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Editorial

Benthic time-series observations in North-eastern European Marine Station: Is a European label needed?

1. Introduction

Nowadays, one of the main challenges for marine ecologists working in marine coastal ecosystems is to identify which part of the global climate change is due to human activities. Analysis of climate change phenomena and their relative components is connected to the need to obtain long-term data, including data on climatic and hydro-climatic evolution, on changes over time of the most important biological compartments (e.g., the phytoplankton the zooplankton, the macro- or macrophyto-benthos and fish) and on proxies for measuring chlorophyll *a*. However, obtaining such long-term data for a period of more than several decades requires a scientific strategy that minimizes the costs of data acquisition, but still allows the data to be used to show long-term changes due to environmental changes. In addition, this data must be compatible with available time-series analysis methods.

Many papers have reported observations of changes in the marine coastal environment (e.g., Southward, 1980, 1991; Southward et al., 1995, 2005; Ducrotoy, 1999; Clark and Frid, 2001; Reid and Edwards, 2001; Hiscock et al., 2004; Rees et al., 2006). Some of the more informative datasets concerned the pelagic ecosystem (i.e., phytoplankton and zooplankton), and several well-documented papers used the data obtained by the Continuous Plankton Recorder to show the diversity and functional changes of plankton due to climate change (e.g., Continuous Plankton Recorder Survey Team, 2004). Nevertheless, when we carefully analysed the available data for the long-term macrobenthic time-series in the North-eastern Atlantic, we see that they are few and far between.

Why there are so few long-term time-series and a total absence of an integrative strategy for long-term studies of the macrobenthos, despite the continued existence of Marine Biological Stations and the emergence three decades ago of European networks and strategies for the observation of marine coastal environment? Is a European strategy needed or are the national strategies sufficient for taking this very important aspect into account in the evaluation of the effect of global climate changes on the coastal marine environment?

2. Faunal and floral inventories: a long tradition for Marine Stations

Knowledge of faunal and floral changes is essential for assessing erosion risks or changes in species richness in an area. Species introductions or disappearances related to habitat destruction or changes in the environmental conditions that are incompatible with the survival of species sensitive to a given pollutant or, on the contrary, that are favourable to the establishment of an immigrant species, are all part of this knowledge. Inventories of the fauna and flora in the coastal zones near marine stations are a long tradition, which appeared with the creation of these stations during the 19th century. This information is mainly qualitative. The presence of a species in an area or in a precise location remains a good source of information about the bio-geographical distribution of a given species in the areas around marine stations.

For certain marine stations, these inventories have been conducted for more than a century, maybe even 150 years, and marine station inventories continue to be enriched regularly. For other marine stations, they may be shorter (e.g., Plymouth marine fauna, Marine Biological Association, 1957). Clearly, species inventories did not encounter the same enthusiasm at all Marine Stations and thus were not constant. For the French marine stations, Roscoff and Banyuls printed booklets, Marseilles and Arcachon compiled simple species lists, and Wimereux published in diverse internal publications, such as the *Revue des Travaux de la Station Marine d'Endoume* or the *Travaux de la Station Marine de Wimereux*. After the Second World War, these inventories encountered a resurgence of interest that continued until the end of the 1960s, when this type of census practically stopped for thirty years before recently resurfacing in the form of databases managed by various research organizations.

Roscoff Biological Station established three computerized inventories, or databases: one for molluscs (424 species), one for fish (142 species) and one for algae (431 species) for a total of a little less than 1000 species in the area around Roscoff (http://www.sb-roscoff.fr/). Similarly, the Houmeau Research Centre on marine and aquaculture Ecosystems (CREMA) near La Rochelle also produced an inventory of the macrofauna collected in the Pertuis, which is also available on the internet (http://www.ifremer.fr/crema) (Montaudouin and Sauriau, 2000).

The French Marine Stations participated in the European Register of Marine Species (ERMS) (Costello et al., 2001), which is now linked to the Marine Biodiversity and Ecosystem Functioning (MarBEF) European Network of Excellence, in which several staff members of the European Marine Stations were involved (http://www.marbef.org/data/erms.php). In turn, MarBEF is linked to the World Census of Marine Life via OBIS (www.iobis.org) and EUROBIS (www.marbef.org/data/eurobis.php). These new supports permit the data to be accessed rapidly, or at least the data included in the database, since all of the available data accumulated by the European marine science community is not included in this database. This new database allows the precise position of the sampled species to be localized, which is not often the case with the paper inventories.

