m@rble

ELectronic conference on MARine Biodiversity in Europe

October 8-26, 2001

Summary of discussions

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MARS

BIOMARE

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VLIZ

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Introduction

GENERAL INTRODUCTION TO THE CONFERENCE

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The objectives of the e-conference were to inventory, synthesize and report on the opinion of Europe's marine biodiversity communities (scientists, science programmers and funding agencies and decision-makers and the public at large) on three issues that we consider important for the development and application of marine biodiversity research:

~ what are the main scientific problems, locally and on the European and global scale, and what is the knowledge required to understand and predict patterns of marine biodiversity in Europe?

~ consequently, how must we organize marine biodiversity research in the changing Europe of tomorrow?

~ what is needed for the application of marine biodiversity research in management and protection of the marine environment?

Since the Convention on Biological Diversity in Rio de Janeiro in 1992 many initiatives for research on biodiversity issues have been launched, most of them local and short-term. The implementation and further development of marine biodiversity research at the European scale was discussed in several meetings over the last years organized by the CEC and the ESF [MAST days Sorrento, 1995 and Lisbon, 1998, CEC/ESF workshops in Plymouth 1997 and Yerseke (1998, 1999)]. The reports of the last two meetings are available from the Marine Board on the ESF web site www.esf.org. From these meetings a consensus had grown in the scientific community in Europe that in order to achieve the long-term and large-scale research that is needed to answer some of the most important questions in biodiversity an important concertation and co-ordination is required. Long-term biodiversity research, i.e. for more than 10 years, is very difficult to implement, even at the national level. Some of the major obstacles are the national and European funding systems and also the lack of an internationally agreed methodology for the measurement of marine biodiversity and the choice of indicators for (the degree of) biodiversity.

In 1994, the European Network of Marine Stations (MARS) Network, a non-profit foundation incorporated in the Netherlands, was founded, to cope with these obstacles. In 2000 a MARS related initiative, BIOMARE (Implementation and Networking of large-scale long-term marine Biodiversity research in Europe) started. This concerted action, supported by the CEC, aims at achieving a European consensus on the selection and implementation of a network of reference sites as the basis for long-term and large-scale marine biodiversity research in Europe, internationally agreed standardised and normalised measures and indicators for (the degree of) biodiversity, and facilities for capacity building, dissemination and networking of marine biodiversity research. Twenty-one institutes co-operate in the concerted action.

Although this is an important initiative, the results of BIOMARE will only become available by 2002. The growing interest in biodiversity in Europe, with Rio +10 and the 6th Framework Programme approaching rapidly, requires broadening the discussion to a wider range of subjects and to a wider audience, by not only including more scientists but science managers and end users as well. There is need for a state-of-the-art summary of the problems related to the scientific issues, to the organization of management of the science and to its application in the future.

The E-conference was organized to address some aspects of biodiversity research and implementation that are relevant in the present political settings of the EU community:

~ European scientists are more and more joining forces in order to study biodiversity patterns in Europe at the scales required, by sharing logistics and exchanging expertise.

~ In 2001 important decisions will have to be taken on flagship sites and their scientific support at the European scale. This research can only be done if sufficient commitment is created not after but during the development of the programme.

~ The bottlenecks of large-scale, long-term biodiversity research have only been addressed until now by scientists. Their solution requires co-operation with managers and politicians. An overview of these bottlenecks will not only help researchers in the future to structure the development of joint research plans but also provides a tool to develop strategies to solve common problems.

~ The application of the Rio definition of biodiversity (genes, species, habitats) requires both scientific thinking and translation of concepts useful for application. A dialogue between end users (e.g. the EEA, the CEC and national monitoring agencies) and the researchers as to what both parties require and deliver is therefore urgently needed.

~ The interest for and the funding of marine biodiversity research lags behind that of terrestrial biodiversity research. One reason for this is that the problems are not well inventoried and recognized. There is not enough discussion between terrestrial and marine scientists. A much better dialogue is required so that both parties understand each other's problems and learn from each other's approaches.

The E-conference was organized to discuss the bottlenecks and their solutions in producing relevant knowledge and the implementation of this knowledge in policy, management and conservation; therefore contributing to the development of a platform for (marine) biodiversity research in Europe.

The three themes

The E-conference consisted of three main discussion themes (fora), which were discussed in three subsequent weeks:

Theme 1. Main issues in marine biodiversity research

European scientists are more and more joining forces in order to study biodiversity patterns in Europe, by sharing logistics and exchanging expertise. The BIOMARE concerted action, based on the Implementation Plan of Marine Biodiversity Research in Europe of the Marine Board, will eventually propose a mechanism to achieve at least the large-scale and hopefully the long-term research as well. Its implementation will require a vast effort of the marine community in Europe. This can only be achieved if a sense of purpose and an agreement on the main scientific issues is created. Although a number of documents are now in the making, especially the ESF Marine Science Plan, the definition and solution of the main issues and special problems in marine biodiversity research require this concertation.

Some topics that were discussed are:

- What are the large-scale patterns of marine biodiversity in Europe?
- What are the ecosystem engineers and key species?
- What is the function of biodiversity in biogeochemical cycling and ecosystem functioning?
- What are the links between taxonomic and functional biodiversity?
- What is the role of species redundancy?
- What is the importance of life cycles in the evaluation of biodiversity?
- What are the differences between marine, freshwater and terrestrial ecosystems?

Theme 2. Implementation and application of biodiversity research

Undoubtedly, biodiversity has become a hot political item. One of the major problems in implementing research on marine biodiversity appears to be the changing concepts of what biodiversity really involves. The term seems to be used in different contexts: in the UN framework biodiversity is treated as a resource that has economic value. To most biologists biodiversity means species diversity, but in UN language it involves the total of genetic, species and habitat diversity.

M@RBLE was set up to discuss what the term ‘biodiversity’ means for the different stakeholders in the marine biodiversity issue in Europe, what information science can provide and how that relates to the format and kind of information the end users need from the researcher providing the knowledge.

