The Census of Marine Life pilot project

PATTERNS AND PROCESSES OF THE ECOSYSTEMS OF THE NORTHERN MID-ATLANTIC (MAR-ECO)

Science Plan

CENSUS OF MARINE LIFE

Version of 29 May 2001.

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Executive summary

Despite the wide distribution and extensive area of mid-ocean ridges, few previous investigations have been dedicated to the study of the animal communities inhabiting these characteristic areas of the world ocean. Ridges may have characteristic faunas, but they may also significantly influence the processes affecting the slope and shelf biota such as intercontinental migration and dispersion.

To enhance the understanding of the identity and ecology of mid-ocean ridge communities, a Census of Marine Life pilot project focusing on the ecosystems associated with the Mid-Atlantic Ridge from Iceland to the Azores is proposed. The main aim of the project, now known as MAR-ECO, is ***to describe and understand the patterns of distribution, abundance and trophic relationships of the organisms inhabiting the mid-oceanic North Atlantic, and identify and model ecological processes that cause variability in these patterns.*** The study will focus on pelagic and benthic macrofauna, and utilise innovative methods and up-to-date technology to map distributions, analyse community structure, study life histories, and model trophic relationships.

The study shall be multidisciplinary and international. An initial workshop on the proposal was held in Bergen 12-13 February 2001 at which an early version of this Science Plan was presented and discussed. An international steering group has already been formed with representatives from USA, Germany, the United Kingdom, Iceland, Portugal, France and Norway. Norway, represented by the Institute of Marine Research and the University of Bergen, has taken on secretarial duties for the project.

The MAR-ECO schedule includes an 18-month planning phase in 2001-2003, a field phase in 2003-2005 (with most activity in the first year), an analytical phase in 2004-2008. Data assembled during the project will be incorporated into OBIS, and strategies for reporting and public outreach are being developed. Active linkages to other relevant CoML projects and regional and international research programmes will be given high priority.

Further information and updates will be available on the MAR-ECO website http://www.efan.no/midatlcensus/.

1. Background

1.1. The Census of Marine Life

The Census of Marine Life (CoML) initiative, formalised in 1997, is an international research programme aiming at assessing and explaining the diversity, distribution and abundance of marine organisms throughout the world's oceans. This ambitious overall goal is to be reached by stimulating well-coordinated dedicated regional research efforts that together provide significant new information on patterns and processes of marine life on a global scale.

Within each region, much effort should be focused on poorly known ecosystems and/or communities for which new information would be particularly important to enhance understanding or model formulations. The vast oceanic areas off the continental shelves, and perhaps in particular the communities of mid-oceanic ridges and the mesopelagic zone, satisfy these criteria.

1.1.1 The CoML goals

The goals and feasibility of the challenging idea of CoML has been discussed at length at many well-attended workshops and meetings (see special issue of Oceanography, 12(3), 1999). Although there has been much debate around the detailed goals of the CoML, the initiative has already attracted support from many parties both within and outside the scientific community.

Three questions encapsulate the CoML (Ausubel,1999): What did live in the oceans? What does live in the oceans? What will live in the oceans? A programme to answer these questions would therefore have 3 components:

The first, paleo component would reconstruct the history of marine animal populations for the past 500 years, since human predation became important, based on sediment records and other historical sources. The second component, addressing what now lives in the oceans, would require an intense observational programme, likely to peak around the year 2004. Voyages of discovery to the many parts of the oceans observing fauna with the best available methods and technology are envisaged. The third question implies prediction, so addressing the question ‘what will live in the oceans’ will involve support from modelling of marine ecosystems that would use the new data collected as well as the historic data. A major outcome of the programme would be an on-line three-dimensional geographical information system which would enable researchers or resource managers anywhere to click on a volume of water and bring up data on living marine resources reported in that area.

There is some concensus that the priority in the programme should be directed to macrofauna (Bannister, 1999; Ausubel, 1999), and that the study should collect information at the species level. Based on carefully collected species-specific data on distribution and ecology, aggregate patterns such as species assemblages and functional groups may emerge (McGowan, 1999). Furthermore, the CoML studies should be systems-orientated. This requires close cooperation between biologists spanning a range of fields, physical oceanographers, and technologists. A central aim is to carry out the field sampling and observations using the most modern but well-tested technology both for capturing and observing the fauna.

The strategy of the CoML is to support a series of near-term, relatively brief studies designed to demonstrate the feasibility of new sampling techniques, technologies, and research concepts. These pilot projects will be supported for a brief planning phase followed by 1-2 year field component and a brief synthesis phase for a total of 3-5 years. Several of these studies are already in the planning phase with workshops and other efforts underway to design the sampling plan and identify funding sources.

1.1.2 The Mid-Atlantic Initiative

In the selection of target systems for pilot projects under the CoML, great effort is to be focused on poorly known ecosystems and/or communities for which new information would be particularly important to enhance understanding or model formulations. The vast oceanic areas off the continental shelves and the communities of mid-oceanic ridges and the mesopelagic zone, represent such target systems.

This is even the case in the North Atlantic where, compared with most other waters, the research effort has been extensive for more than a century. A primary target in this area should be the Mid-Atlantic Ridge (MAR) and adjacent deep-sea areas.

On the basis of previous experience from extensive ecosystem programmes in the Barents Sea and the Norwegian Sea as well as from intensive fishery-related research activities in home waters and internationally, Norway offered to take the lead in developing a regional collaborative pilot project focusing on macrofauna of the northern Mid-Atlantic Ridge from Iceland to the Azores. In a concept paper entitled *"Patterns and processes of the ecosystems of the northern mid-Atlantic"* submitted to the Scientific Steering Committee (SSC) of the CoML in February 2000, Bergstad (2000) outlined the goals and phases of such a pilot project. The idea was to attract partners from many countries surrounding the study area, and thereby draw on the region's best available technological and scientific expertise. This collaborative effort would provide the opportunity for technological innovation, scientific discovery and greater understanding of the mid-ocean ecosystem.

The SSC expressed positive interest in this idea and proposed that a regional workshop be organised with the objective of further developing this idea into a pilot project of the Census. The workshop should bring together prospective participants from the region, and the main outcome of the workshop should be a draft science plan for the pilot project suggested. The Institute of Marine Research represented by Bergstad was asked to organise the workshop to be grant-aided by the CoML. A local steering committee was formed, and a workshop convened in Bergen 12-13 February 2001. Some 30 experts from a wide range of fields and countries were invited to the meeting, and the response was very positive.

The over-riding aims of the study in the oceanic North Atlantic are similar to those proposed by the Monterey workshop (Bradley 1999) as general goals of the global Census, i.e. to address the following questions:

1) What is the biomass of the marine biota, especially higher trophic levels, on a regional scale ?
2) How is this biomass distributed spatially, by size, and by taxon ?
3) How are these distributions maintained and changed ?

