis* cells showed that clearance rate normalized with respect to mussel size is a good parameter to compare mussel feeding capacities. They also showed that *Isochrysis* is a good prey for mussels and can be considered as a reference for investigating mussel feeding on *Phaeocystis*. Based on these results, a mussel size between 30 and 40 mm was chosen for running feeding experiments on *Phaeocystis* colonies. From the available experiments a positive relationship was observed between the average mussel clearance rate on *Phaeocystis* colonies and the average size of the corresponding offered *Phaeocystis* colonies up to an average size of 300 µm. Clearly, as field *Phaeocystis* blooms in BCZ are dominated by large colonies (500 - >1000 µm), more bio-assays involving a dominance of >500 µm colonies are needed to confirm this trend and eventually determine a threshold size above which colonies are detrimental for mussel growth.

Ecological reference for *Phaeocystis* disturbance

A cell reference of 4 10^6 cells L^{-1} for a well-balanced (healthy) *Phaeocystis* ecosystem as well as nutrient thresholds for *Phaeocystis* disturbance in the BCZ have been developed based on microscopic observations of grazable *Phaeocystis* colony number and corresponding colonial cells and historical MIRO model simulations making use of RIVERSTRAHLER simulations of nutrient loads for pristine conditions, assuming a watershed covered by primary forest. The obtained nutrient load of 60 kT N y^{-1} to BCZ might be used as a target for the implementation of nutrient reduction policies. In addition, the *Phaeocystis* reference can now be used to flag in the BCZ ecosystem *Phaeocystis*-problem and non- problem areas based on either real-time monitoring by the FlowCAM/PhytoImage tool or MIRO&CO-3D simulations, the latter for present-day and nutrient reduction scenarios.

Ecological model development

New numerical development were operating on either the ecological code MIRO or the development, implementation and forcing parameterization of the MIRO&CO-3D.

Sensitivity tests on the complex ecological model MIRO have secured the reduction of phytoplankton cell variables from 3 to 2 without changing the phytoplankton dynamics.

The phytoplankton module could be replaced by this aggregated version when running MIRO in highly-resolved physical models. The reduction of the microbial loop complexity (from 5 to 3 state variables) is ongoing but results obtained are not satisfying yet.

The CO_2 module was successfully implemented in the existing MIRO&CO-3D model and the resulting sea surface pCO_2 simulations were validated by comparison with existing data. Result analysis point the role of river loads and hence eutrophication in determining the capacity of coastal zones in absorbing atmospheric CO_2.

The implementation of the MIRO&CO-3D model on the BCZ grid allowed simulations with a better resolution (750m x 750m) and so a better assessment of the role of Belgian rivers on the BCZ eutrophication. Preliminary results have been obtained and are currently analysed and validated. This is promising for the future applications (nutrient reduction scenarios on BCZ).

High frequency total suspended matter (TSM) has been obtained from remote sensing images (MODIS) thanks to the STEREO2-RECOLOUR project and has been used as updated input to the kPARv1 module for water column light (PAR) attenuation calculation. The importance of TSM variability on PAR attenuation has been demonstrated by comparison of MIRO&CO-3D results with *in situ* data. Model simulations obtained with this new TSM forcing show that the spatial variability of phytoplankton bloom timing is closely related to the suspended matter load. Furthermore the interannual variability of the bloom timing depends on the combination of factors such as TSM, incident surface PAR, and nutrients.

Response of the BCZ to nutrient reduction

Scenarios exploring the effect of selected riverine nutrient reductions (phosphorus and/or nitrogen) on the nutrient/*Phaeocystis* distribution and on the eutrophication status of Belgian waters have been performed with the MIRO&CO-3D model using the new criteria for scaling *Phaeocystis* disturbance. Results confirm the need to prioritise N reduction to reduce undesirable *Phaeocystis* blooms.

Furthermore a module for calculating transboundary fluxes in the MIRO&CO-3D domain has been implemented at the C&SNS grid scale and nutrient transports have been computed for the years 1993-2004. Results of these scenarios are under analysis and preliminary results on the transboundary nutrient transport have been reported to OSPAR meetings.