MarinERA Publication No. 5

Anthropogenic and Climate Change Impacts on Marine Biodiversity and Ecosystem Function

MarinERA *A Posteriori* Clustering Workshop 2: Madrid, Spain, 12th September 2007

December 2007

MarinERA

Facilitating the Coordination of National and Regional Marine RTD Programmes in Europe

MarinERA: Facilitating the Coordination of National and Regional Marine Research Programmes in Europe (2004 – 2008).

MarinERA, a EU 6th Framework Programme ERA-NET, is a partnership of leading Marine Research Funding Organisations from 13 European countries, supported by the Marine Board – European Science Foundation. Together these organisations invest over €80 million per annum in competitive marine research.

The specific objectives of the MarinERA Project are to:

1. Map European Marine Research Programmes and Specialised Infrastructures to contribute towards the development of the marine component of the European Research Area, facilitating the creation of an internal market and quantifying the existing European marine research capacity.
2. Facilitate the networking of Marine Research Funding Agencies in the European Union, leading to a more cost effective and efficient use of EU Member State and Associate Member State resources including scientific personnel, specialist infrastructures and planned investments;
3. Contribute to the development of a European Marine Research Policy, identifying future challenges and opportunities and the priority research programmes that need to be put in place to address / benefit from them;
4. Provide a basis for sharing available resources to address priority issues that are beyond the capacities of individual EU Member State and Associate Member States;
5. Progress the reciprocal (mutual) opening of EU Member State and Associate Member State Marine Research Programmes - a key objective of the European Research Area.

The MarinERA Project Partners are:

- IFREMER - French Institute for Exploitation of the Sea (Ifremer) - France
- Marine Institute - Ireland
- Research Council of Norway (RCN) - Norway
- Jülich Research Centre GmbH –Project Management Organisation Jülich (FZJ-PTJ) - Germany
- Spanish Ministry of Education and Science (MEC) - Spain
- Academy of Finland (AKA) - Finland
- Netherlands Organisation for Scientific Research (NWO) - The Netherlands
- Natural Environment Research Council (NERC) - UK
- General Secretariat for Research and Technology, Ministry of Development (GSRT) - Greece
- Fundação para a Ciência a Tecnologia (Foundation for Science and Technology, FCT) - Portugal
- Belgian Federal Public Planning Service Science Policy (BELSPO) - Belgium
- Science and Innovation Administration, Ministry of the Flemish Community (AWI) - Belgium
- Malta Council for Science and Technology (MCST) - Malta
- Ministry of Scientific Research and Information Technology (MSRIT) – Poland
- Marine Board – European Science Foundation - Strasbourg, France

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building the confidence to create a favourable climate in which to pursue the enhanced co-operation and reciprocal opening of EU Member State and Associate Member State Marine Research Funding Programmes.

During the lifetime of the MarinERA Project, it is proposed to extend membership to those European coastal/marine countries who are not currently partners.

For further information on the MarinERA Project see: www.marinera.net

MarinERA:
Facilitating the Coordination of National and Regional Marine RTD Programmes in Europe 2004 - 2008

MarinERA Report No 5 (2007)

Anthropogenic and Climate Change Impacts on Marine Biodiversity and Ecosystem Function

MarinERA *A Posteriori* Clustering Workshop 2.

Madrid, Spain, 12th September 2007

In association with the Spanish Ministry for Education and Science (MEC)

Compiled by:
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EU ERA-NET Contract No: 515871 (2004)

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Copies can be downloaded from:
www.marinera.net/dissemination/tec_reports.html

Workshop Participants

Participants: MarinERA *A Posteriori* Clustering Workshop II, Madrid, Spain, 12 September 2007.

Back row (from left):

Dr Nikos Streftaris, Hellenic Centre for Marine Research, Greece.
Dr Niall McDonough, Marine Institute, Ireland.
Dr Steve Widdicombe, Plymouth Marine Laboratory, UK.
Dr Tasman Crowe, University College Dublin, Ireland.
Prof Carlo Heip, Royal Netherlands Institute of Sea Research, Netherlands.
Dr Josep M Gasol, Consejo Superior de Investigaciones Cientificas, Spain.

Front row (from left):

Dr Saskia Matheussen, Netherlands Organisation for Scientific Research, Netherlands.
Dr Francis Kerckhof, Royal Belgian Institute of Natural Sciences, Belgium.
Prof Maria Jose Costa, Institute of Oceanography, University of Lisbon, Portugal.
Dr Lech Kotwicki, Institute of Oceanology, Poland.
Mr Geoffrey O'Sullivan, Marine Institute, Ireland (Workshop Convenor).
Dr Philippe Goulletquer, Ifremer, France.

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Executive Summary

1. This Workshop on **Anthropogenic and Climate Change Impacts on Marine Biodiversity and Ecosystem Function** is the second in a series of three *a posteriori* clustering workshops planned as part of Work Package 3.3 of the EU MarinERA Project.

2. The Workshop, organised by MarinERA Partner 3 (Marine Institute) and hosted by Partner 6 (The Spanish Minister for Education and Science), was held in **Madrid** on **Wednesday 12th September 2007**.

3. Researchers from **nine European countries**, nominated by the MarinERA partner Research Funding Organisations, attended the Workshop and each made a formal presentation on their current research related to the topic Anthropogenic and Climate Change Impacts on Marine Biodiversity and Ecosystem Function.

4. This Report contains an **extended Abstract** of the nine presentations made at the Workshop in addition to a summary description of the MarinERA Projects Database.

5. General **requirements and challenges for future research identified by the Workshop included**:

- Long-term data series;
- Increased funding and effort on microbial biodiversity research;
- Interdisciplinary academic appointments;
- Maintenance and development of taxonomic expertise;
- Methodologies and tools for the economic valuation of ecosystem goods and services;
- Understanding combined impacts and interactions with climate change;
- A better balance between bottom-up and top-down approaches to defining research priorities; and
- Financial supports for project interaction and development.

6. Perceived "barriers" to international collaboration included:

- Different national rules and cycles make it impractical to collaborate.
- National policy is to achieve national priorities through internal capacity building.
- Insufficient knowledge of similar national programmes.

7. Perceived "enablers" of international collaboration included:

- Tangible benefits from trans-national activities.
- Programme funding source encourages or allows cooperation.
- Links with multi-national framework programmes.

1.1. Introduction and Welcome

Mr Geoffrey O'Sullivan (Workshop Convenor) Marine Institute, Ireland.

First of all, I would like to welcome you all on behalf of our host and Spanish MarinERA Partner, the Ministerio de Educación y Ciencia, (the Spanish Ministry for Education and Science) to their new Headquarters building in Madrid.

By way of introduction, the MarinERA project is one of a number of EU pilot ERA-NET projects which aim to provide a platform for European Member State Research Funding Organisations to better integrate their competitive research funding programmes in order to address the scientific challenges and opportunities facing the Union as a whole.

One of the deliverables of MarinERA Work Package 3 is to organise **three *a posteriori* Clustering Workshops** to bring together researchers, particularly those funded by MarinERA partner Funding Organisations, who are currently working in similar areas with a view to:

- identifying and advising on ways to foster closer co-operation and partnership between such projects to generate both scientific and financial added-value.

In addition, such Workshops offer an important opportunity to exchange information on existing projects, identify research gaps and priorities to be addressed and to explore opportunities for future co-operative research projects.

This is the 2nd Workshop in the series of three. The 1st Workshop "*Thermohaline Circulation in European Seas and Oceans*" was held in Galway (Ireland) on 6th June 2007. The date and venue of the 3rd Workshop, which will focus on "*Marine Technology*", has yet to be decided.

It is now recognised that truly collaborative marine research to tackle major issues at a European scale will require a commitment of funding resources from the national agencies which fund marine research. The challenge is to present the national funding agencies (and, where appropriate, their parent government departments) with mechanisms by which international collaborative research can be funded through national programmes without compromising on the value of the research outputs to the national priorities or resulting in a net reduction of research funding to national researchers and institutions.

MarinERA Work Package 3 aims to address these challenges through direct consultation with members of the marine research community. Marine scientists from each of the MarinERA participant countries are asked to suggest ways in which nationally-funded research projects and programmes could be linked and the research outputs combined to better effect. The MarinERA *a posteriori* workshops also aim to identify the possible "barriers" to such collaboration and "enablers" which can promote it. Finally participants at the workshops are asked to identify research gaps or future research priorities in their fields of expertise which they feel have not been supported by the funding agencies and/or they would like to see feature in future funding calls.

In support of the clustering intitiative, the MarinERA project is in the process of establishing an online database of competitive marine research projects funded by the 14 participating Funding Organisations. This database, which will be described by my MarinERA colleague Dr Saskia Matheussen of the Netherlands Organisation for Scientific Research (NWO), will, we believe, provide an invaluable source of information on current research in Europe and useful tool for networking existing projects.

You all have a Programme for the Meeting (Annex 1), so it now gives me great pleasure to hand over to my colleague Saskia Matheussen to introduce the Marine Projects Database.

1.2. The MarinERA Projects Database

Dr Saskia Matheussen, Netherlands Organisation for Scientific Research

1.2.1. Introduction

In the framework of retrospective or *a posteriori* clustering, an on-line marine projects database is being set up. The database will include summary data (i.e. Project Title, Abstract, Principal Investigator, Host Organisation, Country, Project Start and End Dates, Funding Agency, Country, Grant-Aid, Key Words) on the competitive marine research projects funded by the participating Funding Agencies since 2004.

1.2.2. Data collection

To date, 861 projects have been identified and included in the database. These projects represent an investment of over € 270 million in grant-aid.

Country	Projects	Total grant -aid (€)
United Kingdom	233	81.109.584
Germany	57	60.024.277
Norway	88	35.574.009
Greece	61	21.435.992
Belgium	27	16.241.431
Netherlands	86	16.159.422
Spain	162	15.029.552
Ireland	21	8.063.051
Finland	27	5.952.230
Portugal	46	5.576.789
Poland	34	3.602.300
France	18	1.894.030
Malta	1	65.000
Total	**861**	**€270.727.667**

Table 1.2 1: Number of projects and grant aid per country

1.2.3. Classification Scheme

For the purpose of classification, a simple scheme recognising four main categories is used:

Marine Geosciences 275 projects (32%) **Marine Ecosystems** 365 projects (42%)
Marine Technology 152 projects (18%) **Policy & Socio-economics** 69 projects (8%)

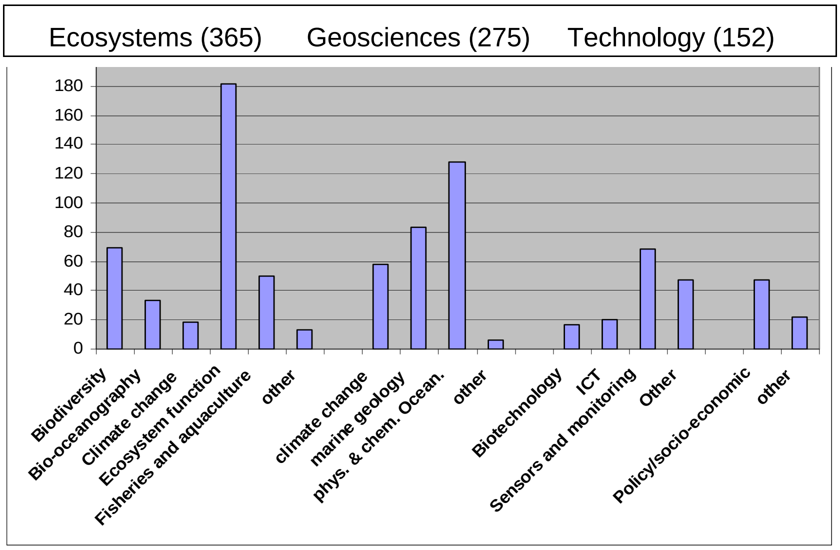

Figure 1.2.1: Number of projects by category.