1.2 The northern Mid-Atlantic Ridge and adjacent ocean

1.2.1 The area

The Mid-Atlantic Ridge (MAR) is the spreading zone between the Eurasian and American plate (Fig. 1). As a result of volcanic and tectonic processes, the ridge is continually being formed as the two plates spread at a rate of about 2 cm/yr. Between Iceland and the Azores the ridge extends over 1500 nautical miles, and it is characterised by a rough bottom topography comprising underwater mountain chains, a central rift valley, recent volcanic terrain, fracture zones, and seamounts. The northern part is the wide and 500-1000 m deep Reykjanes Ridge extending from Iceland to the Charlie-Gibbs Fracture zone. South of this fracture zone the terrain is very rough and there are numerous seamounts. A few hydrothermal vent fields have been found near the Azores, and a single site, the *Steinaholl*, has been recorded just south of Iceland. However, only a few sections of the ridge have been adequately surveyed.

The MAR has an important influence on the deep-water circulation of the North Atlantic, partly separating deep waters of the eastern and western basins. There is flow of deep-water between the basins through the Charlie-Gibbs Fracture Zone. The dominating deep water mass of the region is known as the North Atlantic Deep Water (NADW) which is formed by mixing of the overflowing water masses from the Norwegian and Greenland seas with the Labrador Sea Water. The near surface circulation is complex, but the main feature is the northeastwards flowing North Atlantic Current, i.e. one of the major branches originating from the Gulf Stream. This current carries warm and saline water through the area across the ridge and further onto the European shelf and into the Norwegian Sea.

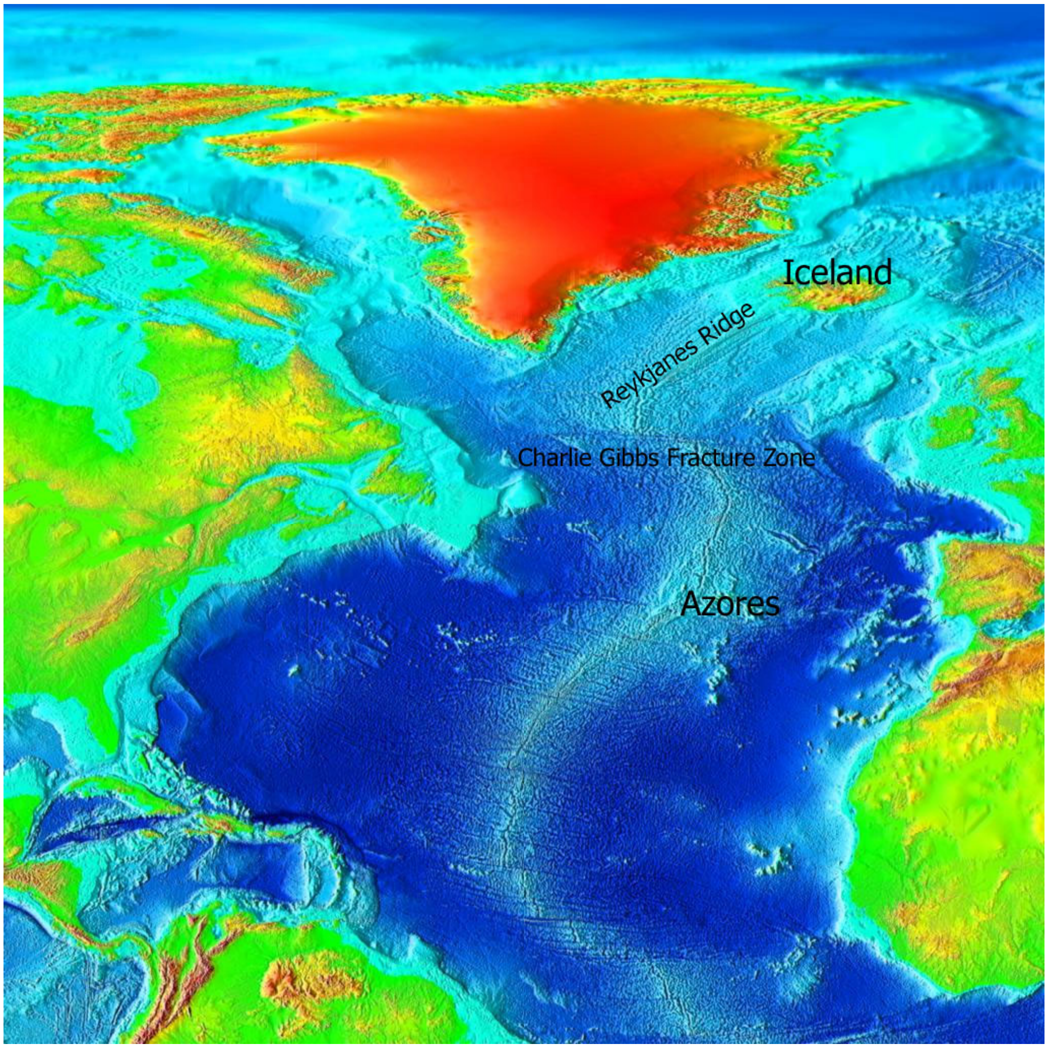

Figure 1. The North Atlantic Ocean, and the Mid-Atlantic Ridge. Image presented by the NOAA National Geophysical Data Center on http://www.ngdc.noaa.gov/mgg/bathymetry/relief.html.

1.2.2 State of knowledge

Globally the mid-ocean ridge systems represent major features of all oceans (Fig. 2). In terms of surface area, the ridge habitats are vast compared with the shelf and slope habitats where most of the biological research effort has been focused thus far. Hitherto many deep-sea biologists have avoided ridge areas because of cost of surveys and difficulties in using existing sampling equipment that would be readily damaged or lost. The exception is the exploration of chemosynthetic ecosystems, e.g. hydrothermal vents which has attracted considerable research effort (e.g. Van Dover, 2000; see also the InterRidge home page http://triton.ori.u-tokyo.ac.jp/~intridge/). A number of expeditions have been devoted to such systems around the world, but very few on the northern part of the MAR. Vent fields represent, however, a very minor fraction of the ridge area and the influence of chemosynthetic production on the overall biological production along the ridges is probably small.

