ESF EUROCORES Programme

Challenges of Biodiversity Science (EuroDIVERSITY)

Final report

European Science Foundation (ESF)

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Until the end of 2008, scientific coordination and networking was funded through the EC FP6 Programme, under contract no. ERASCT- 2003-980409. As of 2009, the national organisations support all aspects including scientific coordination, networking and research funding.

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Cover picture:
Cliffs of Inis Mor, Aran Islands, Ireland

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Foreword

At the start of the Decade of Biodiversity (2011-2020), as recently declared by the United Nations, it is our pleasure to present the final report of the ESF EUROCORES programme EuroDIVERSITY. The report reflects the outcomes of about four years of collaborative research and networking among science teams from 18 mainly European countries. In line with the objectives of the EuroDIVERSITY Programme scientists now better understand biodiversity changes, gained more insights in impacts of biodiversity changes on ecosystem services and explored the interface between biological and social systems.

As confirmed by the international Review Panel who assessed the outcome of the programme, it offered a forum to establish rigorous common sampling designs, experimental and analytical protocols adopted in a wide-ranging comparisons. It enabled broad comparative surveys or common experiments in large geographical, altitudinal and habitat gradients. A further accomplishment is the strong emphasis on microbial ecology, that is seen as a key field of research per se and in many ecosystem processes and services. Finally the collaboration in field work with costly and complex logistics, such as joint deep-sea sampling and data collection was very much valued.

The collaboration that was established by the research consortia through joint training, workshops, exchange visits and fieldwork sparked off new ideas for future research. Some of these ideas resulted already in new funded projects for instance in the frame of the EUROCORES Programme Ecological and Evolutionary Functional Genomics (EuroEEFG). The report provides recommendations for future research topics that need to be addressed and suggests joint funding and support mechanisms.

In conclusion we believe the EuroDIVERSITY Programme was an efficient investment in European collaborative biodiversity research and paved the way to address the challenges as summarised in the mission statement of the UN Strategic Plan 2011-2020: *"take effective and urgent action to halt the loss of biodiversity in order to ensure that by 2020 ecosystems are resilient and continue to provide essential services, thereby securing the planet's variety of life, and contributing to human well-being, and poverty eradication....."*.

With this we would like to thank the National Funding Organisations who participated in this EUROCORES Programme and the international Review Panel for their valuable contributions.

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1.
Description of the EuroDIVERSITY Programme

1.1 Rationale and objectives

Ecological systems across the globe, from local to global scales, are being threatened or transformed at unprecedented rates due to the ever-increasing human domination of natural ecosystems. In particular, massive biodiversity changes are currently taking place, and this trend is expected to continue over the coming decades, driven by the increasing extension and globalisation of human affairs. Human impacts on biodiversity, however, take place against a background of complex ecological and evolutionary processes that have shaped the biodiversity we observe today, and that determine the form and extent of these impacts, as well as the effectiveness of conservation, management and restoration strategies. Understanding how ecological, evolutionary and socioeconomic factors interact to determine the dynamics of biodiversity at different scales, both in space and in time, is an important challenge. Biodiversity change is a matter of concern, not only because of the intrinsic, aesthetic, ethical or cultural values attached to biodiversity, but also because it has numerous potential consequences for our own life support system. In recent years new research has focused on the role of biodiversity in the functioning of natural and managed ecosystems. This recognises the possibility of biodiversity change threatening the capacity of ecosystems to deliver valuable ecological services for humans, such as the production of food and fibre, carbon storage, the maintenance of water quality and soil fertility, the reduction of greenhouse gas emissions, the resistance to climate and other environmental changes, and the maintenance of ecological conditions favourable for human health. However, the scale and focus of ecological research on biodiversity has remained quite local, and has concerned specific processes in specific ecosystems, in particular primary production in grasslands. Our understanding of the broader implications of biodiversity change is still very limited and represents one of the major challenges of today's ecology. Over the same period, economists have addressed the impacts of institutional and market change on habitat loss as a proxy for species loss. They have also sought to value the consequences of species loss for pharmaceuticals, amenity and recreation. However, little effort has been devoted to linking ecological and socioeconomic consequences of changes in ecosystem processes and the flow of ecological services. There has been considerable activity by the scientific community over biodiversity during the past decade, which has resulted in the identification of new challenges for biodiversity science. In particular, there is an urgent need to develop a more integrated and predictive science of biodiversity capable of bridging the gaps that exist between the natural and social

sciences, between work on terrestrial, freshwater and marine ecosystems, between work on plants, animals and micro-organisms, and between theoretical, experimental and observational approaches. This need has been acknowledged by international initiatives such as DIVERSITAS, the international programme of biodiversity science. These initiatives, however, are intended to identify research priorities without providing funding for research itself. The EUROCORES programme EuroDIVERSITY aimed to meet this research need by fostering top-quality biodiversity research in Europe.

