biodiversa

The ERA-Net promoting pan-European research on biodiversity and ecosystem services

Analysis of the outputs of

BiodivERsA funded projects

BiodivERsA 2008 joint call on “Biodiversity: linking scientific advancement to policy and practice”

To cite this report

Lemaitre F. & Le Roux X. (2015) Analysis of the outputs of BiodivERsA funded projects: BiodivERsA 2008 joint call on “Biodiversity: linking scientific advancement to policy and practice”. BiodivERsA report, 63 pp.

Acknowledgements

We would like to thank all the BiodivERsA partners who shaped the procedures promoting the type of research presented here, and who reviewed a previous version of this report. We are also grateful to Cédric Chavériat (FRB) for helping in the construction of the research collaboration map, to Hilde Eggermont (BelSPO) for proof-reading this publication, and to all the members of the funded research projects who accepted to spend time in providing and validating the information used for this report.

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ISBN: 979-10-91015 19 6

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Belgian Science Policy Office (BelSPO), Belgium

The Research Foundation - Flanders (FWO), Belgium

National Science Fund Bulgaria (NFSB), Bulgaria

Estonian Research Council (ETAg), Estonia

French National Research Agency (ANR), France

French Ministry of Ecology, Sustainable Development and Energy (MEDDE), France

New Caledonian Economic Development Agency (ADECAL), France

Guadeloupe Region (GUA-REG), France

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German Aeronautics and Space Research Centre (DLR), Germany

German Research Foundation (DFG), Germany

Ministry of Agriculture (FM), Hungary

Research Council of Lithuania (RCL), Lithuania

Research Council of Norway (RCN), Norway

National Science Centre (NCN), Poland

Portuguese National Funding Agency for Science, Research and Technology (FCT), Portugal

Regional Fund for Science and Technology (FRCT), Portugal

The Executive Agency for Higher Education, Research, Development and Innovation Funding (UEFISCDI), Romania

Spanish Ministry of Economy and Competitiveness (MINECO), Spain

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Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (Formas), Sweden

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Swiss National Science Foundation (SNSF), Switzerland

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Department for Environment, Food and Rural Affairs (Defra), United Kingdom

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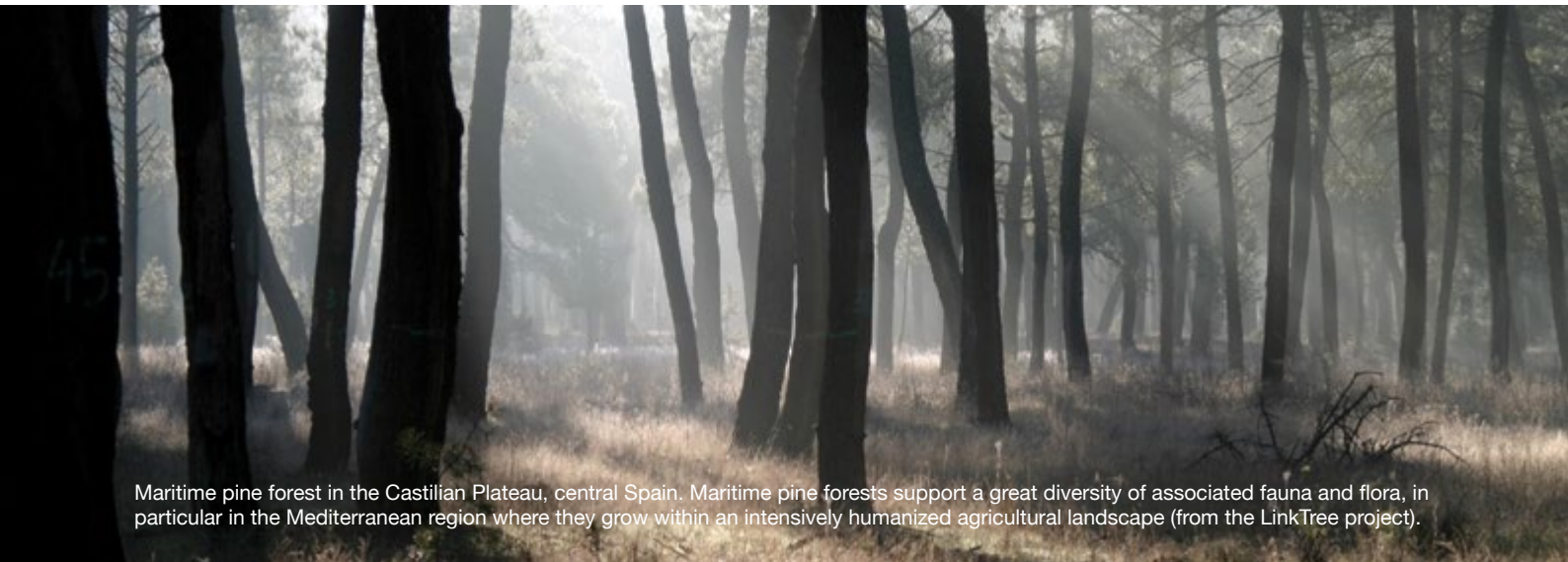
INTRODUCTION

BiodivERsA: promoting both the academic excellence and the societal relevance of research

BiodivERsA was built on the opportunity offered by the European Commission to coordinate European research on biodiversity and ecosystem services under successive framework programmes since 2005. It networks 32 Ministries, local governments, and agencies from 19 countries that program and fund research in Europe and the overseas to provide new knowledge for better protection and sustainable management of biodiversity and ecosystem services. Since 2005, BiodivERsA partners work together to promote high-level and – as needed - interdisciplinary research across Europe, tackling questions that cross national borders and calling upon a varied expertise ranging from natural sciences to social sciences.

Since its creation, BiodivERsA is looking to select research projects that tackle key scientific questions at the forefront of current knowledge and respond to interrogations from society (including policy-makers) on how to protect, interact with and use biodiversity and ecosystems in a sustainable way. To achieve this objective, BiodivERsA partners have designed specific processes to shape calls for research projects and evaluate submitted proposals, insisting on the societal and political relevance of projects they support, in addition to their scientific excellence. In particular, BiodivERsA accounts for suggestions made by scientific experts and pays particular attention to the policy and societal context when selecting topics and designing calls for research. Beyond the use of widely accepted criteria for evaluating academic excellence, the partners have developed explicit criteria for the evaluation of policy relevance and societal relevance of the research that BiodivERsA calls for. In addition, evaluation panels mobilized by BiodivERsA to assess research proposals involve experts in environmental policy, conservation and management of biodiversity and ecosystem services, alongside leading scientific experts.

BiodivERsA also strives to support the research community working on biodiversity and ecosystem services in engaging with their non-academic stakeholders. This is a crucial point for the delivery and uptake of useful knowledge and tools, but it is challenging for many scientists. In 2014, the network therefore published the *BiodivERsA Stakeholder Engagement Handbook* (http://www.biodiversa.org/577). The Handbook is the result of three years of gathering and confronting best practices and consulting BiodivERsA project investigators on their needs and the relevance of particular approaches to engage stakeholders. It provides researchers with a number of concrete steps, tools and case-studies to help understand their stakeholders' interests, positions and needs, as well as on how to best engage them, at what time and using which methods.



Maritime pine forest in the Castilian Plateau, central Spain. Maritime pine forests support a great diversity of associated fauna and flora, in particular in the Mediterranean region where they grow within an intensively humanized agricultural landscape (from the LinkTree project).

The challenge of evaluating the quality of academic productions and policy/society relevant products of research, along with stakeholder engagement

BiodivERsA recognises that using such innovative approaches calling for scientific excellence as well as society and policy relevance is challenging for applicants and ultimately the calls' successes. It is thus logical that BiodivERsA wants to evaluate to what extent this approach is successful, i.e. to what extent the projects funded by BiodivERsA are able to deliver high-profile academic products, while being able to actually and fruitfully engage with relevant stakeholders and deliver a range of high-quality, society-relevant products.

However, such a comprehensive evaluation is rarely done by research funding programmes and institutions (but see the work initiated by the UK Research Excellence Framework 2014[1]), probably because it is particularly challenging. Although important debates exist about the way to evaluate academic quality and excellence (e.g. Garfield and Welljams-Dorof 1992[2], Donovan 2007[3]), a range of methodologies, tools and metrics are available to assess that of research productions (Garfield 1979[4]). The most accessible measurement for a programme such as BiodivERsA is certainly the number of papers produced, and those published in high-impact journals (as a rule of thumb: excellent research will be published in excellent journals, even if defining what an excellent journal is may be more difficult than expected). Some difficulties may arise related to the time scale of research itself and publication time lags, and the identification of published papers that benefited (at least partly) from the support of a research programme. However, analysing stakeholder engagement and the different research outputs relevant for society and policy is much more difficult, and no turnkey solution exists for such an assessment. Here, we developed a methodology based on the typology - presented in the *BiodivERsA Stakeholder Engagement Handbook* - of (i) ways to engage stakeholders in research projects, and (ii) the stakeholder-relevant products this can generate. Given the difficulty to demonstrate societal impact of research and the delay that may exist between a research project's life and the impacts it has, assessing impact was beyond the scope of the analysis. Societal impact of research is indeed 'the demonstrable contribution that excellent research makes to society and the economy' (i.e. embracing all the diverse ways that research-related skills benefit individuals, organisations and nations, like increasing the effectiveness of public services and policy, fostering global economic performance, and enhancing quality of life, health and creative output) (Economic and Social Research Council; see also Bornmann[5], 2013).

The first BiodivERsA call for research projects (closure date in 2008) focused on "*Biodiversity: linking scientific advancement to policy and practice*" and attracted 14.2 Million Euros (in cash) from 8 countries, which allowed supporting the 12 pan-European projects discussed here. This publication presents the academic and society/policy relevant outputs of these projects, analyses how stakeholders were engaged in the research carried out, and evaluates whether a trade-off exists between the excellence of the academic production of these research projects and the excellence of their production of society/policy relevant outputs. We interviewed the Principal Investigator of each funded project - and often interacted with a few other key participants - to check the validity of the information used and of our analysis.

While completing the analysis, we discovered that most projects proved to be very successful, often both in terms of academic excellence and stakeholder engagement/societal relevance. The presentation of projects' outputs, with concrete figures and facts, demonstrates that the research on biodiversity and ecosystem services supported by BiodivERsA is actually linking scientific advancement - with major breakthroughs - to policy and practice thanks to very efficient links and collaboration with relevant stakeholders. We also observed that no trade-off exists between academic excellence and the level of production of society/policy-relevant outputs, or the investment

of research teams in engaging stakeholders. At a time where the co-creation of knowledge between a range of scientific disciplines and stakeholders and the need to go beyond the classical linear model of research of 'fundamental' and 'applied' research are increasingly called for (Mauser *et al.* 2013[6] ; Barot *et al.* 2015[7]), this is a clear demonstration that BiodivERsA has developed processes and skills to promote such co-creation using the stakeholder model of research. Moreover, this demonstrates that many biodiversity researchers have developed skills to conduct research projects that allow collaboration with relevant societal groups, reaching very efficiently the goals of scientific excellence and generation of stakeholder-relevant products.

Entandrophragma (Meliaceae) in a forest in Cameroon, CoForChange project.

[1] The Research Excellence Framework (2014) The new system for assessing the quality of research in UK higher education institutions. http://www.ref.ac.uk/

[2] Garfield E., Welljams-Dorof A. (1992) Citation data: their use as quantitative indicators for science and technology evaluation and policy-making. Science and Public Policy 19:321-327

[3] Donovan C. (2007) Introduction: Future pathways for science policy and research assessment: Metrics vs peer review, quality vs impact. Science and Public Policy 34:538-542

[4] Garfield E. (1979) Citation Indexing. Its theory and applications in Science, Technology and Humanities. Wiley, New York, 149 pp.

[5] Bornmann L. (2013) How to analyse percentile citation impact data meaningfully in bibliometrics: The statistical analysis of distributions, percentile rank classes and top-cited papers. Journal of the American Society of Information Science and Technology 64(3):587-595

[6] Mauser W., Klepper G., Rice M., Schmalzbauer B.S., Hackmann H., Leemans R., Moore H. (2013) Transdisciplinary global change research: the co-creation of knowledge for sustainability. Current Opinion in Environmental Sustainability 5:1–12

[7] Barot S., Abbadie L., Couvet D., Hobbs R.J., Lavorel S., Mace G.M., Le Roux X. (2015) Evolving away from the linear model of research. Trends in Ecology & Evolution 30:368-370

PART I

Methodology

Maculinea arion butterfly studied in the CLIMIT project.

Part I: Methodology

The outputs of funded projects were analysed using the information provided in the final reports of projects required by BiodivERsA, which includes sections for academic and society/policy relevant products, and sections for describing stakeholder engagement. This information and the way to analyse it were then validated with project investigators before finalizing the present report.

When identifying the contribution of a research programme (here the 2008 BiodivERsA call) to the production of scientific papers or society/policy relevant products, one can face several difficulties. Firstly, the research in general, the publication of research results and the delivery of society/policy relevant products from research results correspond to a process that takes time. This is why we completed the present analysis during the first semester of 2015: indeed, most of the projects funded through the 2008 call started in early 2009 and ended in 2013 (mean duration of 4 years). Performing the analysis of research results 2 years after their end-date seems the right delay to assess the productions of research projects, although it still can miss additional productions and outputs that the projects might deliver beyond this time frame.

Secondly, it can be difficult to evaluate the actual contribution of a given research programme to the production of some papers or other products when research teams are supported by different programmes that may partly overlap. In such a case, we relied on the researchers' indications, and their identification of all the productions that were at least partly but significantly supported by the BiodivERsA research programme.

I.1 ASSESSMENT OF THE ACADEMIC PRODUCTIONS

Academic impacts in the present document are computed from the analysis of peer-reviewed publications (including original research papers, reviews and opinion papers) produced by each funded project, as reported by project participants. The screening of publications resulting partly or fully from the BiodivERsA-funded projects is based upon the declarations of project investigators. However, for publications in top generalist journals, we made sure that the 15 papers identified corresponded to a BiodivERsA project, and that the 15 papers actually acknowledged support from BiodivERsA.

The 2013 impact factors of the journals were obtained using the *Journal Citation Reports* (Thompson Reuters).

Because impact factors are known to depend on the disciplines/sizes of the research communities, we also used an index of journal notoriety based on the frequency distribution of journal impact factors for each subject category of the Journal Citation Reports. This is helpful to perform fair comparisons of academic impacts among different disciplines. For each subject category, frequency distribution of impact factors is analysed according to Désiré *et al.* (2013)[7] with box plots identifying 5 journal notoriety groups as presented in Figure 1: outstanding, excellent, good, fair, poor. The groups 'good' and 'fair' correspond to the second and third quartiles of the frequency distribution, respectively.

[7] Désiré M., Magri M.H., Solari A. (2013) Interpretation of impact factors of the Journal of Citation Reports. INRA 341 pp.

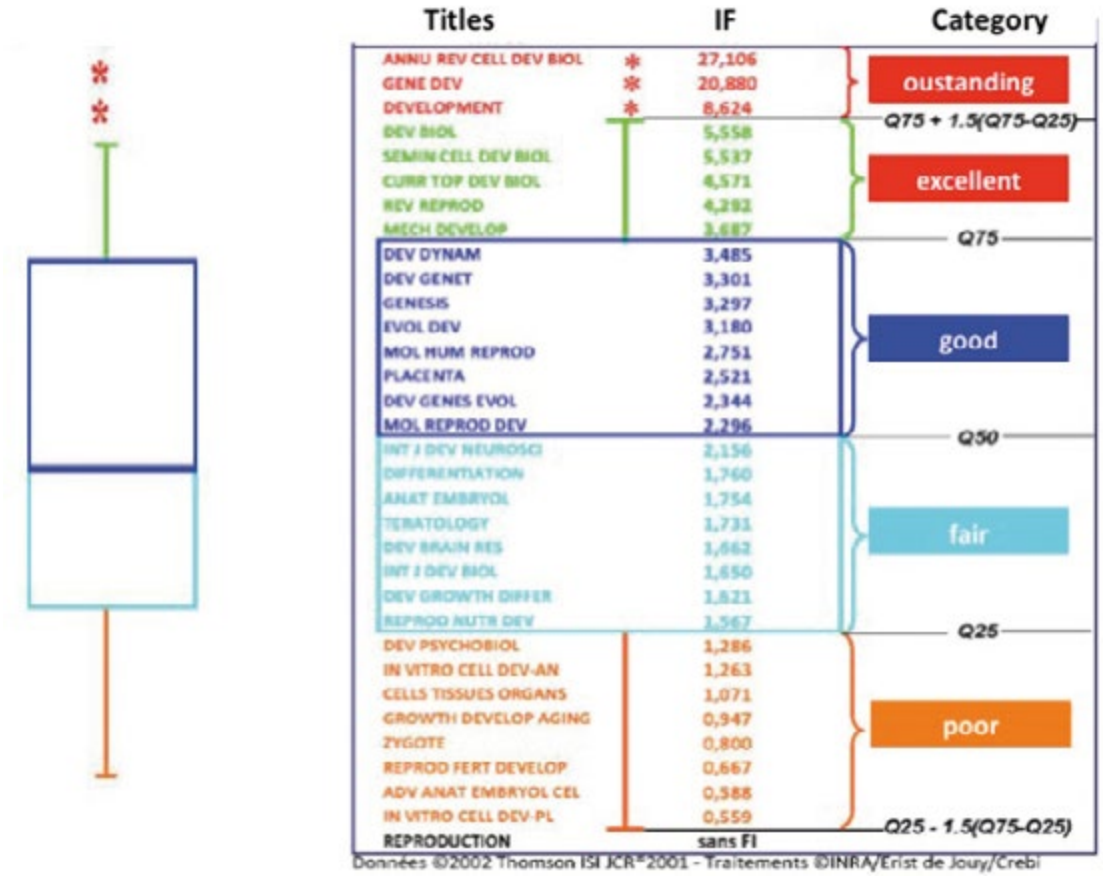


Figure 1: Method used to classify the scientific journals according to the frequency distribution of impact factors for each subject category. According to Désiré *et al.* (2013).

To compute an index of academic excellence of projects based on these journal groups, we attributed the following grades to each group: poor=1; fair=2; good=4; excellent=6; outstanding=8.

We thus used 4 different indices to assess the academic productivity and excellence of each project:

- ➔ the total number of papers published
- ➔ the sum of journal impact factors corresponding to all the publications produced
- ➔ the sum of notoriety grades of journals corresponding to all the publications produced
- ➔ the number of papers published in the four top generalist journals *(Nature, Science, Nature Communications* or *Proceedings of the National Academy of Sciences of the USA* - hereinafter refered to as *PNAS)*.

We also retrieved from the *Journal Citation Reports* (2013) the subject categories associated to these journals.

I.2 CHARACTERIZATION OF THE INTERNATIONAL COLLABORATIONS REVEALED BY SCIENTIFIC PAPERS

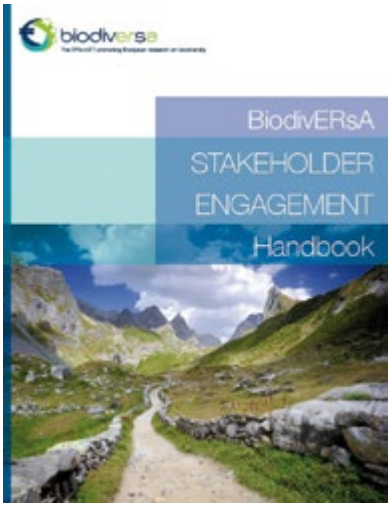
The identification of all the papers published by funded projects and the information on authors' affiliation, in particular country of affiliation, allowed us to characterize the type of international collaborations promoted by the BiodivERsA call. Indeed, adequate methods can analyse and map the collaboration networks revealed by co-authorship of scientific papers (see http://gephi.github.io/features/).

We thus analysed the international networks of researchers based on the countries identified in the addresses of papers' authors for a total of 370 papers produced through this call. For each paper, the link between the country of each author and a given paper was transformed into a link between countries collaborating in this paper, while the information on the number of co-authors from each country per paper was also stored. Finally, a triangular matrix was computed to identify the links between each pair of countries based on the number of papers co-authored by these countries.

