

Patterns and processes of the ecosystems of the Northern Mid-Atlantic (MAR-ECO project) – an international census of marine life project on deep-sea biodiversity

O.A. Bergstad and T. Falkenhaus

Institute of Marine Research, Flødevigen Marine Research Station

N-4817 His, Norway

<oddaksel@imr.no, tonef@imr.no>

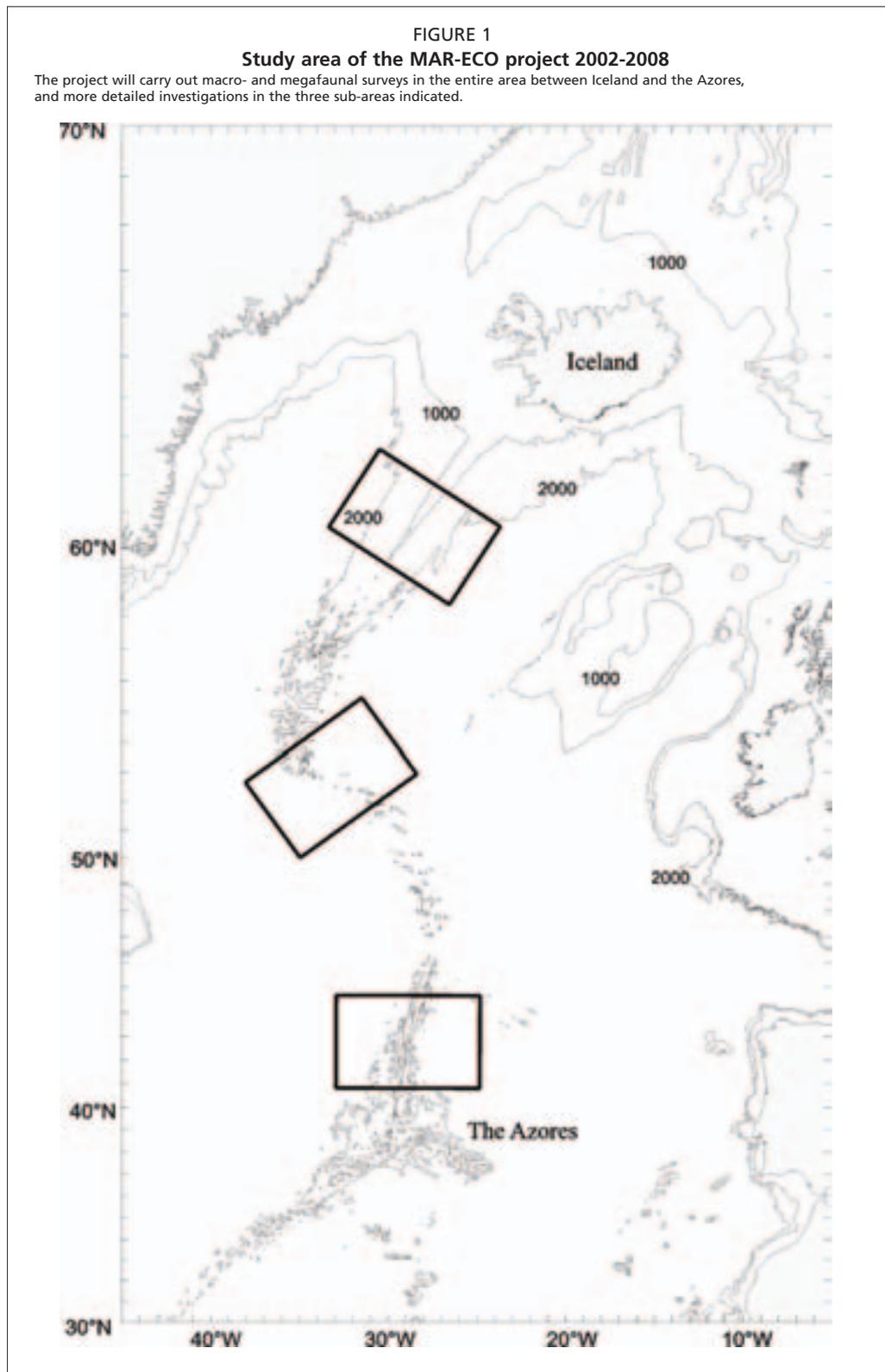
1. INTRODUCTION

Despite the wide distribution and extensive area of mid-ocean ridges (see e.g., Garrison 1993), relatively few previous investigations have been dedicated to the study of the animal communities inhabiting these vast areas of the world ocean. Ridges may have characteristic faunas, and they may also significantly influence the processes such as intercontinental migration and dispersion affecting slope and shelf biota. Compared with the continental shelf and coastal environments, the ecosystems of the mid-oceanic ridges are poorly known and exploratory activity will provide new knowledge on both previously described and undescribed species. However, providing well-documented new information on how mid-oceanic ridge communities are structured and sustained is a challenging task.

The MAR-ECO project (Bergstad and Godø 2002, <http://www.mar-eco.no/>), whose objective is the study of the mobile macrofaunal communities associated with the Mid-Atlantic Ridge between Iceland and the Azores, is one of the field projects of the Census of Marine Life programme (CoML, <http://www.coml.org>). The overriding goal 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 use innovative methods and up-to-date technology to map distributions, analyse community structure, study life histories and model trophic relationships.

2. BACKGROUND

The Mid-Atlantic Ridge (MAR) is the spreading zone between the Eurasian and American plate (Figure 1) is a part of a world-wide system of oceanic ridges. 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 1 500 nm, and it is characterized by a rough bottom topography comprising underwater mountain chains, a central rift valley, recent volcanic terrain, fracture zones and seamounts. The MAR has an important influence on the deepwater circulation of the North Atlantic, partly separating deepwaters of the eastern and western basins.



Globally the mid-ocean ridge systems represent major features of all oceans. In terms of surface area, the ridge habitats are vast compared with the shelf and slope habitats where most marine biological research has been focused to date. Hitherto, many deep-sea biologists have avoided ridge areas because of the cost of surveys and difficulties in using existing sampling equipment that could be readily damaged or lost. The exception is the exploration of chemosynthetic ecosystems, e.g. hydrothermal

