INSTITUT FRANÇAIS DE RECHERCHE POUR L'EXPLOITATION DE LA MER

Assessing the effect of environmental changes on phytoplankton communities and harmful algae blooms in coastal areas

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Summary
The exposure of marine coastal ecosystems to dramatic environmental changes has been documented for an increasing number of ecosystems. Modifications of the structure of phytoplankton assemblages in relation with such perturbations have already been identified as a potential source of change for the whole coastal marine food webs. In this context, long-term phytoplankton and environmental datasets represent an opportunity to better understand and assess past changes. This postdoc position is part of a research project which aims at evaluating whether and how phytoplankton diversity has changed in relation with the main pressures that occurred along the French coasts under contrasted environmental changes and anthropogenic pressures. The postdoc will identify and inventory environmental and climatic drivers of phytoplankton changes, assess temporal and spatial variability of these drivers, build a dataset including climate, meteorology and environment time-series, and contribute to the analysis of causal relationship between phytoplankton species and environmental drivers with the participants to the project. The postdoc will mainly focus on occurrences of Harmful Algae Blooms (HAB), and work tightly with a PhD who started in November 2011 and is addressing changes of phytoplankton communities.

Keywords : phytoplankton biodiversity, HAB, statistical analysis, database, global change, REPHY, environmental drivers

Context and objective

Phytoplankton changes and regime shifts

Coastal zones are particularly vulnerable to anthropogenic pressures (de Jonge et al. 2002). Among ecosystem functions sensitive to human activities, primary production plays a key role by influencing abundance and diversity of other biological compartments through the trophic web structure, as well as climate processes and biogeochemical cycling (Sabine et al. 2004). Phytoplankton changes concern not only biomass (Boyce et al. 2010) but also specific diversity (Penna et al. 2005), species biogeography (Leterme et al. 2008), phenology (Edwards et al. 2001) or functional diversity (David et al., 2012). Besides climate change, intensive land-use is responsible for an increase in nutrient concentration (N, P), in excess to silica and has led to coastal eutrophication (Nixon 1995, Billen and Garnier 2007) with the following consequences: 1) increase in phytoplankton biomass and decrease in oxygen concentration in bottom waters (Diaz et al. 2008); 2) changes in phytoplankton community structure in response to variations of N/P/Si ratios (Philippart et al. 2000); 3) increase in intensity of Harmful Algal Blooms (Hallegraeff 1993).

Regime shifts have been identified in all major ocean basins but the underlying dynamics remain poorly understood (DeYoung et al. 2004, Reid and Beaugrand in press), though they are particularly difficult to explain in coastal systems where atmospheric, oceanographic, watershed and human forcing intersect and can mask climate signals (DeYoung et al. 2008, Cloern et al. 2010). Recent works based on SOMLIT database showed that climate conditions and anthropogenic forcing (human activities and nutrient enrichment) act in synergy, and some climate effect could attenuate the fertility of coastal systems while others amplify the human signals (Goberville et al. 2011). The analysis of 1988–2001 time series of phytoplankton in the central Belgian Coastal Zone revealed that a complex cascade of events links large-scale NAO index variations with local meteorological conditions drive long-term diatom biomass trend and the spring dominance of Phaeocystis colonies (harmful algae, foam producing) over diatoms (Breton et al., 2006).