The information on these links was used by the Gephi software (http://gephi.org/), which allows for a spatial visualisation of the collaboration networks in 2D maps. In the map, the size of a given country (nod) is a function of either the number of times the country is involved in the publications (see Figure 4) or the number of authors from that country involved in the publications (see Annex 2). Links between countries either disregard the fact that several authors from one country can be co-authors of a given paper (i.e. only the number of countries per publication is taken into account – see map in figure 4) or take into account the number of authors from each country per publication (see Annex. 2).

The closeness centrality of each country in the collaboration network was also computed, which represents to what extent the node/country is far from other nodes on average (i.e. the higher the closeness centrality, the more isolated the node from others). This reflects the relative number of collaborations of a given country/node with other countries, and also the diversity of other countries a given node/country has collaborated with.

I.3 ASSESSMENT OF STAKEHOLDER ENGAGEMENT AND RESEARCH PRODUCTS RELEVANT FOR SOCIETY/POLICY



The definitions and typologies used here for analysing stakeholder engagement and research products relevant to stakeholders are derived from the *BiodivERsA Stakeholder Engagement Handbook* (SEH) (http://www.biodiversa.org/577). Here, a stakeholder is defined as any person or group (excluding other scientists) who influences or is influenced by the research. Engagement means their active involvement and participation in some aspect of a research project.

Small scale mowing machine in a wet grassland site of *Maculinea nausithous* (CLIMIT project); mowing the meadows is important to sustain the populations of Large Blue butterflies, and the timing of mowing is crucial.

I.3.1 TYPES OF STAKEHOLDERS ENGAGED

We distinguished 8 main types of stakeholders engaged in the research, classified as follows:

Main type of stakeholders	Sub-categories (not exhaustive)
International policy-makers or advisers	International policy makers or advisers European policy makers or advisers
National and local policy-makers	National governments, policy makers or advisers Local policy makers, policy makers or advisers
NGOs	NGOs and associations for nature protection Other NGOs
Natural resource managers	Protected area & wildlife managers
Users (economic)	Farmers / farming organizations Foresters Fisheries
Other businesses	Other businesses (e.g. rail infrastructure companies, etc.)
Local communities	Hunters and fishermen (hobby) Local communities' representatives Landowners
General public	Media for the general public, General public (e.g. in science festivals), Schools

Table 1: Classification of stakeholders used in this report

The total number of stakeholders engaged per project was used as a first index of stakeholder engagement.

I.3.2 LEVEL OF ENGAGEMENT OF STAKEHOLDERS IN THE RESEARCH

Four levels of engagement were identified, which correspond to different investments in stakeholder engagement for both researchers and stakeholders and often depend on the ultimate aims of engagement activities:

Inform: Most basic level of engagement. It corresponds to communication devoted (at least partly) to stakeholders but without real specific activities and without involvement in the actual research. The objective is for the researchers to make the information about the project or outcomes accessible to those whom it may affect or interest, yet not involving any active exchange with them.
Examples: dissemination of results through newsletters or websites

Consult: Specific questions are asked by scientists to stakeholders, but without a full two-way-discussion or interaction. This middle-level of engagement is designed, for example, to ask their opinion to stakeholders .
Examples: physical or e-consultation of stakeholders on research subject or outcomes; basic consultation to obtain access to study sites or to data without specific interactions

Involve: Middle-level of engagement, with more opportunity for discussions and interactions than in "consult". Here, stakeholders are more fully engaged in the research, and may also provide resources or data.
Examples: organisation of a workshop to review project questions or findings, including two-way exchanges between stakeholders and researchers; discussion and provision of feedback to site owners or data providers; involvement in experimentation/monitoring beyond simple access to study site or existing data

Collaborate: Stakeholders involved to some extent in research activities and/or project decision-making. Fully active engagement is undertaken where stakeholders are partners in the research team, possibly contributing to the suggestion of research directions and perspectives.
Examples: involvement of stakeholders in the project's advisory or steering committee; co-production of a paper or another product co-authored by scientists and engaged stakeholders

A second index of stakeholder engagement was computed for each project based on this typology. The level of engagement for each stakeholder group and each activity was scored using the following: inform=1; consult=2; involve=4; collaborate=8 (the scores aim at reflecting the relative intensity of stakeholder engagement and the relative investment in stakeholder engagement by researchers). The index was the sum of the scores for each activity/stakeholder group computed per project.

I.3.3 STAGE OF ENGAGEMENT OF STAKEHOLDERS IN THE RESEARCH PROJECTS' LIFE

We analysed the stage of stakeholder engagement, i.e. if they were engaged before, during or after the project's life. Stakeholders involved before the start of research project often either helped in framing the research questions, or were consulted as part of preliminary work when building the project. Stakeholders engaged after the research projects most often worked with researchers on preparing new projects, promoting outputs beyond the projects' lives, and even implementing training and monitoring schemes. Activities involving stakeholders during the life span of funded projects were much more diverse (see Figure 9).

No index of stakeholder engagement was computed based on this typology, because the intensity of stakeholder engagement can be similar at the different stages of engagement, depending on the actual activities rather than the stage.

I.3.4 TYPES OF METHODS OF ENGAGEMENT USED BY RESEARCHERS, AND ACTIVITIES PERFORMED BY STAKEHOLDERS

The typology for the methods of engagement of stakeholders used by researchers was derived from the *BiodivERsA SEH* but adapted upon analysis of the methods used in the funded projects, following the table below. The scores aim at reflecting the relative intensity of stakeholder engagement and the relative investment in stakeholder engagement by researchers.

Level of engagement	Scores (for index)	Methods
Inform	1	Web tools (website, newsletters)
	1	Surveys and interviews (responding)
	2	Workshops and conferences* (participation/presentation)
Inform/Consult	3	Practical demonstrations
Consult	4	Training sessions
	4	Consultative web tools, surveys or interviews (performing)
Consult/Involve	5	One to one/small-sized meetings
Involve	6	Workshops* (organisers)
	6	Multi-stakeholder forums
Collaborate	8	Steering committee/advisory board, co-authorships of papers, etc.

*Workshops and conferences as counted above exclude scientific conferences and account only for (at least partly) stakeholder-oriented events.

A third index of stakeholder engagement was computed for each project based on this typology. The types of methods used for engagement was scored for each stakeholder group using the scores in the table above (the scores aim at reflecting the relative intensity of stakeholder engagement and the relative investment in stakeholder engagement by researchers). The index was the sum of the scores for each stakeholder group computed per project.

The main activities undertaken by and roles of stakeholders involved in the project were also identified based on the pre-defined list derived from the *BiodivERsA SEH*, as follows:

Stage of engagement	Stakeholder role
Before/During	Establish agreements on access to study sites
	Networking and awareness raising with non-contributory stakeholders
	Data provision, including capturing new data (monitoring)
	Assist in defining and developing tools
During/After	Implementation of results – testing outputs of the research (e.g. tools, new methodologies, strategies)
	Identify future information, tools and research needs
	Develop stakeholder-led monitoring and networking beyond life of funded project

It should be noted that the co-funding of research is in itself not sufficient to be taken into account as a research stakeholder role here.

I.3.5 TYPES OF RESEARCH PRODUCTS RELEVANT TO STAKEHOLDERS

The types of research products relevant for different stakeholders (including policy makers) were identified. They were classified according to the degree to which they are actively intended for stakeholders or not:

Informative: output not especially adapted for stakeholders, but of interest for them
Examples: projects' blogs and/or promotion flyers, reports with results of interest but not adapted for stakeholders, raw distribution maps

Targeted: output of interest and adapted for stakeholders, but prepared by scientists without direct links with stakeholders
Examples: leaflets and other documents intended for dissemination to a wider audience; reports or recommendations for policy-making; best-practice guidelines; accessible and comprehensive distribution maps

Proactive: output adapted and of interest for (and prepared with) stakeholders in a proactive manner, through their engagement in preparing the output and in its dissemination.

Examples: reports co-developed with project stakeholders; effective transfer of techniques or application of management protocols; direct contribution to policy reports or management plans; production of policy briefs involving stakeholders/professional knowledge brokers

A fourth index of stakeholder engagement was computed for each project based on this typology. The type of products relevant to stakeholders was scored as follows: informative=1; targeted=2; proactive=4 (the scores aim at reflecting the expected relevance of products to stakeholders). The product-based index was the sum of the scores for each product, computed per project.

PART II

Academic productions, international collaborations, stakeholder engagement and research products relevant to society generated at the call level

The PEATBOG team at work, sampling in Linje Bog, Poland

Part II: Academic productions, international collaborations, stakeholder engagement and research products relevant to society generated at the call level

II.1 ACADEMIC PRODUCTIONS

The twelve projects funded through the 2008 BiodivERsA joint call contributed a total of 370 papers published in international peer-reviewed journals, i.e. a mean value of 30.8 papers per project (7.7 papers per project per year).

Most papers were published in journals with impact factors ranging from 1 to 6 (Figure 2), but remarkably 43 publications were also published in journals with an impact factor over 9. The mean impact factor of these papers was just above 5.

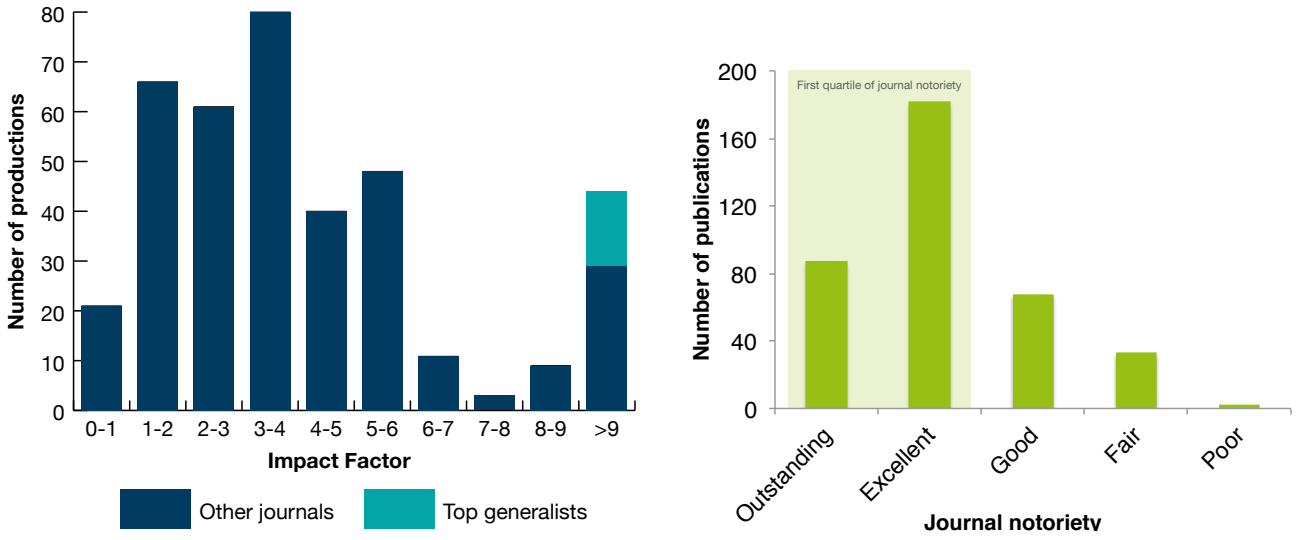


Figure 2: (Left panel) Number of publications per journal impact factor. The 15 papers published in top generalist journals (*Science*, *Nature* and *PNAS*) are indicated in light blue. (Right panel) Number of publications per journal in each journal notoriety groups (see Figure 1 for explanation).

In addition, two thirds of the projects have published papers (15 in total) in top generalist journals, namely *Science*, *Nature* and the *PNAS*. Furthermore, 72.3% of the papers were published in journals with outstanding or excellent notoriety (23.4 and 48.9% for outstanding and excellent, respectively), which corresponds to the top-first quartile of scientific journals (Figure 2 – right). These data evidence the overall high academic quality of the research conducted by these BiodivERsA-funded projects in this call, and the fact that they have produced major scientific breakthroughs in their respective fields.

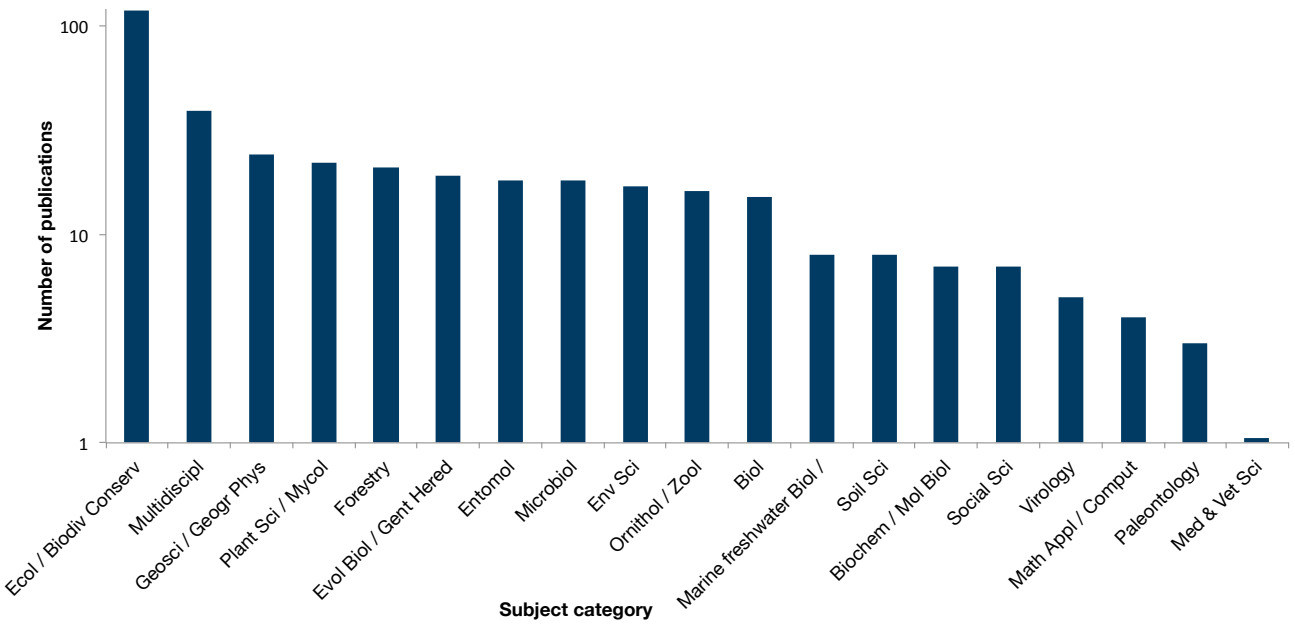


Figure 3: Journal subject categories associated to the papers produced by the projects of the 2008 BiodivERsA call. Note that the Y-axis has a logarithmic scale.

Most papers were published in journals covering 'Ecology' and 'Biodiversity Conservation' and to a lesser extent in 'Multidisciplinary' journals, but also in journals covering 'Geosciences' and 'Physical Geography' (Figure 3).

Only 2% of the papers for this call were published in Social Sciences (including Economy) journals (Figure 3), most likely due to the open nature of the call, and the fact that biodiversity and ecosystem research is originally more calling for disciplines from the natural sciences. BiodivERsA has continuously promoted inter- and trans-disciplinarity since 2008, and these figures should increase in projects funded through the BiodivERsA calls launched since 2010.

Appendix 1 shows the scientific journals mostly used to publish the 2008 project results. Most projects published scientific articles in the generalist journal *PLoS ONE*, with close to 20 articles published in this journal. Many publications were published in ecology and biological sciences journals, along with journals of more applied science such as *Forest Ecology and Management* or *Journal of Applied Ecology*. More technical and methodological advancements can also be observed, notably with publications in journals such as *Ecological indicators* or *Methods in Ecology and Evolution*. Finally, publications in journals such as *Holocene* or *Quaternary Research* come from projects investigating past changes.

The relatively high position of top generalist journals (in dark blue in Appendix 1) is another index of the high scientific quality of academic outcomes of funded projects (respectively 8 publications in *PNAS*, 4 in Science and 3 in Nature).

II.2 INTERNATIONAL COLLABORATIONS TESTIFIED BY SCIENTIFIC PUBLICATIONS

The BiodivERsA call spurred international collaboration beyond countries participating in each project. Figure 4 shows the importance and intensity of such collaborations based on the analysis of the origins of the co-authors of the 370 papers produced in the call so far.

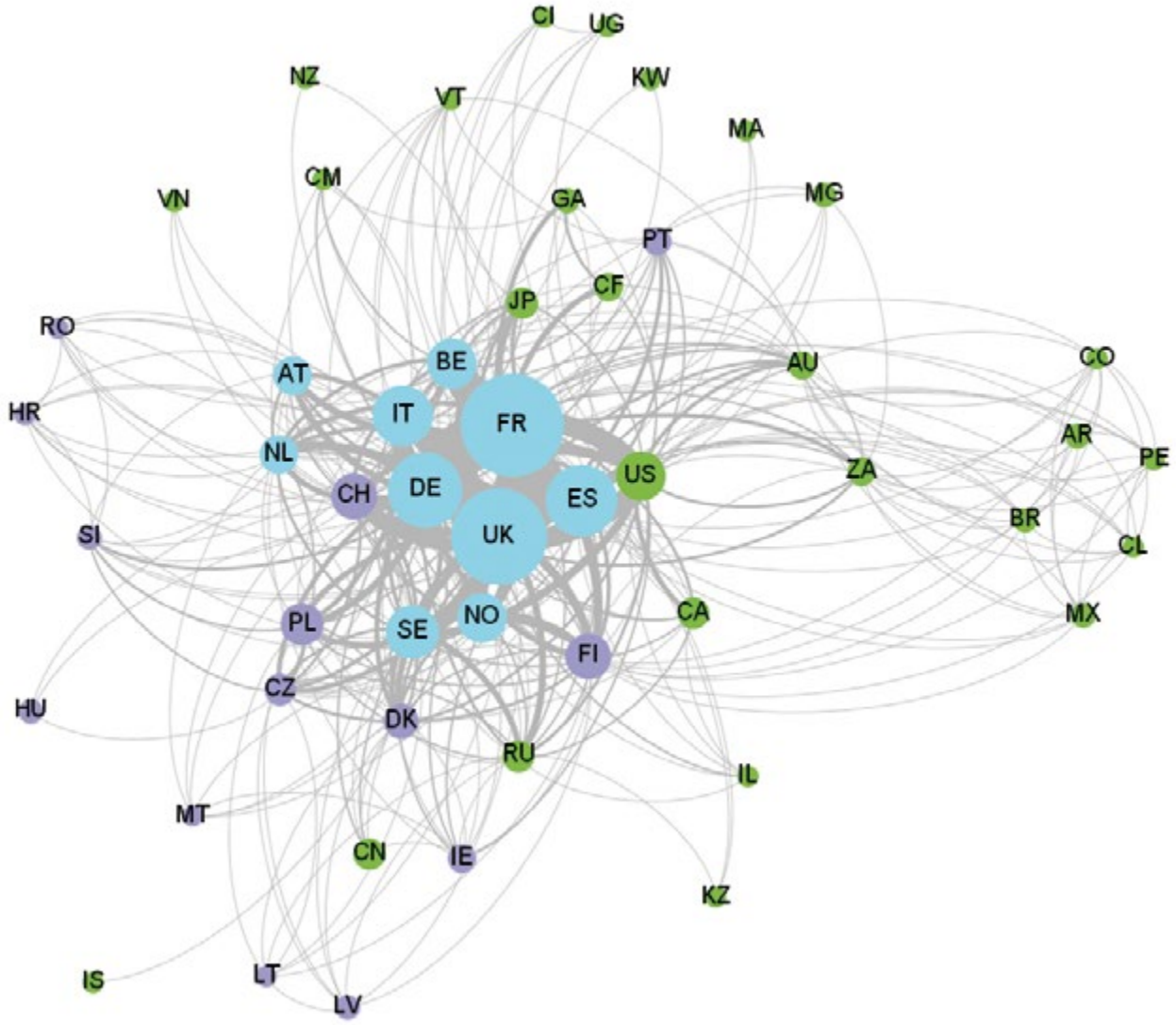


Figure 4: Map of the research collaborations between countries observed in all the projects' publications. Light blue dots are for countries geographically in Europe and participating to the call (including sub-contracted teams); purple dots are for countries geographically in Europe but not participating to the call; and green dots correspond to countries not in Europe and not participating to the call. The size of the nod for a given country is based on the number of times this country is present in all the publications linked to the call, while the width of the links between two nodes/countries are based on the number of publications involving these two countries.