1.2.4. Preliminary Analysis of project clusters

Within the suite of 861 projects and four clusters identified, we can recognise a further breakdown as follows:

- **Biodiversity and Ecosystem Function** (251 projects) where two important research fields can be identified:
    - Effects of human activity on biodiversity/ecosystem function.
    - Effects of climate change on biodiversity/ecosystem function.
- **Physical and Chemical Oceanography and Climate Change** (186 projects). Of these projects, 73 (39%) are related to "Thermohaline Circulation" and can be further subdivided into the following clusters:
    - Understanding climate change in the past to help understand the future (28).
    - The impact of Sea-Atmosphere Interaction on Climate Change (18).
    - Ice - Ocean Interactions driving global circulation (8).
    - Oceanic cycles of energy and matter / circulation processes (19).
    - UK and NL RAPID projects RAPID.
- **Marine Technology** (152 projects). 88 (58%) of these projects are related to marine sensors and monitoring technology research and could be further sub-divided into sub-categories related to:
    - Data management, forecasting and information management.
    - Mathematical modelling.
    - Monitoring.
    - Sensor and Signal processing and Data acquisition.
- **Policy and socio-economics** (47 projects)
    - Coastal Zone Management (20 projects).

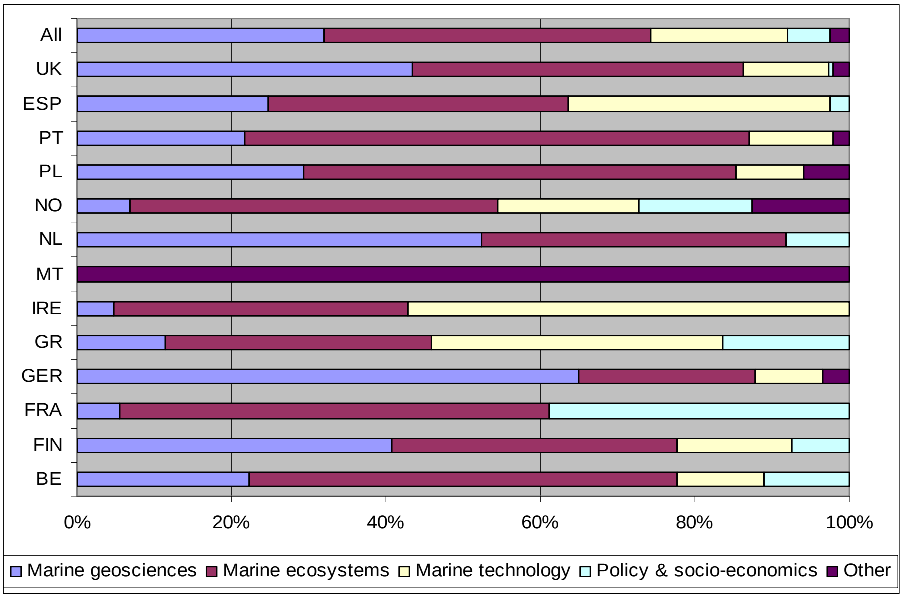

Figure 1.2.2: Projects funded in different countries by main category

1.2.5. Towards an online MarinERA projects database

The next step is to put the Marine Projects Database Online. This action will contribute to the visibility of MarinERA, and both scientists and policy makers will benefit from the public access. The online representation will be similar to the EurOcean database (www.eurocean.org) and is expected to be published on the MarinERA web-site in September 2007 (www.marinera.net).

Addendum:

The MarinERA Projects data-base went on line on 1st October 2007 (www.marinera.net) and currently contains 901 projects.

2.1 *Achievements and Perspectives of Networking Marine Biodiversity Research in Europe*

Professor Carlo Heip

Royal Netherlands Institute of Sea Research and Netherlands Institute of Ecology, Korringaweg 7, 4401 NT Yerseke, **The Netherlands**.

2.1.1 Past European Efforts

The history of coordination and planning of research on marine biodiversity at the European scale can be traced back to an initiative in the early 1990s from the European Science Foundation, DG Research and the European Committee on Ocean and Polar Science. Four grand challenges for marine and polar research were identified, one of which was biodiversity. However, at a meeting in Bremen in 1993, biodiversity was not considered a ripe subject yet. The subject remained somewhat in the twilight zone, despite the organisation of a series of Euro-conferences and a science plan ("Cabdiv") that was developed at a workshop in Noordwijkerhout in 1994.

The next important development was the organisation of a session on "Marine Biodiversity Research in Europe, Do we need it?" at the MAST-Euromar days in Sorrento, Italy in September 1995. At this session over 100 scientists were present and this formed the basis of a series of further actions, for which DG Research, the ESF and the MARS network were the main drivers. Through a careful build-up of the case, including the production of inventories, science plans and scientific cases through two Euro-conferences and two FP5 projects (Biomare and Marbena), the marine biodiversity community was finally ready to propose the EU Network of Excellence MarBEF (Marine Biodiversity and Ecosystem Functioning) that started operation in 2005 and will run until March 2009.

2.1.2 MarBEF: Why a network of excellence?

The justification for creating a network of excellence on marine biodiversity was mainly the lack of knowledge on existing biodiversity, how it changes and what its role in the ecosystem is, our inability to predict changes in biodiversity and the support of mitigation and conservation measures to prevent further erosion of biodiversity. Biodiversity is under pressure from a series of human acitivities:

- Coastal impacts: pollution, eutrophication, physical modification of the coastline
- Fisheries change all oceanic ecosystems: coastal, pelagic, deep sea bed
- Marine living resources are overexploited in many areas
- Marine non-living resources are increasingly explored and exploited (oil and gas, gas hydrates, manganese nodules)
- Species response to Global Climate Change
- Invading Species may destroy local biodiversity
- New threat: ocean acidification

2.1.3 What to do?

- Mapping existing biodiversity, exploring the unknown, reference stations (coverage of European habitats, see fig. 2.1.1), instruments, intercalibration and quality assurance, safeguarding expertise in taxonomy
- Understanding the changes we observe and their consequences for ecosystem functioning: the three MarBEF Themes

    1. Global Patterns of Marine Biodiversity
    2. Marine Biodiversity and Ecosystem Functioning
    3. Socio-Economic Importance of Marine Biodiversity

- Informing people and society on what lives in the oceans, on what threatens biodiversity and contribute to discussing solutions

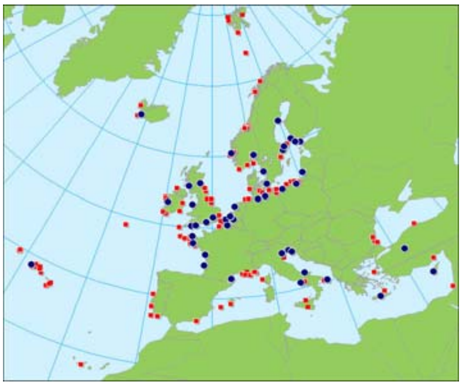

Figure 2.1.1 A series of focal and reference sites for European marine biodiversity as identified and illustrated during the BIOMARE project.

MarBEF has 56 full partner institutes and now 35 associated partners who can participate in its activities. Besides integration in the three core themes, MarBEF scientists have defined over twenty Responsive Mode Projects (RMPs). European expertise in different aspects of marine biodiversity is concentrated within these RMPs.

2.1.4 Perspectives for the Future

As the life-time of MarBEF will come to an end in March 2009, the future of the network in some form has been discussed and a number of options have been identified:

- Continuation of EU support
- Creating A virtual European Centre for Research on Marine biodiversity and Ecosystem Functioning EMBEF (MarBEF+)
- Discuss EraNet support for the creation of such a centre
- Contribute to a network of networks
- Incoporate into a legal Foundation (MARS+)
- Incorporation in ICES, CIESM
- Contribute to the development and implementation of Life Watch

2.1.5 Life Watch

Life Watch was developed as part of the ESFRI process. It is a European plan to link ecological monitoring data collected from marine and terrestrial environments with the vast amount of data in physical collections in a digital environment with analytical and modelling tools. It will construct and bring into operation the facilities, hardware and software and governance structures to create a biodiversity research infrastructure.

2.2 Sandy Beaches – Unique Ecosystem

Dr Lech Kotwicki

Department of Marine Ecology, Institute of Oceanology PAS, Powstancow, Warszawy 55, 81-712 Sopot, **Poland**

Sandy beaches dominate the world's open coastline. They are of prime importance for human recreation, tourism and coastal development. While the economic and social values of beaches are generally regarded as paramount, sandy shores also have special ecological features and contain a distinctive biodiversity that is generally not recognised. Beaches also provide unique ecological services, such as filtration of seawater (COSA- Coastal Sands as biocatalytic filters, EU 5th Framework Programme), not performed by any other ecosystem. They recycle nutrients, support coastal fisheries and provide critical habitats (nesting and foraging sites) for endangered species such as turtles and birds. Hundreds of species inhabit sandy beaches but most of them are small (less than a few mm) and buried (Figure 2.2.1). They occupy interstitial spaces between sand grains. There is a full array of living organisms from bacteria, fungi, microphythobenthos, and protozoa to extremely specialised metazoa on the beach.

These sandy beach dwellers exhibit remarkable physiological and behavioral adaptation to changing environmental conditions. Sandy beaches are dynamic and sensitive places where life is under pressure, practically without a break. Beaches are becoming trapped in a 'coastal squeeze' between burgeoning human populations from the land and the effects of global climate change from the sea.