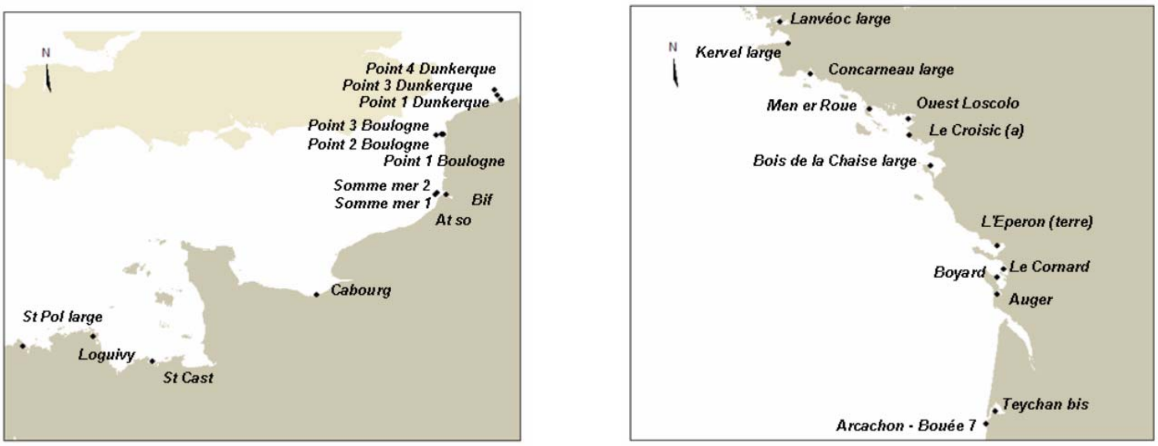
Evidence of HAB events in France

In France metropolitan area, harmful algae (HABs) have been expending not only geographically but also in frequency and number of species (http://envlit.ifremer.fr/). Four major genus are responsible of human contaminations : *Dinophysis*, diarrheic poisoning, first contaminations recorded in 1984 in Brittany and the bay of Seine, now almost present all over the French coast and in all seasons ; *Alexandrium*, paralytic poisoning, first contaminations recorded in 1988 in Brittany, now present also in Arcachon bay and Mediterranean lagoons ; *Pseudo-nitzschia*, amnesic poisoning, first contaminations recorded in 2000 in Brittany, now present in the bay of Seine, in Brittany and along the Atlantic coast in all seasons ; *Ostreopsis*, a benthic microalgae which has been recently recorded in the Mediterranean Sea. The REPHY monitoring network, set up by IFREMER in 1984, has collected data of occurrences of these toxic algae as well as toxicity events. A few statistical studies have been achieved, most of them on pilot sites - e.g. *Alexandrium*, Chapelle et al 2008; *Pseudo-nitzschia*, Siano et al 2012, Schapira et al, 2012; *Dinophysis*, Soudant et al., 2005; Gailhard, 2003; Batifoulier et al., 2012. A general framework of phytoplankton changes in relation to global changes has still to be defined for these most frequent events.

Objective of the postdoc

The main scientific question can be stated: can we relate environmental changes to temporal and spatial occurrences of phytoplankton events, more specifically on HAB events? The postdoctoral position is part of an Ifremer project which aims at delineating climate vs. anthropogenic forcing on phytoplankton biodiversity change using functional approaches. It relies upon the REPHY network set up by IFREMER. In November 2011, a PhD (T. Hernandez-Farinas) has started to address phytoplankton changes under the supervision of D. Soudant, C. Bacher (who will also supervise the postdoc) and C. Belin (in charge of REPHY network). T. Hernandez-Farinas has already selected a number of sites, considering length of time series, availability of environmental data and geographic range (see Figure below). The assessment of phytoplankton changes on some of these sites has already been initiated. On the same sites, the postdoc will identify and inventory environmental and climatic drivers of phytoplankton changes, assess temporal and spatial variability of these drivers, build a dataset including climate, meteorology and environment time-series, and contribute to the analysis of causal relationship between phytoplankton species and environmental drivers with the participants to the project. The postdoc will mainly focus on occurrences of Harmful Algae Blooms (HAB). In 2013, a Master 2 (co-supervised by Chapelle, Le Gendre, Schapira and T. Hernandez-Farinas) will begin to address environmental changes and *Pseudo-nitzschia* blooms and toxicity (ASP) on the Atlantic and Channel coast. Theses links between environment and climatic drivers will be extended by the post-doc to other toxic species (*Alexandrium minutum*, PSP producer; Dinophysis, DSP producer) and will give a general view to the shift between these communities and phytoplankton general biodiversity.

Pre-selection of REPHY sites (from T. Hernandez-Farinas, com. pers.)