Part of the discussion involved the tools that are required for applying biodiversity science in issues such as marine conservation. The first occasion where the results from M@RBLE could already be discussed in such a forum is the meeting of the European Platform for Biodiversity Research Strategy on the Scientific tools for in situ biodiversity conservation (monitoring, modelling and experiments), which is organized by the Belgian EU presidency in Brussels on 2-4 December 2001.

Some other discussion items were:

- Is 'Biodiversity' a scientific concept, or a political issue? If the latter, what are the right scientific concepts to use in the biodiversity debate?
- A debate between the producers of biodiversity related information (marine biologists) and the end users (experts involved in policy making, management, conservation, fishery etc).
    - What kind of information do the end users need?
    - What are the bottlenecks for the production of the required information?
- What kind of tools can the research community and the agencies responsible for monitoring and managing European waters provide for the implementation of large-scale and long-term biomonitoring?
- Information systems in marine biodiversity research

Theme 3. The future of marine biodiversity research

In general, research is not doing well. Europe is not only investing less and less of its resources in progress of knowledge, the image that Europeans have of science is also less positive than it was. Scientific progress seems to inspire as much anguish as hope, and the gap between the scientific world and the people at large is growing. Environmental problems appear to be less high on the public agenda than they used to be. On the other hand, the interest in nature and in the sea is still very high. The sense of excitement and discovery that marine biodiversity can provide must be fed by scientists as much as possible through to journalists and television shows, and increasingly to the Internet. Marine biodiversity research can and should be interesting and attractive to the public and thus to politicians but it must make much better use of the media and the web.

Within the political framework, the recognition that marine biodiversity research serves a purpose is growing but still weak. The point that the seas are not the land and that many biodiversity problems are specific for the marine environment has until now not been made clearly enough. However, marine biodiversity has good visibility in the Marine Science Plan of the European Science Foundation and this now requires translation into the mechanisms that the EU is developing for supporting marine research in the EU in the coming new framework programme. We believe that marine sciences in general and marine biodiversity in particular are ideally suited to make good use of the new opportunities arising within the

European Research Area now being constructed, and that the kind of outline and synthesis that the e-conference can provide will be very useful for that purpose.

But we must also look outside Europe. A world-wide networking of biodiversity research, involving MARS in Europe, NAML in the US, DIWPA in Asia can perhaps be organized through the DIVERSITAS programme or through the Census of Marine Life, an US initiative that is now being expanded to include other parts of the world. There is already a good bilateral relationship between MARS and NAML and transatlantic cooperation in science may be supported within the new framework programme.

ORGANIZATION AND STATISTICS

Edward Vanden Berghe

Flanders Marine Institute (VLIZ), Victorialaan 3, B-8400 Oostende, Belgium

The conference was organized as a moderated bulletin board. Both the introduction to the themes and topics, and summaries of the discussions, were available on the Internet, (www.vliz.be/marble). Contributions to the conference were posted through a form on the web site. Contributions by non-moderators were only posted after approval of the moderator. For this purpose, the moderators had access to a separate form, which allowed editing or deletion of messages.

Three separate themes, as presented in the previous chapter, were discussed in consecutive sessions of one week each. A chair and provocateur were appointed to each discussion item. The chair was responsible to open the discussion, and to provide summaries of the discussions at regular intervals. They were also responsible to provide a general summary and synthesis of the discussion at the end of the week. These were posted on the web and also reproduced here. The provocateurs were responsible to keep the discussion lively. Begin- and end date, chairpeople and provocateurs were as follows:

- theme 1 main issues in marine biodiversity research
    - § date: 8-12 October 2001
    - § chair: Carlos Duarte, Universitat de les Illes Balears, Instituto Mediterraneo de Estudios Avanzados, Spain
    - § provocateur: Richard Warwick, Plymouth Marine Laboratory
- theme 2 implementation and application of biodiversity research in management, conservation and science
    - § date: 15-19 October 2001
    - § chair: Mark Costello, Ecoserve, Ireland
    - § provocateur: John Gray, University of Oslo, Biological Institute, Norway
- theme 3 the future of marine biodiversity research
    - § date: 22-26 October 2001
    - § chair: Ricardo Santos, University of the Azores, Department of Oceanography and Fisheries, Portugal
    - § provocateur: Magda Vincx, University Ghent, Section Marine Biology, Belgium

The basic flow of information of the conference was through the WWW. This was done to stimulate 'external' parties to participate in the discussion. To make sure the conference was widely known, mailing lists of several organizations and activities were used to invite all interested parties to register. Access to the general pages of the conference, and to the summaries, was open to everyone. To be able to post messages and also to view posted messages, registration through a form on the web site was needed. Requests for registration were handled individually;

applicants were informed of successful registration in an e-mail. On the registration form, participants could choose to receive the summaries of the discussions, as drafted by the chairpeople, by e-mail. This was done by the vast majority of the participants.

Halfway through the conference, an evaluation was organized. All participants who agreed to receive e-mail from the conference were invited to answer a questionnaire; the number of questionnaires returned does not warrant an extensive analysis. A number of relevant conclusions could be drawn, however.

Some participants preferred to use e-mail, rather than the WWW, as a means of communication; the majority of the respondents preferred the way m@rble was organized. The ideal solution would consist of a combined system, where contributions submitted through e-mail would be incorporated in the web site by the conference moderators.

The fact that registration was required, and a password entered whenever one wanted to read or write messages on the web site, created a threshold for participation. This was a factor that stopped at least some people from participating.

The themes of the conference, and the discussion topics within the themes, were appreciated by the participants; no new topics were suggested in response to the questionnaire.