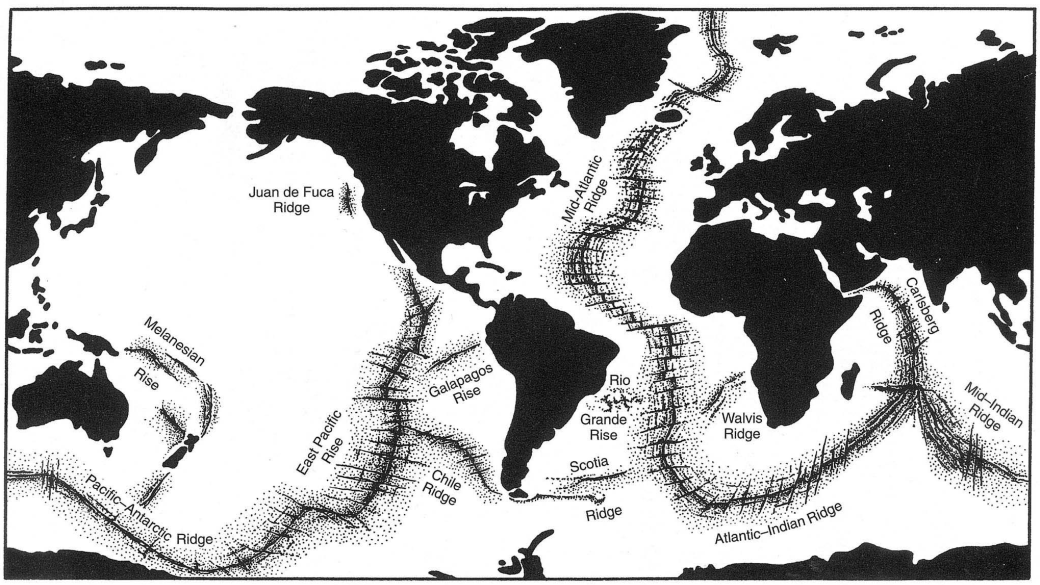

Figure 2. The ocean ridge system (After Garrison, 1993).

The rugged ridge terrain makes any sampling near the sea floor a difficult task, and thus the information on communities inhabiting different depth zones and habitats remains relatively limited. Sampling the pelagic environment has been more extensive, but the need to sample large areas and extensive depth ranges makes pelagic studies very expensive and time-consuming.

The deep water fauna depends ultimately on the rather seasonal photosynthetic production in the surface layers. The annual primary productivity in oceanic waters of the north Atlantic is around 45 g C/m^2 in the south and 90 g C/m^2 in the north, and as much as 125 g C/m^2 southwest of Iceland (Berger, 1989). There are at least two processes by which material can be transferred to deeper layers, i.e. by sinking of aggregates (“marine snow”) and the carcasses of large pelagic animals, and by the diurnal migration of large herbivores and carnivores (Angel, 1997). The biomass of nekton and plankton declines systematically with depth, but the number of species rises to a maximum at a bout 1000 m and thereafter declines. The traditional classification of the pelagic fauna into epipelagic, mesopelagic, bathypelagic, abyssopelagic and benthopelagic communities is generally accepted. However, along the mid-ocean ridge the complicated topography and the effects on the circulation system and production of seamounts and the passage of mesoscale eddies may modify the picture significantly. Most previous studies have been conducted either just off the continental slopes or in oceanic basins, and the understanding of the significance and influence of the mid-ocean ridges on composition and distribution of pelagic and benthic fauna is still limited.

The knowledge of certain very abundant and sometimes very widely distributed taxa such as cephalopods and gelatinous plankton organisms is particularly incomplete. These groups are difficult to sample, and traditionally their significance in pelagic ecosystems have been underrated compared with e.g. fish and crustacean plankton and nekton. In oceanic systems they are very characteristic (Angel, 1997), and there is evidence that these groups play major roles in the food-webs of the ecosystems near the ridges and in frontal zones associated with the major circulation features. The potential for new significant discoveries is particularly great for these groups. There is much more information on mid-ocean pelagic fishes, including those inhabiting deeper layers (e.g. Randall and Farrell 1997; Merrett and Haedrich 1997), but few previous studies have focused specifically on the role of the mid-oceanic ridges in the ecology of neither demersal nor pelagic fishes.

Considerable knowledge of fishes associated with ridge systems has been gained from fisheries-related research. Pelagic fisheries of the open ocean have been targeting tuna, swordfish, sharks and redfish that tend to be found near fronts, eddies and islands. Whales also occur in such areas and, they carry out extensive migrations as well as these epipelagic fishes. The significance of mid-ocean ridge ecosystems for such long-range migrants is however not clear. Traditional demersal fisheries have been conducted on the MAR within the Azorean and Icelandic EEZs for many decades. Icelandic data on the distribution of fishes on the Reykjanes Ridge were summarised by Magnusson and Magnusson (1995).USSR fleets started to exploit deep-living species such as alfonsino (*Beryx* spp.) and roundnose grenadier (*Coryphaenoides rupestris*) north of the Azores in the 1970s (Troyanovsky and Lisovsky, 1995), and Russian fleets and vessels from other eastern European nations still fish in this area. Many nations have carried out exploratory fishing in the 1990s, e.g. the Faroes (Thomsen 1998), Norway (Hareide *et al.* 1993; Langedal and Hareide, 1997), and Spain (Iglesias and Munoz, 2001). The reported landings from the area remain, however, relatively small and variable, and few vessels find the ridge fisheries profitable. The Russian fisheries appear variable (Vinnichenko, 1998), the Faroese have a single vessel fishing successfully for orange roughy (*Hoplostethus atlanticus*), Norwegian fisheries on the Reykjanes ridge has almost ceased, and the Spanish are still mainly exploring, focusing strongly on the Hatton bank. Around the Azores the fisheries are mainly coastal and artisanal, but gradually moving greater distances from the coast and onto seamounts off the islands (Santos *et al.* 1995).

Fisheries investigations have yielded valuable information on the distribution and abundance of fish, but have mainly considered species of commercial interest. Consequently, the exploratory fishing efforts of the past three decades have enhanced our knowledge of the MAR ecosystems, communities, and the processes that structure and sustain the ridge communities only to a limited degree. Surprisingly few studies have aimed at providing basic taxonomical or ecological understanding.

Pioneer USSR studies on the MAR have not been sufficiently known to western scientists, but major research efforts have been reported (e.g. Kukuev *et al.* 2000 and references therein). Comprehensive seamount ecology projects have been carried out in adjacent areas (Hempel 1968; Hempel and Nellen 1972; Rogers 1994; Pfannkuche *et al.* 2000), and several nations have pursued the challenge of exploring hydrothermal vents (e.g. France, USA, the United Kingdom, Russia, Portugal). Overall, the quantity and quality of the available information on ridge communities and their relation with adjacent basin communities and the slope faunas remains unsatisfactory. New technology and international collaboration makes a dedicated effort along the Mid-Atlantic Ridge both feasible, challenging and timely, and in view of the global distribution of ridges, such efforts will provide information of great global interest.

In a recent quality status report issued by OSPAR (the Oslo-Paris Commission) (OSPAR, 2000), a comprehensive review of information on the ecosystems of the oceanic north Atlantic was presented. A number of issues were raised that called for greater research effort in oceanic waters of the North Atlantic, and with regard to biological data the following list of "uncertainties" was provided:

- Basic systematic information about the majority of benthic taxa, especially the smaller organisms;
- The importance of gelatinous organisms in pelagic ecosystems, mainly because the cannot be adequately sampled;
- The role of microorganisms in food webs and many aspects of biogeochemical cycling;
- The zoogeographical patterns and distributions of many keystone species and communities;
- The life cycles of many keystone species;
- The structure and dynamics of most deep-water food webs;
- The biological pathways for contaminants in deep ocean ecosystems;
- The natural variability against which contemporary changes in biological systems can be assessed;
- How long-term cycles in the physical environment affect midwater and seabed communities and processes;
- The links between biodiversity, productivity and other ecological processes;
- The impact of removing top predators, such as fish, from the oceanic ecosystems; and
- How to distinguish between natural variation and anthropogenically-generated change.