Methods and tasks

Existing data

Several sources of environmental data will be used. Climate indicators (North Atlantic Oscillation index, Northern Hemisphere Temperature index, rainfalls, light irradiance - see table below). Satellite data will be extracted from the MSFD atlas of sea surface temperature, suspended particulate matter, chlorophyll from 1986-2009 (Gohin, 2011 *; wwz.ifremer.fr/dcsmm/documentation*). When available, a biogeochemical model developed by SISYPHE, already implemented in a few study sites (e.g. Normandy region), will be used to get nutrient loadings over the past 20 years (Garnier et al., 2010; Romero et al., 2012). It will be completed by data of river flows and nutrient inputs, some of which have been published in previous studies (Guillaud and Bouriel, 2007). Results of operational biogeochemical models which have been developed by PREVIMER project (www.previmer.org; Pénard, 2009) will provide quantitative information on temperature, nutrients, salinity and hydrodynamical conditions in the Bay of Biscay and English Channel coastal waters. Models have already been used to reconstruct 30 years of environmental changes, which coincide with available phytoplankton data in the REPHY database. Environmental data currently collected at REPHY study sites will be used in addition to phytoplankton abundances and biomass (envlit.ifremer.fr, www.wgpme.net).

Statistical tools

During the past 10 years, a series of statistical tools have been developed and implemented as libraries of functions for R statistical package (http://cran.r-project.org) which facilitate the analysis of temporal changes. Among them, the Package for Analysis of Space-Time Ecological Series (PASTECS) was initially developed to analyze oceanographical data and is available for more specific data. More recently, the Temporal Trend Analysis Graphical Interface was created to develop a standard procedure of temporal trend analysis of eutrophication as part of OSPAR dedicated working group. It allows to make time series regular, perform analysis using Kendall tests or cusum function. Other methods, e.g. Sequential T-test Analysis of Regime Shifts (STARS) method applied to detect ecosystem shifts (Rodionov and Overland, 2005 ; Vandromme et al., 2011) will also be useful. Well-known multivariate methods are available as R libraries (e.g. ADE-4) and have been applied by several authors to analyze biological traits, taxon composition and trophic groups structure (Bremner et al., 2003). The postdoc will therefore select and test a series of existing methods. All data analyses will be performed using R programming language.

Planned activities

Tasks are the following (see also timetable below):

- Identify environmental drivers. The objective will be to synthesize causal relationships and to review available indicators of changes in relation with phytoplankton/harmful algae blooms in the selected study sites.
- Build datasets on nutrient fluxes by combining measured or simulated river flows and nutrient concentrations for marine coastal zones selected for the assessment of phytoplankton/harmful algae changes (see Figure above). Retrieve and assemble other environmental and climatic data and analyse temporal trends.
- Characterize phytoplankton events and appropriate temporal and geographical scales of phytoplankton populations (e.g. blooms duration, succession, intensity).
- Analyse HABs events in relation to nutrient inputs, climatic and environmental data by appropriate statistical methods.
- Assess environment/phytoplankton biodiversity links. The postdoc will contribute to the joint assessment of environment and phytoplankton changes in support to the on-going PhD.

The timetable of tasks is given on a 18 months basis in the table below.

Months	1-6	7-12	12-18
Drivers identification			
Dataset building			
Phytoplankton and HAB events			
Environment/HAB links			
Environment/Phytoplankton links			

Expected results

One expected result of this work will be to provide a series of indicators of coastal changes in the Bay of Biscay and English Channel over the past 2 or 3 decades through a combination of data sources (environmental database, models outputs and forcing) which will allow to link nutrient inputs from rivers, rainfall, sea temperature, indicators of climate variability, phytoplankton diversity and HABs events. Data analysis will allow to determine the temporal and spatial scales of changes for these parameters. One direct output will be the detection of trends, abrupt changes, regime shifts and properties related to ecosystem dynamics with respect to algal communities and populations. Special attention will be given to HABs by considering trends, events, new species appearance, geographical shift over time.

Besides scientific insight into causal relationships of HABs appearance, an expected outcome will be to contribute to the Marine Strategy Framework Directive (MSFD) (MSFD descriptor 4 ‘Marine foodweb’). At least one scientific paper will be published by the postdoc as first author at the end of the first year on the assessment of environmental changes in selected sites. The postdoc will be co-author of at least another scientific paper on phytoplankton/HAB changes in relation with environmental drivers.

Supervision and collaborations

The postdoc work will be part of Ifremer project on phytoplankton diversity, toxic algae and eutrophication (DIALTOXE, http://wwz.ifremer.fr/dyneco_eng/Thematiques/Biodiversite-du-phytoplancton-des-especes-toxiques-et-eutrophisation). It will be cosupervised by C. Bacher (Ifremer, modeller), D. Soudant (Ifremer, statistician), Annie Chapelle (Ifremer, HAB ecology) and J. Garnier (UPMC, hydrologist). The postdoc will also work tightly with T. Hernandez-Farinas, a PhD co-supervised by D. Soudant and C. Bacher, F. Gohin (teledetection) and A. Daniel (Ifremer Hydrology network coordinator).