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3. Long-term benthic series

In the 1970s, at the same time as quantitative sampling methods were appearing, the idea arose of regular series of observations. Often started for PhD research, these regular observations did not last more few years, but they permitted the observation of temporal changes for one to three annual cycles. This kind of research started in a period when there was no clearly expressed need for understanding the global changes appearing in the ecosystems. Today, the major challenge for marine ecologists is the identification of changes over time at any spatial scale in order to better understand the effect of global and regional climate forcing mechanisms and the anthropogenic impact on ecosystems.

For the benthic ecosystems, three main kinds of temporal time-series can be identified:

(1) Site sampling over time to determine if the benthic communities have changed over the last 10–70 years. Generally, this type of sampling operation concerns a specific spatial scale (e.g., Massé, 2000; Wieking and Kröncke, 2001; Bradshaw et al., 2002; Franke and Gutow, 2004; Perus and Bonsdorff, 2004; Reichert and Buchholtz, 2006; Callaway et al., 2007; Labrune et al., 2007).

(2) Time-series sampling of a community at a limited number of sites over a long period, but with interruptions in the observations over the time-series (e.g., Southward et al., 2005; Van Hoey et al., 2007).

(3) Time-series sampling of a community at a limited number of sites over a long period, but without interruptions in the observations over the time-series (e.g., Carpentier et al., 1997; Tunberg and Nelson, 1998; Dauvin, 1998, 2000; Kröncke et al., 1998, 2001; Beukema et al., 2002; Frid et al., 2009). Some of these time-series continue today; others finished up several years ago (see ICES, 2007).

Along the French coast, four macrobenthic time-series, corresponding to type 3, have been in operation since the late 1970s/early 1980s: two sites in the Bay of Morlaix, one site in the Bay of Seine and one site in the southern part of the North Sea at Gravelines (Dewarumez et al., 1986; Carpentier et al., 1997; Fromentin et al., 1997a,b). The two series in the Bay of Morlaix started in 1977, one year before the sites were polluted by the Amoco Cadiz oil spill, and they continue today. These series received financial support from several sources: the French Environment Ministry, the French National Scientific Research Centre (CNRS), the Ifremer-National Observation Network (RNO). They are now included in the survey mandated by the European Water Framework Directive. The impact studies in Bay of the Seine started in 1983 and stopped at the end of the 1990s. The Gravelines time-series began in 1978 and continues today with the financial support of IFREMER. This time-series surveys the possible impacts of the thermonuclear installation.

Elsewhere, the long-term series off the Northumberland coast in the central part of the North Sea (Frid et al., 2009) began in 1972 and continues today, normally in March and September each year. At various times, it has received financial support from DEFRA, DETR, DOE, NERC, Northumbria Water plc and the Universities of Newcastle and Liverpool. The long-term benthic studies off the coast of Germany (Kröncke et al., 1998, 2001) were funded by the *Umweltbundesamt*, the Commission of the European Commission and the *Deutsche Forschungsgemeinschaft*.

For each case, it appears that there are several sources of financial support, which probably causes difficulties for maintaining the long-term view that keeps the series alive. As underlined by Southward et al. (2005), many series initiated by the marine laboratories in Plymouth ceased in 1987–1988 during a reorganisation of the UK marine research. At the beginning of the 21st century, due to the resurgence of interest in long-term environmental change, many delayed or cancelled programmes expanded with support from several agencies.

Long-term (>10 years) regular observations (in every season at least, and monthly if possible), such as the ones at the two sites in the Bay of Morlaix in the western part of the English Channel (Dauvin, 1998, 2000), allow a lot of information to be acquired about the structure, functioning and dynamics of the benthic ecosystem, for example:

- Temporal changes in species diversity, abundance and biomass in an entire community;
- Dates on species introductions or disappearances that permit adding to the local inventories;
- Description of new species [e.g., *Ampelisca armoricana* (Bellan-Santini and Dauvin, 1981), the dominant species before the Amoco Cadiz oil spill, which happen in 1978];
- Dynamics of the principal species in a community;
- Dynamics of macrofaunal recruitment under normal conditions and after an accidental disturbance (e.g., the Amoco Cadiz hydrocarbon pollution event);
- Comparison of two hydrocarbon pollution events: Amoco Cadiz (Brittany, France) and Aegean Sea (Galicia, Spain);
- Modelling of the *Ampelisca* dynamics taking into account hydrocarbon pollution and temperature change (Poggiale and Dauvin, 2001).
- Identification of a summer proliferation of the opportunist polychaete species, *Pseudopolydora pulchra*, in 1982, four years after the spill;
- Identification of the relationship between the species dynamics and hydro-climatic factors;
- Development of innovative analysis methods for long-term series, probabilistic methods for detecting species presence and analysis forms for the temporal processes.
- Modelling carbon flows taking all the site information accumulated into account (e.g., primary production, bacteria, permanent and temporary meiofauna, ichtyofauna) (Chardy and Dauvin, 1992).