Statistics

Registered participants: 328
Number of countries: 36
Participants requesting summaries through e-mail: 321
Number of messages: 201
Number of contributors: 39
Hits on M@rble web site: 30,735 (to 6/11/2001)
  Hits on /cgi-bin/marble.exe: 15,387
  Hits on /Marble: 15,348, or approximately 5,100 html pages
    Total number of pages requested: approximately 20,487
  Distinct hosts served: approximately 1,200

Summaries

Summary theme 1

MAIN ISSUES IN MARINE BIODIVERSITY RESEARCH

Chairman: Carlos Duarte

Provocateur: Richard Warwick

MAIN ISSUES IN MARINE BIODIVERSITY RESEARCH

Carlos Duarte

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European scientists are more and more joining forces in order to study biodiversity patterns in Europe, by sharing logistics and exchanging expertise. The BIOMARE concerted action, based on the Implementation Plan of Marine Biodiversity Research in Europe of the Marine Board, will eventually propose a mechanism to achieve at least the large-scale and hopefully the long-term research as well. Its implementation will require a vast effort of the marine community in Europe. This can only be achieved if a sense of purpose and an agreement on the main scientific issues is created. Although a number of documents are now in the making, especially the ESF Marine Science Plan, the definition and solution of the main issues and special problems in marine biodiversity research require this concertation.

1. Large-scale patterns of marine biodiversity

What are the large-scale patterns of marine biodiversity in Europe?

Global patterns on species diversity have already been elucidated, such as clear cline of increasing species richness from Arctic to ca 20oN, and the fact that tropics are not necessarily richest. The pattern in the southern hemisphere is far less clear as we have relatively little data. There is also little doubt that Indonesia has the highest species richness with radial declines from there, but there are 'hot-spots' of high richness that occur elsewhere and need explanation. Yet, we are lacking comparable patterns within basins or sub-basins. The reason for that is that the differences are not as great as those present globally, requiring, therefore, high precision data to resolve them. Examinations at such large scales likely account for only a small fraction of the variance in biodiversity, so that examinations must resolve a variety of scales. Whereas large-scale patterns may be considered quasi-static, those at smaller scales are subject to temporal changes. Coastal areas may also show distinct large-scale patterns.

Evolutionary patterns in marine biodiversity are only evident at the largest scales, for these patterns are blurred by dispersal events (only a few extreme events may be sufficient to lead to established populations), so that within the biogeographic provinces patterns seem to correlate with environmental variability. The potential of analyses of large databases derived from existing sources to ascertain these correlations should be explored, although the patterns may be confounded by inter-calibration problems. These are ever more important as the capacities to professionally identify specimens become more rare. Perhaps technological tools may help to assist identification for some taxa. The myriad of metrics used to quantify beta diversity makes comparisons amongst studies cumbersome. Standard, agreed metrics must be devised is comparative analyses between estimates derived in different studies are to be used. This requires, most likely, an exercise to examine the extent of redundancy between metrics and to explore the statistical behaviour of the different metrics. The close relationship between species richness and effort also implies that, with the current rate of description, robust large-scale patterns would require considerable effort.

The elucidation of large-scale patterns of marine biodiversity requires a proper appreciation of the relevant sampling scales and the samples required to adequately represent marine biodiversity at any one site. Adequate representation of sampling scales, including very large scales as to unravel patterns derived from evolutionary processes from those reflecting shorter-term processes, such as disturbance. The appropriate grain or scale of efforts to elucidate large-scale patterns must be determined, and this may differ across taxa. Exploratory analyses of the scale-dependence of marine biodiversity, across the broadest possible range of scales, is necessary as a support to plan and interpret further research.

The search for patterns on global marine biodiversity will be challenged by an uneven capacity to elucidate species membership across taxa. In addition, estimates of biodiversity, as species richness, are dependent on effort. Approaches that reflect taxonomic breadth or relatedness of species, seem to be better for broad-scale geographical comparisons than absolute estimates of species richness.

Provided these limitations, efforts to establish large-scale patterns in marine biodiversity must be operational, and the desire to describe synoptic large-scale patterns for all of marine biodiversity seems still a distant goal. The use of functional groups may prove convenient. The relationship between species richness and the functional diversity of communities need to be examined, as also stressed elsewhere in the discussion.

Taxonomic distinctness may be difficult to compare across taxonomically heterogeneous groups. These limitations can be circumvented if we use a consistent taxonomy in each case.

In addition, effort to establish large-scale patterns should be driven by the formulation, and testing, of a priori expectations on the drivers of large-scale patterns (e.g. the existence of biogeographic boundaries, strong, permanent water fronts as barriers for dispersal, etc.), which could then be tested on a range of organizmal groups. This approach will be complementary to a strictly explorative one. Availability of suitable habitat is an important control on biodiversity, which may confound other existing patterns. This suggests that it ought to be, therefore, simpler to find large-scale patterns in the distribution of planktonic organizms. For instance, macrozooplankton has distinct latitudinal patterns of species richness, and, unlike benthos patterns, they are rarely endemic of high latitude provinces, although high latitude endemism is more frequent in the southern than in the northern latitudes.

The concerted action BIOMARE has proposed a pragmatic approach towards the elucidation of large-scale patterns in European marine biodiversity that may inspire additional efforts elsewhere. A set of Primary Reference sites throughout Europe has been proposed to establish comprehensive All-Taxon Biodiversity Inventories (ATBIs), which might enable us to calibrate the relationship between overall biodiversity and the diversity of key taxa or biodiversity indicators. Using these biodiversity 'surrogates' or 'indicators', we may then be able to establish patterns of biodiversity on a finer spatial scale at a larger number of reference sites. This initiative is an important step forward to render a complex question operational: by selecting protected areas as the target there may be hope to separate the 'background' large-scale patterns of large-scale biodiversity from effects derived from local anthropogenic forcing. Once the 'pristine' (i.e. as pristine as possible) conditions have been described we may investigate how these may have been affected by 'point source' anthropogenic effects.

2. Biogeochemical cycling and ecosystem functioning

What is the function of biodiversity in biogeochemical cycling and ecosystem functioning?

The evaluation of the relationship between biodiversity and ecosystem function and biogeochemical cycling has proved cumbersome. What communities would be most convenient as subjects to test this notion? Planktonic communities, where synthetic communities can be easily constructed from cultured organizms, may be ideal for 'species addition' experiments, whereas benthic communities may be most convenient for 'species removal' experiments. Meiobenthic assemblages in sediments may be good candidates to test the relationship between biodiversity and ecosystem functioning, since natural assemblages are much easier to maintain in replicated manipulative microcosm experiments in the laboratory than planktonic or macrobenthic assemblages.