Many of these issues raised by OSPAR will be addressed in the proposed pilot project on the MAR.

1.2.3 Scientific and technological challenges

The limited quantity and scope of documented knowledge of the mid-oceanic ridge areas establishes an essential requirement for new basic and original macrofaunal description to be undertaken. This primary challenge must be met by a co-ordinated programme of species identification and distribution mapping; studies of community composition and individual species behaviour and life history; all set in the context of a full suite of environmental and habitat parameterization.

This ambitious campaign will require accurate species identification by traditional and modern methods; quantitative abundance estimates by different gears, including advanced acoustic and optical technologies deployed actively from ship platforms and from semi-automated passive arrays; all supported by a diverse range of shore-based and laboratory work for method evaluation and analysis of results.

Issues central to the understanding of marine ecosystem processes in general will focus on a series of major challenges. These will integrate the faunal and environmental components of the project and provide outcomes of wide significance to the global ocean. Some of these challenges and our responses to them may be stated as follows:-

- Fishes and other macrofauna along and adjacent to the mid-oceanic ridges cannot depend for their livelihood on the primary production along the continental areas. They must somehow survive on the generally very limited local surface production and on advective concentration of phyto- and zooplankton.

  Which mechanisms might enhance production at the ridge ? To determine the trophic positions and relationships between the demersal and pelagic animals will be a central task. Diet analyses based on sorting of the prey for different species and size-groups will be carried out and form the basis of analyses of intra- and interspecific variation in feeding ecology. Trophic patterns will also be analysed by other techniques, e.g. stable isotope analyses. A simplified food-web will be constructed and central processes concerning transfer of energy and matter to and within the deep-living macrofauna communities will be identified.

- Many pelagic and benthopelagic animals tend to occur as aggregations in very limited areas.

  Study of behaviour, integrity and the dynamics of such aggregations is directly relevant to the overall objective of the project, and will be undertaken in selected geographic areas. Characterisation of the physical environment of the faunal aggregations, focusing specifically on current patterns or frontal processes that may advect and concentrate pelagic prey organisms, will be essential.

- The dependence on energy supplied from above or by advection probably limits the turnover and production. Fauna inhabiting the mid-oceanic habitats must have developed life history traits and ecology adapted to this limited production.

  It is often assumed that many of these deep oceanic species grow slowly, have very long life-spans, high ages at maturation, low fecundity and limited mobility. Major efforts will be made to test these assumptions through new investigation of growth and life history traits and systematic comparison of the diversity of these traits between related taxa from different habitats (the better known fauna of the continental slope). Quantification of these life history traits is critical to establishing the relationship between *biomass* and *production* in the ridge ecosystem.

- Some species found on the mid-oceanic ridges are associated with relatively isolated seamounts, but the same species may also occur along the continental slopes of the North Atlantic basin.

  It is of great importance from both a scientific and management point of view to know whether the populations along the mid-oceanic ridges are really isolated from others, and if not, how dispersion occurs. Unique insights into this question will be obtained from studies of population genetics undertaken in collaboration, and for comparison, with other projects working on the continental slope.

- Two processes may be assumed to be particularly significant for the distribution and production of pelagic and demersal fauna on the mid-oceanic ridges and seamounts: the vertical migration by epi-, meso- and bathypelagic organisms facilitating transfer of biomass and energy from the surface layer to deeper layers, and the current pattern around the seamounts may import and concentrate food.

  The oceanic macrofauna ultimately depends either on collecting the food near the surface or waiting for food particles to sink or migrate to a depth where they can be captured. The mesopelagic nekton has adopted the first strategy and performs extensive diel vertical migrations. Benthic and benthopelagic animals rely more on utilising food supply from above through sedimentation and migration. Analyses of these processes of energy and material transport in the vertical dimension will be central tasks in the project.

The *implementation* challenge of this planned campaign on the northern Mid-Atlantic ridge and adjacent ocean will require:

- the careful co-ordination and integration of the portfolio of component projects to be undertaken;
- maximum effort to discover the relevance of the physical oceanic environment to the biological processes investigated;
- optimisation of the heavy shiptime and equipment needs, available from international sources;
- attention to the potential for scaling up the results to contribute reliable generalizations on ocean basin or biome dimensions;
- development of overarching studies in the modelling of marine ecosystem processes;
- full exploitation of complementarity with other Census of Marine Life projects and the potential contribution to OBIS
- adherence to a time scale which will ensure effective delivery of the planned outcomes to the Census of Marine Life and to the full range of sponsors and funding agencies involved in individual component projects.

2. The pilot census in the northern mid-Atlantic.

2.1 Main aim and strategy

The overriding objective of the pilot census of the northern mid-Atlantic is ***to describe and understand the patterns of distribution, abundance and trophic relationships of the organisms inhabiting the mid-oceanic North Atlantic, and identify and model ecological processes that cause variability in these patterns.***

The greatest focus shall be on mesopelagic and benthopelagic macrofauna (nekton and macrozooplankton), and their trophic relationships. Benthic macrofauna shall be described in selected habitats, especieally to facilitate analyses of food-web structure involving e.g. benthopelagic and benthic fishes.

The Mid-Atlantic Ridge (MAR) between Iceland and the Azores extends over 1500 nautical miles and is characterised by a rough bottom topography that has not yet been adequately surveyed.

For the purposes of a species census two kinds of surveys are proposed:

(a) A large-scale pelagic survey attempting some degree of coverage over the whole area from Iceland to the Azores.
(b) Focused studies in sub-areas and along transects across the axis of the ridge (Fig. 3).

A major factor at mid-latitudes is the flow of the Gulf Stream/North Atlantic Drift over the ridge from West to East. The flow of water in deeper layers tends to be strongly influenced by topography, and there is flow through the Charlie-Gibb Fracture zone (Fig. 1). This fracture zone is thus also a hydrographical transition zone between the deep-water to the north and south. Information on the surface circulation and deep flow patterns will influence the final choice of the survey design and the choice of sub-areas for detailed studies. Preliminary criteria for selecting sub-areas were that two comparable sites, i.e. a northern and southern sub-area should allow latitudinal comparisons. In the north, a third topographically more complex area should be selected to provide the opportunity for analyses of effects of topographical differences at more or less the same latitude.