This map was created by taking into account the number of papers co-authored between each pair of countries, but the result is similar when accounting for the number of authors involved in these papers (see Appendix 2). Figure 4 shows that participating to the BiodivERsA call allowed the countries to actually have a central and strong position in the international collaboration network generated.

The closeness centrality scores of the main (27 out of 51) countries involved in the publications generated by the call (Figure 5) confirms the key role of countries participating to the call. It also underlines that Spain was particularly central in the network despite a relatively small publication number.

Figure 5: Closeness centrality in the research collaboration network of the countries associated to the 370 papers. The closer to 1, the more a country has collaborated with others through publications.

In both figures, significant links with countries of geographical Europe not participating to the call can be observed, for example Switzerland, Finland, Czech Republic, Poland or Denmark. This is explained by regional approaches where research teams of other countries from the region (e.g. Scandinavian countries) were mobilized as self-funded partners. To a lesser extent, significant collaborations can also be observed with some countries outside Europe, mainly the USA, Japan and Russia. This is partly explained by the fact that a few funded projects tackle questions relevant at an international scale, or linked to issues of global trade or biological invasions. This demonstrates that, while BiodivERsA reached its goal in placing participating countries from Europe at the centre of the research collaboration networks, it also generated a leverage effect in promoting international collaborations beyond these participating countries.

II.3 TYPES OF STAKEHOLDERS ENGAGED IN RESEARCH

More than 180 individually identified stakeholder groups/organisations have been engaged by research projects under this call (Figure 6.1), i.e. 15 per project on average. This is a conservative estimate as in some cases, the individual identification of stakeholders beyond broad groups engaged proved to be quite challenging and was not detailed, thus counting as one.

Funded projects engaged with a wide spectrum of stakeholders (Figures 6.1 and 6.2), depending on their respective focus and relevance to different stakeholder categories. The most engaged categories correspond to natural resource managers (mainly protected areas and wildlife managers), Non-Governmental Organisations (especially those directly involved in nature conservation) and local and national policy-makers and advisors. To a lesser extent, the researchers also engaged with users (economic) like famers, foresters and fisheries, representatives of local people and communities, and European policy-makers and advisors.

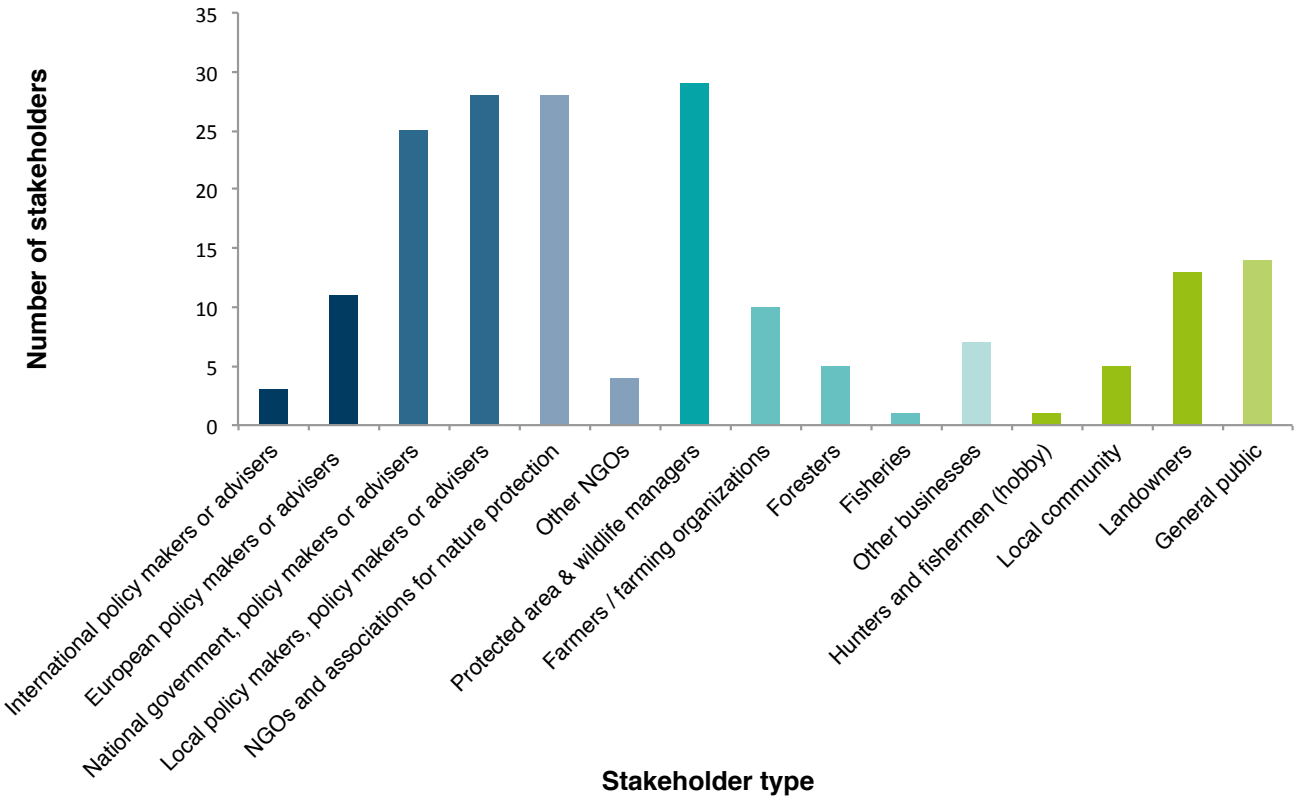


Figure 6.1: Total number of stakeholders engaged in the 12 research projects funded in the call, per stakeholder type. Colours refer to the type of stakeholders defined in Table 1.

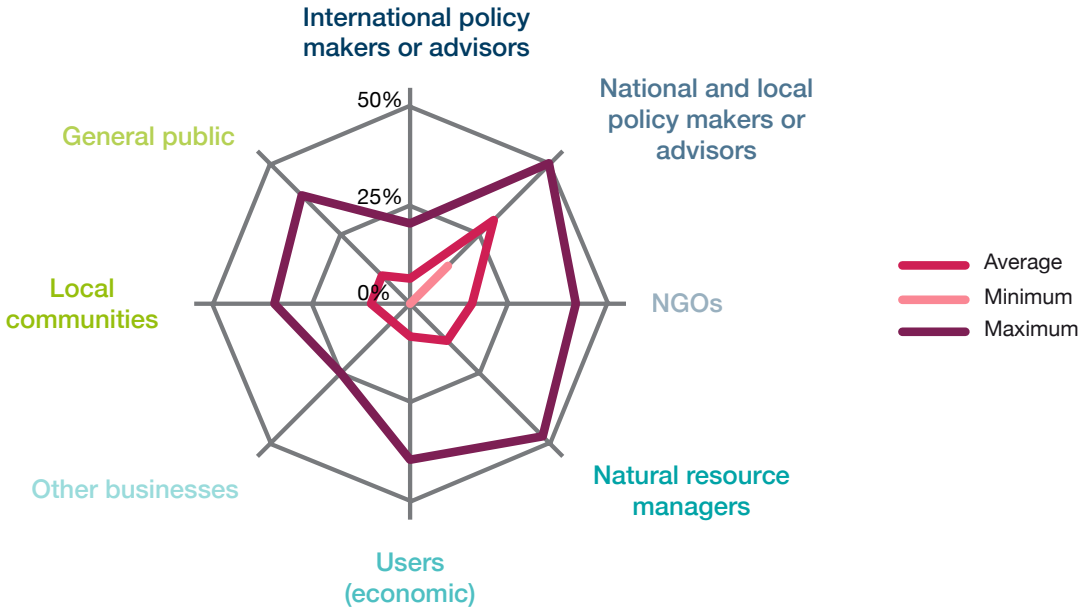


Figure 6.2: Mean (pink, n=12), maximum (purple) and minimum (light pink) percentages of the stakeholders engaged in each project per stakeholder type.

Such results suggest that these types of stakeholders are the most directly concerned by biodiversity research performed under this relatively open call for proposals, and/or the most accessible to many researchers on biodiversity and ecosystem services. The importance of natural resource managers can also be explained by the fact that researchers often have to engage with them to access study sites or existing data, in a similar manner as for landowners. Figures 6.1 and 6.2 also demonstrate that researchers have a relatively easy access to (and capacity to mobilize) policy-makers and advisers at the local and national scale.

A number of projects targeted local communities and the general public to make them aware of the research going on, and the issues they were attempting to respond to. The fact that "economic users" of natural resources, such as farmers, foresters and to a lesser extent fisheries, have been engaged by funded projects demonstrates the economic implications at stake behind the research work and the interest raised in these stakeholder categories. Other forms of businesses, however, such as larger companies, have been less engaged by funded projects. This is likely due to the wide topic of the 2008 call, and to the fact that business-like stakeholders are more difficult to engage by many biodiversity researchers.

International and European policy-makers and advisers have clearly been less engaged by funded projects compared to national and local policy-makers, which is to be noticed for pan-European projects. BiodivERsA partners have quickly realized the difficulty for researchers to engage with European policy-makers, and they decided in 2010 to further support project investigators in engaging such stakeholders. In particular, this has led to the provision by BiodivERsA of additional support to selected funded projects to participate to some European events with policy makers, and to the production of policy briefs mainly targeting European policy makers (http://www.biodiversa.org/policybriefs). Similarly, since 2015, BiodivERsA eases the (otherwise weak) engagement with business-like stakeholders by setting up a mobility scheme between academic research and businesses, and through *ad hoc* activities including workshops devoted to the dialogue and co-construction between businesses and academic research.

II.4 LEVEL OF ENGAGEMENT DEVELOPED

The main level of engagement was 'informative' (Figure 7). Indeed, an important number of stakeholders can have interests in a given project and its outcomes, while less are interested by, or relevant for, more intense collaboration. Some researchers also view this level as appropriate according to the nature of their research (i.e. further engagement might not be systematically needed). Yet, this could also point to the increasing difficulty and need for resources (i.e. skills, funds, time) to engage stakeholders in a real co-design and cooperative way.

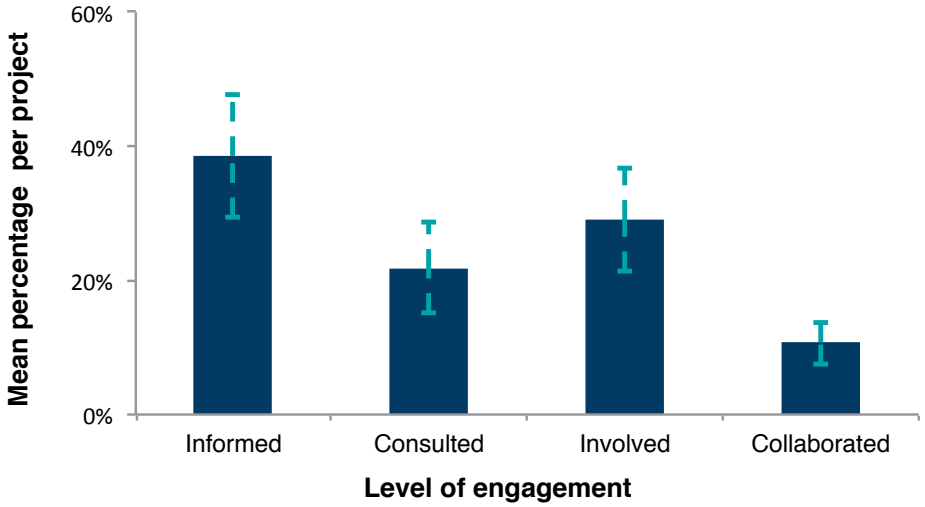


Figure 7: Mean percentage of stakeholders engaged by individual projects, per level of engagement. Bars are standard errors (n=12).

However, an important proportion of the engaged stakeholders have been consulted (one quarter of the stakeholders per project) and even slightly more (30%) were truly involved in the projects. Furthermore, around 10% of the stakeholders engaged per project have directly collaborated in the research projects, and actively participated as team members, or via advisory boards and steering committees. In such cases, these stakeholders often have a very direct and concrete interest in collaborating within the project, for instance to develop a particular tool or method.

II.5 STAGE OF STAKEHOLDER ENGAGEMENT

Two thirds of the stakeholders were involved during the research projects' lives (Figure 8). It is interesting nonetheless to notice that, on average, 10% of the stakeholders were engaged actively by a given project during the conception of the project.

The proportion of stakeholders who remained engaged after the life of the projects was higher (close to 20%) than that of stakeholders engaged very early. This demonstrates an opportunity for researchers to build long-lasting relationships with stakeholders. It was especially noted by several projects that building relationships with their stakeholders allowed them to engage more early with them in following projects, thus significantly increasing the quality of their projects' societal and/or political relevance, or of their communication and engagement plans. In several cases, mobilised stakeholders actively helped in attracting other ones around the table.

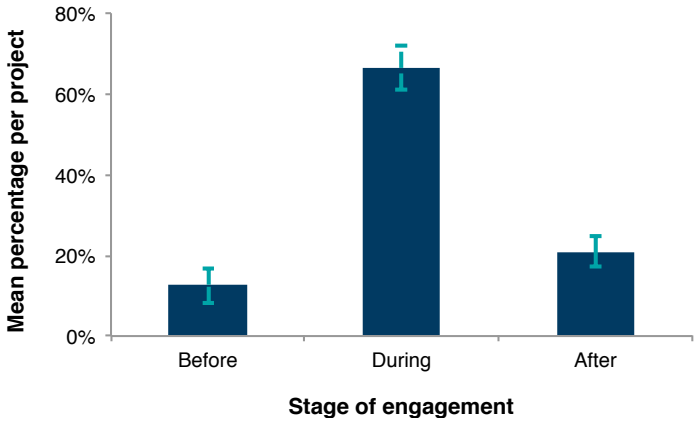


Figure 8: Mean percentage of stakeholders engaged per project, per stage of engagement. Bars are standard errors (n=12).

II.6 ROLES OF STAKEHOLDERS IN THE RESEARCH PROJECTS, AND METHODS OF ENGAGEMENT USED BY RESEARCHERS

While the main activity undertaken by stakeholders concerns networking and awareness raising with non-contributory stakeholders (Figure 9), in some projects this meant a closer collaboration, such as for assisting in defining needs or tools, providing data, or testing results. Finally, two types of activities show that stakeholder engagement sometimes persists beyond the life of the project, i.e. where stakeholders either helped in identifying future research needs, or pursued monitoring and networking activities.

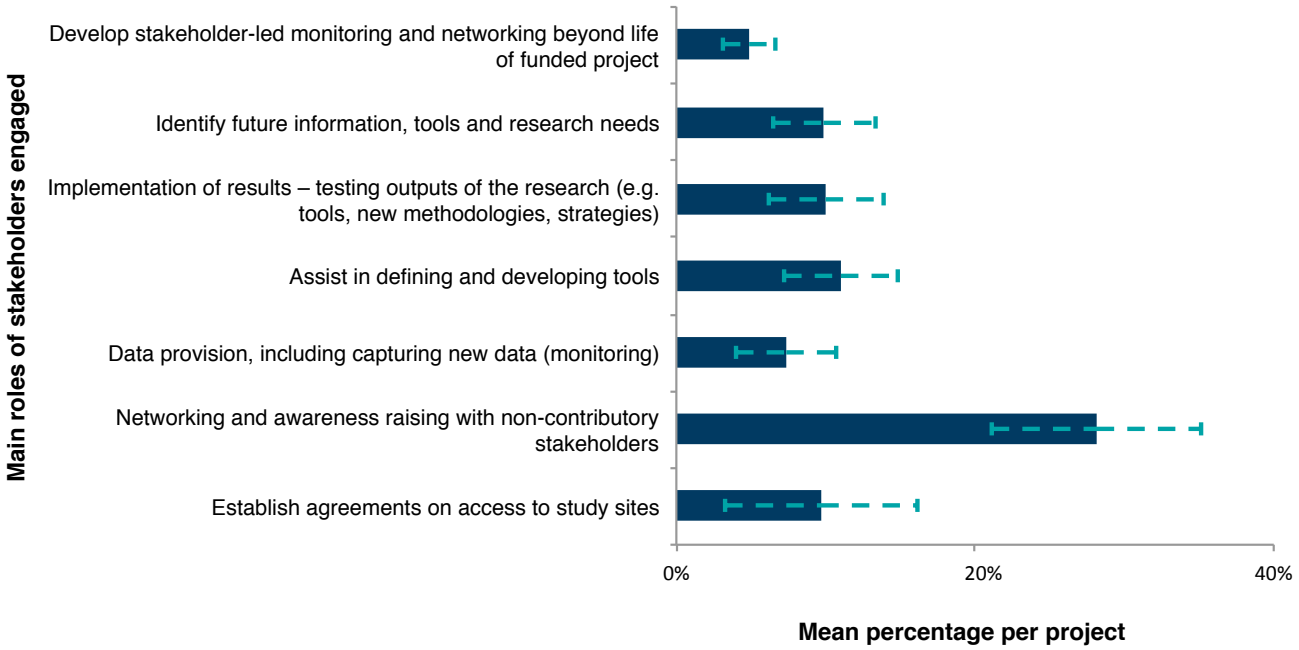


Figure 9: Main roles of stakeholders engaged by research projects (mean % per project, with standard errors, n=12)

At the informative level, the main method used by researchers to engage stakeholders was the participation in specific workshops and presentations at various events and conferences devoted (at least partly) to stakeholders (Figure 10). A predominant method when aiming for consultation was the use of web tools and, to a lesser extent, one-to-one and small-sized meetings, which are clearly very popular when aiming at involving stakeholders without being too formal. Closer involvement and collaborations have been mostly achieved through the organisation of multi-stakeholder forums and the inclusion of non-academic partners in advisory or steering committees.

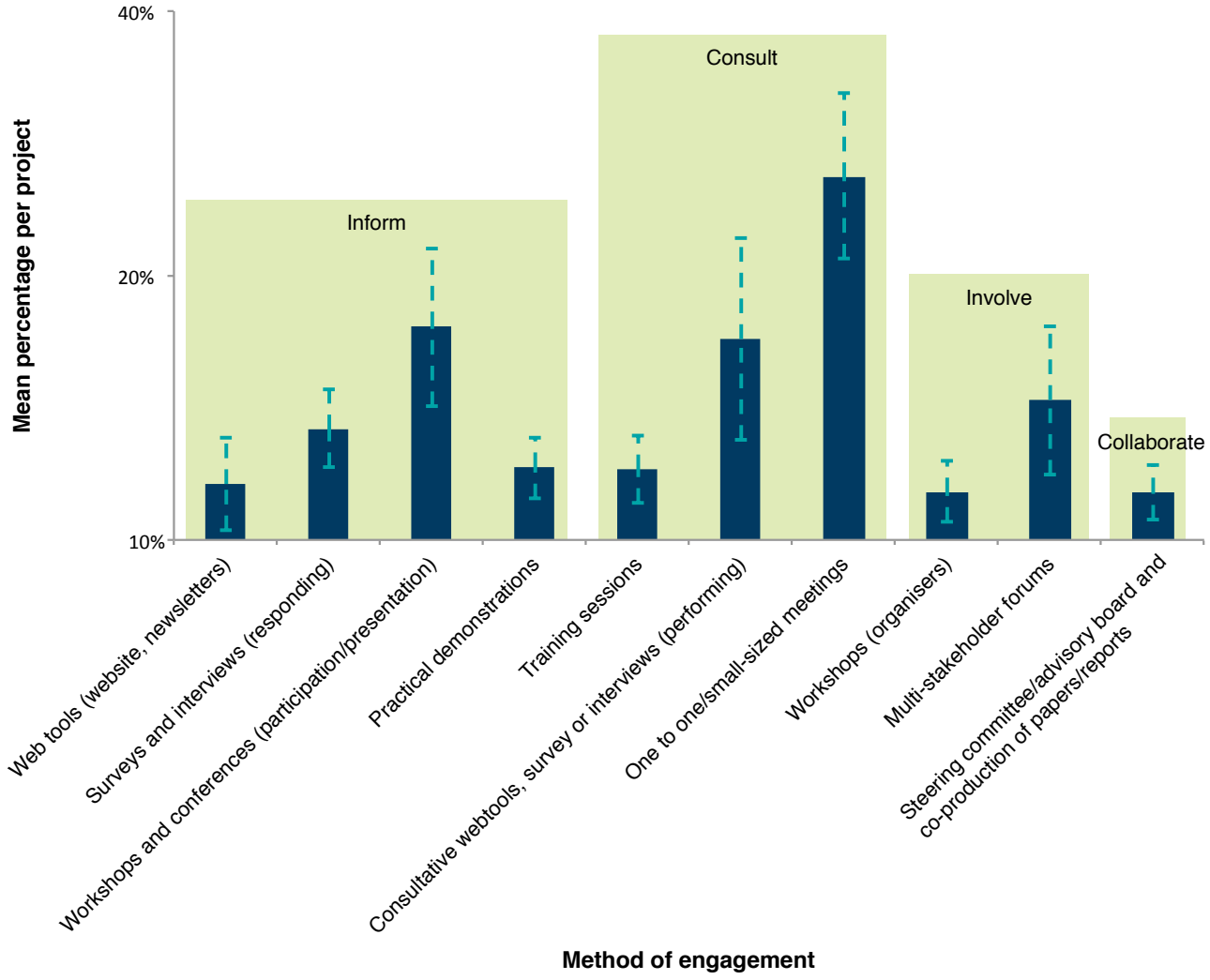


Figure 10: Types of methods used to engage with stakeholders (mean % per project, with standard errors, n=12)

II.7 PRODUCTS INFORMING, TARGETING OR PROACTIVELY ENGAGING STAKEHOLDERS

Figure 11 shows a rather even repartition of the products and outcomes relevant to stakeholders across the three pre-defined types. However, strong differences were observed between projects, because some mainly delivered the products in an informative way, i.e. viewing stakeholders only as targets of the products, while others mainly produced stakeholder-relevant outputs in a pro-active manner, i.e. either co-producing the output and/or actively involving stakeholders in its dissemination and uptake.