Field experiments are complementary of (replicated) laboratory experiments carried out on experimental (or manipulated) communities. The respective advantages and drawbacks of field and laboratory experiments are well-known and this is probably not the place to have this discussion once again. Laboratory experiments are definitely needed in order to unravel the relationships between diversity and ecosystem functioning. However, in this particular context, and due to numerous and complex interactions between compartments, we should consider problems associated to the time scale of our experiments. In other words, what is the exact meaning of manipulating a community to quasi immediately measure one of its functions? Should not we let this 'new community' reach a new equilibrium before carrying out experiments? Do we presently have the experimental infrastructure to do that? If not this should probably be one of our first priorities.

In this context, field experiments may constitute a sound complementary approach provided that 'confounding factors' are reduced. This is probably the case if strong heterogeneity in the composition of the community occurs at small spatial scale. There are cases of such communities for the macrobenthos.

Besides experimental ecology, there is also natural history. And historians do not make experiments. Ecology is a historical science. I concur that in ecology it is possible to perform experiments because it is ethically sound. Bin Laden, if it's him who made it, made a historical experiment, perturbing a system, he made predictions too. But he is not a historian, he is like the hurricane disturbing the coral reef. So, yes, we ecologists can perform experiments in our historical systems, but very small ones. Little questions with little answers. What about the rest? Nothing, because it cannot be tested?

Trophic interactions between organizms, which are sometimes highly species specific (e.g. parasites such as virus), are strong determinants of the fate of populations and, thereby, bulk biogeochemical fluxes. Trophic interactions among organizms explain blooms and population outbreaks, which have been reported to have major effects on both benthic (e.g. sea urchin-kelps) and planktonic (virus-bacteria) populations. Moreover, these trophic interactions, as represented in simple models using Lotka-Volterra-like expressions to link highly selective and less-selective predation with the competitive ability of yield linkages between biogeochemical cycles and diversity than are normally ignored in the literature.

Biofilms and microbial mats are old relicts where biodiversity and biogeochemical diversity are confined within a thin layer. They can be good models to study the link between biodiversity and biogeochemical functioning. Biogeochemical processes are the result of species' activity, and, in particular, bacterial activity. Yet, our understanding of the responses of bacterial biodiversity to perturbation is rather meagre. Yet, particular bacterial groups are responsible for very specific functions in biogeochemical cycling of the elements.

Which functional parameters should we use? One of the main difficulties in relating biodiversity and ecosystem function relies in the fact that both of these parameters are resulting from a great number of complex interactions. Therefore, it is quite unlikely that the relationships between these two kinds of parameters will be simple. An alternative sound approach consists in focussing on function carried out at the level of functional groups (e.g. particle filtration for suspension feeders.....).

Are biogeochemical cycles disconnected from food webs and from life cycles?

These topics are studied by different people in a very reductionist way. Isn't it time to build complex theories putting things together? Is mathematics the formal language of complex systems? Isn't it that such issues are not tackled because the number of variables makes them intractable from a mathematical and an experimental point of view? After having split ecological systems in a myriad of sub units, isn't it time to start to put them together and find a conceptual continuity linking all these disconnected pieces? Ecology is the science of interaction, we tend to forget it for ease of analysis. Reductionism is all right only if it is followed by a synthesis.

3. Taxonomic and functional biodiversity

What are the links between taxonomic and functional biodiversity?

The study of biodiversity is very interesting, not only for the biodiversity itself. It is very interesting both as natural phenomenon influencing the activity of ecosystems, and as a consequence of ecosystem function. The assessment of the link between biodiversity and stability is a difficult one, and needs to be challenged using perturbation experiments.

Are rare species only rare at some spatial or temporal scales but ready to become abundant as the environment changes? Can a currently rare species be a potential key species in the future?

Recent terrestrial and a few marine data sets show a linear relationship between local scale and regional scale species richness. Local species richness is likely to vary from place to place within the region depending on environmental conditions (both natural and anthropogenic), which must add noise to the possible relationship to regional relationship. The investigation of such patterns is fundamental to our understanding of how species richness is controlled. If this is the case, however, the use of species richness as an indicator of local environmental degradation may be difficult.

4. Species redundancy

Is there species redundancy? If so, what is its role?

Species redundancy is an old topic in plankton ecology (i.e. the plankton paradox), which was resolved by invoking non-equilibrium conditions to account for the co-existence of species with similar resource requirements. While the presence of 'functionally redundant' species can be explained, the question as to how much biodiversity can be lost before any effects on ecosystem functions is detected is still unresolved, both for marine ecology as for terrestrial ecosystems, where the experimental demonstration of a link between species diversity and ecosystem functions has proved elusive.

Functional redundancy cannot be readily tested. The concept of functional redundancy implies a near-perfect functional match in all relevant functions. This is impossible to test, since it can be always argued that there may be important functions that were missed by any one test.

The issue of 'functional redundancy' in animals that feed on particles (as opposed to phytoplankton that absorb nutrients in solution) is problematic. Just because there are several deposit-feeders present in a community does not mean that they are competing for resources or that there is functional redundancy. Most smaller species, at least, are very selective about what they eat.

To what extent do apparently redundant species contribute to the resistance and resilience of ecosystem functions to change and disturbance?

There are questions on this topic that can be addressed using planktonic organizms, such as shifts in the relative abundance of silicifiers versus calcifiers in ecological and geological time scales. Diatoms are large, tough, highly diverse and well suited to (physical) disturbance (mixing); coccolithophores are, on the other hand, small, and only outnumber diatoms in conditions of stability (stratified waters). Also, these organizms are available in the geological record (silicate/calcium carbonate sediments seem to be associated with glacial/interglacial periods). In this sense, we may argue that these may be good model organizms to elucidate questions such as (1) why are some marine (phytoplankton) groups more diverse than others in the modern oceans; and (2) how can we explain the lower degree of (genetic) diversity in freshwater ecosystems compared to marine ecosystems (diatom scenario)?