vents, which have attracted considerable research effort (e.g. Van Dover 2000; see also the Inter Ridge home page <<http://triton.ori.u-tokyo.ac.jp/~intridge/>>). A number of expeditions have been devoted to such systems around the world, but few on the northern part of the MAR. Vent fields represent, however, a minor fraction of the ridge area and the influence of chemosynthetic production on the overall biological production along the ridges is probably small.

Most previous deep-sea 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 negligible.

The knowledge of certain abundant and sometimes 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 has been underrated. Such animals are characteristic in oceanic systems (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. Thus, the potential for new significant discoveries is particularly great for these groups.

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. Pelagic fisheries of the open ocean have been targeting tuna, swordfish and sharks that tend to be found near fronts, eddies and islands. Whales also occur in such areas. The significance of mid-ocean ridge ecosystems for long-range migrants such as whales and large epipelagic fishes (e.g. tunas and billfishes) is not clear.

Traditional demersal fisheries have been conducted on the MAR within the Azorean and Icelandic EEZs, for many decades by Iceland (Magnusson and Magnusson 1995), Russia and vessels from other eastern European nations (Trojanovsky and Lisovsky 1995). Many nations have carried out exploratory fishing in the 1990s, including the Faroes (Thomsen 1998), Norway (Hareide *et al.* 1993; Langedal and Hareide 1997) and Spain (Iglesias and Muñoz 2001). The reported landings from the area remain, however, relatively small and variable and few vessels find the ridge fisheries profitable.

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 to only a limited degree. Few studies have aimed at providing basic taxonomic or ecological understanding.

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 feasible and timely although still challenging. In view of the global distribution of ridges, such efforts will provide information of great global interest.

3. MAR-ECO TASKS

Some basic overall questions are to be addressed by MAR-ECO:

- i. Are the MAR communities extensions of the communities inhabiting the North Atlantic continental slope regions?
- ii. Is the MAR a barrier between the pelagic fauna of the east and west North Atlantic basins? Is there a difference in species occurrence on either side of the MAR?

- iii. Do circulation features, such as 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?
- iv. What is the significance of individual seamounts within the ridge system?
- v. 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?