The goal of EuroDIVERSITY was to support the emergence of an integrated biodiversity science based on an understanding of the fundamental ecological and social processes that drive biodiversity changes, their impacts on ecosystem functioning and services, and societal responses to these changes. This should result in new tools and strategies for the conservation, restoration and sustainable use of biodiversity. The programme had a strong focus on generalisations across systems and on the generation and validation of theory relevant to experimental and empirical data. Proposals were expected to contribute to this goal by initiating or strengthening major collaborative research efforts across Europe and worldwide on one or several of the research topics below.

1.2 Detailed description of subfields

Based on the rationale and objectives of the Programme, the following subfields were described in the Call notice as guidance for the applicants to be addressed in their research proposals.

1.2.1 Understanding biodiversity change

- Ecological, evolutionary and socioeconomic processes that drive biodiversity change, and the interplay between these processes.
- Causes and predictive value of biodiversity patterns, including macro-ecological and other emergent properties of complex systems across levels of biological organisation.
- Effects of genetic biodiversity within and among species on population, community and ecosystem processes.

1.2.2 Understanding impacts of biodiversity change on ecosystem services

- Impacts of biodiversity changes (including biological invasions) on ecosystem functioning, stability and services, and their underlying mechanisms.
- Functional role of microbial biodiversity in ecosystems.
- Consequences of food-web and non-trophic interactions for ecosystem functioning.
- Spatial processes across systems, meta-communities, and the dynamics of biodiversity and ecosystem processes at landscape to regional scales.

1.2.3 Exploring the interface between biological and social systems

- Socioeconomic consequences of changes in ecosystem services driven by biodiversity; assessment of opportunities for, and limits to, substitution between these services and man-made capital.
- Identifying the basis of social choice (values, incentives) for the conservation, restoration and management of biodiversity.
- Dynamics of coupled social and ecological systems: effects of cross-scale interactions and mismatch between ecological processes, socioeconomic processes and management institutions.

1.3 Facts and figures about the Programme

- **Funded Collaborative Research Projects (CRPs):**
  10 CRPs, involving 127 research teams (incl. 37 Associated Partners) from 18 different countries
- **Duration of Programme:**
  2006-2010
- **Budget for Research:**
  14 m€

1.4 Overview of funded Collaborative Research Projects

The EUROCORES Evaluation and Selection procedure that was applied to the research proposals that were submitted to the EuroDIVERSITY Call for proposals yielded 10 funded Collaborative Research Projects (CRP). These are listed below with reference to the project-leaders and principal investigators of the involved research teams.

The final reports of the individual CRPs, describing the output that was produced in the time-span of the programme, can be obtained from the Annex to PDF of the Final assessment report at the programme webpage: www.esf.org/eurodiversity.

In line with the quality assurance guidelines for EUROCORES Programmes, the final reports of the funded projects have been assessed in view of the objectives of the EuroDIVERSITY Programme by an international Review Panel. The consensus statements and recommendations of this panel are described in chapter 2, 3 and 4 of this report.

List of funded Collaborative Research Projects

- **The Role of Microbial Diversity in the Dynamics and Stability of Global Methane Consumption: Microbial Methane Oxidation as a Model-System for Microbial Ecology (METHECO)**
  Project Leader: Professor Peter Frenzel
- **Plant Functional Traits and Assembly of Plant Metacommunities in Fragmented Landscapes (ASSEMBLE)**
  Project Leader: Professor Michael Kleyer
- **Coupling Biofilm Diversity and Ecosystem Functioning: The Role of Communication and Mixing in Microbial Landscapes (COMIX)**
  Project Leader: Dr Tom Battin
- **Microbial Diversity and Functionality in Cold-Water Coral Reef Ecosystems (MICROSYSTEMS)**
  Project Leader: Professor Jean-Pierre Henriet
- **Connectivity, Dispersal and Priority Effects as Drivers of Biodiversity and Ecosystem Function in Pond and Pool Communities (BIOPOOL)**
  Project Leader: Professor Luc De Meester
- **Biodiversity of European Grasslands – the Impact of Atmospheric Nitrogen Deposition (BEGIN)**
  Project Leader: Dr Gowing David
- **Ecological Thresholds for Reshaping Ecosystem Networks: Ameliorating Landscapes Driven by Economic Development (EcoTRADE)**
  Project Leader: Professor Paul Opdam
- **Molecular Archives of Climatic History: Exploring Patterns of Genomic Differentiation in Endemic Species Radiations of Ancient Lakes (MOLARCH)**
  Project Leader: Dr Erik Verheyen
- **Biodiversity and Biogeochemical Cycles: A Search for Mechanisms across Ecosystems (BioCycle)**
  Project Leader: Dr Stephan Hättenschwiller
- **Agricultural Policy-Induced Landscape Changes: Effects on Biodiversity and Ecosystem Services (AGRIPOPES)**
  Project Leader: Professor Jan Bengtsson

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2.
Consensus statements by the Review Panel

2.1. Evaluation of the programme on the basis of its scientific achievements

The Review Panel felt that, scientifically, the EUROCORES Programme EuroDIVERSITY can be rated a very successful programme. A full assessment will only be feasible in two to three years, when data compilation, analysis and writing should be ended. Most reports state or suggest that essential parts of these tasks are still being completed. In several projects the major conclusions and publications are yet to be written up. This is no surprise, given the tight span for the programme. However, there is sufficient basis for a comprehensive evaluation at this time.