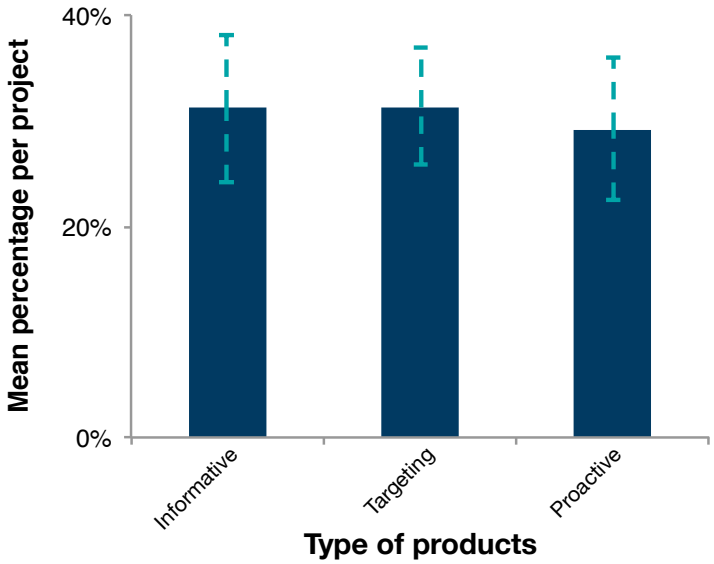


Figure 11: Mean percentage of products informing, targeting or proactively engaging stakeholders per project. Bars are standard errors (n=12).

II.8 TESTING FOR POSSIBLE TRADE-OFFS BETWEEN ACADEMIC EXCELLENCE AND THE INVESTMENT IN STAKEHOLDER ENGAGEMENT AND PRODUCTION OF RESEARCH PRODUCTS RELEVANT FOR SOCIETY

It is often assumed that a trade-off exists for research projects between academic excellence and the investment in engaging stakeholders and generating research products relevant for society/policy. However, using the 4 indices computed here to assess the level and quality of academic production of the 12 research projects, and the 4 indices computed to evaluate the investment in activities performed with and/or for stakeholders in the same projects, we observed a lack of correlation between both aspects (Table 2).

		Investment in activities with/for stakeholders			
		Number of stake-holders engaged	Level-based criterion	Method-based criterion	Product-based criterion
Level and quality of academic production	**Number of publications**	0.63	0.93	0.91	0.25
	Sum of impact factors	0.68	0.44	0.28	0.74
	Sum of notoriety scores	0.81	0.71	0.70	0.52
	Number of top generalists	0.48	0.64	0.65	0.89

Table 2: Summary of the results (p values) of correlations performed between the indices of the level and quality of academic production of the 12 research projects, and the indices of the investment in activities performed with and/or for stakeholders in the same projects. All correlations were non significant (significance would require a p value < 0.05).

Furthermore, no tendency for such a trade-off was observed when looking at the correlations (Figure 12). This clearly demonstrates that academic excellence of the projects was not jeopardized by the investment of researchers in stakeholder engagement nor in the development of products for/with stakeholders.

This conclusion holds for the 12 projects of this call that was, since inception, developed by BiodivERsA to select research that could reach excellence for both academic production and society/policy relevance. It is likely that this conclusion cannot be generalized to the different types of research programmes that exist and are needed to cover all aspects of research programming and support.

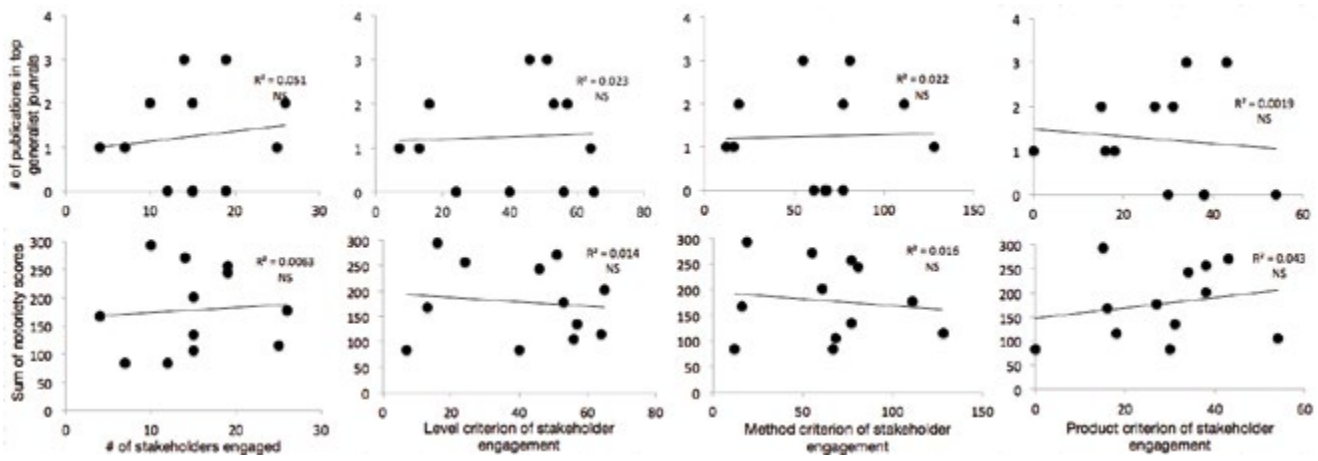


Figure 12: Examples of correlations between 2 indices of the level and quality of academic production of the 12 research projects (Top: number of papers published in *Science*, *Nature* or *PNAS* ; Bottom: sum of journal notoriety scores) and the 4 indices of the investment in activities performed with and/or for stakeholders in the same projects. All correlations have very low R^2 values and are clearly non significant (see p values in Table 2).

Role playing game with farmers from Villare d'Arêne (Hautes Alpes, France) for participatory scenario-building in the VITAL project

PART III

Highlights on academic findings, stakeholder engagement and research products relevant to society generated by each project

Norwegian lemming *(Lemmus lemmus)*, studied both in the Climigrate and Ecocycles projects.

BeFoFu

Combined Effects of Natura 2000, Climate Change and Multi-level Governance on European Beech Forests, and Proposed Solution Paths for the Future

OBJECTIVES

Beech forests are such an important part of the EU's Natura 2000 network that Member States have obligations regarding their conservation. However, the implementation of Natura 2000 has resulted in conflicts related to the designation of protected areas and the management of the forests. These conflicts have impaired the results of local conservation efforts and negatively impacted on the EU's biodiversity policy in general. The BeFoFu project aimed to analyse the governance and management of beech forests under Natura 2000 in order to:

1. Identify specific policy and management related challenges to the implementation of Natura 2000 at different policy levels;
2. Assess the importance of climate change in the context of the management of the protected beech forests;
3. Propose "solution pathways" for the governance and management of European beech forests that can tackle identified challenges.

APPROACHES

The BeFoFu team combined researchers from five different countries for a highly interdisciplinary project, looking into the ecological and institutional aspects of the governance of Natura 2000. This team:

1. Analysed the relationships between multi-level policies and local management strategies relating to Natura 2000 forest sites;
2. Analysed the effects of different forest management strategies on biodiversity;
3. Analysed the importance of climate change for both forest (conservation) policy-making and forest management;
4. Identified core challenges and possible policy solution pathways based on extensive communication between different policy stakeholders and researchers.

MAIN ACADEMIC FINDINGS

- BeFoFu results indicate a generalised decline of beech forests in southernmost regions of Europe, while localised areas will remain. However, beech will also decline in more core areas of its distribution [1, 2].
- The positive effect of Natura 2000, though not yet discernible, is expected to increase in the future [3].
- Persistence of beech forest of particular conservation or cultural value can be improved by management techniques exploiting vegetative reproduction, particularly where reproduction from seed is challenging due to the warming climate [4].
- BeFoFu identified a number of conflicts rising from the implementation of Natura 2000, mainly on land use, administrative and institutional responsibilities, and property rights, which result in continuous challenges in effectively implementing the policy in forests [5, 6, 7, 8].
- More specifically, while local implementation has become more inclusive for various stakeholder demands, often vaguely formulated management plans provide too little guidance in situations where conflicts between conservation and other forestry goals occur [9].

By combining these results with stakeholder knowledge and opinions, the BeFoFu team worked to design and propose policy recommendations and strategies for a better implementation of Natura 2000 and a more successful conservation of beech forests across Europe.

Consortium partners:

Albert-Ludwigs-Universität Freibug, Germany
Coordinator: Georg Winkel
Wageningen University, The Netherlands
AgroParisTech, France
University of Stirling, UK
University of Natural Resources and Applied Life Sciences, Vienna, Austria
Techniche Universität München, Germany

Amount: € 1,395,721

ACADEMIC RESULT HIGHLIGHT

The BeFoFu team assessed how the debate on climate change adaptation affects forest conservation and management under Natura 2000*. Drawing from the concept of argumentative discourse analysis and 213 qualitative interviews with policy-makers and practitioners in 6 Member states, the team identified and analysed major discourses and the type of actors that support them. They found that debates at the European level are much more polarised and politicised, while local debates concerning Natura 2000 and climate change remain rather vague. This indicates that links between climate change adaptation and forest conservation are mostly explored at a higher policy level and used to influence well-known policies and legitimise distinct pre-existing interests.

* de Konig *et al.* (2014) Natura 2000 and climate change - Polarisation, uncertainty and pragmatism in discourses on forest conservation and management in Europe. *Environmental Science and Policy* 39:129-138

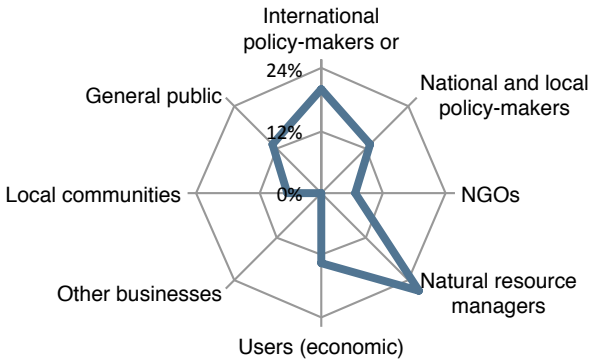
STAKEHOLDER ENGAGEMENT AND PRODUCTS RELEVANT TO SOCIETY/POLICY

- BeFoFu worked extensively with many stakeholders (see figure below), conducting qualitative interviews at different stages of the research process with a range of stakeholders including policy-makers at all levels (EU to local), natural resource managers, farmers and foresters, and NGO representatives.
- The BeFoFu team set up a mixed steering committee for the project, involving three policy makers and three scientists who provided input from project framing to supervision and data collection.
- After drafting initial recommendations based on findings and interviews, the team discussed and proposed strategies with European and national policy-makers, including with the European Commission's ad-hoc working group on Natura 2000 and forests.

BeFoFu produced a set of tools adapted for use by their stakeholders in a proactive manner:

➔ Publication of important project results by each partner in national practitioners journals

➔ Joint recommendations for policy stakeholders at different levels, thanks to the integration of data and discussion across natural and social sciences



Types of stakeholders engaged in BeFoFu

HIGHLIGHTS ON SOCIETY/POLICY-RELEVANT PRODUCTS

- **Policy paper on the implementation of Natura 2000 in forests**: this document identifies five "core challenges" and solution paths (Winkel *et al.*, 2015 - The implementation of Natura 2000 in forests: a trans- and interdisciplinary assessment of challenges and choices. *Environmental Science and Policy*. 52:23-32).
- **"Natura 2000 and Europe's forests" policy brief**, supported by BiodivERsA, that presents key research results and outlines policy solutions to improve the effectiveness of Natura 2000 to conserve and sustainably manage Europe's forest (http://www.biodiversa.org/660).
- **Two databases on innovative forest management**: *the Forest Policy and Innovation Database* (http://policy-database.boku.ac.at/); and the *Innoforce Database of Innovation Cases in Forestry* (http://cases.boku.ac.at/).

BioMarKs

Biodiversity of Planctonic Eukariotes - Its Importance for Global Biogeochemical Cycles and for Monitoring the Health of Marine Environments

OBJECTIVES

Marine unicellular eukaryotic organisms, in particular protists, are among the least explored compartments of biodiversity, yet they are suspected to profoundly impact marine ecosystem functioning, global biogeochemical cycles and climate. They can also offer unexplored functions and be used to propose new indicators of marine environments' statuses. BioMarKs aimed at exploring this unknown compartment of life and assessing the taxonomic and functional complexity of protistan communities along the European coastlines, to:

1. Establish a baseline of protists biodiversity in European coastal waters, and apply this data to environmental and evolutionary questions on protists;
2. Assess new functions that can be derived from this unexplored taxonomic group and evaluate their use to monitor the health of marine environments.

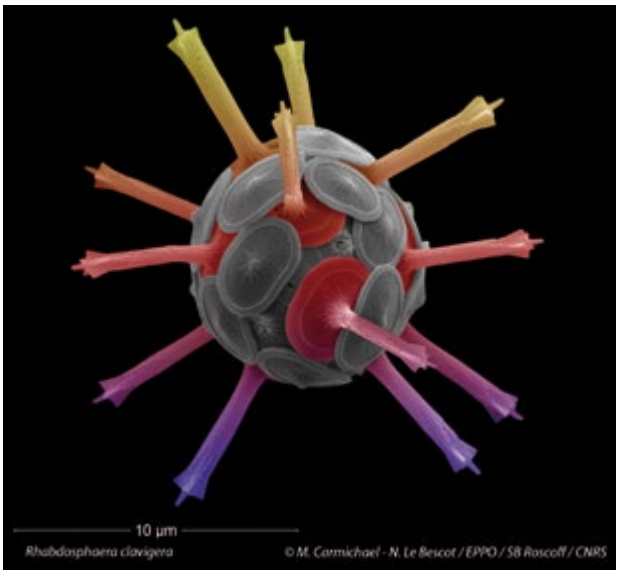
APPROACHES

BioMarKs gathered six research groups from three countries in protist taxonomy, marine biology, molecular ecology and bioinformatics to study marine eukariots along European coastlines, by:

1. Developing effective protocols to obtain genetic, morphological and contextual data on a wide range of protists at different depths in 10 sites from the Arctic ocean to the Italian coast;
2. Using high-throughput sequencing technologies to generate massive DNA datasets and unveil the entire protistan diversity in marine water samples;
3. Developing novel techniques to organise this diversity of protists into coherent units and analyse their ecological distribution and community structuration, exploring links with contextual data on ocean acidification for example;
4. Proposing new indicators to assess the health of marine environments.

MAIN ACADEMIC FINDINGS

- The BioMarKs team gathered a unique collection of over 3,000 genetic and morphological samples linked with contextual data, and derived over 220 million DNA/RNA barcodes of European marine protists [10, 11].
- The team revealed novel diversity, including new toxic species, lineages of parasites, and ancestral groups of marine fungi. They discovered in particular a diverse and primitive group of aquatic fungi that challenge current concepts of the fungal tree of life [12, 13, 14, 15, 16].
- A suite of novel protocols was developed for sampling, molecular ecology analysis, sequencing, bioinformatics screening and ecological statistics, feeding a complete toolbox for modern, cheap and accurate monitoring of marine eukaryotic biodiversity [17].



Consortium partners:

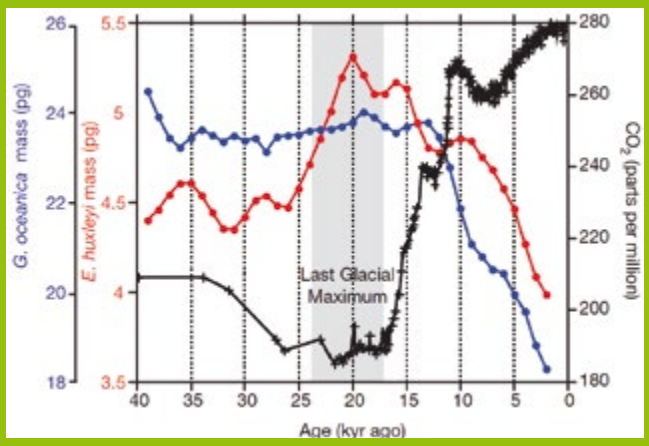
Biological Station of Roscoff, CNRS/UPMC, France — Coordinator : Colomban de Vargas
Institute of Marine Sciences, CSIC, Spain
Dept. of Biosciences, University of Exeter, UK;
Structural and Genomic Information Laboratory, CNRS, France
Oceanography Laboratory, CNRS, France
Dept. of Biosciences, University of Oslo, Norway

Amount: € 1,569,444

ACADEMIC RESULT HIGHLIGHT

The BioMarKs team demonstrated the decline in several coccolithophore populations facing increased pressure from ocean acidification (resulting from elevated atmospheric CO_2 concentration), and a general pattern of decalcification with more acidic oceans. Currently absorbing one-third of CO_2 released into the atmosphere as a result of human activity, the marine carbon cycle could be substantially affected in the light of predicted ocean acidification. However, a noticeable exception was observed for specific types of coccoliths that display a hyper-calcification in highly acidic waters, which may influence the decalcification response of oceans to acidification.

* Beaufort *et al.* (2011) Sensitivity of coccolithophores to carbonate chemistry and ocean acidification. *Nature* 476: 80-83

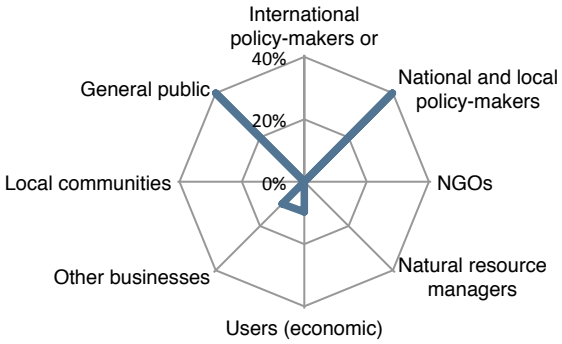


Past variations in the mass of coccolith for two species (red and blue curves) and CO_2 concentration (black curve) over the last 40k years. Note the decline in coocolith mass linked to an elevation in atmospheric CO_2 concentration. After Beaufort *et al.* 2011 (*Nature*)

STAKEHOLDER ENGAGEMENT AND PRODUCTS RELEVANT TO SOCIETY/POLICY

BioMarKs was largely a discovery research project that gathered a limited number of stakeholder types (see Figure). The BioMarKs team concentrated its efforts in communicating findings to the general public, notably through numerous interviews and documentaries in written press and television. However, it also engaged with other types of stakeholders:

- In the UK, BioMarKs worked with the CEFAS, a scientific advisor to the government on aquaculture and fisheries with whom the team developed parasite monitoring methods useful to identify threats to fisheries.
- BioMarKs researchers participated in a number of national educational projects with primary and secondary students in France, Norway and the UK.
- BioMarKs' coordinator gave a « TEDx » talk on the side of the Rio+20 UN conference in 2012 on the « protist power », explaining the importance of such forms of life (https://www.youtube.com/watch?v=ZS3MH79-AY8).