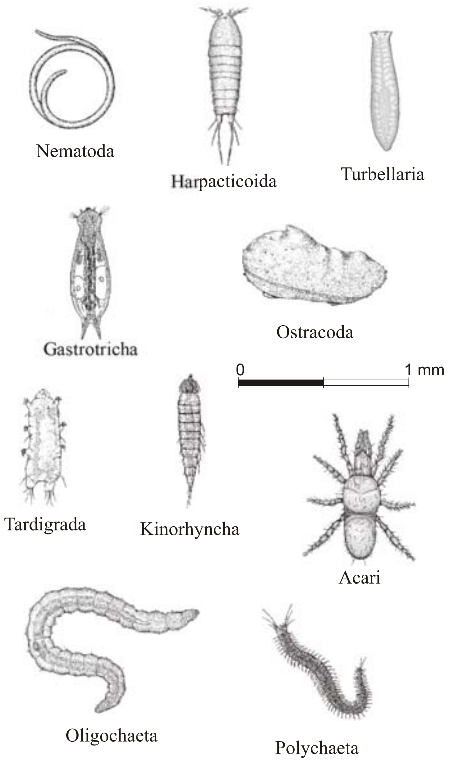

Figure 2.2.1 Representatives of most popular meiofaunal taxa.

To date, the main task of managing the sandy coasts has been to fight erosion in order to protect and preserve roads and public and private housing. This has been achieved by beach nourishment with sand and the construction of various types of breakwaters. Approximately 20% of the Polish coastline has lost its naturalness due to the direct influence of constructions, while a further 40% is indirectly influenced.

Engineering activities can result in severe ecological impacts and loss of biodiversity at local scales, but are predicted also to have cumulative large-scale consequences worldwide. The continued existence of beaches as fully functional ecosystems with their goods and services depends upon direct conservation efforts, based on team-work by engineers, scientists, ecologists, managers and decision-makers.

Most of the human activities on sandy beaches entail adverse effects on ecosystems (Figure 2.2.2 by Schlacher *et al.* 2007). We aimed to study the effects of beach nourishment and tourist activity on tidal zone meiofauna. Four beaches around Wilmington (North Carolina) have been selected: a "pristine" beach protected from beach nourishment and tourist impact and three beaches subjected to nourishment: one seldom visited by tourists, one with intensive tourist impact and one with both beach-combers and vehicle traffic. The beach nourishment effects on meiofauna include decrease of Nematoda density and increase of higher taxa diversity. That is related to changes in sediment characteristics. Nematoda occur in high numbers in fine sediments. In the coarser sediments of nourished beaches their numbers decrease. Differences in diversity result from differences in heterogeneity of habitat sediment sorting. We did not observe any changes which could be related to tourist activity or vehicles. These forms of human activity do not seem to influence density or diversity of sandy beaches tidal zone meiofauna.

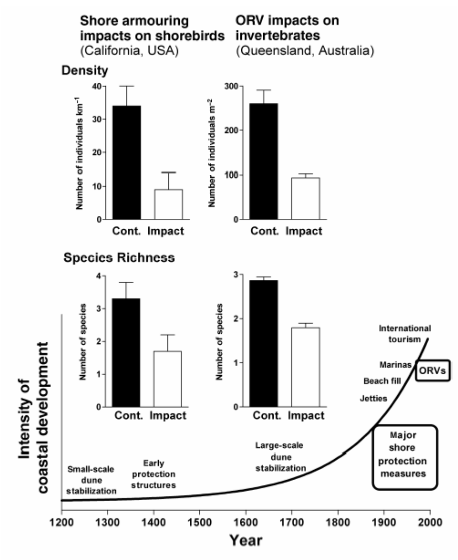

Figure 2.2.2 Ecological impacts of human activities on sandy beach biota illustrated by declines in abundance and species richness of birds on beaches with coastal defence structures, and benthic invertebrates on beaches subjected to heavy traffic by recreational off-road vehicles (ORVs). Bottom panel depicts a generalized trajectory of human modifications to soft coasts (modified from Nordstrom, 2000). Source data for shorebird impacts are from Jenny Dugan and David Hubbard (University California, USA) and from Thomas Schlacher (University Sunshine Coast, Australia) for beach invertebrates. (figure by Thomas A. Schlacher, Jenifer Dugan, Dave S. Schoeman, Mariano Lastra, Alan Jones, Felicita Scapini, Anton McLachlan and Omar Defeo (2007) '**Sandy beaches at the brink**' Diversity and Distributions).

One of the key concepts in ecosystem management is the island biogeography theory developed by Wilson and MacArthur. Recently this theory has been successfully adapted to sandy beach biodiversity analyses, with important implications for management practices. The management of sandy shores relies partly on the belief that particular beach units are interconnected due to free larval drift. This would apply to the Polish Baltic Sea coast with its long, continuous line of exposed sandy beach stretching for almost 500 km. According to our data, the Polish coastline can not be considered as one ecosystem. Single beach is unique and highly valuable and specific action in one coastal place could have significant consequences for the remaining coastline. Despite the fact that the Polish coast of the Baltic Sea is a continuous line of sandy beach we could not fully accept the theory of island biogeography. Even though the beach width is one of the most important factors for abundance and species richness of beach dwellers, it is not the only one. Meiofauna from wide, dissipative beaches represent higher abundance and higher share of Nematoda, while narrow, abrasive beaches exhibit lower species richness but higher diversity. The apparent pattern of taxa occurrence is patchy rather than continuous.

There is a long list of other human pressures which impact our precious beaches in different ways and which governments and the community must confront. The role of scientists should be to elucidate the functioning of coastal sands and to promote sustainable use of coastal sandy sea floors.

2.3 *Impact of climatic and anthropogenic changes on living resources in the Bay of Biscay*

Dr Philippe Goulettquer

Ifremer, BP 133 Mus de Loup 17390, France

Fisheries and aquaculture are of major importance to the coastal communities throughout the Bay of Biscaye. Almost half of French fishermen rely on catches from the Bay which achieve an estimated first sale value of more than €525m annually. Moreover, emblematic species such as eels have an additional social as well as economic value for coastal communities. Similarly, the main French shellfish rearing areas are located within the Bay of Biscaye. They contribute predominantly to the yearly spat (mussel & oyster) recruitment, used to sustain the entire French shellfish industry. These activities have a direct impact on ecosystem functioning and biodiversity. Meanwhile, drastic environmental changes have been reported over the last 30 years, including a climate change pattern inducing additional ecosystem changes. Nutrient influx from freshwater outputs have quantitatively and qualitatively changed affecting coastal communities (e.g., impacts on benthic communities, or *Solea solea* population dynamics (nursery grounds)). The average seawater temperature has increased by 1.5°C over the last 25 years in subsurface and deeper waters.

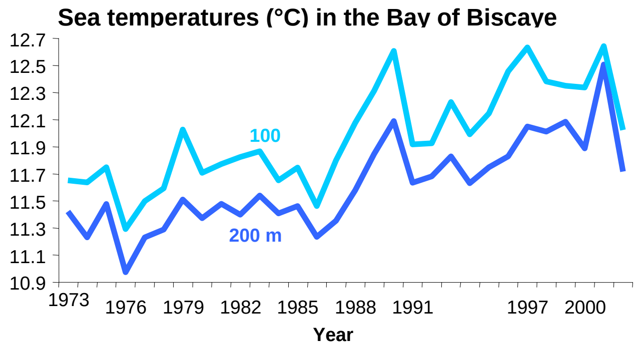

Figure 2.3.1 Seawater temperature profiles at 100m and 200m depths between 1973 and 2000.

Biogeographic patterns have also changed (e.g. macroalgae, exotic species). Fishing effort combined with climate change has induced significant side-effects on fishery landings, whereas most of the fishing stocks are presently overexploited. The ratio of boreal *vs* subtropical species has also evolved. An on-going research project (CHALOUPE) using an ecosystemic approach and funded by the ANR (French 'National Research Agency') aims to improve our understanding of interactions among fishing effort, climate change, recruitment patterns and socio-economic issues including governance. Comparisons with the fisheries of Morocco (upwelling) and French Guyana are also being carried out. Moreover, climate variability has increased significantly as characterized by drought and storm events, leading to landward intrusion of seawater in estuaries and irregular flooding of coastal wetlands. Risks associated to species introduction by ballast water and sediment discharges have, therefore, increased.

Irregular shellfish recruitment over the last 10 years has led to industry disruptions. For example, there was almost no recruitment of shellfish in 2007 due to a cold summer. This has prompted the shellfish industry to request a national research project to improve our understanding of oyster recruitment variability (VELYGER), and then to propose remediation options. It will include an assessment of seawater acidification on larval survival rate. In contrast, the seawater temperature increase has a direct impact on the shellfish stocking biomass and the subsequent carrying capacity as well as on uncontrolled expansion of the pacific cupped oyster along the Atlantic coastline. Actually, *Crassostrea gigas* has become an invasive species in several regions as it colonises new areas in a northerly direction. Similarly, a change in pluviometry patterns has led to earlier primary production lagged with secondary production. Besides *C. gigas*, the number of exotics and IES (invasive exotic species) along the Atlantic coastline has increased from 104 to 153 in 2002 and 2006 respectively. The oyster driller *Ocinebrellus inornatus* and predator *Rapana venosa* are both examples of uncontrolled expansion of exotics. *O. inornatus*, likely introduced 30 years ago at the same time as *C. gigas*, has only recently become invasive due to temperature increases and worsened by shellfish transfers.

Besides the seawater quality, the relationship between HABs and climate change should be investigated. Demonstration that pycnoclines and seawater stratification are correlated with the confinement of several phytoplanktonic blooms of harmful algae should prompt the scientific community to assess links between further oceanic current pattern changes resulting from climate change and variability (EC 6th Framework Programme HABIT project). Moreover, further research will likely require the development of regional-scale models to develop new projections and climate feedbacks, to simulate further impacts on living resources (cooperation among oceanography, meteorology, ecology etc.) and exotics and to facilitate future decision-making and new management options.

Figure 2.3.2 Map of the Marennes Oleron embayments on the west coast of France showing the major mussel and oyster growing areas.

Species should not be studied in a single way, but as full part of the environment where they thrive.

Alexander Von Humboldt, 1793 !

2.4. *Gilson and The Hinderbanken: A gateway to the past, lessons for the future*

Dr Francis Kerckhof

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The sea floor in Belgian marine waters consists mainly of soft sandy and muddy sediments. However, in some areas, further offshore, pebbles, cobbles and boulders occur, a fact that until recently was largely forgotten, let alone studied. Between two of the offshore sandbanks in the Hinderbank area, this substrate is known to have once supported an oyster bed, which was commercially depleted by UK oystermen in the second half of the 19th century.

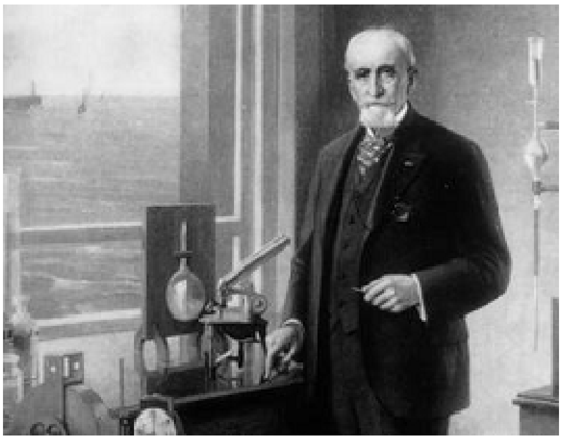

Figure 2.4.1 Gustav Gilson, Director of the Royal Belgian Institute of Natural Sciences in 1900.