The majority of the final reports that were assessed by the panel are very positive in assessing their projects and they strongly assert the importance and essential role of EuroDIVERSITY in fostering research in their area. Given the strong competition for EuroDIVERSITY, all selected projects were expected to carry out their proposals and they did so to a large extent. However, not all of them have shown noteworthy results to date.

The panel listed some specific accomplishments that indicate the unique contribution of EuroDIVERSITY in view of the initial objectives of the programme:

1) The establishment of rigorous common sampling designs, experimental protocols, lab procedures, analytical protocols, adopted in wide-ranging comparisons. In general, large-scale surveys or comparative analyses to date have had to rely on data gathered for different goals and using different methods and criteria. This critical limitation to broad-scale ecological studies can only be overcome by establishing common procedures, and this was highlighted in many reports as an outstanding advance made possible by EuroDIVERSITY.
2) Broad comparative surveys or common experiments in large geographical, altitudinal and habitat gradients. To be carried out, these required both the establishment of common procedures, and the collaboration of research groups in different locations and countries. Again, the scale of integration was emphasised in most reports as a major contribution of EuroDIVERSITY to their respective areas.
3) A strong emphasis on microbial ecology, which has received relatively little attention in the initial phases of biodiversity research. This is certainly a vital forefront for future work, given its importance per se and as a key element in many ecosystem processes and services.
4) Collaborative projects on field work with costly and complex logistics, such as joint deep-sea sampling and data-collection (*e.g.*, MICROSYSTEMS).

Understanding the impact of biodiversity change on ecosystem services did not advance as much as one might have wished, although several projects proposed to. Methodological barriers and the need to develop new conceptual tools and models may have been beyond the achievable scope of these projects. Note, in this respect, that few approved CRPs proposed theoretical work and model development as a major goal, and those who did seem not to have made much progress (*e.g.*, BioCycle), with the possible exception of COMIX.

The third major research topic of EuroDIVERSITY, 'Exploring the interface between biological and social systems', ended up as the major theme of only

one project, EUROTRADE, although land-use parameters entered as important variables in AGRIPOPES and in some other CRPs. This interface thus is apparently where EuroDIVERSITY seems to have been least effective in terms of its stated goals.

2.2 Evaluation of the programme on the basis of networking, training and dissemination

According to the Review Panel, networking was one of the most successful components of EuroDIVERSITY. In almost all cases, intra-CRP networking was recognised as a key element for achieving proposed goals. Joint training, workshops, exchange visits, collaborative field work, etc. were incorporated by all CRPs, especially the most successful ones.

Integration among CRPs clustered according to thematic affinity and personal links. Combined workshops were clearly very profitable for all participating CRPs, though they rarely produced high-impact joint publications. One striking lack of integration seems to have been between METHECO and MICROSYSTEMS, both of which focused on methane-consuming microorganisms.

Judging from authorship of publications and presentations, integration and involvement of senior investigators was very high in many projects, but very variable in some cases. In some projects, most publications are authored by one or two research groups, and some Principal Investigators (PIs) do not appear in any publication. This may be due to incomplete reporting; possibly, some PIs dropped out from projects and this may have been explained in intermediate reports.

Training and capacity-building seems, again, to have been very well achieved in most CRPs. However, the number of funded PhDs seems fairly low compared to the number of senior investigators listed in Individual Projects; it would have been interesting to know how many other PhD candidates or post-docs were involved in CRPs with support from other sources, since these were not listed in the reports. Several post-docs and some PhD students had a significant role in most projects, and their participation was a key element for the success of the most productive CRPs. Thus, the extended funding of these project participants to enable them to write up results would accelerate the visible products of the CRPs.

In contrast to the foregoing, the dissemination of the CRPs was felt to be very timid and restricted to local press coverage, with some striking exceptions. This suggests that better support for the CRPs or liaison with major media by way of a more proactive press office would help to enhance coverage and visibility. It was also noted that no manuscript was submitted to halfway journals such as *Frontiers in Ecology and the Environment* or *Ambio*.

2.3 Recommendations to ESF and funding agencies

It seems clear to the panel that, on a fairly short-term scale, a programme such as EuroDIVERSITY may stimulate the development of novel methods and approaches, but these cannot then be applied extensively in the same time frame. In this case, the key contribution of the programme will be to set the ground for future work, which will be accomplished in ensuing integrated programmes or by individual research groups that choose to adopt the new tools or protocols. As another strategy, the programme may foster extensive surveys or common experiments that produce large-scale results in a fairly short period. However, this can only be accomplished when methods and protocols are already available and, as a rule, also by building on a preexisting core of links and collaboration among research groups. Both strategies are important but they cannot be expected to advance simultaneously within a single project unless it has much longer duration.