Types of stakeholders engaged in BioMarKs

HIGHLIGHTS ON SOCIETY/POLICY-RELEVANT PRODUCTS

- BioMarKs collaborated with Marine Harvest SA, a fishery company, to **develop environmental monitoring in salmon farms.**
- The BioMarKs team prepared **check-lists of microbial eukaryotic genotypes** identified in European marine coastal waters (http://www.biomarks.eu/), identifying their potential implications in terms of human health, environmental hazards, and technology.
- BioMarKs **informed the general public** during many large audience conferences, press interviews and articles related to Tara Oceans, a high-profile oceanic campaign coupled to a major communication operation.

Climigrate

Understanding and Better Forecasting the Impact of Climate Change on Mammals by Integrating Ancient DNA analysis and Ecological Modelling

OBJECTIVES

Forecasts accounting for future changes in temperature tend to predict high rates of species extinctions over the next 100 years. In particular, there is growing concern about the survival of mammal species in Europe. However, such predictions include high uncertainty in how species respond to environmental change and habitat availability, i.e. whether species will chase new habitats, adapt or go extinct. In this context, the Climigrate team has investigated what happened in the last Ice Age, when dramatic changes in temperature lead to large-scale re-distribution of many species, which can reduce uncertainty as to future predictions. More precisely, the Climigrate team aimed at:

1. Significantly improving the understanding of species/population responses to large-scale environmental change by analysing ancient DNA and responses of species distribution in the last Ice Age;
2. Improving forecasts of future species responses to climate change, reducing their uncertainty and allowing for an improvement of conservation strategies.

APPROACHES

Climigrate assessed the consequences of climate change on the demography of a set of cold and temperate mammal species by looking at the effect of past changes in climate across Europe. The team recovered DNA from a large number of specimens ranging from present day to 50,000 years old and analysed both cold and warm-adapted species including collared and true lemming, woolly mammoth, arctic and red fox, Neanderthals, brown and polar bear, cave lion, red deer and willow and rock ptarmigan. The team then explored local climate and environmental data, identifying the timing and route of expansions or local extinctions, their genetic consequences and correlations with broader climate trends and major temperature increases following the last Ice Age.

MAIN ACADEMIC FINDINGS

- Climigrate allowed building or completing datasets on present and/or past (^{14}C-dated fossils) DNA for thirteen mammal and bird species.
- The team demonstrated that past environmental changes have had a considerable effect on the demography and distribution of both cold and warm-adapted species [18, 19, 20, 21, 22, 23, 24, 25, 26, 27].
- The general pattern observed in studied species during warming periods shows that these appeared unable to track habitat availability, leading to drastic extinctions of southern communities and exacerbating reductions in genetic diversity [21, 26, 28].
- However, both studied ptarmigans (*Lagopus* birds) have been able to track and follow shifts in habitats distribution during major temperature increases at the end of the last Ice Age.

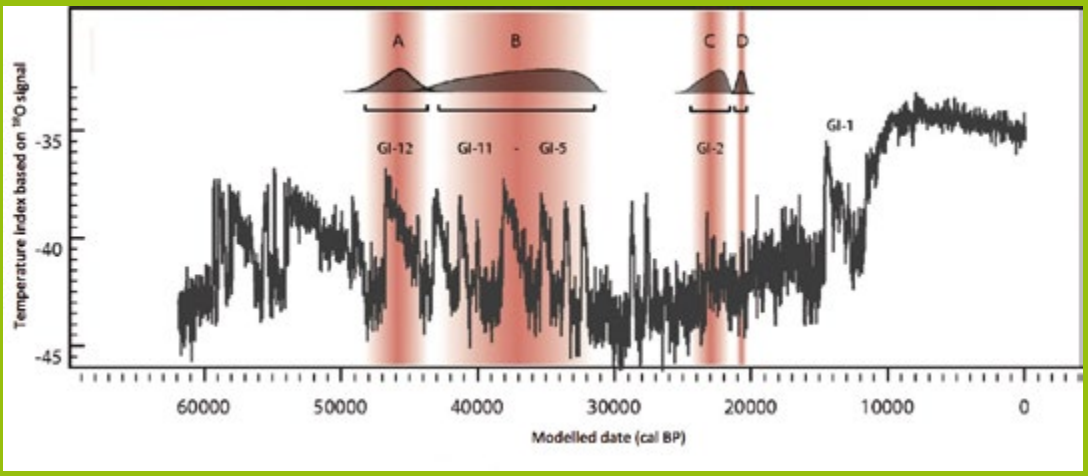
Using both present and fossil record data, the researchers predicted the future response of ptarmigan in Europe, and found that even if ptarmigan manage to track future changes in habitat resulting from temperature change, their overall abundance is likely to decrease due to a 30 to 50% habitat loss in modelled projections running up to 2080.

Consortium partners:

School of Biological Sciences, Royal Holloway University of London, UK
Coordinator: Ian Barnes
Dept. of Evolution, Genomics and Systematics,
Uppsala University, Sweden
Dept.of Biology, University of Tromsø, Norway

Amount: € 843, 595

ACADEMIC RESULT HIGHLIGHT



Past genetic turnover events (A,B,C & D, lineage turnover events represented in red) for collared lemming occurred during periods of climatic oscillation, in particular the climatic warm peaks, Greenland Interstadials GI-12 and GI-2. After Brace *et al.* 2012 (*PNAS*).

The global extinction of many terrestrial mammal species during the Late Pleistocene has been a subject of intensive scientific study. Yet, previous studies on the effects of past climate changes have mainly focused on large mammal species, in particular those that went extinct, whereas smaller mammals were overlooked and considered less affected. The Climigrate scientists focused on a small mammal species (collared lemming – *Dicrostonix torquatus*) and explored its response to past climate changes using ancient DNA techniques sampled across three sites in North-West Europe.

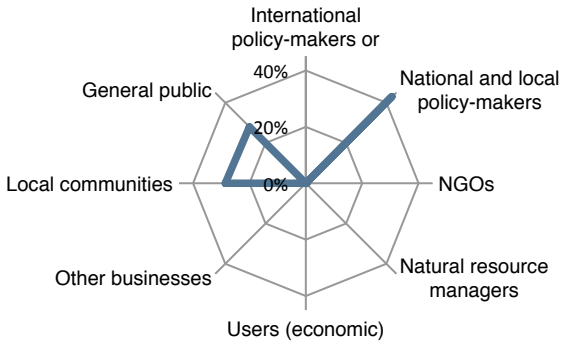
The results of the study reveal a dramatic reduction in genetic diversity in this species over the last 50,000 years. Repeated regional extinctions in this key prey species were climate-associated and likely had an impact on the wider steppe-tundra community. This shows how climate change has been a major force in structuring Late Pleistocene biodiversity, even for small mammal species (and the species that depend on them).

* Brace *et al.* (2012). Serial population extinctions in a small mammal indicate Late Pleistocene ecosystem instability. *Proceedings of the National Academy of Sciences of the USA* 109: 20532-20536

STAKEHOLDER ENGAGEMENT AND PRODUCTS RELEVANT TO SOCIETY/POLICY

Climigrate worked mainly retrospectively on the effect of past climate changes on biodiversity, which explains the particular profile of types of stakeholders involved in the research (see Figure).

- Climigrate informed a number of stakeholders on the lessons learned from ancient DNA, and on the effects of climate change on biodiversity. For example, they informed local people with the Swedish Saami association, school children during presentations in the broader context of polar research, and the general public by giving interviews. In particular, Climigrate scientists participated to the "Mammoth, back from the dead" documentary of National Geographic (https://www.youtube.com/watch?v=UcBGOC8-mCI).



Types of stakeholders engaged in Climigrate

- Climigrate also interacted with the Swedish Foreign Ministry and the Embassy of Russia in Sweden during workshops and fora, presenting results and promoting support for transnational cooperation in arctic research to strengthen collaborations in the region.

CLIMIT

Impacts of Climate and Land Management Changes on Grassland Insects, and Adaptive Management Practices for their Conservation

OBJECTIVES

The CLIMIT team assessed the combined effects of human-induced changes in climate and habitat (area, isolation, patch quality) on some of Europe's most specialized and threatened grassland insects that depend on ants (so-called myrmecophiles), comparing the results with other taxa like birds. The researchers studied the insects' local adaptations, changing niches and different needs across local climates ranging from the Mediterranean to the North/Baltic Seas, in order to:

1. Compare the fates of species that have relationships with ants under different land use change scenarios and their potential to evolve and adapt to new environments; and
2. Test current adaptive management practices to conserve myrmecophiles and mitigate global change impacts.

APPROACHES

The CLIMIT team completed existing data sets on myrmecophiles' distribution, habitat requirements and hosts (ants) dependency across EU climates. The data collected in the project was used together with long-term data sets for modelling the evolutionary consequences of global change on the interactions between myrmecophiles and their hosts, and on their population dynamics. The CLIMIT team conducted fieldwork in the UK to evaluate the potential of the butterfly *Maculinea arion* to adapt to changing conditions, including changed plant phenology. These results and experiments manipulating environmental conditions such as sward height, slope and aspect, were used to test the potential of adaptive habitat management for myrmecophiles' conservation.

MAIN ACADEMIC FINDINGS

- CLIMIT allowed completing data sets on niche breadth and host interactions of myrmecophilous species in Europe, filling gaps for southern Europe [29, 30, 31, 32, 33, 34].
- New insights into the mechanisms of host specificity linked to acoustic communication with host ant species were provided for *Maculinea* butterflies [35, 36, 37, 38].
- The CLIMIT team showed a limited potential of such species to adapt to changing environmental conditions due to strong adaptation to local host ants [39].
- Long term data analyses revealed that there is little variation in butterfly populations at the margin of their distribution, while Europe is more and more dominated by species associated with higher temperatures [40].

- Analyses on *M. arion* in the northern range of Europe revealed an important plasticity in its phenology, showing a capacity to track and adapt to temperature change over time, which may be the result of the use of optimum habitats [29, 41, 42, 43, 44].

The CLIMIT team tested new ideas for adaptive management by experimentally manipulating environmental conditions of myrmecophiles' habitats (e.g. sward height, slope and aspect). The results suggest that these are suited to create microclimatic conditions that help species persist under current and future climates [41, 42].

Consortium partners:

Helmholtz Centre for Environmental Research, Germany — Coordinator: Josef Settele

Dept. of Zoology, University of Oxford, UK (Co-Coordinator: Jeremy Thomas)

Dept. of Physical Geography and Ecosystems Science, Lund University, Sweden

NERC Centre for Ecology and Hydrology, UK

Institute of Systematics, Evolution and Biodiversity, CNRS/MNHN, France

Dept. Of Life Sciences and Systems Biology, University of Turin, Italy

Amount: € 1,202,183

ACADEMIC RESULT HIGHLIGHT

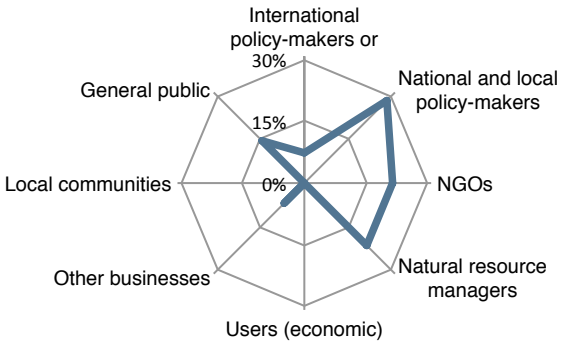
The yearly change (1990–2008) in composition in response to climate change was quantified for 9,490 bird and 2,130 butterfly communities across Europe*. Changes in community composition are rapid, equivalent to a 37 and 114 km northward shift in bird and butterfly communities, respectively (see Figure). However, the northward shift in temperature in Europe was even faster, leaving a 'climatic debt' of birds and butterflies corresponding to a 212km and 135 km lag behind climate. This has implications for forecasting climate change effect on biodiversity in the next decades.

* Devictor *et al.* (2012). Differences in the climatic debt of birds and butterflies at a continental scale, *Nature Climate Change* 2: 121-124

Variations in the temporal trend of bird and butterfly Community Temperature Index, CTI, per studied country in Europe. The CTI reflects the relative composition of high- versus low temperature dwellers in local communities. After Devictor *et al.* 2012 (*Nature Climate Change*).

STAKEHOLDER ENGAGEMENT AND PRODUCTS RELEVANT TO SOCIETY/POLICY

- CLIMIT informed a broad number of stakeholders (see Figure) on the pressures that climate change forces onto threatened insects, especially NGOs, policy-makers, natural resource managers (e.g. German Federal Agency for Nature Conservation and the UK National Trust). The general public was also reached through interviews and press releases.
- A number of stakeholders were closely involved in the project, for example NGOs and local authorities, to support the reintroduction of threatened butterfly species. Work in the UK with Natural England and DEFRA lead the co-production of distribution maps and to agreements on several sites to provide suitable habitat for *M. arion* through management practices (in total approx. 700ha).



Types of stakeholders engaged in CLIMIT

- Numerous training sessions were organised with natural site managers to advise on site management, help with agri-environment applications, teach, and provide feedback from monitoring and experiments.
- The project contributed to a joint analysis of monitoring data from 13 countries to update the European Butterfly Climate Change Indicator (van Swaay *et al.* (2010) The impact of climate change on butterflies communities 1990-2009. In B.C.D. *Vlinderstichting* (Ed.),(Report VS2010.025). Wageningen) as part of the Climate Change indicators of the European Environmental Agency.

CLIMIT produced a set of tools adapted for use by key stakeholders in a proactive manner:

➔ Inventory of 64 sites with broad management prescriptions needed to restore butterfly habitat

➔ Policy recommendations, which are summarized in a CLIMIT policy brief supported by BiodivERsA (http://www.biodiversa.org/553).

HIGHLIGHTS ON SOCIETY/POLICY-RELEVANT PRODUCTS

- **Dos and Don'ts for butterflies of the Habitats Directive of the European Union**: this document gives guidelines on what to do (and not to do) to conserve the butterflies on the Annexes of the Habitats and Species Directive (van Swaay *et al.* (2012) Dos and Don'ts for the butterflies of the Habitats Directive of the European Union. *Nature Conservation* 1:73-153).

- **Distribution Atlas of Butterflies in Europe**: this document intends to help policy-makers in setting conservation priorities from a truly European perspective. It contains full colour distribution maps of all 441 European butterfly species (http://www.ufz.de/european-butterflies/index.php?de=22179).

- **"Heads of Agreement" with Network Rail**: the CLIMIT team provided close support to Natural England in preparing and implementing a "Heads of Agreement" with the business company 'Network Rail' (UK) to help preserve butterfly colonies on their land and create new potential land suitable for colonization.

CoForChange

How and where will tree species survive increasing pressure: providing diagnostic and decision-making tools to attenuate the effect of global change on biodiversity in the Congo Basin forests

OBJECTIVES

The Congo Basin hosts the second largest un-fragmented area of rainforests, providing numerous services for local populations, states and the international community. In the coming decades, these forests will face increasing pressures from a changing climate and from human activities. The CoForChange team analysed how and where tree species could survive these increasing pressures to then produce diagnosis and decision-making tools to attenuate their effects on forests' biodiversity. The main objectives of the research were to:

1. Assess whether climate or human activities are the main pressures on the region's forests;
2. Project the impact of global change on forests' characteristics;
3. Produce decision tools for conservation and management strategies to adapt to the consequences of global change.

APPROACHES

CoForChange gathered a multi-disciplinary team of researchers (remote sensing, populations and communities ecology, functional ecology, hydrology/climatology, pedology, paleoecology, anthropology and modelling), from 16 European and African institutions in partnership with 11 timber companies to conduct a large-scale study of semi-deciduous rainforests in Cameroon, the Central African Republic and the Republic of Congo. The team studied the influence of main environmental and historical factors shaping forest structure and composition: geological substrate, and past (up to 6,000 years) and recent climatic and human-induced disturbances influencing water availability, water table depth and light availability. The collected information was then crossed to propose diagnosis and decision-making tools to attenuate global change effects on these rainforests.

MAIN ACADEMIC FINDINGS

- CoForChange evidenced the predominant influence of geological substrate on the floristic and functional composition of Central African forest stands [45, 46, 47, 48].
- It found that forest deciduousness increased with the severity of the dry season, but the increase was stronger on resource-rich than poor soils [49].
- It showed that tree species in the region are highly resistant to drought, at the juvenile and adult stages, with the exception of some short-lived pioneer species; highly disturbed forests might thus be more vulnerable in a context of increasing drought frequency and severity [46, 49].
- Ancient and recent human activities were found to have had a significant effect on forest composition, leaving them dominated by long-lived pioneer species or giant herbs [47, 50, 51, 52].
- The project is leading to the production of the CoForTraits database of traits for 1100 tree species (and over 300 other life form species), allowing to identify and map the different forest ecosystems and assess provided services (e.g. provision of food and medicine).

The CoForChange team then proposed a diagnosis of forest resilience to climatic and human-induced disturbance, identifying possible management options ranging from more intensive timber production in productive forests on rich soils to extensive timber production associated with protection measures for forests on poor soils.

Consortium partners:

Tropical Forest Goods and Ecosystem Services, CIRAD, France — Coordinator: Sylvie Gourlet-Fleury

Gembloux AgroBioTech, Liège University, Belgium

Institute of Evolution Sciences of Montpellier, CNRS/IRD, France

Geosciences Environment Toulouse, CNRS/IRD/ University Toulouse 3, France

Forest Resources Management (engineering company), France

Dept. of Plant and Soil Science, University of Aberdeen, UK

Oxford University Centre for the Environment, UK

and subcontracted partners in 9 African institutions.

Amount: € 1,319,412

ACADEMIC RESULT HIGHLIGHT

CoForChange studied the effect of soil types (see picture) and physical constraints (soil depth and hydromorphy) on biomass in undisturbed rainforests in the Central African Republic, crossing the information with species' wood densities*. Soil physical conditions constrain the amount of biomass stored in these forests, while contrarily to previous reports, biomass is similar on resource-poor and resource-rich soils. Both soil characteristics and species' wood density have to be taken into account when trying to predict regional patterns of biomass. These results have implications for the evaluation of biomass stocks in tropical forests in international negotiations on climate change.

* Gourlet-Fleury *et al.* (2011) Environmental filtering of dense-wooded species controls aboveground biomass stored in African moist forests. *Journal of Ecology* 99: 981-990

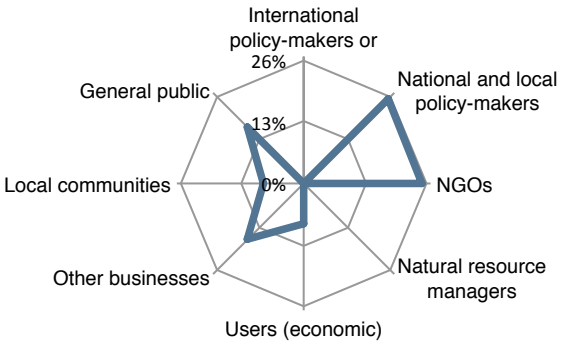
STAKEHOLDER ENGAGEMENT AND PRODUCTS RELEVANT TO SOCIETY/POLICY

- Forest Resources Management, a private forest engineering company, was part of the project members, helped framing the project, participated in mapping exercises and actively helped involving other stakeholders.
- CoForChange also involved a number of foresters, timber logging companies, national policy-makers and NGOs, in order to help frame stakeholder expectations from the project and disseminate knowledge produced (see Figure). In particular, the project's stakeholders discussed initial results and helped framing and then refining the list of tools and information awaited from the project in a dedicated workshop.
- A number of private forest managers in timber companies provided access to inventory data to constitute the CoForChange inventory dataset.