Gustave Gilson, a scientist (and later Director) of the Royal Belgian Institute of Natural Sciences (RBINS), investigated the fauna of Belgian marine waters extensively around 1900. He found in the Hinderbank area a high biodiversity, although he could only find oysters in low densities. He also identified the area as an important spawning ground for herring. The detailed accounts of his investigations, and many samples, still exist, and were revisited in the research project, 'Hinders'. In this project, Gilson's sampling stations were re-sampled and a literature review was carried out in search of older data to document observed and ongoing changes. The project demonstrated that the gravels are still present and the new research highlighted the ecological importance of gravels in the Westhinder sandbank, off the western Belgian coast. Besides providing a first description of the seafloor, the project has evidenced three major aspects of biodiversity hitherto poorly documented:

1. A high species richness and taxonomic breadth compared to the surrounding sandy areas, with a community typical for the Eastern Channel;
2. The former occurrence of wild beds of the European flat oyster *Ostrea edulis*, overexploited in the 1870s. The beds have disappeared, but the species probably still sparsely occurs in the area;
3. The former occurrence of North Sea (Downs) herring *Clupea harengus* spawning stock, nowadays undocumented in this part of the North Sea.

The study of the century old samples of Gilson indicates, however, that the current community is impoverished and many species have almost or completely disappeared. Since no other human activity is affecting this offshore area, the likely reason for the deterioration is the intensive demersal and dredge fisheries, which started centuries ago, but especially impacted the bottom during the 19th century (oyster dredging) and during the 20th and 21st century. The area is currently intensively fished by trawlers (mostly >300hP) using very heavy gear (beam trawls with chain mats).

Literature from the 1970s has indicated that herring larval survival might have been affected by bottom trawling at spawning sites during spawning season. The possible relationship between abundance of large branching species and herring spawning success through stabilization of the egg-mat is one of the questions that needs to be addressed. The assumption that bottom trawling is involved in alterations of the benthic community was confirmed by the discovery of refuges for large branching species in less trawled areas. This observation suggests that a restoration process could be expected to take place if mechanical seafloor disturbance was removed. Further anecdotal results were acquired, e.g. the collection of a seahorse (*Hippocampus hippocampus*), listed in the IUCN red list of threatened species.

The information resulting from the HINDERS project has been used in an evaluation of Belgian candidate sites for MPA designation under the OSPAR directive 2003/3 (Haelters *et al.*, 2007). This is a "burning issue" since the creation of a "coherent network" of marine protected areas is targeted by 2010 in the OSPAR convention and by 2012 in the Convention on Biological Diversity (CBD). Both conventions are ratified by Belgium. The analysis concludes that the area of the Hinder banks best matches OSPAR criteria towards MPA designation. It proposes a zone for future implementation of protection and/or management measures in order to initiate the debate.

Decisions on such a conservation framework will require a range of investigations in order to identify the legal framework, compliance with national and international strategies for conservation of marine biodiversity, the points of view of the different stakeholders, and the alternative production modes that can be proposed. However, above all, such an initiative must rely on a range of basic data on biodiversity patterns and threats. Such data, especially on fishing activities are, as yet, lacking.

In 2006, based on results obtained in the framework of the HINDERS project, the Westhinder site was proposed as an "ATBI+M" site (*All Taxa Biodiversity Inventory + Monitoring*) in the framework of the EDIT project ("European Distributed Institute of Taxonomy" - www.e-**taxonomy**.eu). EDIT has recently joined MARBEF network of excellence (www.**marbef**.org) for the marine realm. Calls for experts will be issued through the EDIT/MARBEF "ATBI+M" forum to stimulate interest and involvement on this site from marine taxonomists.

Last but not least, the location of the site, at the southernmost part of the North Sea, its high taxonomic breadth and the existence of century-old baseline data could make it an ideal observatory for ongoing climate-induced changes in biodiversity patterns in the North Sea. This aspect could provide another argument to implement specific conservation measures and scientific monitoring procedures.

Reference

Haelters, J.; Kerckhof, F.; Houziaux, J.-S. (2007). De aanduiding van mariene beschermde gebieden in de Belgische Noordzee: Een mogelijke uitvoering van OSPAR Aanbeveling 2003/3 door België. [The designation of marine protected areas in the Belgian part of the North Sea: a possible implementation of OSPAR Recommendation 2003/3 in Belgium]. Koninklijk Belgisch Instituut Voor Natuurwetenschappen/Beheerseenheid Mathematisch Model Noordzee: Brussel, Belgium. 45 pp.

2.5. *Human impacts on marine biodiversity and consequences for ecosystem functioning: national and European comparisons*

Dr Tasman Crowe

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Human activities are causing a reduction in global biodiversity, but the relationship between localised anthropogenic impacts, biodiversity and the functioning of ecosystems is poorly understood. There is an urgent need to develop indicators of loss of biodiversity and to predict the consequences of such loss for the functioning of ecosystems. These objectives can be met most effectively by multidisciplinary research replicated widely at national and international levels.

Scope for Growth (SFG) is an indicator of integrated environmental stress based on physiological measurements made on live mussels. It has been shown repeatedly to be sensitive to increases in the presence of a number of environmental contaminants. However, the effectiveness of SFG as an indicator of loss of biodiversity has rarely been tested in the field. In a study of six sites on the west coast of the UK, the diversity of macrofaunal communities associated with mussels was reduced at sites with low SFG compared to those with high SFG (Crowe *et al* 2004. J. Appl Ecol 41: 114-123). These findings represent a significant step towards a biotic indicator of environmental quality which integrates impacts across a range of levels of biological organisation (from intra-individual to community). A project is currently underway to further investigate the potential of SFG as an indicator by testing its relationship with diversity of a wider range of taxa in a wider range of habitats on the west coast of Ireland. The overall objective is to develop a comprehensive data set that will allow us to identify and ground-truth cost-effective tools for long-term monitoring of marine environmental quality. Findings will also be integrated with work in freshwater and terrestrial habitats as part of a large project funded by the Irish Environmental Protection Agency (www.biochange.ie).

Given high rates of extinction and potential loss of ecosystem 'goods and services', there is a clear need to understand the consequences of loss of biodiversity for the functioning of ecosystems. Although documented global extinctions are rare in the marine environment, local extinctions and dramatic changes in abundance are widespread. Research to date has been controversial, with debate over the effects of losing numbers of species versus particular species and the potential for compensation for the loss of some species by others. A field experiment using cage enclosures was used to test the hypothesis that loss of diversity of grazing gastropods will affect the diversity of and potential export of production by intertidal algal communities. Results indicated that it is the identity rather than the number of species present that most strongly affects ecosystem function in this case. The loss of limpets *Patella ulyssiponensis*, alone or in combination with other species led to an increase in total cover of macroalgae. The function of *Patella* could only be fulfilled by increased densities of *Littorina littorea* and *Gibbula umbilicalis* under some circumstances (O'Connor and Crowe 2005. Ecology 86: 1783-1796).

BIOFUSE is a sub-project within the MARBEF network of excellence (www.marbef.org/projects/biofuse). Its objectives are to compare stability at sites of naturally differing degrees of diversity, test effects of disturbance on ecosystem functioning and stability under different levels of biodiversity and compare systems & regions to test influence on biodiversity-functioning relationships of (a) the initial diversity of the system and (b) environmental conditions (salinity, substratum, nutrient levels, etc.). It involves 46 researchers from 19 institutions throughout Europe and is achieving its objectives by (a) collation and meta-analysis of existing data sets, (b) a long term sampling programme to test stability of European rocky shores of differing diversity and (c) field-based experimental manipulations repeated throughout Europe on rocky shores, sedimentary shores and seagrass beds.

Existing data sets (n = 28) from 11 European partner institutions have been included in a meta-analysis of relationships between the diversity and temporal variability of marine ecosystems. Analyses used species richness measurements at the scales of quadrat (cm) and site (100's m). The data sets cover various spatial scales (10s m- 100s km) and temporal patterns (1976-2005) in different benthic habitats (e.g. subtidal, rocky and sedimentary shores) under various regimes of disturbance (e.g. waves, nutrients, anthropologic perturbations). Significant relationships between diversity and temporal variability were observed in only 3 and 4 out of 19 cases for the univariate analyses (quadrat and site scales respectively) and 4 and 3 cases for the multivariate analyses. All significant relationships were positive except one involving multivariate data at the quadrat scale. Results of meta-analyses showed that the overall effect size was significant and positive for univariate analyses at both quadrat and site scales. This means that the relationship between species richness and its variability is slightly positive for the univariate analyses, suggesting that biodiversity *per se* is important for the stability of ecosystems. When using community level data (multivariate), variability was or was not correlated with diversity, suggesting either no effect of diversity or idiosyncratic effects of individual species.

The long-term sampling programme focuses on rocky shores and is currently ongoing (will continue until Feb 2008). After three sampling dates, the preliminary analysis of 8 of the 10 partners' data sets showed no significant relationships between temporal stability (in terms of variability of richness with time) and diversity at either the quadrat or site scale. These results are preliminary; there will be two additional sampling dates.

Simple manipulations of diversity and disturbance are being replicated on rocky shores, sedimentary shores and seagrasses. Preliminary analyses from experiments on rocky shores from 10 regions indicate significant changes in community structure as a result of manipulations of diversity and disturbance which are partially reflected in measures of ecosystem functioning (such as community respiration and production). Again, these results are preliminary; the experiments will be complete in September 2007.

Findings from the meta-analyses, the long-term sampling programmes and experiments being undertaken in parallel in different systems and geographic regions will be compared to enable us to draw general conclusions about the role of biodiversity in European marine ecosystems.

2.6. Climate change impacts on estuarine fish fauna

Prof. Maria Jose Costa

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It is now widely accepted that the Earth's climate is changing, and whether this change is human- or natural-driven, it has become clear that the Earth's atmospheric temperature is rising, and will continue to do so. This will undoubtedly impact on sea surface temperature, rainfall patterns and wind regimes which will, in turn, influence estuarine environments.

2.6.1 Possible impacts on fish fauna

One of the most significant roles of an estuary is to function as a nursery ground for fish communities. Estuaries usually present high primary productivity rates and provide sheltered waters that act as a buffer for the highly variable conditions found in the open sea, making them ideal locations for early life-stage development. However, estuaries are more sensitive to rises in water temperature than coastal waters and their salinity is highly dependent on both rainfall regimes of their watersheds and sea level. Therefore, the climate change scenarios proposed present significant implications for these ecosystems. Sea-level rise will also cause many supratidal and intertidal areas to become subtidal. For instance, a reduction in salt marsh areas is likely to seriously impair estuarine productivity, as in many cases human intervention prevents the formation of new marshes further upstream.