In retrospect, the portfolio of projects for EuroDIVERSITY seems to have been well selected, but even so, 10 projects could hardly cover the very wide-ranging agenda proposed for the programme. Future programmes would benefit from a somewhat tighter thematic focus at the onset.

Support for projects should be decided in concert and, once they are approved, need to be implemented completely and simultaneously by all agencies concerned. Clearly, several projects suffered delays and some major setbacks from (a) some key participants – even the project leader – not being funded, (b) partial if not insufficient funding of some component projects, (c) lags in making funds available. Though no project failed completely because of this, several achieved less than they could. A better integration among agencies, and more decisive and cohesive support for approved projects, would certainly enhance the efficiency and cost-effectiveness of the entire programme.

The panel would like to state that biodiversity will not only remain a key area for research work, it is likely to keep growing in importance as its rami-

fications and consequences for the future well-being of human populations become clearer. However, biodiversity research differs from other major research areas in some key respects. First, the minimum time scale to enable and carry out extensive field work or field experiments and process the resulting samples. This is laborious and can be expedited to a very limited extent; it depends on seasons, replication is over years and useful time-series are even longer. Thus, biodiversity research has intrinsically longer time spans. Increasing the project duration by one or two years would have a tremendous positive effect on the quality and import of results. Second, the yield of publications will be significantly higher when monitored two or three years after the completion of the experimental work, because that is the time it takes to process the gathered data into publishable results. The panel also noticed that several authors do not properly acknowledge ESF in their papers or the publications are not resulting from the work that has been carried out under the EuroDIVERSITY header. Third, biodiversity research cannot be switched among sites at will; therefore, including or excluding research groups with experience in certain regions and habitats has a much greater impact on integrated projects than changing the combination of research groups in other subjects which are not site-specific.

Finally the Review Panel would like to recommend that key areas for future projects should include, once more, the improved understanding and modelling of ecosystem processes and services with respect to key biodiversity features; and the joint investigation of social, biological, physical and economical processes as reciprocally affecting interactors. This has been the stated goal of an increasing number of integrated programmes, but workable and applicable models remain yet to be produced.

A more detailed analysis and view from the scientific community on topics for future research programmes concerning biodiversity is given in Chapter 4, Future Perspectives.

3. Highlights in research, networking and dissemination

A few highlights from the vast list of events and achieved milestones were selected to demonstrate the overall networking performance within the programme.

The Review Panel highly appreciated the achievements of the BIOPOOL project. The framework of the project was based on the ingenious idea of using pond and pool ecosystems as models of aquatic and terrestrial ecosystems that are more complex, with less clearly defined borders, and are thus more difficult to manipulate. The ponds and pools are also convenient to sample, easy to model and may be used to artificially create mesocosms through inoculation with key auto- and heterotrophic inhabitants that can be transferred from even remote locations. Moreover, the natural pond ecosystems are often destroyed by drought or ice, and the process of community assembly remains a common phenomenon there, thus allowing lots of field data to be collected and compared to data from experimental systems or mathematical models. The careful combination of the model, field and experimental studies has allowed the project's investigators to make numerous novel observations on the process of community assembly, with the forces of dispersal, priority effects and adaptation mediating the output of the emerging community structures across different European landscapes.

The novelty of the scientific achievements of the project, as reported in the most important ecological journals, may give an important impulse to European limnology. After the vigour of the 1980s and 1990s, stemming from the concepts of biomanipulation and trophic cascades and from the inspiration derived from behavioural and evolutionary questions, this field has stagnated recently. New approaches to questions of eco-evolutionary dynamics and the mechanisms of community assembly pioneered by the project might provide much needed inspiration for the next generation of European limnologists.

The *Nature Reviews Microbiology*[1] and the *Nature Geoscience*[2] papers, resulting from the METHECO project, got very good press responses. Press releases were massively covered by numerous magazines and daily newspapers, and by various websites around the globe.

In terms of industrial applicability of results the COMIX partners gained attention from AkzoNobel, International Paints, who were interested in the model of biofilms to address biofouling issues on ship hulls. Unilever showed interest in the biogeography of skin microbes.

The ECOTRADE consortium was asked to provide comments on the green paper of the European Commission on market-based instruments for environment and related policy purposes (2007). The presentation of the ECOTRADE Game, a multiplayer online game of a tradable permit market, at the Wissenschaftssommer (Science Fair) in Leipzig from 28 June to 4 July 2008 was an outreach activity that generated visibility to the general public.

An ECOTRADE partner organised a workshop about the case study (the Green Heart area in the Netherlands) with stakeholders from both science and policy backgrounds. This resulted in awareness about the concept and the project with the stakeholders, and stakeholder contribution to the project by providing data sets that enabled market-based

1. BATTIN, T.J. *et al.* (2007) Microbial landscapes: new paths to biofilm research. *Nature Reviews Microbiology* 5, 76-81.
2. BATTIN, T.J. *et al.* (2008) Biophysical controls on organic carbon fluxes in fluvial networks. *Nature Geoscience* doi:10.1038/ngeo101.

instruments to be tested in a real-world context, December 2007.