5. Life cycles

What is the importance of life cycles in the evaluation of biodiversity?

What is the relative importance of the dispersal (e.g. planktonic larval stages) vs. adult stages in determining the large-scale biodiversity patterns of sessile organizms?

What is the contribution of settling diversity to community diversity?

There is no evidence that benthic assemblages dominated by species with planktonic larval stages are any more or less diverse than those with direct development. There may also be a feedback between the diversity of the community and that of settlers.

6. Comparison with freshwater and terrestrial ecosystems

What are the differences between marine, freshwater and terrestrial ecosystems?

Are large-scale patterns in marine biodiversity driven by similar gradients (elevation-depth, latitude) than those of land and freshwater biota?

Freshwater habitats are clearly more ephemeral (except deep lakes as Baikal etc.) than marine habitats, so isolation processes and species turnover in freshwater biogeographic regions may be expected to be enhanced compared to the marine.

How does biodiversity change along salinity gradients? There are excellent data-sets that should help find any general patterns that may exist.

7. Rate of recovery following disturbance

What are the rates of biodiversity recovery following disturbance? What role does biodiversity has in setting recovery rates?

Establishing rates of biodiversity recovery is a key goal. There may be sufficient data as to conduct a meta-analysis for some particular taxa, however, it is difficult to standardise the disturbances as to render the recovery rates comparable. Patterns of recovery in macrobenthic communities are well established. In contrast, at local scales, rates of recovery seem to be much more variable and depend on e.g. hydrography, season, extent and nature of disturbance.

Are we able to predict rates of recovery?

Examination of case studies suggests that there may be no general answer to these questions. The decline of biodiversity following disturbances caused by physical disruption, pollution, over-fishing and introduction of exotic species differ in their mechanisms, and so will the possible recovery, taking into account differing spatial and temporal scales. There is an urgent need to establish the 'point of no return' for those disturbances in different communities - when is the change too extensive for a turnaround.

8. Ecosystem engineers and key species

What are the ecosystem engineers and key species?

The concept of keystone species is identical with intermediate disturbance. These concepts are probably important to understand species roles, but cannot be used to decide priorities in conservation. Advice to manage biodiversity may be premature before we have solid scientific evidence to base our advice upon. Engineer species modify habitat conditions and, therefore, possibly the pool of species to be encountered therein. These effects may be either positive or negative, but it is clear that such species (e.g. mangroves, seagrasses, kelps, some corals, etc.) hold a prominent position on the biotic control of biodiversity, and their loss or appearance may lead to important – albeit still poorly understood – changes. There should be particular targets for management once these interactions are understood

A link between species richness and stability has been assumed for decades, but there is no robust evidence, and it is yet to be demonstrated. This should be one of the main questions to address experimentally (comparative analyses are much to confounded with other co-variates to be useful as a test of the concept).

Do engineer species really have such a prominent position, or is this merely an artefact of the restricted scales we study? Obviously they often sustain a high species density. But often they take a small area only on a regional (a few 100 km) scale. Therefore, in many species the majority of individuals may be scattered in the surroundings and the 'hot spot' of species richness may not be very important for regional population endurance. So, what happens if an ecosystem engineer is removed? Is there any lasting effect on the other species, or is it readily replaced by formerly rare (possibly outcompeted) species within a few decades (what would appear as a sudden change on an evolutionary time scale). Finally, if the environment changes dramatically, wouldn't conservation of an established engineer prevent natural succession?

Humans can also be considered as engineer species in coastal ecosystems. Do artificial structures enhance coastal biodiversity? The public rarely has a ‘direct view’ of marine species richness, except for habitats such as coral reefs and shallow rocky reefs. As a consequence there is a tendency by coastal managers to ‘enhance the quality’ of coastal habitats by using artificial structures. Artificial structures are also claimed to contribute to habitat conservation and restoration. This human activity often acts at large spatial scales on a very short temporal scale. Moreover, if little is known about species engineers, often acting at a very slow rate, even less is known about questions such as: ‘What are the effects of artificial structures on coastal ecosystems?’ ‘How do they affect biodiversity?’ Deployment of artificial substrata on coastal sandy bottoms obviously increases the number of species in the area and makes it more ‘economically valuable’. However, alterations of ecosystem functioning (e.g. trophic webs, energy fluxes etc.) and of the abiotic features (e.g. hydrodynamic regimes, sedimentation rates etc.) need a careful assessment before planning the creation of artificial rocky islands.

Whereas preserving ecosystem engineer species would preserve species that are of ecological importance, species that contribute most to preserving the evolutionary history of a taxonomic group need particular attention too. Species that diverge close to the base of a phylogenetic or taxonomic tree and have few close relatives will preserve more evolutionary history than those that diverge further up and have more congeners. There is quite a big literature on the use of taxonomic distinctiveness in the selection of species for conservation, but little evidence for its application in practice.

9. Non-equilibrium conditions

The larger the spatial scale, the more we may expect diversity to be a reflection of the steady-state conditions. So, what is the spatial scale of a 'particular marine community' (respectively, the spatial scale we should use in a study on diversity)?

There may be an inverse relationship between disturbance frequency and spatial scale, which may support the proposed likelihood that large-scale patterns reflect some sort of steady-state, or average, conditions, whereas local biodiversity patterns may more often reflect non-equilibrium situations.

Summary theme 2

IMPLEMENTATION AND APPLICATION OF BIODIVERSITY RESEARCH IN MANAGEMENT, CONSERVATION AND SCIENCE

Chairman: Mark Costello

Provocateur: John Gray

IMPLEMENTATION AND APPLICATION OF BIODIVERSITY RESEARCH IN MANAGEMENT, CONSERVATION AND SCIENCE

Mark Costello

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The discussion during week two concentrated on how to apply biodiversity science. In contrast to discussions that may have occurred 10 years ago, there was consensus that the Convention on Biological Diversity definition of biodiversity, covering the population (genetic), species and ecosystem levels was a workable concept both politically and scientifically. While 'species' were the most practical measure of biodiversity, its protection and management had to focus on habitats. While, management often worked over larger areas (seascapes) composed of several habitats, ecologists tended to work within habitats. Studying biodiversity now meant that ecologists needed to work at different spatial scales, from seascapes to habitats. The concept of biotopes (a habitat with a reoccurring assemblage of species) was not discussed but it provides a useful approach to combining the species and physical habitat for management purposes.