CoForChange produced a set of tools adapted for use by their stakeholders in a proactive manner, in particular:

➔ Thematic maps, presenting the oldest, the less resilient, the faster-developing, or the more diverse tree communities (Fayolle *et al.*, 2014, Forest Ecology and Management);

➔ Ranking of species sensitivity according to future climate and/or anthropogenic changes (Bénédet *et al.*, Cofortraits, African plant traits information database. version 1.0).



Types of stakeholders engaged in CoForChange

HIGHLIGHTS ON SOCIETY/POLICY-RELEVANT PRODUCTS

- **Policy brief on "Improving tropical forest characterization for a more sustainable management"**, including recommendations for policymakers based on a synthesis of project's results (http://www.coforchange.eu/products/policy_brief).
- **Vegetation structure and greenness map (from MODIS imagery)**: it is a detailed mapping of 22 vegetation types, with enhanced vegetation index profiles and their seasonal dynamics (http://www.coforchange.eu/products/maps), designed for an assessment of the types of forests and options available, would it be logging, community-based management or conservation to preserve carbon storage services.

Ecocycles

Cascading Effects of Climate Change and Land Use on Cyclic Herbivores and Predators of Conservation Concern

OBJECTIVES

Many ecosystems are dominated by regular fluctuations in abundance of grass-eating small rodents, which are prey for many predator species. These ecosystem "heartbeats" have been changing recently, raising concern about their drivers and possible broader effects on ecosystems. The Ecocycles team has studied the causes and consequences of changing rodent abundance cycles, by testing that:

1. There has been strong changes in small rodent cycles during the last decades all over Europe, due to land use and climate change;
2. These changes have disproportionate impacts on the demography of predator species, challenging their viability;
3. These demographic changes in prey and predator species have cascading effects on the whole ecosystem food-web;
4. Conservation measures need to account for these ecosystem "heartbeats".

APPROACHES

Researchers in France, Norway, Spain and the UK worked on understanding these changes by testing the hypotheses above, following a step-by-step approach to:

1. Determine the patterns and correlations in prey dynamics changes by analysing long records on the abundance of grassland voles, some going back 50 years;
2. Characterise the impacts on predator demography and predict responses of different types of predator species;
3. Explore potential for profound ecosystem disturbance under joint climate and land use change impacts;
4. Suggest evidence-based conservation measures.

MAIN ACADEMIC FINDINGS

- The Ecocycles team demonstrated a consistent dampening of the amplitude of rodent cycles in many places across Europe, probably reflecting common climatic driver and involving a reduction of winter population growth [53].
- Locally, human activities such as the irrigation of arid areas in Spain, and grazing pressure by cattle or agri-environmental schemes, influence rodent dynamics. Yet global patterns are tending to override their effect [54, 55, 56].
- Ecocycles established that vole predator populations - such as owls and skuas - will decline in response to such changes in prey dynamics, with varying time frames reflecting species' specific habits [57, 58, 59 60, 61].
- The Ecocycles team also identified spreading effects of these changes, notably a now reduced spillover predation following low abundance cycles, meaning that some endangered predators such as the Arctic fox face a heightened competition with other predators, eventually challenging the survival of these endangered species [62, 63, 64, 65].

Consortium partners:

Population Ecology Research Group, University of Aberdeen, UK
Coordinator: Xavier Lambin

Dept. of Arctic and Marine Biology, University of Tromsø, Norway

Institute of Research in Game Resources, CSIC/UCLM, Spain

Chizé Centre for Biological Studies, CNRS/University of La Rochelle, France

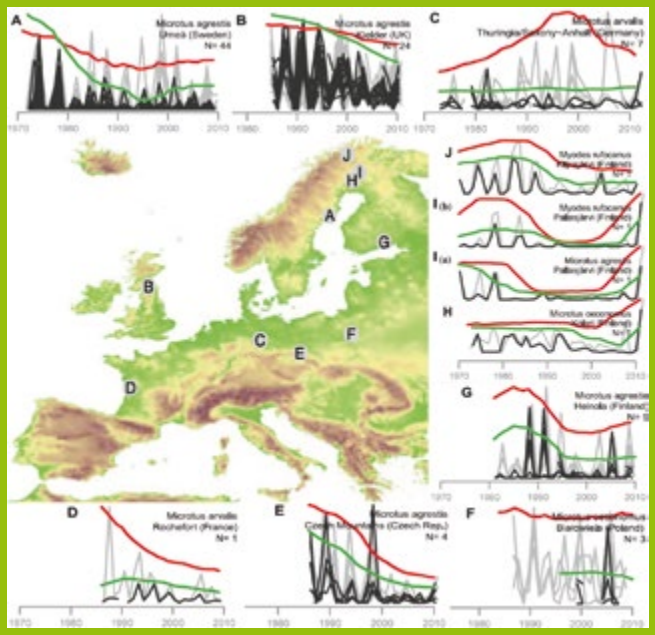
ETSIIAA, University of Valladoid, Spain

Amount: € 1,249,279

ACADEMIC RESULT HIGHLIGHT

The Ecocycles team analysed the temporal trends of vole abundance series for spring and autumn in several sites across Europe* (see the dark and grey curves, respectively, in the Figure). The variation in the amplitude of fluctuations for spring and autumn (red and green curves, respectively) decreased over time all over the continent, which suggests a major role of a continental-scale environmental change like climate.

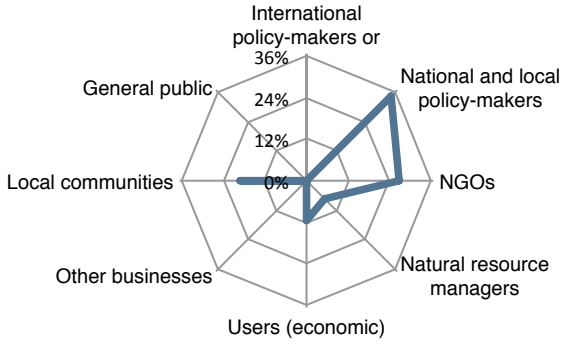
* Cornulier *et al.* (2013) Europe-wide dampening of population cycles in keystone herbivores. *Science* 340: 63-66



Changes in grass-eating vole populations during the last decades. Note the dampening of the fluctuations in abundance at many sites. After Cornulier *et al.* 2013 (*Science*)

STAKEHOLDER ENGAGEMENT AND PRODUCTS RELEVANT TO SOCIETY/POLICY

- Ecocycles researchers worked with a wide range of stakeholders (see Figure), involving and consulting local authorities, NGOs, farmers' organisations and natural resource managers through national consultative fora in Spain, Norway, France and the UK.
- In several countries, farmers and regional authorities were directly involved in vole monitoring and management experiments, for example with the participation of rangers from the Forestry Commission in the UK, which also provided data to the project.
- In Spain (Junta de Castilla y Leon), Ecocycles allowed overcoming past conflicts and provided the initial steps and framework for a positive collaboration between farmers and local authorities concerning the impact of vole outbreaks on agriculture thanks to evidence-based information and sustained dialogue.



Types of stakeholders engaged in Ecocycles

- Ecocycles lead to the funding of a number of subsequent projects with and by NGOs and local authorities involved in the project in Spain, France and the UK.

Ecocycles produced a set of tools adapted for use by their stakeholders in a proactive manner:

➔ A report co-produced with National Consultative Fora on research priorities for upland management

➔ Contributions to forging agreements for experimental management in biological control of outbreaks between NGOs and Regional Government Farmland Managers in Spain.

HIGHLIGHTS ON SOCIETY/POLICY-RELEVANT PRODUCTS

- **Leaflet on state-of-the-art knowledge and recommendations for management of vole outbreaks**: disseminated widely in the Junta de Castilla y Leon in Spain, this comprehensive leaflet provided evidence-based information on vole outbreaks and their role, and on management by the local community.
- **"Ecocycles protocols"**: specific vole monitoring methodologies produced by the project were applied jointly by NGOs and Junta de Castilla y Leon in Spain.
- **Contributions to the National management plan for Arctic fox in Norway**: the Ecocycles team wrote parts of the Norwegian management plan to conserve this predator species relying heavily on small rodent preys.

FIREMAN

Fire management to maintain biodiversity and mitigate economic loss in forests and heathlands in Europe

OBJECTIVES

Fire is a natural part of many forest, shrubland and grassland ecosystems' natural functioning, having effects on species dynamics and diversity, physical structure of ecosystems, and on services they provide. Fire-ecosystem relationships are modified under changing climatic conditions, and fire regimes (i.e. the pattern, frequency and intensity of fires in a given area) have been heavily modified due to human activities, with both ecological and economical implications. Intense or inappropriate fires can cause enormous damage, and extreme fires experienced in Europe since the year 2000 have called for co-ordinated European policy on fire management. In this context, FIREMAN aimed at analysing fire-biodiversity relationships and generating policy guidance and management tools for the appropriate use of fire to foster biodiversity in three major European ecosystems (boreal forests, wet upland heathland/moorland and Mediterranean shrub-forest systems).

APPROACHES

Gathering researchers from four countries across Europe, the FIREMAN team's approach was to:

1. Establish fire-biodiversity "baselines" (i.e. reference relationship between fire and biodiversity) in the studied ecosystems;
2. Develop site-specific models of fire-biodiversity relationships and a regional model of climate-fire-vegetation relationships, and produce scenarios at local and regional scales;
3. Develop and disseminate practical decision tools and regional burning guidelines for policy-making, including an evaluation of societal preferences towards prescribed burning, fire prevention and biodiversity management.

MAIN ACADEMIC FINDINGS

- Looking back several thousand years at fire histories in Europe by analysing sedimentary charcoal data, FIREMAN found a progressive increase in fire activity during the last 3,500 years, even more drastic during the last 250 years and declining abruptly after the industrial era. The long-term control of fire is best explained by land-cover change linked to human activity, plant litter availability and climate-related parameters [66].
- FIREMAN mapped fire risks for Northern Europe based on forecasted climate change and found most significant increases in fire intensity/frequency for southern Scandinavia and the Baltic States.
- Most current Scandinavian fire regimes could be more appropriately managed to foster biodiversity [67].

Based on their work and results, the FIREMAN team developed local fire-biodiversity models in study sites for the UK and Scandinavia, including burning timing, frequency, location and intensity. The models were used as a basis for management tools. In addition, the project developed a regional model accounting for vegetation impact and emissions caused by fire.

Consortium partners:

School of Environmental Sciences, University of Liverpool, UK
Coordinator: Richard Bradshaw

Swedish Forest Society Foundation (Skogssällskapet), Sweden

Peak District National Park Authority, UK

Institute of Evolution Sciences of Montpellier, CNRS/IRD, France

Faculty of Economic Science, University of Santiago de Compostela, Spain

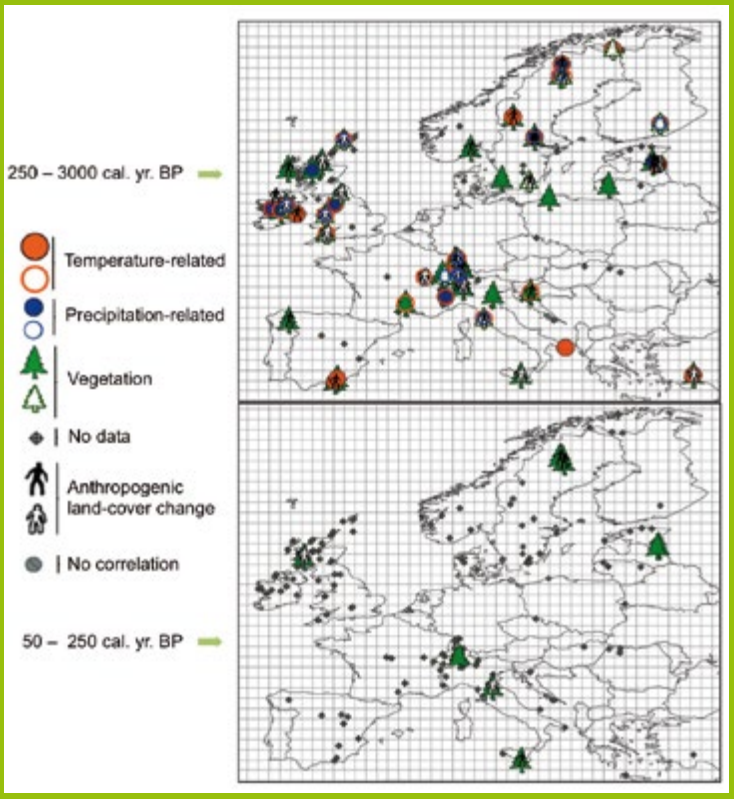
Dept. of Physical Geography and Ecosystems Science, Lund University, Sweden

Amount: € 1,628,709

ACADEMIC RESULT HIGHLIGHT

The FIREMAN team investigated Holocene fire activity based on 156 sedimentary charcoal records from across Europe and covering the last 9000 years. Combined with palaeoclimate, vegetation and fire indices simulated by a dynamic vegetation model, these data show that a progressive increase in fire frequency began around 3500 cal. yr bp and rose sharply from 250 cal. yr bp onwards, reaching a maximum during the early Industrial Era and then declining abruptly. When considering the whole Holocene, the long-term control of fire is best explained by anthropogenic land-cover change, litter availability and temperature-related parameters (see Figure). The 20th century decline in biomass burning is likely due to increased landscape fragmentation and active fire suppression policies.

* Molinari *et al.* (2013) Exploring potential drivers of European biomass burning over the Holocene: a data-model analysis. *Global Ecology and Biogeography* 22: 1248-1260

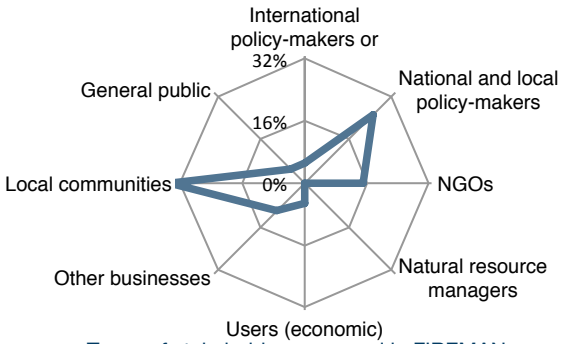


Best predictor of major changes in fire activty in Europe for the different selected timescales (here: 250-3500 cal. yr. BP and 50 to 250 cal. yr. BP). After Molinari *et al.* 2013 (*Global Ecology and Biogeography*)

STAKEHOLDER ENGAGEMENT AND PRODUCTS RELEVANT TO SOCIETY/POLICY

The FIREMAN team interacted with a range of stakeholders (see Figure) in different ways, thanks to:

- Annual National Consultative Fora involving project stakeholders from the government and local authorities, forest industry, landowners, fire fighters, etc;
- A European-wide survey of attitudes towards fire, evidencing a North-South gradient as to the apprehension of risks posed by uncontrolled or prescribed burning;
- The involvement of the Peak District authorities in the UK as a project partner. Beyond accessing sites, the provision of background data and a close collaboration led to the development of a specific management tool developed for the Peak District moorland burning system;



Types of stakeholders engaged in FIREMAN

- Active provision of advice to NGOs involved in nature protection and government authorities in charge of prescribed burning, providing evidence-based recommendations;
- Provision of information and recommendations at different policy-levels, for instance within the Forest Europe Ministerial Conference.

HIGHLIGHTS ON SOCIETY/POLICY-RELEVANT PRODUCTS

- **Proof of evidence**: FIREMAN actively provided advice on both prescribed burning practice, wildfire risk and moorland management part of a DEFRA Public Inquiry on a conflictual situation involving the owners of moors in the UK and an NGO. The contribution of FIREMAN allowed unlocking this particular situation with an evidenced-based defence of prescribed burning.

- **Technical review**: FIREMAN team members built on project results to contribute to an IUCN technical review on the impacts of burning management on peatlands (http://www.iucn-uk-peatlandprogramme.org/publications/commission-inquiry/work-commission/impacts-burning-management-peatlands).

LinkTree

Tree Genetic Variability Can Improve Ecological Responses to Environmental Changes in Forest Ecosystems

OBJECTIVES

Forests cover approximately 25% of Europe and are a key reservoir of genetic diversity that can play a decisive role in climate change mitigation through adaptation. The response of forest trees to current and future environmental pressures depends on the levels of genetic variability (standing genetic diversity) that they carry. The LinkTree project investigated how trees adapt to new environments, by focusing on:

1. Identifying genes playing a role in tree adaptation to climate change or environmental hazards, for instance through drought/cold tolerance or response to fire;
2. Providing detailed understanding on how the genetic variability of forest trees may confront and respond to rapid environmental change and on the implications for forest functioning and dynamics;
3. Assessing how management of tree genetic variability by forest habitat managers can increase forests' adaptation capacity to environmental changes.

APPROACHES

LinkTree gathered six research groups from five countries to analyse the effects of environmental changes on tree standing genetic diversity. To generalise results, it also used simulation models at both local and wider scales, accounting for predicted climate change and focusing on a range of tree species ecologically and economically important for Europe. More precisely, the approach was to:

1. Identify and characterize genes of targeted tree species involved in drought resistance, cold tolerance and phenology using high throughput sequencing and genotyping methods;
2. Analyse genetic variability and its ecological context at local and large scales in order to understand and assess the adaptation capacity of European forest trees to climatic stresses and its determinants;
3. Use eco-genetic models to provide forest managers and other stakeholders with better information on the genetic make-up of trees and their adaptive potential, thus helping them to sustainably manage forest tree populations in a changing environment.

MAIN ACADEMIC FINDINGS

- LinkTree demonstrated that forest trees maintain a very high genetic variability not only across Europe and across different landscapes but also at the very local scale, because of micro-scale and year-to-year environmental and biotic variations [68, 69 ,70, 71].
- Simulations carried out in LinkTree demonstrated that local climate gradients can generate genetic adaptation as "fast" as in five generations, a timeframe compatible with moderate climate change scenarios, which could thus prevent local tree extinctions [72].
- The LinkTree team found that gene networks and alleles responsible for local adaptation in one place, such as those involved in drought resistance, are different from the ones involved for the same trait in another habitat. This is very important for assessing the merit of transferring genetic material form one place to another as a climate change mitigation measure and suggests that promoting the evolution of local genetic material may be a better option [70, 73].
- LinkTree demonstrated that forest management strategies can foster, increase or reduce genetic diversity by affecting tree density and grouping, and that management strategies at landscape scale should aim at maintaining genetic diversity for long term adaptation [74].

Consortium partners:

Forest Research Centre, INIA, Spain

Coordinator: Santiago Gonzalez-Martinez

Desertification Research Centre, CSIC/University of Valencia, Spain

Biodiversity, Genes and Communities Unit (BIOGECO), INRA/University of Bordeaux, France

Ecology of Mediterranean Forests Unit (URFM), France

Faculty of Biology, Philipps-University of Marburg, Germany

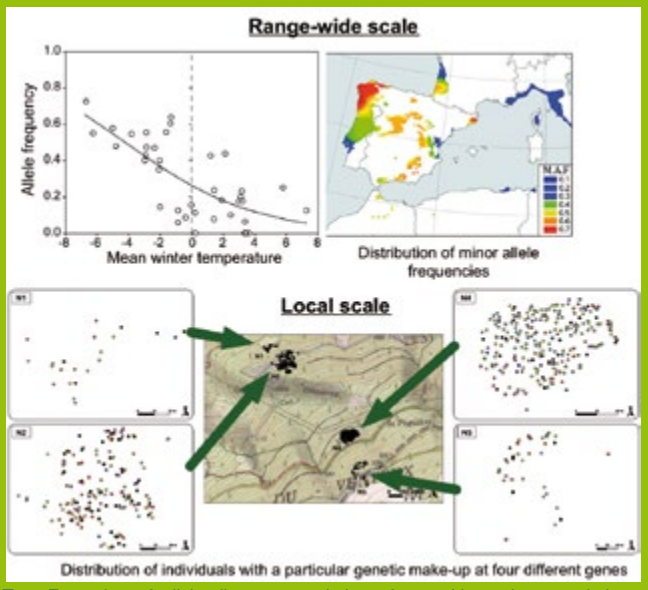
Dept. of Ecology and Genetics, Uppsala University, Sweden

Amount: € 1,174,433

ACADEMIC RESULT HIGHLIGHT

Studying the genetic effect of environmental gradients in forest tree populations across Europe, LinkTree contributed significantly to understanding the effects of local adaptation at the genomic level and the determinants of demography versus natural selection on patterns of allelic variation*. LinkTree provided a wealth of data on candidate genes showing gradual changes of allele frequencies at large, range-wide geographical scales and at small spatial scales over local gradients (see figure), contradicting theoretical models that predict abrupt shifts of allele frequencies within a short distance over environmental gradients. LinkTree also highlighted the need for new research linking genomic, phenotypic and environmental information to better understand the spatial scale and pace of genetic adaptation, particularly in the context of global change.