The joint paper of Geiger et al. (2010)[3] was well received in the many newspapers and professional journals on agriculture and environment. It created general outreach in the countries of the teams that participated in the AGRIPOPES project

Some CRPs developed a project related website. The web-links are listed below:

- MOLARCH: http://www.naturalsciences.be/institute/structure/molelabo/vertebrates/projects/molarch
- ASSEMBLE: http://www.uni-oldenburg.de/landeco/20670.html
- AGRIPOPES: http://agripopes.net
- BIOPOOL: http://bio.kuleuven.be/de/dea/biopool
- BioCycle: http://biocycle.cefe.cnrs.fr

The collaboration among the BioCycle partners across separate scientific communities yielded a cross-systems perspective on the role of biodiversity in biogeochemical cycling published as a review article in *Trends in Ecology and Evolution*[4]. The new ideas developed in the paper were strongly influenced by the common activities in the CRP and the possibility to meet regularly and discuss face to face.

EU-Southeast Asia Expert Meeting on conservation and sustainable management of biodiversity (Hanoi, Vietnam, 25-27 January 2010) – A BioCycle partner participated in a biodiversity expert workshop organised by SEA-EU-NET, a project funded under the EU FP7 to expand scientific collaboration between Europe and Southeast Asia (SEA). Based on the experience in the BioCycle CRP, workshop participants were asked to provide input to the European Commission (EC) on the potentials for cooperation between European scientists and SEA scientists on research topics of mutual interest.

A joint workshop was organised by ASSEMBLE, BioCycle and BEGIN at the Free University of Amsterdam in April 2008, entitled 'Current Perspectives in Functional Ecology'. The workshop aimed to assist project members to remain at the forefront of recent developments and to have the opportunity to discuss the relevance of new advances to the EuroDIVERSITY programme.

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Professor Michael Kleyer
(Project Leader, ASSEMBLE, Carl von Ossietzky University of Oldenburg):
"I would like to thank ESF for bringing the EuroDIVERSITY programme into being. It came at the right time (when EU FP6 required consortia of large sizes that couldn't be handled any more by universities alone) and it proposed advanced research questions."

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Dr Stephan Hättenschwiler
(Project Leader, BioCycle, CEFE-CNRS Centre of Functional Ecology and Evolution):
"We found our participation in EuroDIVERSITY an extremely rewarding way of collaborating with research teams across Europe. The clearly defined European-wide collaboration, based on a bottom-up approach within a defined research area and the administrative workload kept to a minimum is perhaps the most obvious added value. The latter is achieved by an effective combination of national funding practices, to which the individual researchers are already used, and supplementary ESF-level funds to facilitate networking activities and meetings within and across individual projects. This is likely one of the most efficient funding strategies for European level research. From my perspective as a project leader, the ESF administration is slender, efficient, transparent, and refreshingly un-bureaucratic, all of which maximises the actual time spent doing research. The EUROCORES programme in general is a scientifically highly respected initiative of considerable prestige, and being part of such a programme provides excellent awareness of the research activities among colleagues."

The BIOPOOL project generated broad media coverage on several occasions. The network was reinforced and extended through meetings like: EURECO-GFOE Conference 'Biodiversity in an Ecosystem Context' (Leipzig, 15-19 September 2008). In the framework of the EuroDIVERSITY Programme, several workshops were organised by the METHECO consortium, often in collaboration with other CRPs. To name a few:

- Workshop on Theoretical Landscape Microbial Ecology, University of Glasgow, Scotland, 20-22 February 2008, Organiser: Dr Bill Sloan (COMIX).
- Workshop on Microbial Diversity and Ecosystem Functioning, WasserCluster, Lunz, Austria, 7-11 March 2007, Organiser: Dr Tom Battin (COMIX)

3. GEIGER, F. *et al.* (2010) Persistent negative effects of pesticides on biodiversity and biological control potential on European farmland. *Basic and Applied Ecology* 11, 97-105.
4. GESSNER, M.O., SWAN, C.M., DANG, C.K., MCKIE, B.G., BARDGETT, R.D., WALL, D.H., and HÄTTENSCHWILER, S. (2010) Diversity meets decomposition. *Trends in Ecology and Evolution* 25 (doi:10.1016/j.tree.2010.01.010).

and Professor Peter Frenzel (METHECO).

- ESF Exploratory Workshop: Valuing Biofilm Services: the Beauty and the Beast, 19-22 September 2007, WasserCluster, Lunz, Austria, Convenor: Dr Tom Battin.
- Workshop on Metacommunity Dynamics and Biodiversity, Odalgarden, Uppsala, Sweden, 12-16 May; attended by researchers Stephen Woodcock, Katharina Besemer, Iris Hödl.
- Graduate course on Microbial Metacommunity Ecology, University of Uppsala, 2009. Participation by PI Battin (and by PI Bengtsson and PI de Meester from other CRPs).