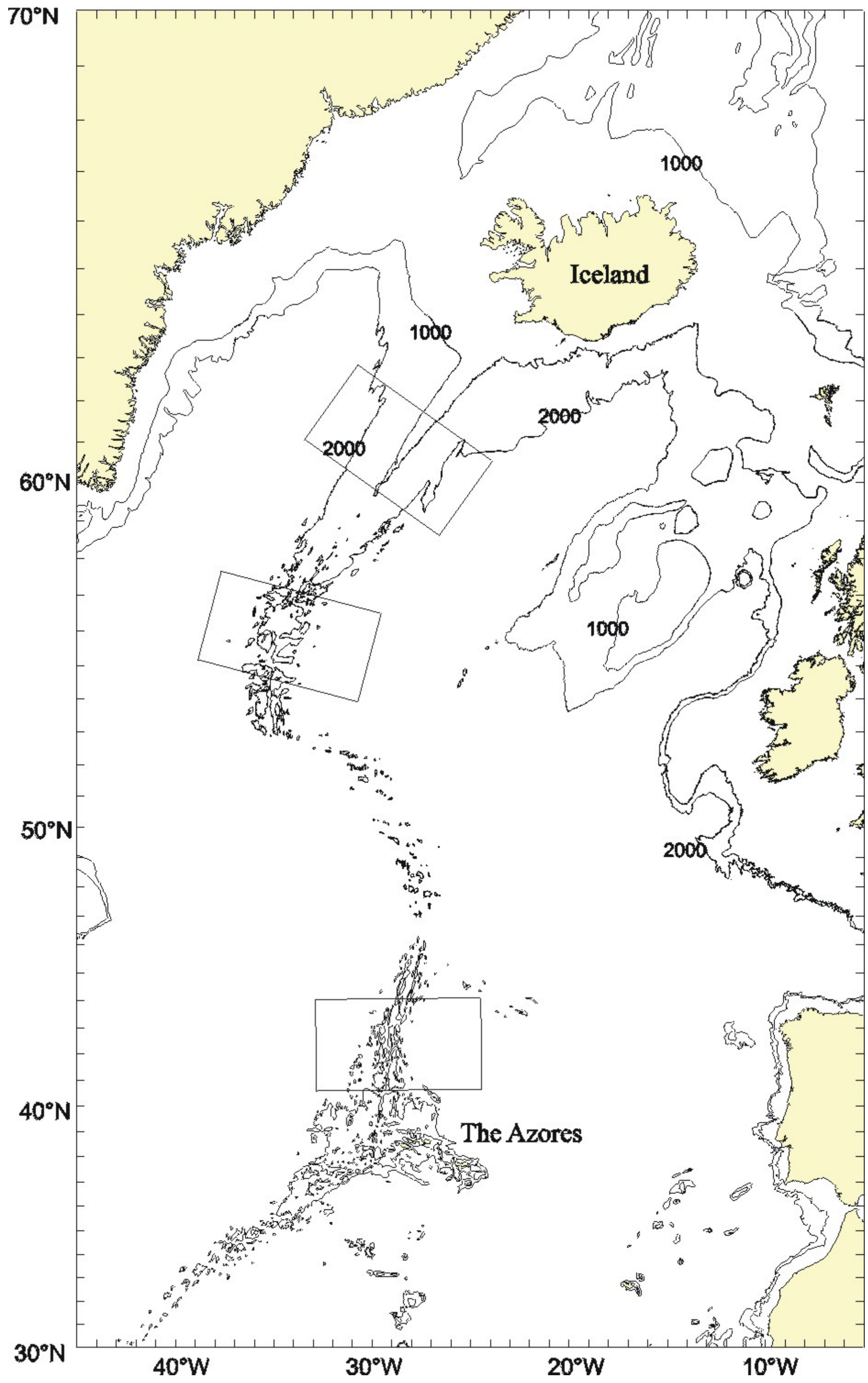

Figure 3. Sub-areas selected for detailed studies. The exact locations are to be decided during the planning phase.

2.2 Work programme

2.2.1 Planning phase

Five inter-related actions will have to be accomplished simultaneously during the planning phase of this project:

Action 1. *Project building*. Based on current knowledge and ideas (see Action 2, below), testable hypotheses central to the study of patterns and processes will be developed and refined to tackle the three core tasks defined for the field and analytical phases of this project (see 2.2.2 and 2.2.3). These hypotheses will provide greater focus for the pilot project and provide guidance for investigators of the individual tasks. Investigators will have to commit themselves to specific tasks and responsibilities. The writing of component project proposals and acquisition of financial resources are essential activities of the planning phase (see Action 4, below). The stimulation of project building has already begun, and writing of proposals shall be facilitated by networking activity and focussed workshops, the first in January 2002.

Action 2: *Literature studies and data mining.* Although the mid-ocean ridge system is perhaps the least studied large ecosystem on earth, information pertinent to this project exists. Such information includes results of exploratory fishing on the Mid-Atlantic Ridge, open-ocean studies in the deep Atlantic Ocean, and seamount studies from around the world. Some of this information is in formats that may be difficult to obtain or to interpret. In addition to journal publications, such information includes data and project reports, databases, “grey-literature”, and publications in languages that are not widely understood. For example, extensive background information is thought to have resulted from exploratory fishing on the Mid-Atlantic ridge by former Soviet block nations. Compilation and evaluation of current and archived information will be an important part of the planning process, as well as an important task in the entire project. This research task will therefore begin during the planning phase and continue during the field phase. Early results of this action will be used to refine hypotheses to be tested during the field phase. Information accumulated will be stored in a format compatible with OBIS.

Action 3: *Technological adaptation and fitting of research vessels*. A main aim of the project is to gain new knowledge through the application of new technology. A workshop will be convened to decide on technology and methods to address each task of the field phase. When appropriate, materials and methods will be coordinated with other CoML projects so that broader-scale comparisons are optimized (see Action 5, below). Prior to the main field effort, necessary new technologies should be adapted to and tested in realistic environments. Preliminary cruises by the Norwegian Institute of Marine Research and the US National Marine Fisheries Service are being planned and could serve as platforms for such testing. Purchase of additional equipment and outfitting and scheduling of research vessels for the field phase will be a responsibility of individual investigators and their funding agencies but will have to be begun during the planning phase as sub-projects addressing the field tasks are funded.

Action 4: *Promotion of the pilot project and the field activities.* Assembling the proposed research and building support for it will require establishment of an international communications network. It is important to focus this effort on three subtasks: (a) recruiting potential investigators, (b) informing funding agencies, and (c) educating other interested parties, including the general public.

(a) In order to accomplish the research outlined in this Science Plan, investigators interested in particular aspects of the plan will have to apply to appropriate funding agencies to support their specific activities. A team of qualified researchers will be assembled to ensure that the tasks of the field study and the analysis, assimilation and modeling phases of the project are accomplished. As soon as the Science Plan is approved, the Steering Committee will disseminate it to major research institutes on both sides of the Atlantic and through resources such as the BIONET.BIOLOGY.DEEPSEA and the Deep-sea Newsletter (see http://www.le.ac.uk/biology/gat/deepsea/deepsea.html). Interested persons will be able to obtain additional information from the MAR-ECO web site which has already been established (http://www.efan.no/midatlcensus/). A general-interest article explaining this project will be written and translated to several languages. Submission to a broadly circulated science publication (e.g., *Science* or *Nature*) is also planned.