4. European approach to long-term benthic observation series

COST is an intergovernmental framework for European Cooperation in Science and Technology, providing a forum for research cooperation (Commission of the European Communities). An exciting exercise on long-term series analyses, COST 647 (1979–1991) focused on coastal benthic ecology. This project organised a Symposium on Long-Term Changes in Coastal Benthic Communities. This was the first time Europe had paid special attention to long-term data series, concentrating on the relevant biological variables collected in different benthic habitats over a large geographical range in several European countries: Norway, Sweden, Denmark, Germany, the Netherlands, Belgium, the United Kingdom, Ireland, France, Spain, Portugal, Greece and Italy (Heip et al., 1986).

Later, an analytical exercise was organised, again as a part of the COST 647 project on Coastal Benthic Ecology (Keegan, 1991), analysing space- and time-series data from the intertidal and subtidal zones. Louis Cabioch reported (Keegan, 1991) that this European project suffered from a lack of financial support from the countries concerned. Despite this lack of support, the project researchers managed to conduct very important work, coordinating independently obtained and thus very disparate data time-series, some of them without any guarantee of long-term

continuation after the exercise. The last COST 647 meeting was the 1994 meeting between European and American researchers in Galway (Ireland) to compare experiences with long-term benthic studies on both sides of the North Atlantic Ocean (Keegan et al., 1997).

Some other European opportunities have been initiated, mainly to share each country's experiences and to compare the data sets at a European scale, as was the case with COST 647, but not to organize a strategy for sampling and recording data about the benthic ecosystem. On this theme, the only topic at the 17th European Marine Biology Symposium (EMBS) in 1982 (Brest, France) was "Fluctuation and succession in marine systems" (Cabioch et al., 1983). The papers presented mainly examined the effects of natural or man-made disturbances on individuals, species and communities, in the light of two fundamental questions: "Is it possible to distinguish between short-term and long-term variations and abnormal fluctuations in marine ecosystem?" and "What strategy should be adopted for the study of the ecosystem itself?". Other EMBSymposiums (notably the 41st EMBS in 2006 in Cork, Ireland) have had special sessions on "Global climate change and marine ecosystems", and this theme has been relatively persistent since then at the EMBS.

The International Council for the Exploration of the Sea (ICES), with its Benthos Ecology Working Group, also helps to compile metadata from long-term series and long-term comparisons of benthic fauna in the OSPAR Region (ICES, 2007). Similarly, a recent effort to collect European data about the benthos was completed by the Marine Biodiversity and Ecosystem Functioning (MarBEF) platform, a European Network of Excellence (NoE). The MarBEF platform contains data about the long-term large-scale distribution patterns of marine diversity. A part of this platform, the MacroBen database contains quantitative data about samples of soft-bottom benthic infauna collected in European continental waters, from the Arctic Ocean to the Black Sea. This database contains a total of 44 datasets, including 465,354 distribution records from 22,897 sampling sites and 7,203 valid taxa (Somerfield et al., 2009).

5. French and European Network of marine stations and organisations

In 1994, the National Marine Station Network (RNSM) was created by the French National Institute for Universe Sciences (INSU) in order to obtain more knowledge about the littoral and coastal natural environment and to develop a national policy for the protection of France's natural coastal heritage. Most French Marine Stations were created at the end of the 19th century, with the oldest being Concarneau in 1859, then Roscoff in 1872 and Wimereux in 1874, to name but a few. More recently, the appearance of University marine laboratories increased the number of the stations linked to the RNSM network. These marine stations are connected to several public organisations – for example, universities, the National Museum of Natural History, the College of France and the National Centre for Scientific Research (CNRS) – under the supervision of the Ministry of Higher Education and Research. The activities of the RNSM network touch a wide spectrum of research from biology to physics, chemistry, earth science and ecology (www.sb-roscoff.fr). Today, this network links 15 stations, including 14 in Metropolitan France and one in Moorea in the Pacific. Of the 14 metropolitan Marine Stations, 10 are situated along the Atlantic coast and four along the Mediterranean coast.