All these changes will impact fish communities both directly, by causing habitat loss and fragmentation, and indirectly, via the modification of lower trophic level assemblages. Also, as the coastal SST rises, the distributions of coastal fishes are also likely to shift, thus modifying the composition of estuarine fish communities. With estuaries being one of the most important fishing grounds worldwide, these changes present economical implications that must also be taken in consideration.

2.6.2 Seeking evidence

As climate change is mainly a long-term process, in order to properly evaluate its impacts it is essential to have solid time-spanning data series for both physical (e.g. temperature and salinity) and biological data, preferably across the food chain. Monitoring projects provide invaluable information to assess long term changes in estuarine ecosystems, whether they are climate change-induced or otherwise.

Although this type of trend analysis allows some insight into the impacts of a changing environment, changes in the structure of estuarine fish communities are better predicted if the distributions of the coastal fish species are taken into account, as they account for a significant part of the estuarine assemblages, especially for those species which use the estuary as a nursing ground. Therefore, broad-scale geographical data constitutes an important resource in predicting which new species enter the community and which current species leave the estuary.

2.6.3 Past and ongoing research

The Oceanography Institute has been involved in several Environmental Impact Assessment projects, including three ongoing extensive monitoring projects on the Tagus estuary. These are providing long-term data series of the estuarine communities, especially for benthic invertebrates and fish, but also covering plankton, salt marshes and birds.

The ERIC (Effects of River Inflow Changes on Estuarine and Coastal Fish Communities) project provided insight into the ecological and socioeconomic consequences of changes in freshwater inflow of the three largest Portuguese rivers.

The NURSERIES (Estuarine and coastal nursery areas' importance in maintaining commercially exploited species' stock) project investigated eight estuaries and coastal lagoons across the Portuguese continental coast. The results allowed a better understanding of the nursery function of these estuaries, their importance in maintaining commercially exploited fish stocks and the anthropogenic pressure exerted on these communities.

Impacts of coastal climate change on the Portuguese biological communities (dynoflagellate cysts, fishes and birds) is being evaluated in the PORTCOAST (Present and future Portuguese coastal climate and its impacts on the biological communities) project.

2.6.4 The Tagus estuary

The Tagus estuary is the largest estuary in Western Europe, covering an area of approximately 320 km^2, 40% of which is comprised of intertidal areas and salt marshes. It's a mesotidal estuary, presenting tidal amplitude of about 4 m, most of it being less than 5 m deep. It suffers heavy anthropogenic pressure due to urban sewage systems, industrial and agricultural pollution, numerous engineering projects and intense fishing activity.

The first fish community studies began in 1978/79, with beam trawl sampling being conducted from 1979 to 1981 in five distinct areas of the estuary basin, capturing over 40,000 specimens. Re-sampling was performed between 1995 and 1997. By comparing results, changes in the composition of the fish assemblages were observed, namely a decrease in the abundance of Flounder (*Platychthys flesus*), Fivebeard rockling (*Ciliata mustela*), European sprat (*Sprattus sprattus*), Pouting (*Trisopterus luscus*) and Tub gurnard (*Trigla lucerna*), in parallel with an increase of Toadfish (*Halobatrachus didactylus*), Meagre (*Argyrossomus regius*), Senegal sea bream (*Diplodus bellottii*), Senegalese sole (*Solea senegalensis*), Gilthead sea bream (*Sparus aurata*) and Thinlip mullet (*Liza ramada*).

This shows a tendency for the increase of species usually found in warmer waters (e.g. the Senegalese sole), whilst the northern species decreased their abundance, which can be explained by the higher mean water temperature observed in the later sampling period, giving a clear example of the influence of climate change on the estuarine fish community's structure.

2.7. *Impact of ocean acidification on marine benthic diversity and nitrogen cycling*

Dr Steve Widdicombe

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Surface ocean pH has been maintained between 8.0 and 8.3 pH units for the last 25 million years (Figure 1). However, the current rate of increase in atmospheric CO_2 concentrations is so great that the processes which buffer pH change are insufficient to prevent seawater acidity from increasing. Since the onset of industrialisation, seawater pH has fallen by 0.1 pH unit producing a 30% increase in the concentration of H^+ ions. The current rate of acidification stands at 0.015 pH units per decade. The Intergovernmental Panel on Climate Change (IPCC) has predicted that atmospheric CO_2 levels could reach 800 ppm by 2100, producing a global surface water pH reduction of up to 0.4 units, and 0.7 units by 2250. In addition, seawater carbonate concentrations are decreasing and it has been predicted that in as little as 40 years parts of our surface oceans will become under-saturated with respect to calcite and aragonite. In light of these impacts, the Royal Society of the UK concluded that "Research into the impacts of high concentrations of CO_2 was in its infancy and needs to be developed rapidly".

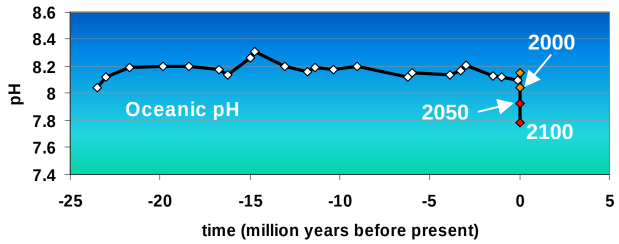

Figure 1: Past and predicted variability of surface ocean pH (Blackford & Gilbert, 2006)

At the 1992 Earth Summit in Rio de Janeiro, world leaders agreed on a comprehensive strategy for sustainable development. One of the key agreements adopted at Rio was the Convention on Biological Diversity (CBD).The Convention recognised that the loss of biodiversity may change the function of ecosystems and reduce the range of goods and services, from which mankind constantly draws. The convention acknowledged that current levels of biodiversity loss are unsustainable and committed signatory countries to its conservation and the sustainable use of its components. The oceans harbour tremendous biological diversity. Of the 29 non-symbiont animal phyla that have been described so far, all but one has living representatives in the ocean and 13 are represented only in the oceans. With all of these phyla having representatives in the benthos and most having representatives in marine sediments, it is considered that the majority of the species diversity in marine ecosystems consists of invertebrates either residing in (infauna) or on (epifauna) the seafloor. Recent work has already identified significant variability in pH sensitivity for a number of different benthic taxa. Even amongst organisms which depend on calcium carbonate structures, variability in tolerance has been observed with echinoderms showing less tolerance to pH change than molluscs. Such variability in sensitivity could have considerable implications for both the diversity and functioning of sediment communities in seas with declining pH.

The sediment environment is characterised by strong geochemical gradients. For example, the pH at depths of 30cm or so can be as much as 1 unit lower than the pH of the sediment surface and overlying water. In the face of such geochemical variability it is difficult to imagine how benthic sediment systems could be affected by the relatively small pH changes resulting from ocean acidification. However, by considering the distribution and activities of sediment dwelling organisms, it is possible to identify areas where these small changes could have potentially large consequences for sediment communities and biogeochemical processes. The communities of benthic sediments are strongly stratified with different species characteristically occupying different depths. The surface layer is the most densely inhabited and is home to the majority of multi-cellular, infaunal organisms, whilst only those species capable of oxygenating their immediate environment are able to dwell below the redox discontinuity depth. Microbial communities and the functions they perform (e.g. nitrification and denitrification) also differ considerably between the oxic surface sediments and the deeper anoxic layers. The presence of these depth-constrained niches means that although benthic systems as a whole are already subject to a relatively large range in pH, many of the organisms and processes that exist within them are not. Whilst the majority of macrofaunal species are restricted to the upper oxic layers, others are able to inhabit the deeper sediment layers. They do so through the creation of permanent burrows through which they are able to draw down oxygenated water from above. The burrows created by these macrofauna experience significant oscillation in pH (as much as two pH units) and dissolved oxygen concentration (between saturation and near anoxia) generated by the periodic ventilation of burrows. Such oscillation is absent at the water/sediment interface. Consequently, animals which inhabit permanent burrows may have a greater tolerance to changes in pH than non-burrow builders. This potential difference in pH tolerance between benthic species could lead to the selection of more tolerant species and thereby substantial changes in the structure and function of sediment communities in the face of changing levels of pH.

In coastal and shelf sea environments the sediment system plays a crucial role in a number of key ecosystem functions and processes. For example, in shallow (<50m) coastal areas productivity in the overlying water column relies heavily on the sediment system with up to 80% of the nitrogen required by phytoplankton coming from the bacterial regeneration of organic matter within the seabed. It is also recognised that organisms living within the sediment have the ability to alter the physical and chemical characteristics of their immediate environment, contributing significantly to the rate of nutrient fluxes at the sediment/water interface and the maintenance of biodiversity. In soft sediment habitats the single most important mechanism by which this occurs is bioturbation. Any factor that alters the rate of bioturbation will have considerable implications for the functioning of marine ecosystems and, as some bioturbating species rely on calcareous structures, an increase in the acidity of coastal seas could be such a factor. Therefore the potential for major differences in the response of bioturbating organisms, from both different taxa and functional groups, to reduced pH would have a considerable impact on the functioning of marine sediments and the "goods and services" they provide. Consequently, whilst changes in seawater pH may have a direct effect on biodiversity, sediment and seawater chemistry, these effects may be exacerbated by changes in the type and intensity of bioturbation.

This presentation will introduce the mechanisms causing ocean acidification and discuss the implications for biodiversity and nutrient cycling in coastal marine sediments.

2.8. *Detecting and predicting changes on marine ecosystems: the SESAME project*

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The SESAME IP[1] (Southern European Seas: Assessing and Modelling Ecosystem changes), is designed to study the past, present and future environmental changes in the Mediterranean and Black Sea ecosystems, and how these affect their abilities to provide goods and services with fundamental societal importance such as tourism, fisheries, mitigation of climate through carbon sequestration and ecosystem stability through conservation of biodiversity. By assessing the changes that have occurred in the Mediterranean and Black Seas over the last 50 years, while simultaneously predicting changes in their ability to sustain essential ecosystem functions in the next 50 years, SESAME will involve and assist the relevant stakeholders to develop and implement sustainable management policies under the current climate change debate.