The postdoc project originates from the Work Package N°1 of an ANR project submitted in 2011, but not funded (ANR “Changements environnementaux planétaires et sociétés”). It completes the workplan of a PhD started in November 2011, cofunded by Ifremer and “Fondation de France”, regarding the assessment of links between phytoplankton biodiversity and environmental drivers in the context of global change. The postdoc position corresponds to one task which is feasible with the large amount of data already available. Complementary funding will be investigated through enlarged collaborations with coastal laboratories in the English Channel and Bay of Biscay regions. Such collaborations will allow to gain expertise from the scientists involved in phytoplankton, HAB and environmental monitoring. Links to other initiatives will also be considered – e.g. SEASERA projects on eutrophication modelling which also involves SISYPHE and Ifremer.

Interest for Ifremer

The postdoc project contributes to Ifremer Strategy on phytoplankton biodiversity defined in 2010. Project outputs are of special interest for Ifremer contribution to the EU directives (WFD, MSFD). They also will contribute to Ifremer expertise to the ICES working group on Phytoplankton and Microbial Ecology (WGPME http://wgpme.net) (D. Soudant), and to the GEOHAB working group on Harmful Algae Bloom (A. Chapelle).

On a more fundamental side, scientific projects involving DYNECO/PELAGOS aim at developing other indicators of phytoplankton changes over a longer period of time (e.g. a century) by looking at biological traces (cysts, spores, fossil DNA) stored in coastal sediments. The postdoc project will provide the statistical methods and environmental datasets which will facilitate the assessment of past changes and links between environment and phytoplankton.

List and description of databases

The table below is a preliminary review of climatic and hydrological available data that will be used in the course of the postdoc.

Name of data base	Contact	Nature of Data	Property rights checked / written convention	Comments
Quadrige2	Ifremer http://envlit.ifremer.fr/surveillance/phytoplancton_phycotoxines	Abundance of microphytoplankton species, temperature, turbidity, salinity	Public under the Aarhus convention. Public portal under development. All data are available on Ifremer server	Data are available since 1992 in dozens of sites as part of a national programme (REPHY). Several sites also contain environmental data
WGPME	http://www.wgpme.net	Phytoplankton, temperature anomalies	Limited access for phytoplankton data, full access to temperature anomalies	A few REPHY datasets have recently been selected and merged with international datasets collected by WGPME
HYDRO	http://www.hydro.eaufrance.fr	River flow	No property rigtht for the extraction and use of limited datasets. Credit to the producter of the data is mandatory	National database on river flows
Nausicaa	Ifremer	Sea surface temperature, sea colour, turbidity, irradiance	Data are available on a public server, with no limitation. Credit to the source is mandatory	Data are available on a daily basis since 1986 (temperature) and 1999 (sea colour)
Meteorological data	Website http://www.cru.uea.ac.uk/cru/data/ncep	Sea level pressure and wind intensity, precipitation	Data are available on a public server, with no limitation. Credit to the source is mandatory	Source of data : National Center for Environmental Prediction (NCEP, USA) and National Center for Atmospheric Research (NCAR, USA)
Climate indices	Website: http://www.ub.edu/gc/English/wemo http://climexp.knmi.nl/ http://www.st.nmfs.noaa.gov/nauplius/copepodite/html/toolkit-start.html	Climate indices	Data are available on several public servers, with no limitation. Credit to the source is mandatory	Source of data: Western Mediterranean Oscillation (WeMO Northern Hemisphere Temperature (NHT) anomalies : Hadley Centre for Climate Prediction and Research, Meteorological Office (Exeter, UK). Atlantic Multidecadal Oscillation (AMO)

	http://www.st.nmfs.noaa.gov/nauplius/copepodite/html/toolkit-start.html http://www.cpc.ncep.noaa.gov/products/precip/CWlink/pna/nao.shtml			Hadley SST time series from 1900 iCOADS Wind time-series (1960-2010) Monthly North Atlantic Oscillation (NAO) index : NOAA-Climatic Prediction Center

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