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Professor Paul Opdam

(Project Leader, ECOTRADE, Wageningen University and Research Centre):

"The EURODIVERSITY programme has provided us with the opportunity to conduct research in an interdisciplinary, international context. It is very positive that it was possible to develop our research project without much restriction on content like in most EU research programmes.

As a European research project we are internationally more visible. The Centre for Environmental Research of Leipzig (UFZ) team presented the ECOTRADE project in the context of workshops organised during visits by Professor Steve Polasky (University of Minnesota, USA) and Professor Nick Hanley (University of Stirling, UK) at UFZ. The added value of being part of the EUROCORES programme to our project could have been stronger if there would have been more common ground between our strongly interdisciplinary project, with an emphasis on ecology, regional scale spatial planning and environmental economics, and the other projects with their emphasis on hard core biology."

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Professor Jean-Pierre Henriet

(Project Leader, MicroSystems, Ghent University):

"The bottom-up approach open to any new idea, the flexibility and cost-effectiveness of this programme, the added value of short-term grants and incentives for workshops which come as a bonus when the need is expressed, the no-nonsense reporting and evaluation procedures, the flexibility to pick up associate partners in an ongoing programme when justified have turned EUROCORES into a unique and essential instrument for the benefit of European and international science.

Sea-going research is by nature an intrinsically networking activity. All cruises (R/V Marion-Dufresne, R/V Belgica, R/V Pelagia, R/V Merian, R/V James Cook, etc.), much more numerous than announced in the proposal, brought together scientists from various MICROSYSTEMS teams. By these cruises and subsequent analyses, strong collaborations evolved between participating research groups, most if not all resulting in joint publications."

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4.
Future perspectives

Biodiversity research is overwhelmed by the fast pace of observed changes and has difficulties to move beyond observational studies in the attempt to develop a mechanistic basis for both the determinants of biodiversity loss and the consequences of this loss for ecosystem functioning. The search for mechanisms should be a high research priority, because the mechanisms would contribute to the urgently needed tools to predict the consequences of biodiversity loss for ecosystem functioning. Related to this issue is the need to make a specific effort to bring together the scientific communities of theoretical modellers, modellers developing mechanistic models, and experimentalists. While this need is widely recognised, programmes that successfully fund common projects across these communities are rare or inexistent. One important challenge for such a common programme is to bridge the very different temporal and spatial scales that these scientific communities are used to consider.

1. Eco-evolutionary dynamics

A clear need is felt for calls that include studies on eco-evolutionary dynamics, *i.e.*, studies that quantify interactions among ecological and evolutionary processes and how these impact responses of populations, communities and ecosystems to environmental change. Fields of research that involve eco-evolutionary dynamics are studies on 'evolving metacommunities', 'community genetics', 'geographic mosaic of coevolution', etc. There is growing evidence that the interplay between ecology, evolution and space (dispersal, landscape structure) may be very important in determining the biological responses to anthropogenic impact, including climate change and exotic species. Eco-evolutionary dynamics ideally should include the broad range of disciplines, going from genomics even up to ecosystem services.

2. Biological responses to multiple stressors

There is a need for research programmes that tackle biological responses to multiple stressors, *e.g.*, the combined action of different anthropogenic stressors (*e.g.*, toxic substances and temperature) as well as of anthropogenic and other stressors. Here too, the range of approaches could/should go from genomics to ecosystem responses, and here too there would/should be room for eco-evolutionary dynamics.

3. Priority effects and biodiversity conservation

The impact of priority effects, including evolution-mediated priority effects, on nature conservation should be the focus of targeted study. When, for instance, new habitats are being constructed or degraded habitats are being restored, they are likely to be first colonised by opportunistic species – it is insufficiently known to what extent that reduces the power of nature conservation measures in protecting biodiversity. The issue of priority effects becomes more important also in the light of climate change and its associated problems of differential migration of species.

4. Biodiversity and ecosystem services in a landscape context

There is a need for more studies on the impact of biodiversity on ecosystem services – studies that should also include aquatic systems, forests and other systems that are understudied so far. Importantly, there is a strong need for a landscape approach, so as to design the optimal strategies for biodiversity and

ecosystem conservation that both take biodiversity and ecosystem system hotspots into consideration, and how these two aspects interact. Importantly, the impact of biodiversity on ecosystem resilience needs to be documented further, especially given the ever increasing environmental challenges ecosystems are confronted with, especially in the light of climate change.

5. Priority effects, evolution and biodiversity in aquatic systems

This is a plea to extend the 'BIOPOOL' approach to other aquatic systems such as groundwater (drinking water quality), larger lakes (recreation) and rivers.

6. Dispersal capacity as a filter in ecological processes

Dispersal is an important process that determines metapopulation and metacommunity structure, diversity at a regional level, and responses to environmental change. Species within and among trophic levels may differ strongly in their dispersal capacity, and we feel that the consequences of this variation is a vastly understudied theme.