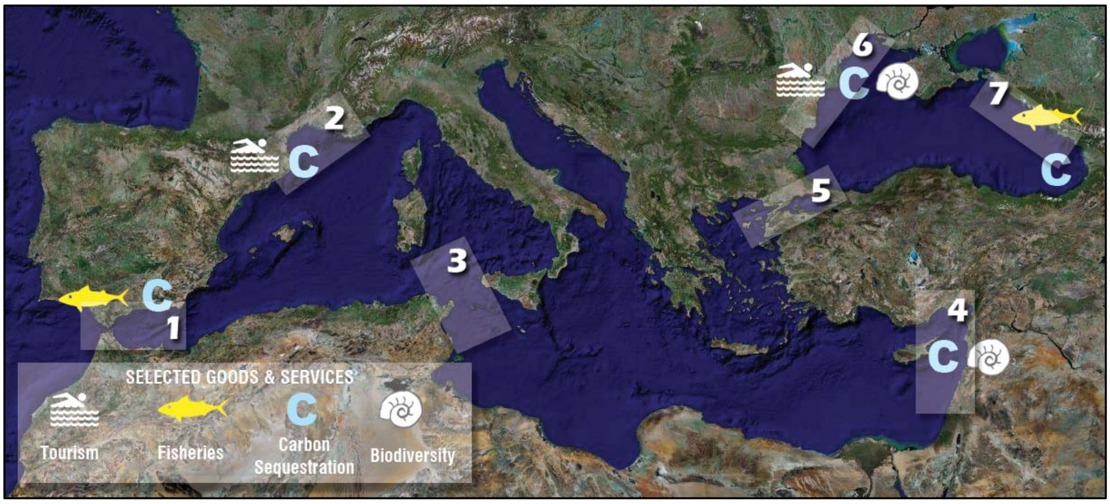

Figure 2.8.1. SESME Project: The five study areas over which the semi-quantitative fields of economics and social sciences will be fully addressed.

The project approaches the two seas as a coupled climatic/ecosystem entity for the first time, and its innovation lies in the large-scale merging of economic and natural sciences. SESAME takes advantage of past efforts made in the Mediterranean and Black Sea regions and over its implementation period, existing information, model simulations and scenarios will be integrated. SESAME interprets and brings together available and new observations, identifies gaps in knowledge, understands past changes through hindcasting and will explore possible future changes. For the first time, the structural and functional ecosystem changes (e.g. regime shifts, carbon sequestration, nutrient cycling) will be explored through long-term numerical simulations in connection with past and (potential) future changes in the natural and anthropogenic forcings. Process-oriented predictive dynamic models will be upgraded and/or developed to embrace the broad spectrum of physical and ecological features and processes that characterise the Mediterranean and Black Seas, focusing on the whole region as one entity. Furthermore these models will include, where appropriate, higher trophic levels not used in models of this scale and will be calibrated against past and present data, collected and assessed under SESAME's activities. Therefore, the SESAME modelling effort will simultaneously look at the recent past (second half of the 20th century) and near future (first half of the 21st century) in a unified and coherent way from the point of view of the modelling tools and the forcing.

[1] SESAME IP (www. sesame-ip.eu) was launched in November 2006, funded by the a 6th EU FP.

This will provide an unprecedented model-based hindcast analysis of the Mediterranean – Black Sea ecosystem dynamics, and an (equally unprecedented) exploratory analysis of the changes possibly occurring under international consensus-based scenarios of change in the global climatic system as well as in the coastal economic and demographic context.

SESAME will provide a close interactive link between physical – biogeochemical and socioeconomic approaches aiming to explore potential future ecosystem changes in relation to possible alternative development paths. This will be done by forcing the physical and biogeochemical models with evolving environmental pressures (from nutrient river load to fisheries) predicted/appropriately derived from socioeconomic models. Indices/indicators for ecosystem changes connected to societal scenarios and needs will be developed and functions will be defined to transfer these predicted ecosystem variables into socioeconomic drivers, useful to define policies for the sustainable management of the SES under solid scientific information

Within the research area Biodiversity and Ecosystems, SESAME will contribute to a better understanding of ecosystem dynamics at both the quantitative (biogeochemical cycling) and qualitative (ecological structure of food webs) levels, without artificial divisions between them. Existing and new observations will be integrated with information arising from numerical simulations to assess and predict the past, present and future state of the marine ecosystem in relation to changes in natural and anthropogenic forcings. Such an assessment and prediction effort includes the valuation of key goods and services provided by the Mediterranean and Black Seas. It will provide a scientific basis for understanding and minimising the negative impacts of human activities on ecosystems (e.g. halting the loss of biodiversity) and support the development of policies for the sustainable management of natural resources.

In relation to biodiversity and ecosystem stability, SESAME will provide information for the different habitats in the SES; for example SESAME will address, among others, changes that occurred in *Posidonia oceanica* meadows during the last 50 years, which will be deeply investigated in connection with changes in environmental conditions. It will at the same time provide the link with habitat destruction. Furthermore, SESAME will produce outputs from the developed complex biogeochemical models that could be used in order to appraise possible biodiversity changes such as temperature, ecosystem metabolism (e.g. rates of primary production, recycling), pH, gelatinous species occurrences, alien species, trophic index, and structure and functioning of the trophic food web (regime shifts).

Within the spirit of the European Research Area (ERA), innovative and interdisciplinary approaches should be used to define, prioritise and propose actions to address environmental problems of the marine ecosystems across the European seas, estimate the environmental variability and thresholds and assess the capacity of European Seas towards sustainable management resources. Stakeholders and end-users from policy-making communities should be made fully aware of the services the marine ecosystems are providing as well as of the inherent ecosystem variability that should be fully acknowledged and reflected in the policy design process aiming to effective environmental sustainability. The scientific and technological approaches adopted in SESAME are orientated towards that approach focusing on the study, assessment and prediction of the environmental changes in the Mediterranean and Black Sea ecosystems, in response to natural changes and anthropogenic forcing (regime shifts) and how these affect their abilities to provide goods and services with fundamental societal importance such as tourism, fisheries, mitigation of climate through carbon sequestration and ecosystem stability through conservation of biodiversity.

For further information see: www.sesame-ip.eu

2.9. *Microbial Observatories as a tool to detect and describe changes in marine (microbial) diversity and ecosystem functioning: lessons learnt from the Blanes Bay Microbial Observatory*

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Unlike larger marine organisms, microbes cannot be easily identified based on morphology alone. This is particularly true for the smallest ones, archaea and bacteria, but also holds true for most protistan eukaryotes where crypticity is a widespread characteristic. However, prokaryotes comprise most of the Earth's living biomass, are the most abundant living particles in the sea, are the only relevant dissolved organic matter (DOM) transforms in the sea and comprise the largest living surface in the ocean. Furthermore, they are the largest "unknown" pool of genomic and metabolic (i.e. functional) diversity. As an example, a recent report (Yooseph *et al.* 2007, PloS Biol. 5: e16 doi:10.1371/journal.pbio.0050016) analysing metagenomic data from the ocean's surface has identified >1000 new bacterial protein families, indicating that there may easily be many unknown functions yet to be discovered in the ocean and that can be assigned to microbes.

Microbes are also extremely diverse. Surveys of bacterial richness can show hundreds of different organisms per sample depending on the methodology used. But this is based on methodologies which might show only the "tip of the iceberg" of bacterial diversity. Newer, more recent methodologies, adopting a massively parallel tag sequencing strategy, have shown that bacterial communities of deep water masses of the North Atlantic and diffuse flow hydrothermal vents are one to two orders of magnitude more diverse than previously reported for any microbial environment. A relatively small number of different populations dominate all samples, but thousands of low-abundance populations account for most of the observed phylogenetic diversity. This ''rare biosphere'' is very ancient and may represent a nearly inexhaustible source of genomic innovation. The areas of biodiversity that involve small microbes that drive the bulk of ecosystem processes can be analyzed by these newest molecular tools and this makes possible the integration of microbial diversity into studies of ecosystem processes.

In terms of quantifying diversity, however, the problem has to be solved of what to do with the reported microbial microdiversity that is present in the samples when analysed using molecular methods: these are extremely similar sequences, that might represent neutral diversity but, simultaneously, sources of variability for subsequent adaptation. The fact that day after day there are new molecular approaches being developed, indicates the relevance of creating i) well organized repositories of microbial genetic material, accessible to scientists with ideas on how to analyze the material, and ii) ecologically-referenced, with as much ancillary ecological and biogeochemical data collected as possible. While the first metagenomic study of the ocean's microbes was done without even referring to the temperature and chlorophyll data of the sample (something that decreased the relevance of the findings), current programmes should focus equally on the ancillary biogeochemical and food web data.

Studies of this type in well-standardized sites are the basis of what has come to be called "Microbial Observatories" (MO). The long-term goal of the MOs is to study and understand microbial diversity over time and across environmental gradients. The guiding themes are i) discovery of large numbers of, as yet, undescribed microorganisms and microbial consortia from diverse habitats, and ii) characterization of novel biochemical, metabolic, physiological, genomic, and other properties and processes of newly described or poorly understood microbes and microbial assemblages and communities. The American National Science Foundation (NSF) has launched a series of calls for MOs across the USA, encouraging proposals that would "increase knowledge of the biochemical, genetic, physiological and ecological properties and processes that enable diverse microbes to occupy and interact in natural and disturbed habitats"

(Kane 2004, Microb. Ecol. 48: 447-448). Some projects aim to study and characterize entire communities, including viral, bacterial, archaeal, and eukaryotic microbial members. Others consist of targeted studies of assemblages or physiologically and/or phylogenetically defined microbial groups that are of great interest due to genomic, metabolic, ecological, and/or evolutionary aspects of their biology.

Since 1998 we have been running a Microbial Observatory in the Northwestern Mediterranean (the Blanes Bay Microbial Observatory, http://www.icm.csic.es/bio/projects/icmicrobis/bbmo), a coastal site that reflects well the typical Mediterranean seasonality. The suite of techniques currently in use at the Blanes Bay MO include a special focus on single-cell analysis techniques that can be used to relate the function of a given organism with its phylogenetic characteristics, thus linking biodiversity and ecosystem functioning. This is a long-term strategy that seems particularly adequate to determine the effects of global change in microbially-driven ecosystem function. As an example, we have established how anthropogenic and climate forcing can alter the response of the microbial communities to the addition of nutrients, and how bacterial carbon processing is altered by small seawater temperature rises. We believe that the combination of experimental work in tandem with long-term observational studies is the best strategy to predict the effects of global change on the ocean biogeochemistry.

Finally, the establishment of MOs allows going back and forward in time, because we are living in times in which molecular methodologies are developing rapidly. Analyses currently not possible may become so with the development of new or improved (and more affordable) methodologies in the future. Then we can go back to the stored DNA and do the analysis. Just imagine how good it could have been to have DNA collected from the world's oceans from Darwin's times: we would be able to test whether the oligotrophic ocean back then was dominated by SAR11 and Prochlorococcus as is now, and whether these organisms have had genetic changes with the time passed. Our stored DNA is equivalent to the herbaria that can be searched again by interested scientists.

Microbial observatories require team effort. No a single scientist can pretend to run a MO studying microbial diversity and ecological functioning. We are fortunate to work in an environment that allows collective work and promotes interaction. This is also beneficial because it allows the research to be funded for longer times than the typical three-year projects.