Rapid habitat and biotope mapping, such as by acoustic surveys, video or scuba diving, was becoming a more established method in marine surveys. Less well established were automated species identification tools, already available for some diatoms and dinoflagellates. Such rapid surveillance methods at the habitat and species level could make biodiversity assessment much more cost effective and provide standardization that facilitates analysis over great spatial and temporal scales. Good taxonomy was an essential part of quality control in all approaches to biodiversity assessment.

Modern taxonomy needs to avail of electronic systems that aid species identification, and disseminate information on species via the internet. A top priority to enable good science and management of biodiversity is to make information on species rapidly accessible via the internet. This would include correct names, descriptions, distribution, ecological and economic information. A global approach is needed here to make best use of the limited expertise in taxonomy. The availability of this information will reduce time wasted by taxonomists and ecologists in checking the literature and giving species the wrong names, and also improve efficiency and quality control in biodiversity science.

The following summary has been written by the session chairman to try and capture the key points raised in discussion. The original messages should be studied to get the full information and exact wording by the contributors.

Summary of discussion on 'Biodiversity: concept or political issues?'

It is possible and appropriate to measure biodiversity at population, species and ecosystem levels. (Filip Volckaert)

Species richness is only one measure and the Convention of Biological Diversity definition of biodiversity is now the most appropriate one to use. (John Gray)

Species lists are a fundamental element of biodiversity measures and biodiversity management, as they are valuable in their own right and characterize the communities, habitats (biotopes) and ecosystems. (Ferdinando Boero)

European Union should learn from the success of the USA National Science Foundation 'PEET' research program, and consider such 'partnerships for the enhancement of taxonomy'. (Ferdinando Boero)

We do not have to determine how many species there are to protect species; rapid mapping of habitats is a first priority as then protecting these habitats will protect biodiversity. (John Gray)

The challenge is how to develop integrated measures of biodiversity; this requires interdisciplinary collaboration (e.g. between ecologists and economists) and some translation centres so information is more accessible to non-scientists in different languages. (Nikolai Shadrin)

Habitats do not tell us enough about biodiversity, so we cannot study, monitor and protect biodiversity without knowing what species are present. (Ferdinando Boero)

Summary discussion on 'Producers versus users of biodiversity information'

Scientists tend to work on local spatial scales but managers on larger ones; how can these sciences be extrapolated to the management units? One way is using 'indicators of ecosystem health'. However, public health is measured from the health of individuals and it may not be possible to measure ecosystems health in the same way. (John Gray)

Marine conservation is slavishly following terrestrial approaches without rethinking what is best for marine systems. (Richard Warwick)

There is a disconnection between biodiversity researchers and resource users; the latter are more concerned with ecosystem health as this affects their resources (quantity and quality). Thus more research into the link between biodiversity and ecosystem health is critical. (Antoine Gremone)

We cannot understand, predict or manage biodiversity if we do not know its components; i.e. what species are there and what are they doing. (Ferdinando Boero)

We should be more concerned with protecting the 97% of the ocean outside protected areas than the 3% within them. (John Gray)

Summary discussion on 'Tools for biomonitoring'

Tracking the long-term genetic makeup of selected marine species, such as invasive species, should assist in understanding the causes of shifts in species distribution patterns. (Filip Volckaert)

Data on biodiversity function (e.g. generation time, growth rate, reproduction rate) should be inventoried and made accessible via databases to modelers. (Wulf Greve)

An EU (MAST3) project (ADIAC) has developed rapid automated computerized methods to identify diatoms. Such tools could be developed for at least other phytoplankton that can be slide mounted (Hans du Buf); and a system is available for dinoflagellates (DiCANN) (Phil Culverhouse)

Automated tools for taxonomy are the way to go in the future – faster and more consistent than people (Phil Culverhouse), and the EU must fund this work (Hans du Buf). For further reading see report on 'Workshop on automatic categorisation of marine biological material for ecosystem research and monitoring (1996)' available at http://newlyn.cis.plym.ac.uk/dicann/papers/vigo.pdf

Notable monitoring approaches include long-term photographic surveys and the Continuous Plankton Recorder. We cannot monitor genetics directly but we can monitor populations and species distributions as a surrogate. (Ferdinando Boero)

Computerized identification systems can help taxonomy, and free up experts time for other research (Hans du Buf)

Bathymetric and acoustic surveys can predict benthic habitats and from there, biotope distribution and diversity. (Carlo Franzosini)

One USA group has automated field instruments that can identify species, and European researchers could also develop such tools. (Phil Culverhouse)

Species lists and habitat mapping are just the foundation of information for biodiversity management. Information systems need to include human impacts on species, trophic relationships, physio-chemical limits, etc. (Bill Trusewich)

Summary discussion on 'Information systems in marine biodiversity research'

We urgently need databases with all published species information in order to make progress in biological research. Another priority is the need to develop electronic tools for describing unknown species. (Magda Vincx)

Databases of biodiversity knowledge (taxonomic, molecular, etc.), and access to distributed databases must be priorities. (Alexey Zapevlin)

Many databases will disappear with their creators. We need a global approach to species information systems. (Tim Deprez)

Bibliographies are the building block of knowledge, including taxonomy and systematics. Species descriptions, especially from old and obscure journals, need to be made available on-line (Ferdinando Boero). It is remarkable that there is not more effort in this area. (Edward Vanden Berghe)

A single system is unlikely to be possible but it may not be necessary. Most effort is in data entering and quality assurance. What is needed is more communication between people, and interoperability between databases. (Edward Vanden Berghe)

Summary theme 3

THE FUTURE OF MARINE BIODIVERSITY RESEARCH

Chairman: Ricardo Santos

Provocateur: Magda Vincx

THE FUTURE OF MARINE BIODIVERSITY RESEARCH

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Topic 1 - Disseminating information beyond the scientific community

Marine biodiversity research can and should be interesting and attractive to the public and thus to politicians. Dissemination, education, interpretation for the general public and the media was a major issue for the participants of the forum. Quality and intelligibility of the information was of foremost concern.