7. Climate change, dispersal vectors, and diversity and community composition in ponds and lakes

The distribution of migratory water birds appears to be shifting in response to climate change, and predictions for future changes in breeding distribution have already been made, although models predicting changes in timing and extent of migrations are so far lacking. Such changes have unknown consequences for the viability of plant and invertebrate populations dependent on these vectors. At the same time, passive dispersal by birds will facilitate the northwards movement of plants and invertebrates required to compensate for temperature increases, yet it is currently unclear whether such dispersal rates will be fast enough to match the speed of temperature increase. Pond and lake organisms are interesting model systems to study these interactions between dispersal, environmental change and climate change. Estuaries may also be an interesting model for such studies. More in general, it is felt that the 'cascading' effects of (long-term) landscape changes on waterfowl distribution/movements, wetland connectivity, metacommunity composition and eco-evolutionary dynamics would be a very promising and important area of research.

ECOTRADE is one of the first studies ever exploring the interface between economy and ecology in spatially explicit dynamic conservation systems. The consortium has uncovered interesting perspectives for merging conservation and sustainable development, but also that they have only touched the tip of the iceberg. The following research priorities are therefore proposed: The cooperation of economists, ecologists and modellers has been productive and beneficial for the analysis of habitat banking. The results would not have been produced within a disciplinary working group.

The study of market-based instruments for biodiversity conservation is still in its infancy. Funding should be directed towards better understanding of how to design them effectively and cost-effectively. This should also include funding for projects in developing countries as there is an increasing relevance of such instruments (like Payments for Environmental Services – PES and the idea of Reducing Emissions from Deforestation and Degradation – REDD).

More specific aims are:

- Fundamentally improve knowledge and theory on species response to changing configurations of habitat at regional scales. Insight is needed into the time and spatial scale ranges in which spatial turnover of habitat patches does not result in species loss. This requires empirical (time series) and metapopulation modelling studies at a variety of scales and for slowly- and fast-developing ecosystem types.
- Improve integration between spatial planning of sustainable development and static conservation systems. Compare market-driven conservation network dynamics with spatial policy regulated dynamics, and find out where (under which economic and spatial conditions) different combinations of the two systems result in cost-effective and ecologically viable biodiversity conservation.
- Extend valuation systems. For a proper integration of ecosystems into sustainable development it is necessary to extend the valuation of habitat and species (which in ECOTRADE was based on intrinsic value only) in with ecological, economic and social value of biodiversity (ecosystem services). This will connect ecosystem function with societal benefits.
- Develop interactive planning and design systems suitable for collaborative planning at the regional and local scale, for communities of farmers, citizens, entrepreneurs, land managers and conservationist groups. Such systems should be developed to facilitate these planning groups in gaining insight into their common values and perspectives with respect to ecosystems and biodi-

versity, and also must allow them to explore spatial solutions for landscape adaptation in which biodiversity is a full and viable part of the regional socio-ecological system.

Considering global change and the enormous role of microbes and microbial processes in all biogeochemical cycles, it is essential to include microorganisms in future biodiversity research. Ironically, studies on microbial biodiversity and ecosystem functioning may even be hampered by the rapid progress in method development. Great innovations during the last decade have generated a multitude of approaches, methods and protocols. Promises of the new techniques are great, in particular answering questions about microbial biodiversity, but both standardisation and backwards compatibility are missing. Comparing results between environments and/or research groups needs standardisation, and comparing established to actual methods calls for a careful analysis of the respective information content. Along with new techniques like high-throughput sequencing, the training of young scientists in bioinformatics becomes more and more essential. We are at risk that the scientific community will split up in two: one that is at the cutting edge following innovations in methods development; the other doing ecology, but not mastering the sensible tools necessary to measure microbial biodiversity.

The state of the art in microbial biodiversity research is still the qualitative assessment hunting for the yet unseen diversity. While this is important, future work in microbial ecology should cover the following topics:

- Quantitative assessment of ecological relevant microbial populations, and of their activities.
- Development of tractable strategies connecting phylogenetic and functional diversity, leading to a trait concept for microbes.
- Scaling of microbial populations and processes from the aggregate, where microbes interact, to the ecosystem, where services are affected.
- Exploring constructed and engineered microbial systems as models for BEF studies.
- Exploring resistance and resilience of microbial communities and their functioning in a changing world.

From the multitude of threats affecting microbes and microbial processes the following are important both at the European and global scale:

- Soil degradation, already a high risk, *e.g.*, in the Mediterranean.
- The increasing amplitude and/or frequency of fluctuations (rainfall, freeze-thaw cycles).
- The over-proportional warming of certain regions from the Boreal to the Arctic.

To solve these questions, coordinated efforts at the European level are required. A COST Action focusing particularly on methods development and standardisation could be an option. Another effort could be an ESF EUROCORES theme focusing on microbial ecology and bringing together bioinformatics, methods development and standardisation, and application to sensible microbial functions and environments. Such a programme should be accompanied by an inter-CRP training of young scientists during extended workshops as done so successfully in EuroDIVERSITY. It should also be considered that such a project would profit very much from a time scale longer than the three-year period available for EuroDIVERSITY.