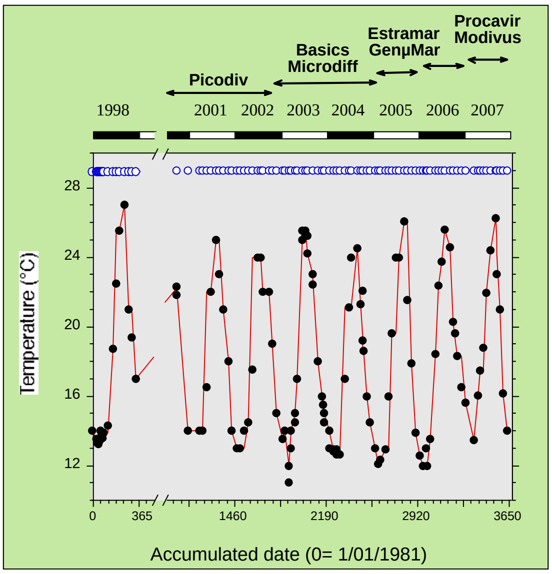

Figure 2.9.1 Temperature profile recorded at the Blanes Bay Microbial Observatory sampled from 1998 to 2007. The upper names are the EU or Spanish projects supporting sampling. The blue dots are those samples in which DNA was collected and is maintained in the DNA repository.

3.1. Identification of barriers to and enablers of co-operation

One of the goals of the MarinERA Project is to gain an insight into the factors that are perceived by marine researchers as major barriers and/or enablers of international research collaboration. This is the principle focus of MarinERA Work Package 2.2 and will be the subject of a special MarinERA Technical Report (No. 2) to be published in late 2007.

To assist a preliminary discussion on barriers to and enablers of research co-operation, participants were each provided with a questionnaire listing ten barriers and ten enablers (based on the Optimat "Guide to Good Practice (2005) Report")[2] and asked to score each of them in order of their importance (see Figures 3.1.1 and 3.1.2).

Data collected at the Madrid Workshop will be compared with that arising from the other *a posteriori* clustering Workshops and with the findings of the main barriers/enablers report (MarinERA Technical Report No. 2) at a future date.

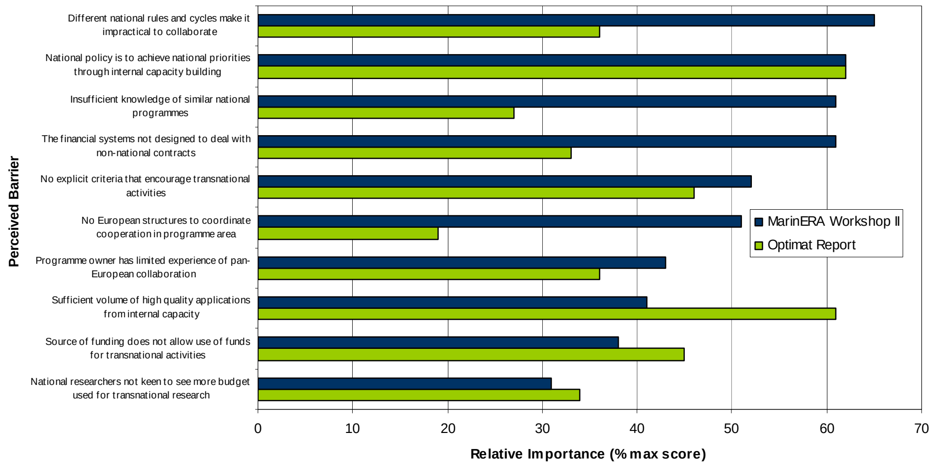

Figure 3.1.1. The relative importance of perceived "barriers" to the enhancement of interaction between national marine research projects and programmes within Europe.

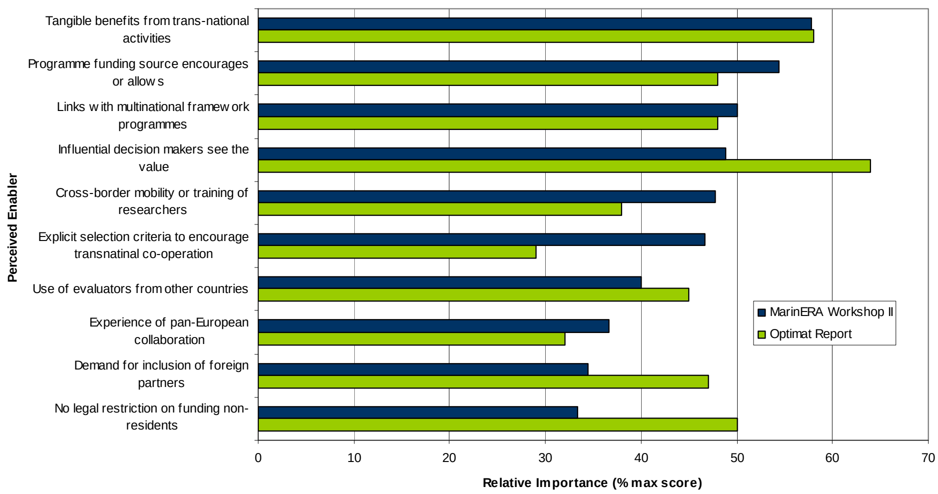

Figure 3.1.2. The relative importance of perceived "enablers" to the enhancement of interaction between national marine research projects and programmes within Europe.

[2] Guide to Good Practice: Increasing the impact of National Research Programmes through Transnational Co-operation and Opening (2005). Report prepared by Optimat Ltd – VDI/VDE Innovation and Technik GmbH for EC-DG RTD.

3.2. Identification of needs and gaps in European Biodiversity and Climate Change Impacts research

3.2.1. Identification of Research Needs / Gaps

Participants from the nine European countries represented at the Workshop were asked to identify topics or ideas for future research projects within the broad area of anthropogenic and climate change impacts on marine biodiversity and ecosystem function. They were asked to support their comments with a written paragraph outlining a proposal for a research project or programme that would, in their opinion, meet an existing shortfall in the European research effort.

The proposals are listed below as they were submitted. This is followed by a brief analysis of the collective response, identifying common areas and themes.

Prof. Carlo Heip, Royal Netherlands Institute of Sea Research.

There is a general lack of knowledge on patterns of marine biodiversity and its role in ecosystem functioning and many research questions have been formulated (e.g. in the 1998 ESF Marine Board document, "A Science Plan for Marine Biodiversity Research in Europe"). Many of those are now being addressed in national programmes, but **an inventory of national programmes in this field is not available yet**. The EU network of excellence MarBEF, through its Responsive Mode Projects, links many of them. The clustering of EU biodiversity projects in FP5 has not been continued in FP6.

A general failure of marine biodiversity research (and especially observation and monitoring) is **up-scaling to the right geographical level**, i.e. linking observations in such a way that knowledge on changing patterns of species distributions at large scales (and on long time scales) is done in a meaningful and consistent way.

One area that is, at present, supported but where efforts should be strengthened is **microbial diversity** (including microbial eukaryotes) and its applications in marine biotechnology and the development of pharmaceutical and industrial products. In the field of marine microbiology it is clear that with the present level of funding, Europe is running behind US and Japanese efforts.

A second gap is multidisciplinary research focusing on the **central role of humans and human societies in marine ecology and ecosystems**. Such research is hindered by disciplinary research councils and funding agencies and the lack of multidisciplinary departments and tenured positions at universities and research institutes.

Dr Lech Kotwicki, Institute of Oceanology, Poland

Some key areas for future research on sandy beaches include:

- Impact of accretion/erosion dynamics on ecosystem/community processes and recovery trajectories.
- Impact of direct human activities, such as recreation and harvesting of beach biota.
- Pollution effect on key processes, such biological filtration of coastal waters.
- Impact of habitat fragmentation on metapopulation and source-sink connectivity.

Dr Philippe Goulletquer, IFREMER, France

All evidence demonstrates that we have actually underestimated the effects of climate changes as well as environmental feedbacks to those changes on complex ecosystems. Complexity is aggravated by entangled processes among anthropogenic factors (e.g., fishing effort) and more global changes such as climate variability. Therefore, significant research effort could be focused on:

1. Improving and maximising links between on-going environmental observatories (coastal & off-shore) (EC ESONET, HERMES, ORE, MFSTEP etc.).
2. Increasing research effort to develop regional models to obtain new projections and comprehensive ecosystem feedbacks resulting from climate changes. This represents a critical step to further simulate environmental impacts on living resources as well as exotics.
3. A multidisciplinary and ecosystem approach, combining at least oceanography, meteorology and ecology is recommended. This eventually should facilitate future decision-making and better management of marine resources.

Dr Francis Kerckhof, Royal Belgian Institute of Natural Sciences, Belgium

There is a need for sound and **long-term basic data/datasets** (including reconstruction work on time series), even on so-called well studied components of the marine ecosystem such as benthos.

It is difficult to address questions such as climate change or the impact of alien invasive species, the impact of fisheries or even the impact of certain disastrous events, in the absence of an *a priori* knowledge of a baseline situation. A one-off sampling is not enough; there is a need for ***regular monitoring* at *selected stations* over *a long period***, and not only of those species or events that are of (immediate) commercial relevance such as commercial fish stocks. It is no longer acceptable to defer such detailed monitoring programmes on the basis of excess cost and effort.

The continuing erosion of **taxonomic expertise** is also a major problem. This is not about lonely scientists sitting in a dusty museum, but people disseminating their experience in a practical way so that others can use it. Interactive tools could be developed (further) that would make identification much easier and also the production of distribution maps and other products and tools. Hence further development of on-line resources such as reliable and maintained databases with specialist and species information (e.g. Marlin, Fish base, Algaebase, ERMS etc) and interactive on-line tools to facilitate the use of all sorts of data. The valorisation of museum collections as depositories and reference points and for evidence and control would also be very beneficial.

Dr Tasman Crowe, University College Dublin, Ireland

1. **Combined impacts of different pressures:** Traditionally, impacts of anthropogenic pressures such as climate change (storminess, temperature, sea level), ocean acidification, pollution, exploitation and invasion have been studied in isolation. It is necessary to study their combined effects because a number of pressures may affect a given ecosystem simultaneously, with synergistic or interactive effects that are currently unpredictable. Investigating interactive effects requires experimental research, ideally in the laboratory and *in situ*.
2. **Multi-disciplinary research to develop an ecosystem perspective**: Understanding and predicting human impacts on ecosystem structure and functioning requires a multidisciplinary approach which is only possible in large-scale projects which are comparatively unusual at a national level. Impacts on an ecosystem (e.g. at the scale of an embayment) can be mediated by effects of a range of pressures at different levels of biological organisation (intra-individual, individual, populations, communities), on different taxa and in different habitats. Assimilating and combining the necessary mechanisitic insight and data requires the combined expertise of specialists in a range of disciplines and the integrated application of a number of different approaches to research, both empirical (observation, experiment) and theoretical (modelling). SESAME is a good example of this approach. More such projects are needed for different regions if the European Marine Strategy is to be implemented effectively.