* Savoleinen *et al.* (2013) Ecological genomics of local adaptation. *Nature Reviews Genetics* 14: 807-820



Top: Examples of allele-climate associations for maritime pine populations at the range-wide scale. Lines within the scatter plot (left) indicate clines of allele frequencies under a logistic regression model. Distribution of MAF are shown for potentially adaptive genetic variations amongst individuals. After Jaramillo-Correa *et al.* 2015 (Genetics - in press)

Bottom: Maps showing the distribution of different European Silver for trees in four plots along an elevation transect in Mont Ventoux (France). Plots show the distribution of individuals with a particular genetic make-up for four different genes involved in resistance to environmental stress. Genetic variability is at maximum at the micro-envrionmental scale, among individuals within the same population, which is cruicial for local adaptation under climate change (Fady *et al.*, unpublished)

STAKEHOLDER ENGAGEMENT AND PRODUCTS RELEVANT TO SOCIETY/POLICY

- LinkTree partners worked closely - including during the planning of the project - with a number of stakeholders (see Figure), i.e. national or local authorities from several countries and international policy programmes such as EUFORGEN.
- A number of NGOs, protected area managers and policy-makers were directly involved in LinkTree and listed major challenges faced by forests under climate change in Europe from their own perspective.
- National forest managers were approached in each of the 5 countries to conduct field experiments and sampling of collections. They notably provided information that led to the selection of the test sites used in the project.

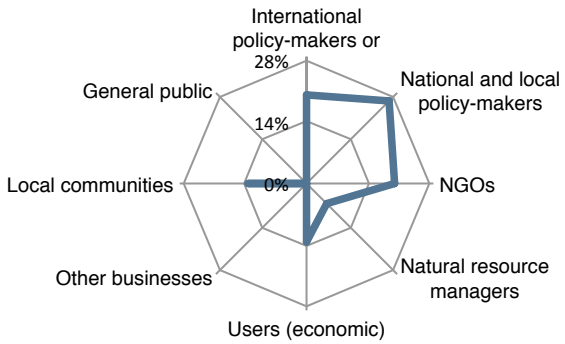
LinkTree produced a set of tools adapted for use by forest stakeholders in a proactive manner by providing:

➔ Several publications in national practitioner journals;

➔ A set of criteria and indicators for forest management;

➔ A Public-awareness interview and article on "Forest adaptation to future environments" (http://www.igv.fi.cnr.it/linktree/data/p96-98_Linktree-HD.pdf);

➔ A policy brief for European and national policy-makers, and a movie presenting the project, both supported by BiodivERsA (http://www.biodiversa.org/694).



Types of stakeholders engaged in LINKTREE

HIGHLIGHTS ON SOCIETY/POLICY-RELEVANT PRODUCTS

- **"Forests and global change: what can genetics contribute to the major forest management and policy challenges of the 21st century?"** This document was prepared jointly by the project's scientists and stakeholders and provides insights on the role of genetics in European forests' response to climate change (Fady *et al.* (2015) Regional Environmental Change 15(6): 1-13).

- **FAO's "State of the World's Forest Genetic Resources 2013"**: the LinkTree team directly contributed to this thematic study of the FAO, in particular for the part on "Indicators of forest genetic diversity, erosion and vulnerability" (see also Graudal *et al.* (2014) Forest Ecology & Management 333: 35-51).

- **Technology transfer**: the LinkTree team transferred molecular techniques from the project for the characterisation of forest tree reproductive materials to the Spanish Ministry of Agriculture, Food and Environment.

PEATBOG

Nitrogen Pollution and Climate Change Threaten Peatland Biodiversity and Biogeochemistry

OBJECTIVES

Meter for meter, peatlands store more carbon than any other terrestrial ecosystem. Peatlands also support unique biological communities and provide important ecosystem services such moderating flood risk and removing pollutants. These exceptional ecosystems are threatened by environmental change, particularly climate warming, increased summer drought, and atmospheric deposition of reactive nitrogen (N). Many studies have shown that increased N deposition favours fast-growing species such as grasses at the expense of species adapted to low nutrient levels, including many mosses. It is feared that the elevated N deposition due to intensified agriculture and fossil fuel combustion, together with warmer and drier summers, could favour grasses and shrubs over the characteristic peat-forming Sphagnum moss and specialised plants such as the insectivorous sundew. Beyond compromising the unique biodiversity of these habitats, it would severely impact the ability of peatlands to remove and store atmospheric CO_2 by growing and accumulating *Sphagnum* moss.

The aim of PEATBOG was to provide new understanding of both the sensitivity and resilience of peatlands to environmental change, and give meaningful guidance to policy-makers and managers on the risk posed to peatland ecological and functional integrity by air pollution and climate change.

APPROACHES

PEATBOG gathered researchers from five countries with the over-arching goal of understanding how N deposition, warming and drought impact the ecological communities and ecosystem services provided by European peatlands. They carried out a survey of the above- and below-ground biodiversity of 59 peatlands across Europe, combined with laboratory and field experiments on hydrology, temperature and carbon and nitrogen cycling and storage.

MAIN ACADEMIC FINDINGS

- PEATBOG discovered that European peatlands are increasingly accumulating N in *Sphagnum* moss and peat. With the highest N deposition, more N percolates down to lower layers [75, 76].
- By some measures, peatlands are more resilient to N pollution than other sensitive habitats. It appears that wet and cold conditions restrict the growth of non-peatland species, and that more pollution-tolerant *Sphagnum* can replace species adapted to nutrient-poor conditions [77, 78].
- Despite apparent resilience to background levels of pollution, *Sphagnum* is particularly sensitive to acutely high concentrations of gaseous or aerosol N such as concentrated ammonia downwind from intensive agricultural operations. Should agricultural production continue to intensify, such direct damage to peatlands from N will increase [76, 79].
- In addition, peatlands enriched with N accumulated over decades, even at modestly elevated levels, may be poised to change rapidly should the environment become more favourable for the invasion of grasses and shrubs through warming and drying. As these vascular plants sequester far less carbon over the long term than peat-forming *Sphagnum*, the key peatland quality of slowly removing and lastingly storing carbon would be lost if a replacement occurs [77, 79, 80].

Thus climate change, together with long-term elevated N deposition across large areas of peatland in Europe, render the risk of reaching a tipping point in peat land biodiversity and biogeochemistry very realistic. The team incorporated these results in the “PEATBOG model” [76, 81], a tool intended to predict long term responses of a peatland to different climate and pollution scenarios.

Consortium partners:

Dept. of Environmental and Geographical Sciences, Manchester Metropolitan University, UK
Coordinator: Nancy Dise

Dept. of bioogy and Evolution, University of Ferrara, Italy

Dept. of Biochemistry, University of Bayreuth, Germany

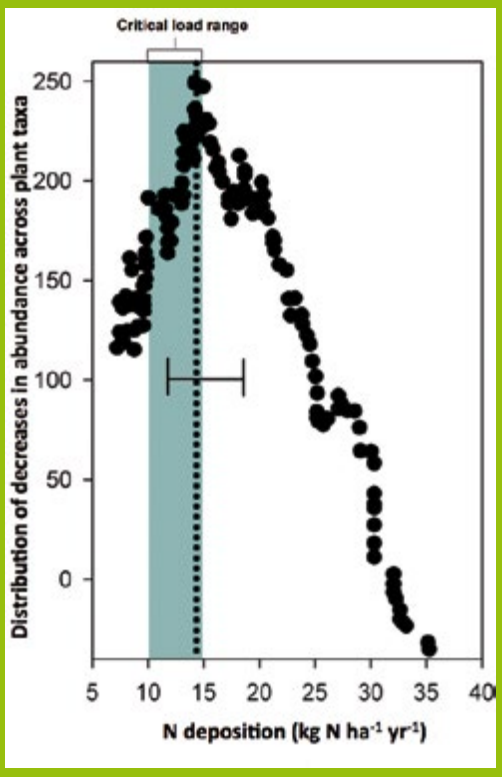
Dept. of Clinical and Experimental Medicine, Linköping University, Sweden

Dept. of Biology, Utrecht University, The Netherlands

Amount: € 1,509,140

ACADEMIC RESULT HIGHLIGHT

Using a large data set from European peatland along a gradient of nitrogen deposition, the PEATBOG team evaluated critical nitrogen loads, a key index of policy tools for the assessment of air pollution. They found that close to 60% of vegetation species reduced in polluted environments start declining at or below the currently established critical N load range (see figure). If this result is verified more widely, the underlying principle of "no-harm in pollution" policy may need to evolve into one of "how much harm is acceptable".



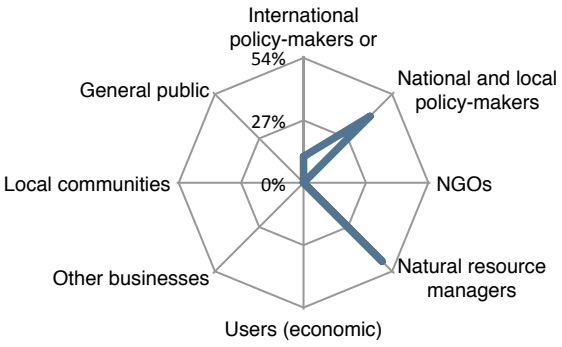
Vegetation community change for species reduced in abundance showing critical load, inferred community threshold (dotted line) and 5-95% bootstrap percentage range. After Payne et al. 2013 (PNAS)

* Payne *et al.* (2013) Impact of nitrogen deposition at the species level. *Proceedings of National Academy of Sciences of the USA* 110: 984-987

STAKEHOLDER ENGAGEMENT AND PRODUCTS RELEVANT TO SOCIETY/POLICY

The PEATBOG team interacted with policy advisors and other stakeholders at European or local level (see Figure) using two bodies in the governance of the project:

- A Core Advisory Group gathered advisors in EU policy on climate change, pollution, and biodiversity and peatland conservation. They were involved very early in the process, providing advice on research aspects that were particularly relevant for policy. They were then kept regularly informed of project progress and results.
- A mixed scientist and stakeholder group collaborated during the cross-European survey for field work and data analysis, in some cases co-authoring papers.
- The large-scale survey was an opportunity for the team to exchange with an important number of local and national authorities and protected areas managers owning land of the study sites about the project's work and findings.



Types of stakeholders engaged in PEATBOG

- PEATBOG organised a science/policy conference during the 2013 meeting of the Society of Wetland Scientists on « Integrating science with policy and management priorities ».
- PEATBOG also suggested the need for a pan-European monitoring scheme acting as an early warning system.

HIGHLIGHTS ON SOCIETY/POLICY-RELEVANT PRODUCTS

- **PEATBOG tool to develop scenarios for peatlands under global change**, based on key project's findings (individual indicator plant species, efficacy of critical loads for biodiversity, …). The PEATBOG model can be used on demand by scientists, policy-makers and managers to predict the long-term response of a peatland to different scenarios of changing climate and pollution. (see reference 81).

- **Sensitivity maps**: using information on nitrogen-related changes in plant community composition, sensitivity maps were produced for grassland, peatland and heathland across the UK (Payne *et al.*, Nitrogen deposition impacts on national scale vegetation biodivesity over time, in preparation).

RACE

Risk Assessment of Chytridiomycosis to European amphibian biodiversity

OBJECTIVES

The RACE team had found that an emerging infectious pathogen, *Batrachochytrium dendrobatidis (Bd)*, poses a widespread threat to amphibians in Europe. The disease chytridiomycosis, caused by *Bd*, was previously undiagnosed and yet had already caused population declines and extinction in amphibians worldwide. The RACE team aimed at:

1. Assessing the risk that this invasive infectious disease poses to European amphibians; and
2. Implementing the first pan-European attempt to mitigate it.

APPROACHES

The RACE team used field-data and next-generation sequencing to identify the disease's lineages present in Europe and to understand its vectors of introduction and spread, as well as environmental conditions influencing the impact of this disease. A total of 226 sites in 12 countries (www.bd-maps.net) were studied. These findings then fed a risk assessment. RACE also developed mapping tools to build a live-representation of the diseases' spread and disinfection protocols, which were used to propose and test a European Threat Abatement Plan. The RACE team invested significant efforts in working with policy-makers from local to European level in order to use the outputs of the project and influence the development of appropriate policy at both scales.

MAIN ACADEMIC FINDINGS

- RACE mapped the *Bd* distribution in Europe and demonstrated the widespread of the disease [82].
- The most vulnerable amphibian species and geographical regions were determined, as well as the most likely vectors (mainly three *Bd*-asymptomatic species) and pathways (global trade of live specimens intended to serve as pets, for biomedical research or consumption) for the disease in Europe [83].
- Biotic and abiotic factors leading to the emergence of the disease were described and modelled [84, 85].
- Five different lineages of *Bd* were identified, three in wild and two in captive specimens, which vary in virulence. This explained the increasing *Bd* impact in Europe while major declines are observed in the USA, Central America and Australia, and gave clear evidence of the role of global trade in spreading the disease [86].

The RACE team identified a suite of environmental- and host-dependent variables (in particular ultraviolet radiation and temperature for environmental variables, and *Bd* genotype and microbial water community composition for biological variables) determining the viability of an infected amphibian population. By manipulating these factors, they could successfully mitigate the disease's impact on European amphibian populations, and in some cases obtained complete eradication of the pathogen, for example on the island of Mallorca.

Consortium partners:

School of Public Health, Imperial College London, UK — Coordinator: Matthew C. Fisher

Institute of Zoology, Zooligcal Society of London, UK

Experimental Ecology Centre of Moulis, CNRS, France

Laboratory of Alpine Ecology, CNRS/University of Grenoble/University of Savoie, France

Helmholtz Centre for Environmental Research, Germany

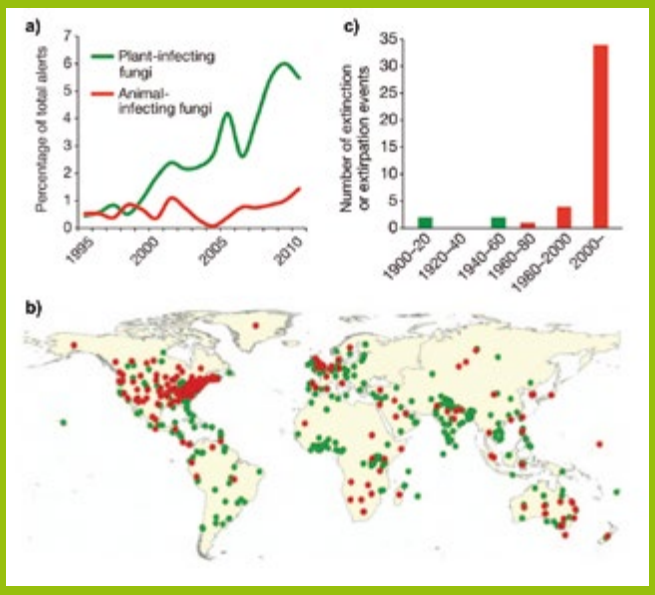
Dept. of Biogeography and Global Change, National Museum of National Sciences, Spain

Amount: € 1,569,444

ACADEMIC RESULT HIGHLIGHT

Part of the project, RACE produced **a synthesis on emerging fungal threats***. In particular, the authors documented the increasing occurrence of pathogenic fungi of plants and animals during the last 15 years and the spread of occurrence (see Figure). They also reported that the number of species extinction and/or extirpation events due to fungal pathogens has broadly increased since 2000 mainly for animals (see red curve in top right panel of the Figure).

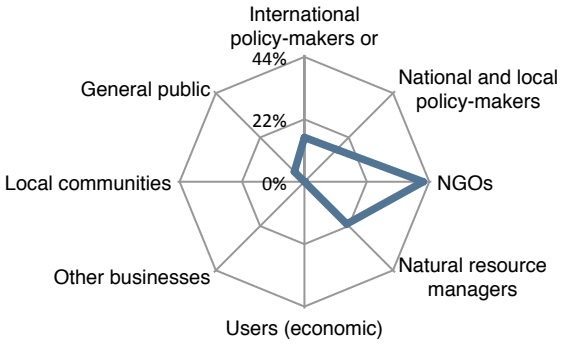
* Fisher MC *et al.* (2012) Emerging fungal threats to animal, plant and ecosystem health. *Nature* 484: 186-194



Recent spread of fungal pathogens and their impacts on biodiversity worldwide. After Fisher *et al.* 2012 (*Nature*)

STAKEHOLDER ENGAGEMENT AND PRODUCTS RELEVANT TO SOCIETY/POLICY

- RACE informed a broad number of stakeholders on the threat *Bd* poses to amphibians, in particular NGOs in nature conservation, local and national policy-makers and the general public (see Figure).
- Training sessions with protected area managers were organised in France, Italy and the UK, leading to the adoption of strategies for standard hygiene protocols of the project to limit the spread of *Bd*.
- A number of NGOs were either consulted or involved in the project, for example through participation in the UK Amphibian Specialist Group.
- The project organised a multi-stakeholder workshop in Brussels with key European and international policy-makers and NGOs (e.g. several DGs from the European Commission, CITES Animal Committee, Amphibian Survival Alliance) to present project outputs and identify gaps in the international legislation and opportunities in the preparation of the EU Animal Health Law.



Types of stakeholders engaged in RACE

RACE produced a set of tools adapted for use by their stakeholders in a proactive manner:

➔ Maps of *Bd* distribution (http://www.bd-maps.net/maps/), a citizen alerting system in France, and hygiene protocols were all designed to fulfill the needs of protected area managers;

➔ Policy recommendations summarized in a RACE policy brief supported by BiodivERsA (http://www.biodiversa.org/552).

HIGHLIGHTS ON SOCIETY/POLICY-RELEVANT PRODUCTS

- **The European Threat Abatement Plan** under development by RACE is an analysis of possible responses to the disease spread embedded in the context of EU and international legislation for wildlife trade, invasive species, and animal health, including a set of concrete recommendations to policy-makers. It is currently being completed with the new chytrid salamander-destroyer, *Batrachochytrium salamandrivorans*, that is emerging in Belgium and the Netherlands (for a preview see http://www.biodiversa.org/552).

- **Protocols for mitigation and remediation in specific sites** were developed and tested. These allowed progress in mitigating the burden of infected populations and in some cases completely cleared the infection.

- **Standard hygiene protocols to reduce spread by humans** were adopted to limit anthropogenic spread of *Bd* in French regional and national parks and in la Sierra de Guadarrama National Park (Spain).

TenLamas

The Functionality of Ecological Networks and Landscape Management Approaches for Species Conservation

OBJECTIVES

In a context of rapid global change, habitat loss and fragmentation are considered one of the main drivers of biodiversity loss, with numerous effects on ecosystems. To counter these effects, some conservation strategies explicitly focus on the improvement of landscape connectivity (between local patches of biodiversity) and the establishment of ecological networks that should allow organisms to move among different habitats and populations. The functionality of these networks, however, has rarely been tested, due to the complexity of determinants of its efficiency. The TenLamas project aimed at:

1. Evaluating different models of the functionality of ecological networks aiming at linking isolated populations in fragmented landscapes and assessing the relevance of several connectivity estimates;
2. Comparing different scenarios of landscape structures to investigate implications for population connectivity.

APPROACHES

To respond to this challenge, the TenLamas team focused on model species (lizards, toads, birds and butterflies) in test landscapes in France and Germany and one in Africa for which they had long-term data on population dynamics. They compared three different methods to estimate connectivity (simple structural connectivity, least-cost paths, and individual-based models of animal movements). Each method's predictions were compared to measures of effective dispersal by looking at the genetic structure of inter-connected local populations. The final objective was to assess the reliability of each of these methods for estimating the extinction probability of the target populations.