From 1991 to 1999, the French National Programme of Coastal Oceanography (PNOC), mainly financed by IFREMER and CNRS-INSU, ran a research project about long-term observation series (SLT). The PNOC-SLT project had for objectives the recording of long-term series (>10 years) and the development of new time-series analysis methods. An international symposium was organized in February 1995 in Arcachon (France) on the theme of "Long-term changes in marine ecosystems: methods of analysis, case studies and between-site comparisons". This symposium had nearly 200 participants from 20 countries, and its acts were published in Oceanologica Acta (Bachelet et al., 1997). Two methodology workshops were also organised: (1) one in February 1998 in Marseilles (France) on methods for comparing tables, images and charts in oceanography (Dauvin et al., 1998) and (2) one in February 1999 in Wimereux (France) on the long-term changes in ecosystem diversity (Leprêtre et al., 1999). Then, in the early 2000s, the French Coastal Environment Research Programme (PNEC) continued the elaboration of numerical methods to study the influence of hydro-climatic and anthropogenic factors on the spatio-temporal variability of coastal ecosystems (Beliaeff and Durbec, 2006).

The European Network of Marine Research Institutes and Stations, called the MARS Networks or MARS, was created in 1995 in Paris at UNESCO. According to its website, it is a foundation created by and opens to Europe's Marine Research Stations. MARS serves furthermore as a forum and as an interest group and communicates with international organisations and the managers of European research, including the Commission of the European Community in Brussels and the Marine Board of the European Science Foundation in Strasbourg. MARS members are located all over Europe, along the shores of the Atlantic Ocean and the North, Irish, Baltic, Adriatic, Black and Mediterranean Seas. This foundation promotes cooperation in the domain of scientific research, prepares international exchange programmes for students and researchers and provides large infrastructures to its members (www.marsnetwork.org).

According to its website, the Marine Board of the European Science Foundation was established in 1995 to facilitate enhanced cooperation between European organizations involved in marine science (both research institutes and research funding agencies) towards the development of a common vision on the research priorities and strategies for marine science in Europe. In 2009, the Marine Board represents 30 member organizations from 19 countries (www.esf.org/research-areas/marine-sciences.html).

The European Federation of Marine Science and Technology Societies (EFMS) was founded in 1998 in Paris at the Oceanographic Institute. This federation groups eight non-governmental European associations working on marine environmental research and education. The actions of the EFMS are particularly discreet. According to its website, the objectives of the Federation are (1) to contribute to the advancement of research and education in marine sciences and technology and (2) to disseminate information to promote the advancement of marine science and technology in Europe (see www.uof-assoc.org).

6. Conclusions and perspectives

As highlighted above, over time there have been several attempts to organise a census of the available data from long-term surveys of benthic marine coastal ecosystems at the European level. A census collects two kinds of data: *species data* in order to map their bio-geographical distributions and *quantitative data* about the intertidal and subtidal continental communities in order to analyse the community changes over time and compare these changes at a mega-scale of observation.

Long-term surveys of the coastal environment can be coordinated at the national level. However, Morel et al. (1999) has underlined the need in France for a better coordination of the observation networks not only by IFREMER and INSU-CNRS, but

also with other national organisations interested in littoral environmental quality. One decade later, the same statement can be made. The national context became more complex with the implementation of the European Water Framework Directive (WFD) and the 2007 creation of the National Office of Water and the Aquatic Environments (ONEMA). ONEMA also has jurisdiction over the littoral environment and is, as well, in charge of coordinating and setting up a water information system. In addition, a Benthic Network called REBENT was created in Brittany at the beginning of the 21st century as a response to the absence of a frame of reference for the ecological status of the littoral before a hydrocarbon pollution event, such as the ERIKA oil spill in 1999 (www.rebent.org). In 2009–2010, the French RNSM collected all the available information in the marine stations on pelagic and benthic ecosystems into a database. This database can be used in the future by the marine stations that contributed information, for example, sharing the data to identify main changes in coastal environments.

The more pragmatic example of the English scientific community is interesting. Coordinated by DEFRA (Department of the Environment, Food and Rural Affairs), two national networks [Marine Environmental Changes Network (MECN) www.mba.ac.uk/MECN and Marine Climate Change Impacts Partnership (MCCIP) www.mccip.org.uk/arc] were financed to record the long-term observations of the marine laboratories scattered around Great Britain and to create databases for these observations (Frost et al., 2006). These two initiatives, which have secured significant financing to insure the coordination of a network of various Great Britain partners, could be used as model for France and other European countries.

Recently, the European Commission has proposed a new European Marine Observation and Data Network (EMODNET) in order to improve the availability of high-quality marine data in Europe. Pilot projects are being set up for biological, chemical, hydrological and geological data and for habitat mapping. The Biological Portal, coordinated by the Flanders Marine Institute (VLIZ), will provide access to biological marine data of known quality in a standard format and will identify gaps in the geographical and temporal coverage. This portal will be based on an existing system called EurOBIS (www.eurobis.org). VLIZ has recently started a comprehensive data inventory and gap analysis of the available marine biology research and monitoring data in Europe.