Specific issues requiring research can best be identified by the use of comparatively open calls, eliciting **'bottom-up'** responses from the research community in a transparent way. Relatively open calls should not be equated with blue-skies research, but can perfectly well be used to address issues of economy, policy and management. For example, a call to improve knowledge to underpin ecosystem-based approaches to management of national fisheries could either be broadly defined purely in those terms (a more 'open' call), or, as is more usually the case at the moment, in very specific terms (e.g. habitat mapping in scallop fishing beds). A larger proportion of the research community is likely to respond with suggestions for potentially valuable research to the former than to the latter.

Prof. Maria Jose Costa, University of Lisbon, Portugal

The composition of estuarine fish assemblages is dependent on the coastal fish species, whose stock is, in turn, conditioned by the nursery function of the estuary. Research should be carried out to model this connectivity, as well as larval dispersal and habitat loss, as ongoing monitoring projects will be continued in order to extend the existing time-series.

The numerous implications of climate change, ranging from temperature to rainfall, from wind regimes to sea level, requires holistic approaches to be implemented, creating the need for integrating chemical, hydrological and biological data. Also, due to its large spatial scale, climate change impacts on both physical and biological aspects, must be assessed by wide-scaled research, which can be greatly improved by enhancing collaborations and networking between research centres, allowing for greater data and knowledge integration and thus better modelling.

Dr Steve Widdicombe, Plymouth Marine Laboratory, UK

The problem: Surface ocean pH has been maintained between 8.0 and 8.3 pH units for the last 25 million years. However, the current rate of increase in atmospheric CO_2 concentrations is so great that the oceans are predicted to experience unprecedented changes in seawater pH and carbonate chemistry. It is thought that this could impair basic biological functions, including reproduction and physiology.

So what is needed?: There is a pressing need to **predict the ecosystem response to ocean acidification** and this creates a number of challenges for the research community: the emerging species specificity in response, the possibility of adaptation and acclimation, the need to represent such processes in model systems. In meeting these challenges the scientific community must also be mindful to address the concerns and needs of policy makers in what is a rapidly evolving management issue. Whilst over prioritisation of process investigation is premature, given the degree of variability and uncertainty so far observed, there is a clear need to investigate diversity of response within functional aggregations.

The close coupling of the benthic system and euphotic zone in shelf systems poses several questions not yet addressed including the cycling rate of carbon and nitrogen through the benthos, the balance between benthic respiration and burial, the short-term buffering capacity of the sediments and the direct effect of acidification on the benthic system. There is a need for an integrated approach involving models, experiments and observations so that each community plays a role in designing the other's methodology. A key challenge for experiments is to move away from rapid perturbations to trans-generational designs that address the decadal-scale rate of acidification. Observations should encompass the physical, chemical and biological processes that drive the marine carbonate system.

A final challenge is to take account of the climate alterations predicted over the same time scale.

Dr Nikos Streftaris, Hellenic Centre for Marine Research, Greece

Within the spirit of the European Research Area (ERA), innovative and interdisciplinary approaches should be used to define, prioritise and propose actions to address environmental problems in marine ecosystems across the European Seas, estimate the environmental variability and thresholds and assess the requirements to achieve sustainable management of the resources of European Seas. Stakeholders, end-users and policy-makers should be made fully aware of the services that marine ecosystems provide as well as of the inherent ecosystem variability that should be fully acknowledged and reflected in the policy design process. The scientific and technological approaches adopted in SESAME are oriented towards that approach focusing on the study, assessment and prediction of the environmental changes in the Mediterranean and Black Sea ecosystems, in response to natural changes and anthropogenic forcing (regime shifts). The project is also investigating how these changes affect the ability of these seas to provide goods and services with fundamental societal importance, such as tourism, fisheries, mitigation of climate through carbon sequestration and ecosystem stability through conservation of biodiversity.

Dr Josep Gasol, Consejo Superior de Investigaciones Científicas, Spain

- There is an urgent need to realise that long-term monitoring cannot be funded with 3-yr or 5-yr projects. Funding to support monitoring programmes need not be prohibitive but must be provided for long periods.
- Analysis of microbial diversity requires expensive technologies, akin to those used in biomedical research. Projects must be funded sufficiently so that sampling is done on a regular basis, and stocks are maintained.
- There is a need for an efficient way of organising nucleic acid stocks, and for accessing them.
- Ancillary biogechemical data should be collected as part of studies to assess and monitor microbial biodiversity. The more complete the information, the more we will be able to understand microbial biodiversity and how this affects ecosystem function.
- We need at least one microbial observatory from each of the European coastal and deep oceans and we also need deep-sea microbial observatories. There should be some form of agreement to work in cooperation to collect, treat and maintain the DNA using standard methodologies.

3.3 General Requirements and Challenges for Future Research

3.3.1 Long-term data series

For scientists to be able to implement cause and affect analyses of climate change impacts on, for example, biodiversity, there is an urgent need to put in place the infrastructure and commitment to long-term monitoring programmes in the marine environment. Workshop participants consistently identified a need for national and/or European resources to be targeted toward the development and management of long-term series of biological and physico-chemical data. The question of who would manage the data (and who would pay for its management) was also raised.

It was noted that this was a factor that was recognised by national and European Marine Research Funding Agencies but that it was very difficult for the Funding Agencies to make long-term funding commitments when they generally operate short-term programmes (e.g. five years). However the Funding Agencies represented on the MarinERA project are acutely aware of the need to support long-term collection, storage and management of data.

3.3.2. Importance of Microbial Biodiversity

While research projects and programmes on the biodiversity of larger organisms have come to the fore since the mid-1990s, there is still insufficient attention paid to microbial biodiversity. It was noted that we are only "looking at the tip of the iceberg" by ignoring microbial biodiversity. The role of Observatories (e.g. Blanes Bay Microbial Observatory in Spain) was highlighted as key to microbial biodiversity assessment and research.

3.3.3. Recognition of Interdisciplinarity in Academic appointments

While funding agencies aim to promote interdisciplinarity, research institutions have not adapted to this need by creating tenured positions for academics to work at the interfaces of disciplines (e.g. science/humanities/economics).

3.3.4. Loss of traditional taxonomic expertise

Molecular approaches and genomics represent efficient and advanced mechanisms to identify and differentiate species and populations. However, there is still a need for traditional taxonomy based on form and morphology to ensure quality-control and continuity in relation to historical records. Classical taxonomic skills are rapidly disappearing as exponents age and retire and few new scientists follow this career path. While this may not be perceived as an exciting or interesting area for specialisation, there is little doubt that the need for taxonomic expertise is greater than ever.

3.3.5. Economic valuation of ecosystem goods and services

In order for the goods and services provided by marine ecosystems to be properly appreciated by policy makers, there is a need to develop tools and methodologies to place an economic value on marine environments and processes.

3.3.6. Understanding combined impacts and interactions with climate changes

There is a need to better understand how the environmental changes arising from climate change interact to impact on biodiversity. For example, how will biodiversity in an inshore bay be affected by the interaction of a change in the seasonal temperature regime and the practice of aquaculture?

We also need to examine better the interaction between seawater chemistry and climate variables and identify the mechanism of how changes in biodiversity happen by taking account of physiological changes in keystone or at-risk species attempting to adapt to changing environmental conditions.

3.3.7. A better balance between bottom-up and top-down approaches to defining research priorities.

A number of researchers voiced concern at the current trend wherein both Member State Funding Programmes and the EU Funding Programmes (e.g. Framework Programme) appeared to be dominated by top-down defined topics and projects. This approach left little scope for testing new ideas and approaches or for innovation. Researchers, while recognising the need for top-down approaches to address immediate policy issues, emphasised the need for more open calls for competitive research and noted that investigator-defined research has a significant role to play in meeting future policy and societal needs. This concern was also expressed at the 1st *a posteriori* Workshop.

3.3.8. Financial supports for project interaction and development

Financial supports ("soft" or "seed" monies) should be available to national researchers to facilitate networking between researchers working in nationally-funded projects to travel and meet with other international experts to discuss research complementarities and to formulate joint proposals and/or publications.

It was noted that such financial supports are available in some MarinERA countries and that it may be a useful exercise to analyse exactly what funding supports are available.

Annex 1:

Anthropogenic and climate change impacts on marine biodiversity and ecosystem function

Ministerio de Educación y Ciencia (Spanish Ministry of Science)
C/ Albacete nº5, 28027 MADRID-SPAIN

Date: Wednesday 12th September 2007.

PROGRAMME

09.00 Introduction

Welcome & Introduction: Aims & Objectives of Workshop
Geoffrey O'Sullivan (Convenor – MarinERA WP3 Leader) – Marine Institute, Ireland.

Presentation of the MarinERA Projects database
Dr Saskia Matheussen, Netherlands Organisation for Scientific Research, The Netherlands.

10.00 Presentations

Achievements and perspectives of networking marine biodiversity research in Europe
Prof. Carlo Heip, Centre for Estuarine and Marine Ecology, Yerseke, **The Netherlands.**

Sandy beaches – unique ecosystems
Dr Lech Kotwicki, Dept of Oceanography and Fisheries, Institute of Oceanology, Sopot, **Poland**.

Impact of climatic changes on living resources in the Bay of Biscay
Dr Philippe Goulletquer, IFREMER, **France.**

Microbial Observatories as a tool to detect and describe changes in marine (microbial) diversity and ecosystem functioning: lessons learnt from the Blanes Bay Microbial Observatory
Dr Josep Maria Gasol, **Spain.**

Gilson and the Hinderbanken: in search of the past, lessons for the future
Dr Francis Kerkhof, Royal Belgian Institute of Natural Sciences, Oostende, **Belgium**

11.15 Coffee break

Human impacts on marine biodiversity and consequences for ecosystem functioning: national and European comparisons
Dr Tasman Crowe, Dept of Zoology, University College Dublin, **Ireland.**

Climatic change impacts on estuarine fish fauna
Prof. Marie José Costa, Oceanographic Institute, Faculty of Science, University of Lisbon, **Portugal.**

Impact of ocean acidification on marine benthic diversity and nitrogen cycling
Dr Steve Widdicombe, Plymouth Marine Laboratory, **UK.**

Detecting and predicting changes on marine ecosystems: the SESAME project
Dr Nikos Streftaris, Hellenic Centre for Marine Research, **Greece.**

12.45 Lunch

14.00 Round-Table 1: Identification of research gaps

15.30 Coffee Break

Round Table 2: Co-operation / partnership – linking existing research projects

17.00 End

Annex 2

List of participants

Country	Participant	Organisation
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MarinERA

Facilitating the Coordination of National and Regional Marine RTD Programmes in Europe

Funded by the EC FP6 ERA-NET Programme
Contract No ERAC-CT-2004-515871