It was discussed how deep the scientists should be involved in dissemination in contrast to leave these tasks to specialised organizations. Who should lead the process? Either one way or the other it was unanimously recognized that dissemination and education should be part of any research project dealing with marine biodiversity, and it was probably better that the projects associated organizations particularly devoted to these matters. There was a general agreement that good dissemination may help funding good science. Thus education, dissemination, extension of science for a wider public, but principally for school children, should be included for funding when projects are submitted, either at European or national levels. This should be considered part of science as well. Research on marine biodiversity needs special organizations that help with the translation of science to a broader public and to the science policy (and thus the politicians). Scientists can collaborate with these organizations. If a research project is EU funded, scientists may claim for a budget for such activities. Proposers may include professional science communicators as partners within the project, who do more than just produce web pages (which is not 'disseminating' results).

The historical role of the museums and aquaria was recognized. The importance of high standard TV series, like The Blue Planet was referred to as enabling the creation of very favourable momentums that may help raise the interest of the public in relation to marine biodiversity, including research. Some programs and/or institutions were identified as good examples to follow.

Topic 2 - Marine biodiversity and the EU and ESF

Marine biodiversity has good visibility in the Marine Science Plan of the European Science Foundation. This now requires translation into the mechanisms that the EU and ESF are developing for supporting marine research in the EU in the coming new framework programme.

The role of the ESF and the diverse programs running, like Diversitas, seem to be lacking of funding to launch effective research. It was pointed out that there is a need to identify potential sources of funding for marine biodiversity research.

Participants were aware of the importance and favour trans-European efforts of integration of marine biodiversity research. The PEET USA program was referred to.

It was recognized that the main source of funding is still through central Government (National, EU, ESF etc). The trouble is that these are political and tend to take a short-term attitude to funding. Research on marine biodiversity needs long-term programmes.

The other area of funding that has to be tapped is industry. Industry is after all one of the causes of loss of biodiversity and habitat degradation. Participants have recognized that, in general, getting funds out of industry is hard work and often not very rewarding, but it should be a goal to reach. Industry is a user of natural resources. Industry should be constrained to fund monitoring and research of the same subjects (genes, species, ecosystems, etc.) they make use of. Any activity that, directly or indirectly, has impact on the natural world should have associated specific economic instruments (i.e. specific funds) applied to scientific research. Any utilisation of natural resources should have associated economic instruments to fund the monitoring and research towards conservation and sustainability.

The prime objective should be to create a system in which the best science is funded. Marine biodiversity research should not simply be aimed at supporting something like the Habitats Directive but at actually finding out what 'biodiversity' means in terms of the way the marine system operates - going all the way back to Odum's paradigm if necessary.

Finally, several participants at the forum have raised the question that scientists are spending (= loosing) to many hours preparing paper documents (e.g. statements, proposals, reports) without an equivalent effect on funding.

Topic 3 - Integration beyond Europe

Should Marine Biodiversity Research in Europe focus on European seas only, or should this research be more ambitious and global? What should be the strategic investments? What should be the strategic links to be created in view to develop marine biodiversity research in Europe and beyond Europe?

Participants favoured enhanced contact between existing networks of biodiversity. It was also found that it is important to integrate research at all levels. Networks should involve deep sea, pelagic and coastal marine biodiversity.

At another level, PEET (Partnership for the Enhancement of Expertise in Taxonomy) was again referred to. Europe should strengthen links with PEET, thus developing a global network.

At the same time it was considered to be a fatal mistake to invest now on creating something totally new like a large European biodiversity institute. This could result in most of the money being wasted to build up new infrastructure, with an obvious danger that the new positions will be filled, not with scientist producing new data on basic biodiversity (= taxonomy), but with bio-politicians and bureaucrats 'filling new containers with old wine'.

A question was put forward: should European biodiversity research solely be confined to Europe? Countries and their scientific resources have a responsibility for studying and conserving biodiversity all over the globe. Most European countries have polar research projects, but why not a concentrated European initiative on tropical biodiversity? There are few developed countries in the tropics and we need data and studies on critical areas such as Indonesia and not least S. America. What are the patterns of biodiversity there? Europe should be engaged in global marine biodiversity research as the US is.

Topic 4 - Restoration, preservation, discovery and strategic hotspots for marine biodiversity research

What is left of marine biodiversity in Europe? Will the future of research be more dedicated to restoration of habitats and of lost biodiversity or to the preservation of pristine habitats and associated biodiversity? What should be the balance for research?

Monitoring biodiversity in all levels and identifying long-term succession series of species is an important topic in the follow-up of restoration and preservation of ecosystems. Marine scientists have to be aware in the first place that restoration and/or preservation of marine biodiversity will be the result of a very complex set-up of marine management for sustainable development. Marine scientists should put priorities about conservation aims. The value of nature should be above the economic status of our planet. Conservation of pristine environments (in Europe as well as in other parts of the world) has to be a major concern where people should be prepared to spend some time and energy for. It has a lot to do with respect for nature, environment, heredity, and other moral values. People have to be aware that destroying nature (i.e. not preserving the biodiversity of our planet) is destroying themselves. Pristineness should not be the only criterion in selecting sites of particular interest. Monitoring and experimental approaches on those systems which have shown important recent changes may indeed provide valuable information regarding consequences of changes in biodiversity.

On the taxing of the economic value of the environment, including the marine environment, important scientific progress has been made. To deal with nature in this way, represents definitely a language understood by administrators, managers, politicians, economists, lawyers and the like.

The sorts of wealth protection that business people might understand are the value of nature dealing with sewage effluent, discharges of contaminants, coastal defences etc. The value of undiscovered drugs and genetic material is of course high and is already appreciated. People also do value undisturbed nature. So it is possible to start getting a handle on biodiversity not at the species level but rather at the habitat level. So perhaps there is a need to focus on habitats and their value.