(b) To assist potential investigators in securing support for the research encompassed by this Science Plan, the steering group, in coordination with CoML staff, will inform major national and international funding agencies of the importance of this research and how it fits into the broader goals of the Census of Marine Life. The Steering Committee will offer to evaluate all proposals submitted under the auspices of this project for relevance and to eliminate duplication of effort.

(c) A central goal of CoML and its pilot projects is that the activities and results become common knowledge. It is therefore essential that a strategy for information exchange and public relations be developed at an early stage. The MAR-ECO website will be a central focal point for education and outreach. Investigators will also be encouraged to coordinate with education agencies and non-governmental organizations to establish outreach activities such as real-time on-line coverage of field work. Dissemination of results in popular press and mass communications media, in addition to peer-reviewed scientific publications, will also be encouraged and facilitated.

Action 5: *Coordination.* All phases of this project will require both internal and external coordination. As noted above, the Steering Committee will coordinate sub-projects addressing tasks by working with investigators during proposal development and with funding agencies during the proposal review process. This is to ensure that all tasks are addressed but without unnecessary duplication. Members of the Steering Committee will also be designated for liaison with other CoML projects. If relevant similarity among separate CoML projects can be maximised, then broad-scale comparisons (e.g., between the MAR and the slope and seamounts off the Gulf of Maine or the slope of the Bay of Biscay) will be facilitated. Of particular importance will be coordination with OBIS to ensure that data from this project can be encorporated directly into that information system. Although coordination is obviously integral to all tasks, the Steering Committee feels that the importance of coordination for a project this complex is so great that designation of coordination as a separate task is warranted.

2.2.2 Field study

The following is a list of three central tasks and a compilation of hypotheses and suggestions resulting from discussions during the Solstrand Workshop 12-13 February 2001. The list of tasks will remain, but as the planning progresses, changes must be anticipated in the exact formulation of hypotheses and strategies.

The three tasks are obviously inter-related. Also, all the tasks rely on understanding the abiotic environment. A multidisciplinary approach will be emphasised to conduct analyses of watermass distributions, advection patterns, detailed topography and substrate distributions, illumination patterns etc. It is essential that biologists and physicists work together in a mutually fruitful manner.

Task 1: Mapping of species composition and distribution patterns

Some basic overall hypotheses or questions to be adressed are:

a) Is the MAR an extension of the North Atlantic basin continental slope regions? Are species occurring at the same depths at which they are found on the continental margins?
b) Is the MAR a barrier between the pelagic fauna of the east and west North Atlantic basins? Is there a difference in species occurrence either side of the MAR?
c) Do circulation features, e.g. the Gulf Stream, act as barriers between the northern and southern fauna? In the region of the Gulf Stream, what is the effect of eastward drift and import of material from the west?
d) What is the significance of seamounts within the ridge system?

The most central activity will be the mapping of species distributions and species composition using both traditional and innovative methods, but analyses of population genetics and dispersion patterns will also be included. Therefore, two themes have been defined:

Theme 1: Identity and distribution patterns of macrofauna.

The central aim of this sub-task is to determine a broad scale distribution of the pelagic and benthopelagic communities. A description of the benthic macrofauna in a limited number of typical habitats or along selected cross-ridge transects will be carried out, especially to provide input data to food-web studies.

Specific questions regarding the pelagic and benthopelagic community are:

- Does the MAR form a focus for pelagic communities ?
- Is there a distinct mesopelagic boundary community near the MAR ?

- Are seamount communities different from ridge communities, and if so, what are the characteristics of each?

Approach:

To design a wide-ranging pelagic survey, information on seasonal variation in distribution, abundance and production should be considered and used as the basis for stratification of effort. If biomass is concentrated near the ridge the survey should include increased short transects over the ridge with wider spaced long transects into the basins. Consideration needs to be given to surveys in different seasons. Satellite data may provide guidance on the spatial patterns of phytoplankton and surface parameters near the ridge and the sizes and location of patches. Special attention should be given to the location and variability of the Gulf Stream.

A range of methods for observation and sampling will be adopted, including sighting, listening and tracking techniques for mammals, turtles and birds, and trawling, net sampling, acoustics and optics for fish, cephalopods and smaller animals. Co-operation with on-going survey and monitoring programmes will be developed. Acoustic systems will provide multifrequency and extended depth data through the use of deep towed systems to provide up to 1000m of the water column, and lower frequencies to provide data on the reduced biomass in deeper water. Pelagic trawling strategies will be based on a regular grid enhanced by opportunistic trawls, aimed at identification of traces observed on the echosounder systems. Abundance will be estimated from swept volume estimates of pelagic fish and cephalopods, where possible using target strength data. Multifrequency data should be used to help with species allocation.

Consideration should be given to the use of AUVs to provide intertransect data in the most variable areas. A strategy of short AUV missions over the ridge may provide additional data while a survey vessel is carrying out extended transects into the ocean basins.

Macroplankton distributions should be mapped using multiple opening and closing sampling gears. In addition high frequency acoustic data should provide broader scale spatial distribution for the upper part of the water column. Special attention should be given to developing good sampling and observation methods for gelatinous plankton.

Application of autonomous towed instrument packages containing similar acoustic and environmental sensors for use on ships in transit through the area will be considered. This data augmented by the main survey should provide some seasonal coverage to put the main survey in the context of the annual cycle in the pelagic community. Fixed stations with CTD and bioacoustic packages should be placed at selected sites to provide detailed daily and seasonal data.

There are no adequate fine scale charts of the whole MAR. The possibility of conducting a survey to the study area to provide a basis for planning of the near-bottom sampling programme will be explored. Multibeam charting will be essential, and the observation and sampling shall be carried out with an arsenal of instruments and methods, involving ROVs, baited cameras and landers, traps, longlines, trawls, sledges, grabs etc., and if available, manned submersibles. Fixed stations may again provide very useful data.

Theme 2: Population genetics and dispersion studies

Central questions are the following:

- Does the MAR act as a barrier to dispersal of transoceanic species?
- Are populations continuous along the ridge or is there evidence for genetic isolation of populations along the ridge and between the ridge and continental shelf?
- Do off axis seamounts (chains e.g. the Horseshoe seamounts) act as stepping stones from the continental slope to the MAR – and hence from the east to the west side of the Atlantic?
- Is there genetic evidence for hydrographic / topographic isolation of seamount/ ridge populations and are they therefore a source for speciation?