A major challenge of the project is to overcome observation difficulties in distant waters at great depths and in rugged terrain. A central objective is to use modern remote sensing technology (e.g. with acoustics or optics) using advanced instrument carriers (e.g. towed vehicles, ROVs, etc. AUVs etc.), in addition to more traditional sampling and observation methods. The application and testing of new approaches, techniques and equipment is intrinsic to the MAR-ECO, and technological advances made in the deep-sea area may also prove useful 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.

The Science Plan available at <http://www.mar-eco.no/>, presents the three central tasks of MAR-ECO and a compilation of hypotheses to be examined.

Task 1: Mapping of species composition and distribution patterns

Theme 1: Identity distribution patterns of macrofauna

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 substantially modify the picture. Many pelagic and benthopelagic animals tend to aggregate in limited areas. Study of behaviour, community integrity and the dynamics of such aggregations will be undertaken in selected geographic areas. An essential component of the project is the 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.

Theme 2: Population genetics and dispersion studies

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 much 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. Insights into these questions will be obtained from studies of population genetics undertaken in collaboration with, and for comparison with, other projects working on the continental slope.

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

The deepwater fauna along, and adjacent to, the mid-oceanic ridges must somehow survive on the, generally limited, local surface production and on advected concentrations of phyto- and zooplankton. 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: vertical migration by epi-, meso- and bathypelagic organisms facilitates 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. The project will analyse how the ridge system affects the processes of energy and material transport in the vertical dimension. The determination of the trophic relationships among the demersal and pelagic animals is a central task for MAR-ECO.

Task 3: Analyses of life history strategies

The dependence on energy supplied from above or by advection probably limits turnover and production within the ridge community. Fauna inhabiting the mid-oceanic habitats must therefore 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 long life-spans, high ages at maturation, low fecundity and limited mobility. Major efforts will be made to test these assumptions through new investigations 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

4. ORGANIZATION, SCHEDULE AND FIELD EFFORTS

An International Steering Group organises and oversees the planning, financing and implementation of the project. Norway has taken on the secretarial duties for the project and the responsible co-ordinating institutions are the Institute of Marine Research (IMR) and the University of Bergen.

During the planning phase of MAR-ECO in 2001–2003 the International Steering Group stimulated the network of experts to formulate component projects and commit resources. Science plans for 10 component projects have been formulated and short versions are available on the website: <http://mar-eco.no/>. The 2003–2005 field phase has been initiated, and data and material from the first field season are available. Several countries have committed research vessel time and personnel to the project. The new Norwegian research vessel **G.O. Sars** will be at the centre of the international multi-vessel operations and the vessel will be used for a two-month cruise in the summer of 2004. The field work is to be followed by an analysis and synthesis phase in 2004–2008. Data will be incorporated in the CoML project Ocean Biogeographic Information System (OBIS) in 2005 and later. The completion of the project and a final synthesis is scheduled for 2008. It is anticipated that extensive material will be available for examination and further analyses also after this final year.

5. INITIAL FIELD EFFORTS

The work area of MAR-ECO is the waters associated with the mid-Atlantic Ridge between Iceland and the Azores (Figure 1), both the pelagic zones and near-bottom habitats on the flanks of the ridge to a depth of 3 500 m. The field investigations will comprise both large-scale zig-zag surveys of the entire area and more focused studies in three sub-areas (Figure 1). The strategy for large-scale surveying will be acoustic and intermittent multi-purpose station sampling.

In 2003 field sampling observations were made using vessels from Iceland, Russia, Germany and Portugal. The Icelandic vessel **R.V. Arni Fridriksson** conducted studies and sampling of mesopelagic fish and zooplankton in the northern end of the study area, the Reykjanes Ridge. The Russian vessel **R.V. Smolensk** and the German vessel **R.V. Walther Herwig** also conducted some sampling in the northern area. These efforts were extensions of an ICES co-ordinated survey of redfish (*Sebastes* sp.) in the Irminger Sea.

Perhaps the most remarkable effort was made by the Russian vessel, the **R.V. Mstislav Keldysh** and its manned submersibles MIR-1 and -2. This was a Russian-

US collaboration, and scientists from both countries made two double dives in the Charlie-Gibbs Fracture Zone (in the middle MAR-ECO Sub-area) to depths of 3 000–4 500 m, an area never before visited by man. Analyses of the observations and samples obtained are ongoing and detailed results will be presented elsewhere. However, preliminary analyses of videos recorded during the dives show the occurrence of many fish species, cephalopods and swimming holothurians, as well as diverse sessile macro- and megafauna dominated by suspension feeder. The density of “marine snow” and phytodetritus on the bottom appeared higher than expected, and a particularly interesting finding were high densities of juvenile macrourid fish and holothurians.