Still, all these initiatives have the same objective: to first collect the available data and then later permit the scientific community to analyse the long-term ecosystem changes. No European strategy for observation of benthic habitats has yet been designated. For the moment, this has stayed at a national, regional or local level, probably due to the need to acquire financing, not only in terms of money for scientific cruises and sea sampling, but also money to pay technicians, engineers and researchers who will undertake the long-term monitoring. More than 10 years ago, Keegan et al. (1997) recommended that scientists and funding agencies harmonise their views on what is scientifically feasible, applicable, and financially sustainable for long-term studies. Unfortunately, few long-term studies have been made since Keegan and his colleague made this recommendation!

The existing European financial support from such institutions as EU Programme for Research, the Network of Excellence (NoE) and the MARS Network is probably not suitable for the long-term series of sampling, sorting and identifying species. After all, the sampling design proposed for obtaining benthic data under the WFD strategy was not appropriate for obtaining long-term data series in the coastal water bodies due to a too-long interval between two surveys (from one to six years depending the country and the water body). But all national and European networks are interested in gathering the available data from long-term series of observations. So, there is a paradox between the need to continue to observe the changes in the coastal ecosystems and the difficulty of obtaining persistent financial support, as well as the numerous requests to assemble the available marine biology data.

In reality, there are several problems that need to be dealt with to insure the durability of more long-term series of observations of benthic communities. These long-term series are all located in the North Sea and the English Channel (Frid et al., 2009; Kröncke et al., 1998, 2001; Dauvin, 1998, 2000; Carpentier et al., 1997) and, for several reasons, need extra financial support. First, the scientists who initiated the series will retire in the next decade, and thus there is a need to train young engineers and researchers and obtain jobs for them. Second, there is a long period of time between the gathering of information and their analysis and publication. This is little compatible with the existing pressure to publish the results rapidly.

However, it appears that only long-term study can determine whether the putative anthropogenic impact is "real" or merely part of a long-term natural cycle. Many short-term pollution monitoring surveys are of limited value since they fail to address natural temporal variability. It is always critical to isolate the natural from the artificial (Keegan et al., 1997).

Some paths can be suggested for the future. First, we need to promote rigorous quality controls for data acquisition and management; this will greatly improve the data resolution and reliability for inter-comparability. In fact, to insure the quality of such analyses, international standards like the ISO have been imposed, and calibration and intercalibration exercises have been established to insure the competence of the laboratories in species identification (Dauvin, 2005). This also implies encouraging a renaissance of traditional taxonomy (i.e., using the morphology of the species) (Boero, 2010).

Second, the scientific community working on the macrobenthos suffers from the rarity of long-term temporal series without interruptions, although this compartment is examined in numerous research projects and monitoring impact studies, for example. Over time, a lot of new data series start, but most of them will stop less than 10 years after they began. The dispersion of the data acquired by many laboratories and research organisations is also another handicap, but today the gathering and recording of data is not a real problem if these data are validated.

It is probably not necessary to have a very large number of survey/observation sites at the European or national scale; neither is it necessary to examine all the taxa in a benthic community, which can be very numerous in some cases (>100). Keegan et al. (1997) suggested that, with sufficient background on community structure, it may be more cost-effective to focus on species that have key roles in communities. By concentrating on the key components, it should be possible to enhance our predictive capacities with respect to the whole communities. The selection of surrogate species that are good indicators of the alternation of cold and warm winters, such as the barnacles for the intertidal rocky shores, (see Southward, 1991; Dreves, 2001; Southward et al., 2005) can be a very good index of species responses to climatic changes. It will probably be more efficient to select particularly accessible benthic communities, such as those on the intertidal rocky shore, and communities, such as the subtidal *Abra alba* muddy fine sand community that are very extensive in the north-eastern Atlantic. These soft-bottom habitats have been very well studied in the European coastal seas and are very important as nurseries for numerous fish, especially the flatfishes.

Finally, to ensure the not-very-numerous existing long-term series (>30 years), I suggest that the network MARS, which may be the most appropriate European organization for this task, deliver a "European Label" to these long-term observation series as a Common Heritage for the scientific community, like UNESCO's "Man and Biosphere" label. This MARS "European Label for Long-Term Series" can serve as an additional argument to prevent their eventual disappearance in each country. Furthermore, if the site is included in or near a Marine Protected Area, financial support can be obtained and the study perpetuated as a contribution to the long-term knowledge about biodiversity changes.

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