Approach:

These hypotheses will be approached by genetical methods and tagging studies. Genetics can offer:

1. Analysis of spatial and temporal genetic structure of species. Methods include analysis of sequence variation, microsatellites, other types of sequence marker (RFLPs, DGGE, SSCP etc.)
2. Molecular phylogenetics and detection of cryptic species. This will be coupled with taxonomic studies.
3. Molecular methods for species identification. These are currently in development especially for systematically difficult groups.

Tagging experiments will be used to study movements of animals. For deep sea fish, ingestible transponders are available. These are detected by sonar stations on the sea floor. There is also an Icelandic system for tagging of fish automatically as they pass through a cod end of a trawl. The latter technique requires recovery of the tags in a fishery. Both these systems overcome the problem that recovery of deep sea fish to the surface is generally lethal. For surface dwelling fish conventional techniques can be used.

Overall the quantity of data on the genetic structure of slope / ridge / seamount populations is extremely low. Generalisations about spatial (and temporal) genetic structure of such populations cannot be made. Evidence suggests that topography does have a strong influence on the genetic structure of populations but life-history and hydrographic processes related to dispersal are also very important. The evolutionary history of species may also have an extremely strong influence on genetic population structure to the point where it may obscure processes that influence population structure in the present day. Such genetic data on past colonisation / extinction processes are valuable in their own right. It is clear that designing sampling programmes for studies of the genetic structure of species that are distributed over an entire ocean is highly complex and an area where international collaboration is crucial. An approach based on several different types of genetic marker is also important in order to separate current dispersal processes from historical influences on population structure. New sampling will be necessary for such studies with tissue samples preserved for genetic analysis along with collection data (sampling data, age, sex, maturity etc).

PIs of proposals will be encouraged to deposit voucher specimens, and tissues fixed appropriately for molecular analyses, in archival collections at internationally recognised museums. Budgets of proposals should include funds for transfer and maintenance of these voucher collections.

Task 2: **Identification of trophic interrelationships and modelling of food web patterns**

In conjunction with analysing and mapping the characteristic faunal communities of the northern mid-Atlantic ecosystem a major subject deriving from field work will concentrate on investigating the trophic structure of the target area. One central question will be addressed: *Is the trophic structure of the northern mid-Atlantic ecosystem similar to that on the slope regions of the eastern and western sides of the Atlantic?*

Alternative patterns include:

a) Trophic structure differs along an east-west gradient.
b) Trophic structure varies from north to south.
c) Trophic structures do not follow seasonality patterns as shown in continental slope regions.
d) Seamounts, particularly abundant in the southern part of the study area, are characterised by unique food web patterns.

Trophic interrelationships and food web patterns will be of particular importance at the various seamounts occurring in the target area, because it can be expected that these areas may serve as “oases” in the mostly oligotrophic open ocean. Seamounts are undersea mountains that rise steeply from the sea bottom to below sea level. They have been defined as having an elevation of more than 1000 m, an angle of gradient up to 60° and a limited extend across the summit. They occur in all oceans, and due to volcanic processes mainly consist of hard substrates (Menard 1964). So far it is well documented, (1) that most seamounts show a higher standing stock of organisms in nearly every part of the food chain, (2) that they play an essential role in the reproduction and life history of many species, and (3) that seamounts appear to show significant levels of endemisms. In contrast to the adjacent open ocean seamounts are characterized by increased biomass and species diversity (Koslow 1997).

The high standing stocks of seamount ecosystems are characterized by the occurrences of commercially exploitable pelagic and benthopelagic fishes. Three processes may be responsible for this pattern: (1) an increased pelagic primary production due to local upwelling processes or within so-called "Taylor columns“ (Dower et al. 1992); (2) an enhanced benthic primary and secondary production due to a low but steady supply of organic and inorganic nutrients through the prevailing current systems (Boehlert & Genin 1987); and (3) migrating zooplankton is transported during the night - time ascent on top of a seamount where it serves as food source for benthic and benthopelagic organisms (Koslow 1997).

Within the eastern boundary of the sub-tropical gyre of the East Atlantic Ocean there are more than twenty seamounts which provide productive environments with appropriate conditions for all trophic levels and all life stages. The influences of seamounts on the oceanic environment which lead to higher biomass concentrations seem to be manifold and are still not fully understood. In many aspects the questions asked by Hubbs (1959) "what factors are responsible for the abundance of life over seamounts?" still need to be answered.

Approach:

Extensive trophic ecology studies have been conducted in slope waters on either side of the Atlantic (see e.g. Merrett and Haedrich 1997), so data for comparisons with slope waters are available. This is at least the case for fishes and crustaceans, but for other groups such as cephalopods and gelatinous organisms, extensive new studies are needed and the possibility for collaboration with on-going slope studies will be explored. The trophic ecology work on MAR will be concentrated in the sub-areas selected for detailed studies, and only general aspects will be considered on the more extensive transects mapping pelagic animals.

Improved methods for reliable sampling of stomach contents need to be developed. E.g. a major problem in collecting stomach contents from fish is that many species tend to regurgitate and some feed in the net. To sample epipelagic species not caught on the research vessels, observers on e.g. tuna vessels may be hired to collect stomachs. For some groups, e.g. benthic macrofauna, detailed diet studies may be impossible or beyond the scope of the study, and conclusions will have to be drawn based on morphological characteristics that provide information on feeding modes. Gelatinous animals such as cnidarians, ctenophores and salps are suspected as major food sources to deep-living fishes and cephalopods, and stable isotope data may be particularly useful for the study of the trophic positions of these and other macroplankton groups, e.g. crustaceans. In general, detailed stomach content analyses, and stable isotope analyses focussing on typical macrofauna species will form the basis to document and further develop conceptual food web models. The linking of as many as possible biological system components to model the trophic interrelationships will be achieved by applying steady-state compartment models such as provided by the ECOPATH software (Christensen and Pauly, 1992). The advantage of such models is the holistic approach which covers the whole ecosystem and the possibility to unravel trophic interrelationships with a high degree of complexity.

Task 3: Analyses of life history strategies

Life history strategies are important in controlling the distribution and population structure of the species inhabiting the MAR and seamount regions. Available information on the large scale distribution patterns of deep water fishes indicate that some are found on both sides of the North Atlantic Ocean while others only occur on one side of the ocean and along the MAR. The same may also apply to some of the other less studied groups of pelagic animals. Distribution patterns such as these must be related to life history strategies. To what extent the fauna of the MAR and seamounts have developed unique life history strategies is unknown. For wide-ranging species, only certain life stages may depend on the ridge ecosystem.

Assuming that the MAR and adjacent seamounts can be considered a single system, a number of hypotheses have been proposed:

a) Pelagic organisms aggregate over MAR and seamounts and draw advantage from utilising these areas in their overall life history strategy.
b) Seamount macrofauna has a strategy to reduce export/dispersal away from this habitat.
c) The MAR and seamounts are refugia and nurseries for slope fauna with wide dispersal capability.
d) Life history strategies vary with depth.
e) Alternation of life history phases may be a major factor contributing to the vertical exchanges of material and energy.