In the southern area, MAR-ECO benefits from activities of a German-led EU-funded project OASIS focusing on seamount ecosystems. Several cruises were made by Portuguese, German and UK vessels to the Sedlo seamount just south of the southern MAR-ECO Sub-area. Of particular interest were efforts to sample and study macrofauna by the Portuguese vessel **R.V. Archipelago** of the Azores. This vessel operates longlines and provides samples e.g. for studies of trophic ecology, fish genetics and hydrography.

6. THE MAR-ECO VISION

New information is 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.

A major overriding aim of MAR-ECO 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 of such areas. New knowledge thus has a great value in itself, providing humanity with a greater understanding of the environment shared by all. The MAR-ECO objective is that, following the 2001–2008 project period, the identity, distribution patterns, food-webs, and life history patterns of the macrofaunal communities of the northern Mid-Atlantic Ridge and its flanks will be better understood and well known both to the scientific community and the interested public.

The website <<http://mar-eco.no/>> is the main source of updates, contact information, and documents relevant to the project.

7. ACKNOWLEDGEMENTS

MAR-ECO is aided by the A.P. Sloan Foundation who, together with the NOAA Ocean Exploration Initiative, supported the **R.V. Mstislav Keldysh** cruise. Support from many national agencies and governments is also acknowledged.

8. LITERATURE CITED

- Angel, M.V. 1997. Pelagic biodiversity. In: R.F.G. Ormond, J.D. Gage, & M.V. Angel (eds.). *Marine biodiversity: patterns and processes*. Cambridge University Press, Cambridge, U.K. 449 pp.
- Bergstad, O.A. & O.R. Godø 2002. The pilot project “Patterns and processes of the ecosystems of the northern Mid-Atlantic”: aims, strategy and status. *Oceanologica Acta* 25: 219-226.
- Garrison, T. 1993. *Oceanography: An invitation to Marine Science*. Wadsworth, Belmont, California.
- Hareide, N.-R., E. Skarboevik., M. Kjerstad, V. Shibanov, V. Vinnichenko & K. Gorchinsky 1993. Forsoeksfiske etter orange roughy paa Den midt-atlantiske rygg med fabrikktraalaren M/TRamoen, 1 September–8 October 1993. Report, Moere Research, Aalesund, Norway and PINRO, Murmansk, Russia. 80 pp.+appendices (in Norwegian).

- Iglesias, S. & P.D. Muñoz** 2001. Spanish investigations on deep-sea resources in northern Mid-Atlantic Ridge and adjacent areas. Working Document presented to the Workshop on the CoML pilot project "Patterns and processes of the ecosystems of the northern Mid-Atlantic, Bergen 12-13 February 2001. 7 pp.
- Langedal, G. & N.-R. Hareide** 1997. Rapport fra forsoeksfiske paa Reykjanesryggen/ Midt-atlanterhavsryggen med M/S Skarheim juli 1997. Report, Norwegian Directorate of Fisheries and Moere Research, 58 pp. (in Norwegian).
- Magnusson, J.V. & J. Magnusson** 1995. The distribution, relative abundance and the biology of the deep-sea fishes of the Icelandic slope and Reykjanes ridge. p. 161-200 in: Hopper, A.G. (Ed) Deepwater fisheries of the North-Atlantic Oceanic Slope. NATO ASI Series, Series E. Applied Sciences, vol. 296, 420 pp.
- Thomsen, B.** 1998. Faroese quest of orange roughy in the North Atlantic. ICES C.M. 1998/O:31.
- Troyanovsky, F.M. & S.F. Lisovsky** 1995. Russian (USSR) fisheries research in deepwaters (below 500 m) in the North Atlantic. p. 357-366 in: Hopper, A.G. Deepwater fisheries of the North-Atlantic Oceanic Slope. NATO ASI Series, Series E. Applied Sciences, vol. 296, 420 pp.
- Van Dover, C.L.** 2000. The Ecology of Deep-Sea Hydrothermal vents. Princeton University Press. 424 pp.