- Funding of integrated and multidisciplinary projects for the study of microbial ecosystem functioning, especially in marine research where sea-going expedition logistics, geophysics and exploration tools, geochemistry and microbial molecular ecology are required to carry out innovative studies on the role of microbes in the geochemical cycles and to develop predictive models regarding microbial ecosystem functionality under changing conditions.
- Funding of new molecular approaches (metagenomics) in microbial ecology and environmental sciences.

The research dealing with aspects of cold water coral occurrences, habitats and ecology in combination with carbonate mound development will remain a major research topic because it affects the potential for fisheries, and new discoveries of cold water coral occurrences will underline the need to create marine protected areas and support maritime policy.

Furthermore, the studies relate to carbonate reservoir studies which stand high on the agenda in the oil industry. In addition, the microbial control on carbonate formation and its relationship with gas in the sub-seabed is just beginning to be appreciated.

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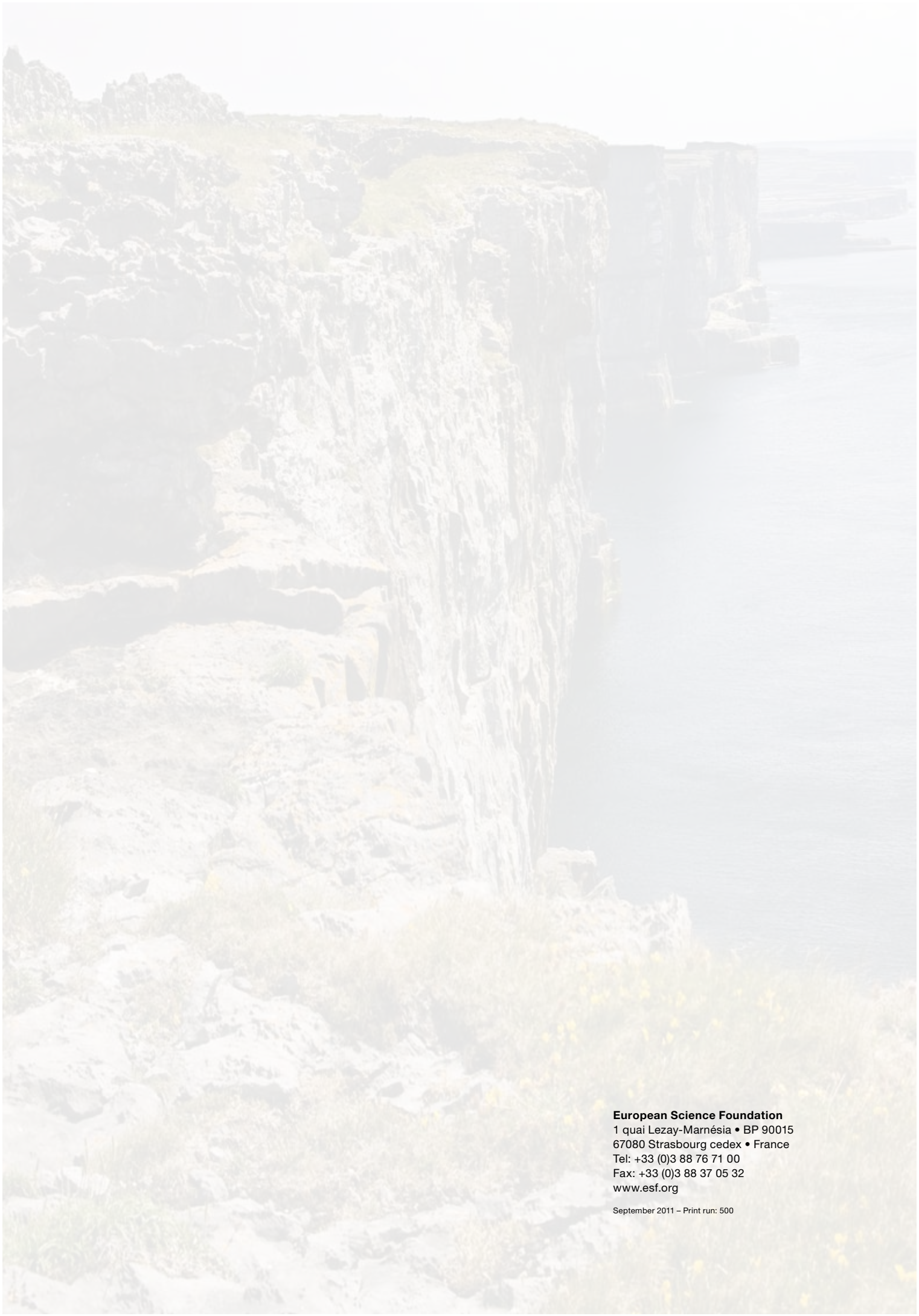
ISBN: 978-2-918428-51-0
Printing: Ireg Strasbourg



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September 2011 – Print run: 500