General conclusions

OVERALL SUMMARY OF THE M@RBLE CONFERENCE

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Marine ecological biodiversity research is a scientific field with few observational data to support a weak theory largely borrowed from terrestrial ecology and lacking in experimental verification. The lack of scientific interest and effort until recently was a consequence of the general feeling that marine biodiversity is far less threatened than terrestrial biodiversity. This view is not sustainable. There is now ample evidence of widespread changes in most coastal habitats in populated areas around the world (coral reefs, mangroves, seagrass fields, intertidal rocky shores and subtidal sediments on the continental shelf and margin) due to exploitation of marine resources, introduction of exotic species and the increased pressure from mariculture and fisheries. The sustainable exploitation of the seas requires development of a sound theoretical framework for marine biodiversity, including genetic, species and habitat diversity and especially the relationships between them. At the present state of knowledge such a general theory is still far from being reality. Developing a sound theoretical framework underpinning the management of marine resources requires scientific networking and cooperation beyond the classical ways in which biologists are doing research.

What are the priorities? Surprisingly, even some of the basic facts are not known. Large-scale patterns of biodiversity are inferred from what is known from land and the concept of biodiversity hotspots is now emerging in marine studies as well, but they have not really been identified for Europe. Within basins, even within the entire western Mediterranean or northern Atlantic, the differences between regions are not so clear. Evolutionary patterns are only evident at the largest scales and seem to correlate with environmental variability within regions. Patterns must be studied at a variety of scales, within and between habitats, regions and basins and studies must be based on agreed and standardised methodology. Efforts such as the EC Concerted Action BIOMARE are necessary to prepare for the study of large-scale patterns and a lot of logistic problems need overcoming.

Another problem is the lack of taxonomic knowledge and expertise. Complete species inventories do not exist for any area in Europe, but for some areas there is more information than for any other area in the world. A recent EC funded network of over 170 scientists listed almost 30,000 species from European seas in the European Register of Marine Species ERMS. Despite a long history of research in Europe, the rate of discovery of marine species still shows no sign of decreasing. An inventory of micro-organizms can only now be made for the first time. A major challenge for the near future will be to synthesise all this knowledge, make it available to the policy makers and the public alike, requiring a major effort in bio-informatics.

A further step must be to elucidate the role of biodiversity in ecosystem functioning. Experiments in the marine environment are altogether very difficult and expensive, except for some easily accessible habitats, which can be reached on foot or by diving. Nevertheless field experiments remain an essential tool in scientific research. Mesocosms, when carefully handled, are an intermediate step between the field and the laboratory. But experiments only improve our knowledge on small parts of the systems and there is a clear lack of a synthetic theory. In the near future a comparative approach in which key species or functional groups are studied in different habitats may provide better insight in the link between species and biogeochemical processes. But the concept of key species itself needs careful scrutiny before it can be applied in conservation issues.

The third step in developing scientific theory is good models that can be applied in assessments of changing biodiversity and its causes. Classical ecological theory has concentrated on describing and predicting species interactions but it is unclear whether species richness in any one area depends on these interactions or is a consequence of the local and regional physico-chemical environment. Models also require boiling down biodiversity to a restricted number of tractable units and should involve adaptation and the evolutionary constraints on species in order to represent better the biological features of marine ecosystems.

There are thus clearly a number of major problems in developing a theory of marine biodiversity, which can only be solved by making the field attractive for researchers. This is even more true when we consider that the definition of biodiversity used in policy making also involves genetic and habitat diversity. The links between the three components have been subject of research for many decades but not within this context and not in an overall picture.

Many scientists in the past have dismissed the political biodiversity concept as a non-concept scientifically, which would then require translation of scientific concepts to policy making and vice versa. The same is true for the concept of ecosystem health, which is widely used in policy making and still needs scientific underpinning as well. There remains a gulf between academics concerned with the development of biodiversity theory and those concerned with the practice of marine conservation: this gulf needs to be bridged. Within M@rble, most participants were convinced that the Biodiversity Convention is the right framework for both the politics and the science and that most of the application of marine biodiversity science would be within the convention. There are however other conventions, such as the Barcelona, Oslo and Paris conventions, and the different regulations of fisheries, mariculture and shipping that also require biodiversity information. Species are the focus and also one of the most practical measures of biodiversity but their conservation requires a knowledge of genetics on the one hand and habitats on the other. Ecological research as well will increasingly require inter-habitat comparisons. One major obstacle is the technology required for studying larger scales rapidly and economically. The technology for mapping the sea floor has greatly expanded over the last decade but is still not used enough in scientific research. Image analysis and flow cytometry can provide methods for rapid determination and another top priority is to make information on species identification available through the Internet. Species lists and taxonomic keys do exist for many areas and recently efforts to bring them together have been made, but much more needs to be done.

It is clear that marine biodiversity research is urgently needed to get the facts right, to understand them and put them in context and to use them for solving many problems concerning the protection of the marine environment and the species that it contains. Moreover, science has an obligation to the public to make the facts known. Dissemination and education should be part of any project as only public support will in the long term assure funding for the research. Internet, television, public aquaria and museums are obvious ways to reach the public but only a concerted effort from the scientific community can make this work. The funding of marine biodiversity research should not necessarily come from public funds only. Industry and private charities may be addressed as well. Major industries (tourism, fisheries, shipping, oil and gas exploitation) make use of the seas and have an impact on biodiversity.

Europe has a great potential for marine biodiversity research. There is a network of marine research stations MARS whose member institutes have studied the marine environment for more than a century and that has long standing relationships with hundreds of university research groups all over Europe. Europe still has a large (though decreasing) taxonomic expertise that should be involved in the overall effort to study better marine biodiversity. Major museums of natural history in Europe also have formed networks that are essential for an integrated study of marine biodiversity. The situation is complex and will require a major initiative for infrastructure development at the European level.

Europe must expand its view and apply its expertise outside the continent and work together with colleagues from the US and Canada (through the NAML network and the Census of Marine Life programme), the Far East and especially connect with scientists and scientific institutions in the tropical regions of the world.

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