Approach:

For selected typical/the most important inhabitants of the MAR region, studies of life history strategies will be conducted in order to allow comparison to the better investigated nearby slope regions. Data such as age, growth, fecundity and occurrence of larval forms will be collected. Analyses of reproductive modes, number and size of eggs and larvae, dispersal modes and retention of larvae, growth patterns and longevity studies are particularly relevant.

These analyses will draw on the experiences from previous island and seamount investigations conducted in neighbouring waters and in the Pacific. Some of the aspects need to be adressed via detailed process investigations, e.g. around seamounts, others such as analyses of age structure and reproductive modes of deep-water fishes and cephalopods may be conducted on the more wide-ranging surveys.

Information on hydrography and currents is particularly important in the context of studies of life history strategies.

2.2.3 Analysis, modelling, and synthesis

The substantial amount of data and material collected on surveys and during process studies need to be analysed and processed, synthesized and the information will be integrated in models. As the project proceeds, results will be reported and findings disseminated both on its web page, via the internet and through press releases.

This work will take time, and a period of five years (2004-2008) has been dedicated to this work. Experts from a wide range of fields will be involved in this process, including scientists not taking part in the field study.

Information collected during the pilot project shall be provided in a format suitable for OBIS (Grassle, 2000), and the inclusion of data or linking of databases to OBIS is a central final task.

The final synthesis will also include the convening of a symposium where the scientific findings from the MAR-ECO project will be presented. Further the possibility of the publication of the main findings of the project in a popular book will be explored.

2.3 Organisation and collaboration

An international steering group has been set up to organise and oversee the planning, financing, and implementation of the pilot project. Throughout the process, tight links with the CoML scientific steering committee are essential.

Members of of the Steering committee are:

Dr. Odd Aksel Bergstad, IMR, Norway (chairman)
Prof. Peter Boyle, Univ. Aberdeen, UK
Dr. Olafur S. Astthorsson, MRI, Iceland
Dr. Ricardo S. Santos, Univ. Azores, Portugal
Dr. Uwe Piatkowski, Univ. Kiel, Germany
Dr. Michael Vecchione, NOAA, NMFS, USA
(Dr Pascal Lorance of IFREMER, France was appointed in Bergen but had later to decline. A new French member may be appointed in the near future).

Norway has offered to take on secretarial duties for the project, and the responsible institution will be the Institute of Marine Research in collaboration with the University of Bergen. The forum for the planning process will be a project formally embedded in the current activity plan of IMR but open to multi-institutional and international participation.

The new research vessel *RV G.O. Sars* will be at the disposal of the project activities, and may form a central focus of international multi-vessel operations.

Collaboration and data sharing with other CoML pilot projects and activities, as well as other programmes working on related topics or in neighbouring areas will be organised and stimulated throughout the project period. This is essential for conducting comparative analyses between communities in the oceanic areas and along the continental slopes and shelves. Chemosynthetic ecosystems are not included in MAR-ECO, partly because another proposed CoML pilot project, the ChEss, in the same waters will focus specifically on such systems (see http://www.wm.edu/coml/). Other projects/programmes/agencies of particular interest are e.g. the CoML Gulf of Maine pilot project (http://www.whoi.edu/marinecensus/), a planned CoML project in the Bay of Biscay, the UK NERC Marine Productivity programme, ICES co-ordinated surveys (e.g. the redfish surveys in the Irminger Sea) and Study Group activity, international cetacean sightings, ICCAT co-ordinated monitoring of large pelagic fish such as tuna and swordfish, NOAA Office of Ocean Exploration.

2.4 Time frame and schedule

Planning phase:	2001-2003
Field phase:	2003-2005
Analysis, synthesis:	2004-2008
Incorp. in OBIS:	2005-2008

The planning phase is scheduled to last 18 months, starting in the autumn 2001. This will be followed by the main field effort planned for 2003. Additional field work may be carried out in 2004 and 2005, but will then be overlapping with laboratory analyses of the material and data acquired in the 2003 cruise(s). Incorporation in OBIS is scheduled to begin in 2005 and the completion of the project and a final synthesis for 2008. It is anticipated, however, that extensive material will be available for examination and detailed analyses also after this final year.

2.5 Justification, and scientific and societal benefits

A major overriding aim of the mid-Atlantic pilot project is to provide society with well-founded knowledge of patterns and processes of the mid-oceanic ridge ecosystem. The ridge system is a global feature found in all oceans, but surprisingly few focussed studies have been conducted in ridge systems. New knowledge thus has a great value in itself, providing man with a greater understanding of the environment shared by all. Compared with the continental shelf and coastal environments, the ecosystems of the mid-oceanic ridges represent “last frontiers” where new exploratory activity will provide new knowledge on both previously described and undescribes species. Providing well-documented new information on how mid-oceanic ridge communities are structured and sustained is a challenging task that would provide appealing new information for science and the general public.

New information is also required by governments and international bodies to design and implement environmental and fishery management plans for mid-oceanic systems. Designing relevant assessment and monitoring programmes, or indeed giving correct and relevant advice on actions to be taken, requires far more information than is available at present. The mid-oceanic ridges have slowly become fishing areas of an international fleet of trawlers and longliners, and many of the species targeted have life histories that make them particularly vulnerable to overfishing. Effects of drilling activities and diffuse pollution from distant sources should also be assessed, but requires better knowledge of this system which is distant from most human activities. On a larger scale, improved monitoring and assessment methods would be needed to record the perhaps subtle changes in the oceanic environment caused by global climate change.

The Mid-Atlantic Ridge is a major feature of the Atlantic, it is topographically complicated with its many seamounts and fracture zones. A lot of the macrofauna appears to be associated with seamounts, and from fishery-related research there are indications that the fauna associated with the seamounts differs along a north-south gradient. The topography and the association of biota with features such as seamounts represent particular challenges for technological innovation, both with regards to observational equipment and sampling gears. The application and testing of new approaches, techniques and equipment is intrinsic to the proposed project, and technological advances made in the deep-sea area may prove very useful also in shelf waters. The focus provided by an international multi-disciplinary project in a challenging environment such as the deep-sea is a great motivation for technological innovation on many fronts.

Considerable geophysical research has been and is conducted in the Mid-Atlantic Ridge area, and some knowledge on the ecology of organisms at selected seamounts and hydrothermal vent sites have been gathered. However, technological constraints and the lack of collaborative initiatives have limited the observational capabilities of most projects. Many countries have pressing tasks in the coastal zone, and international collaboration would seem necessary to fund and run projects in mid-ocean waters, areas that for the most part lie outside national EEZs. This calls for an international initiative such as the Census of Marine Life.

MAR-ECO will provide good training opportunities at various levels, from school children following the development of surveys and visiting web-based information sources, to post-graduate students basing their theses on work conducted on component projects of the pilot project. It will create unique opportunities for the training of sea-going scientists. Also in the post-project years, there will probably be material or data available for several student projects.

3. Literature

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