MAIN ACADEMIC FINDINGS

- The TenLamas team developed two sophisticated movement and dispersal modelling packages (SMS - Stochastic Movement Simulator; and RandomWalker) and demonstrated that accounting for cognitive decision processes in movements is important for the assessment of dispersal and connectivity [87, 88, 89].
- The team showed that one modelling approach (structural methods) works well for studied butterflies, while another (individual-based models) is more suitable for studied toads. This shows that best-suited tools depend on species.
- TenLamas demonstrated that spatial genetic data can be used to test and compare different movement models, which would be straightforward and faster compared to present methods based on the direct records of animals by movement tracking or capture-mark-recapture experiments [90].
- The project also demonstrated the robustness of dispersal distance predictions based on life history traits for butterflies. This original result has been now extended to other taxa (plants, vertebrates) by other teams, showing the importance of this procedure because dispersal distance predictions are regularly missing from population viability studies, which has important implications for conservation planning decisions [91, 92].

TenLamas provided evidence that it should be possible to use genetic methods combined with mechanistic movement and dispersal models to assess the efficiency of connectivity and ecological networks for species conservation [90].

Consortium partners:

Institute of Systematics, Evolution and Biodiversity, CNRS/MNHN, France
Coordinator: Michel Baguette

Evolutionary Ecology Group, University of Wurzburg, Germany

Institute of Biology and Environmental Sciences, University of Aberdeen, UK

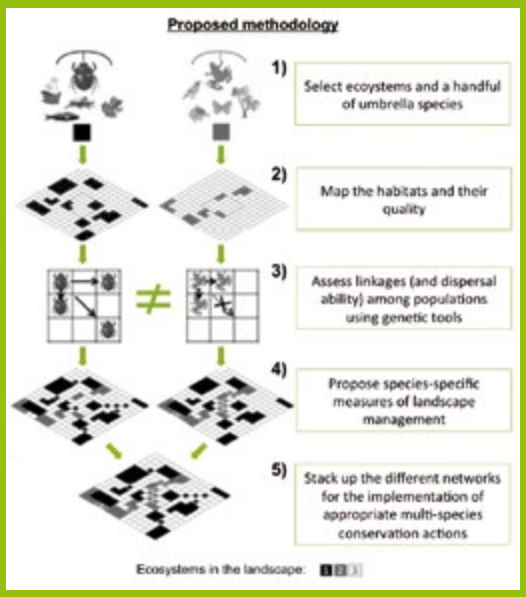
Experimental Ecology Centre of Moulis, CNRS, France

Amount: € 626,781

ACADEMIC RESULT HIGHLIGHT

The TenLamas team reviewed whether landscape connectivity estimates could gain in precision and generality by incorporating fundamental outcomes of dispersal theory. It proposed a 5-step approach* (see Figure) for the design of ecological networks allowing multi-species conservation actions, using genetic and dispersal modelling tools to assess linkages and dispersal ability among populations for different umbrella species.

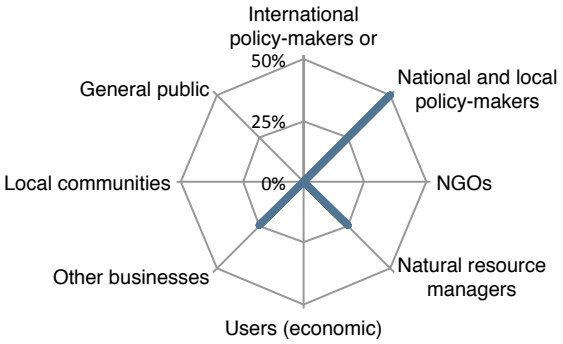
* Baguette *et al.* (2013) Individual dispersal, landscape connectivity and ecological networks, *Biological Reviews* 88: 310-326



Five step-approach, based on connectivity models and linkage strategy proposed by TenLamas, for designing ecological networks suitable for multi-species conservation actions. After Baguette *et al.* 2013 (*Biological Reviews*)

STAKEHOLDER ENGAGEMENT AND PRODUCTS RELEVANT TO SOCIETY/POLICY

- In France, the TenLamas coordinator worked with the Ministry of ecology as part of an *ad hoc* expert group on connectivity issues.
- TenLamas also fostered close links with the French natural heritage service in charge of deploying the ecological networks. They were involved in the scientific council and the service also actively communicated about TenLamas, helping to disseminate the project's results.
- In the UK, TenLamas engaged with the government scientific advisory agency whose representatives were kept informed on project results and regularly participated to project meetings. They notably participated to disseminating new knowledge and insights on how to assess ecological networks in the organisation.
- TenLamas also allowed to build lasting relationships with the project's stakeholders and lead to the funding of new projects in collaboration with several of them.



Types of stakeholders engaged in TenLamas

HIGHLIGHTS ON SOCIETY/POLICY-RELEVANT PRODUCTS

- **Orientation documents of the French Service for the Protection of Nature**: TenLamas members directly contributed to two orientation documents of the authority in charge of implementing the French ecological network aiming at proposing test procedures of its efficiency.
- **SMS software and collaboration with TerrOïko (http://www.terroiko.fr/)**: in 2012, a former TenLamas student launched a start-up company in ecological engineering, applying novel technologies to environmental issues. Part of their evaluation tools are based on the TenLamas Stochastic Movement Simulator (SMS), which is an original individual-based model for predicting the movements of dispersing animals between breeding habitat patches through a heterogeneous landscape.

VITAL

Ecosystem service provision from coupled plant and microbial functional diversity in grasslands: current status and scenarios under changed climate and management

OBJECTIVES

Extensively managed or restored grasslands (hereafter semi-natural) are key elements of European landscapes and provide multiple services central in supporting local livelihoods. In a context of environmental change and search for better sustainability, European agriculture is increasingly required to provide multiple ecosystem services ranging from economically viable production levels to carbon storage and water quality preservation. However, basic understanding of the ecological opportunities and constraints underlying this multi-functionality is still missing. The VITAL project aimed at testing the hypothesis that the delivery of multiple ecosystem services in semi-natural grasslands, including their vulnerability to climate and social change, largely relies on plant and soil microbial diversity and their coupled impacts on carbon and nitrogen cycles.

APPROACHES

The VITAL team gathered researchers from five countries in a collaborative project with testing at three mountain sites (France, UK and Austria). Their approach was to:

1. Identify key ecosystem services associated with fertility of semi-natural grasslands, and how these are influenced by management and the needs of local and regional stakeholders;
2. Develop a model linking plant responses to management practices, associated effects on microbial soil diversity and functioning, and cascading effects on ecosystem services. Model results were validated at test sites;
3. Develop scenarios of land use, management and climate with local and regional stakeholders, and model, under these scenarios, the coupled biodiversity and functioning of plants and soil microorganisms, and their effects on a range of ecosystem services. Results were used to understand how to meet the identified needs of the stakeholders and preserve multifunctionality of grasslands and local livelihoods.

MAIN ACADEMIC FINDINGS

- Drawing from experiments at individual plant and community level, the VITAL team demonstrated the key role of combined plant and microbial functional diversity on carbon and nitrogen cycles and linked ecosystem services, identifying key functional traits associated to processes and services like biomass production, nitrogen retention and carbon sequestration [93].
- The project observed that the extensification of management promotes plant and microbial communities favouring nitrogen retention and carbon sequestration [93].
- Using co-designed scenarios of future change, the VITAL team identified a number of trade-offs between services at landscape scale that originate from ecological functional trade-offs linked to coupled plant and soil microbial communities (e.g. nitrogen retention and carbon sequestration versus fodder production) [94, 95].

By highlighting the key roles of plant functioning diversity and soil microbial diversity in the provision of essential ecosystem services of local and regional interest, VITAL drew the attention to the “hidden” side of biodiversity in sustaining benefits of ecosystems to society.

Consortium partners:

Laboratory of Alpine Ecology, CNRS/University of Grenoble/University of Savoie, France
Coordinator: Sandra Lavorel

Laboratory of Microbial Ecology of Lyon, CNRS/INRA/ University Lyon1, France

Institute of Fundamental and Applied Biology, INRA/ University of Caen, France

Institute of Ecology, University of Innsbruck, Austria

Lancaster Environment Centre, Lancaster University, UK

Gezrman Research Centre for Environmental Health, Germany

Dept. of Vegetal Biology, Universitat de Barcelona, Spain

Amount: € 1,190,100

ACADEMIC RESULT HIGHLIGHT

Using plant trait-based models, the VITAL team disentangled the effects of climate change and land management change on grassland ecosystem functioning and bundles of ecosystem services*, applying different scenarios of global change (see Figure). Overall, the supply of services was more sensitive to climate than management changes because of farmers limited adaptation capacity.

* Lamarque *et al.* (2014) Plant trait-based models identify direct and indirect effects of climate change on bundles of grassland ecosystem services, *Proceedings of the National Academy of Sciences of the USA* 111: 13751-13756

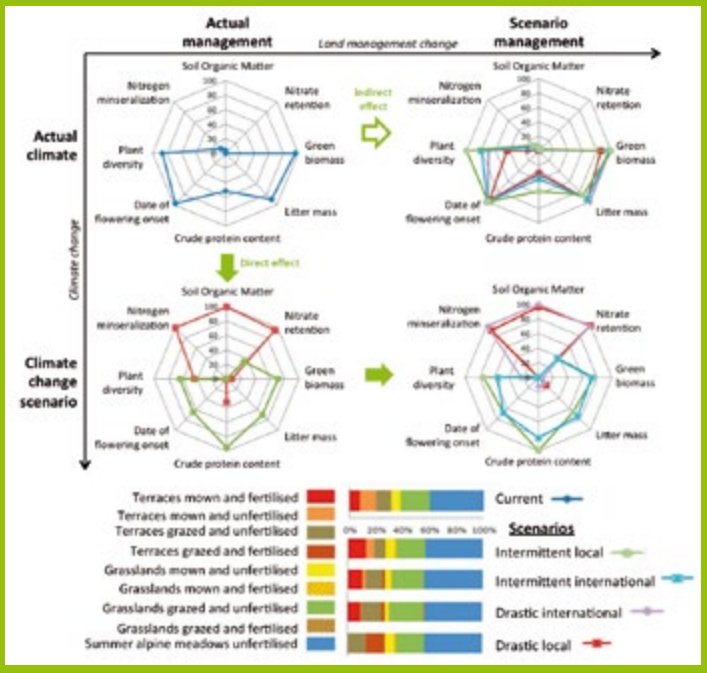
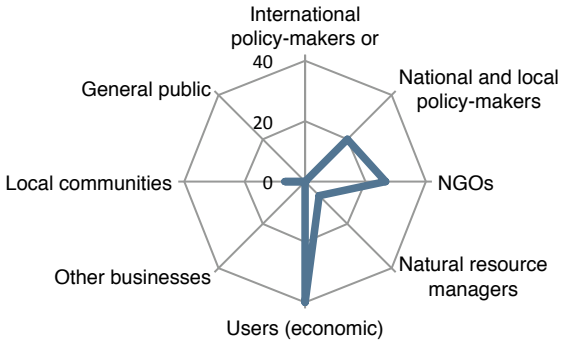


Illustration of ecosystem properties and services predicted by trait-based models under (top) current climate or (bottom) climate change scenarios, and under (left) current land management or (right) co-designed land management scenarios. After Lamarque *et al.* 2014 (*PNAS*)

STAKEHOLDER ENGAGEMENT AND PRODUCTS RELEVANT TO SOCIETY/POLICY

- The VITAL team worked closely with local farmers, regional and local NGOs, and policy advisors (see Figure) to identify their perceived most important ecosystem services in semi-natural grasslands, and to develop scenarios for land management change and associated storylines. Local farmers at study sites took part in a role-playing game to assess their responses to different scenarios and their resulting management decisions
- The VITAL team organised a number of field days involving local authorities, protected area managers, and technical advisors in charge of implementing agri-environmental schemes



Types of stakeholders engaged in VITAL

- The close interaction with Natural England in the UK lead to the funding of new projects by BBSRC on optimal grazing management and on the impacts of restoration management on ecosystem services provision by grasslands

Overall, VITAL provided essential knowledge to guide the development of feasible, multi-sectoral policies and management plans while considering the socio-economic context of mountain livestock farming and the need for technical and active learning support for farming communities.

HIGHLIGHTS ON SOCIETY/POLICY-RELEVANT PRODUCTS

- **"Meadows matter"**: this toolkit for managers of mountain grasslands and students is based on several learning activities, card games and outdoor (optional indoor) activities. It has been successfully tested in a secondary school (ftp://ftp.uibk.ac.at/private/c7701026_20160518_226d60a4afcac7b43901ecea75488cdb).
- **Stakeholder perceptions of ecosystem services**: list of services that stakeholders associate with fertility for each site, perceived relationships between these services, and associated indicators (Lamarque *et al.* (2011) Stakeholder perceptions of grassland ecosystem services in relation to knowledge on soil fertility and biodiversity. *Regional Environmental Change* 11(4): 791-804).
- **Stakeholder-based report on options for policy measures to be taken at national and/or EU level**: intended for policy-makers, this report focuses on implications for sustainable management of ecosystem services in grasslands (http://www.project-regards.org/VITAL/VITAL%20policy_report_final.pdf)

Conclusion

Analysing the academic excellence and stakeholder engagement in the research funded in 2008 by the BiodivERsA network proved to be a tough, yet rewarding exercise. The network demonstrates through this work the relevance of its approach for funding excellent research relevant to policy and society. This analysis also points out some areas of improvement, for example in the engagement of some categories of stakeholders, such as large businesses. Most importantly, these analyses show to what extent funded projects are able to deliver high profile academic outputs while at the same time being able to engage fruitfully with relevant stakeholders to generate a range of products of interest for society and policy.

Of course, projects differ in their profiles of scientific journals used to publish their results, types of engaged stakeholders and ways to engage them, and types of society/policy-relevant products delivered. This is to be expected given the variety of subjects addressed (from the discovery of new marine planktonic organisms to the analysis of Natura 2000 scheme and associated stakeholder discourses) and disciplines mobilized (from ecology to policy sciences, and from marine biology to physical geography). Despite this high project diversity, the overall figures detailed in Part II of this analysis show how projects funded by BiodivERsA in 2008 have achieved remarkable advancements in terms of science, for example looking at the number of high profile publications, in parallel with a strong engagement of stakeholders such as natural resource and wildlife managers, local and national policy-makers and their advisors, or non-governmental organisations.

A demonstrated academic excellence, with a strong positioning at the international level

Several figures clearly demonstrate that the funded projects had a high productivity with overall very high quality of academic productions: 31 papers published per project on average; mean impact factor of projects' papers of 5; 15 publications published in either *Nature, Science* or *PNAS* generated by 2/3 of the projects; and 72.3% of the papers published in journals with outstanding or excellent notoriety. This is a clear indication that pan-European consortia of researchers funded by BiodivERsA meet the highest criteria of academic excellence. In addition, the analysis of the international research collaborations promoted by the funded projects demonstrates an efficient positioning of national teams at the core of a well-developed international collaboration network for countries participating to BiodivERsA calls. This is a further incentive for BiodivERsA members and the European Commission to participate to this type of pan-European call for research proposals, and more generally to reinforce the European Research Area in this domain.

Actual and efficient stakeholder engagement, and concrete products of interest for stakeholders

A closer look at individual projects' achievements in terms of stakeholder-intended outputs shows how a number of the projects accounted for stakeholder needs at the heart of their research, involving them in the design of their research questions or testing their findings.

Most projects produced very concrete tools and recommendations for a broad range of non-academic stakeholders. For instance, the RACE project developed both hygiene and decontamination protocols for the studied amphibian disease, intended for managers of natural areas and the public, while also addressing recommendations for policy-making on global disease transmission vectors and embedding their findings in the context of international trade policy. The CLIMIT project is an equally good example of such an achievement, with the "Do's and Don'ts for butterflies of the EU Habitats Directive" and the distribution atlas of butterflies in Europe intended

for guiding policy-making, while also implementing very concrete activities such as the preparation and implementation of heads of agreement on the management of butterfly colonies on corporately owned land together with the concerned company and an NGO in nature protection.

For several projects, stakeholder engagement even led to the co-production of products that would hardly have been produced by only scientists or stakeholders alone. For instance, the LinkTree project co-authored its policy recommendations on the role of genetic resources in forest adaptation with several of the engaged stakeholders.

These types of activities and outputs for stakeholders obviously depend on the topic studied and are not relevant for all projects. Some areas of biodiversity and ecosystem services research do not require the same type of stakeholder engagement and generate different types of non-academic products. This is the case for instance with the BioMarKs project, working on a vast and unknown compartment of biodiversity, marine protists, which are increasingly recognised as playing a crucial role in global carbon cycling with considerable implications for ocean biogeochemistry and climate. Informing the political players on the advancements in knowledge and potential stakes, and more widely raising awareness of the public on the existence of such forms of life, is the key issue here. Nonetheless, the work performed and stakeholder engagement allowed the research team to propose new indicators to assess and monitor the health of salmon farms and more generally of marine environments.

Interdisciplinarity and participatory approaches

The present analysis also showed that interdisciplinary approaches or participatory approaches were developed when required by the issue at stake and have provided very relevant results. For example, the highly interdisciplinary BeFoFu project has identified the core challenges in implementing Natura2000 in forests and provided concrete solution paths for policy-making. Highly participatory approaches have also been observed in several projects, for example in the VITAL project where farmers were directly involved in the building of scenarios, ensuring the high relevance of their outputs and reducing uncertainty linked to human decision-making.

Lack of trade-offs between academic excellence and stakeholder engagement

When crossing the collected data on academic productivity and quality on one hand, and stakeholder engagement and associated outputs on the other, no discernable trade-off (and no synergy) was observed between the two. In other words, this demonstrates that the academic excellence of the projects was not jeopardized by the investment of researchers in stakeholder engagement and the generation of products for/with stakeholders. As mentioned previously, the nature of the research can obviously set constraints or offer opportunities in this context. Nonetheless, the habits and skills of (at least some of) the research teams in engaging with stakeholders, and possible pre-existing links they had with stakeholders before the project, likely have influenced the actual added value of stakeholder engagement. On this aspect, several researchers interviewed have pointed out how their BiodivERsA project helped in instigating longer lasting relationships with some stakeholders with whom they have then co-developed new research questions. This is particularly promising for the quality and possible outcomes of their engagement in future research projects.

The lack of trade-off was robust since it was observed when relating the 4 computed indices of academic productivity and excellence (i.e. the number of papers published; the sum of impact factors or notoriety scores of the journals that published these papers; and the number of publications in top generalist journals) to the 4 indices

computed to assess the investment in stakeholder engagement and in generating stakeholder-relevant products (i.e. the number of stakeholders engaged; and the indices based on engagement levels, engagement methods, and types of stakeholder-relevant products).

BiodivERsA: continuous innovation in the way to program and support excellent and societally relevant research

As outlined in the present report, the BiodivERsA approach to promoting societally relevant research built on scientific excellence and stakeholder engagement is offering tangible results. It will be particularly interesting to pursue the present assessment for projects funded through the following calls launched by BiodivERsA, which tend to have more focused topics. The impact of a range of BiodivERsA activities to help researchers engaging with stakeholders and to increase the benefits gained from this engagement, for instance with the production of the *BiodivERsA stakeholder engagement handbook* and the organisation of science-society/policy meetings and workshops, will also have to be evaluated on the longer term.

The co-creation of knowledge between different scientific disciplines and stakeholders, and revisiting the ways to perform and promote research, are increasingly called for. The analysis of the results of the projects funded via the 2008 call clearly demonstrates that BiodivERsA promotes an innovative alliance allowing to work beyond the traditional dichotomy between basic and applied research, avoiding the trade-off often observed between academic excellence and stakeholder engagement. This also demonstrates that many biodiversity researchers have developed skills to collaborate with relevant societal groups, reaching very efficiently the goals of scientific excellence and relevance of research results for society and policy.

Adult *M. Arion* egglaying on *Oreganum* flowers: under cool climates they oviposit on low-growing *Thymus* flowers in spots that are hot enough for the sequential host *Myrmica sabuleti* ants; under hot climates (and as climates warm) they switch to using *Origanum* growing in taller shadier turf, which has the same soil temperature as short turf in the north (from the CLIMIT project).

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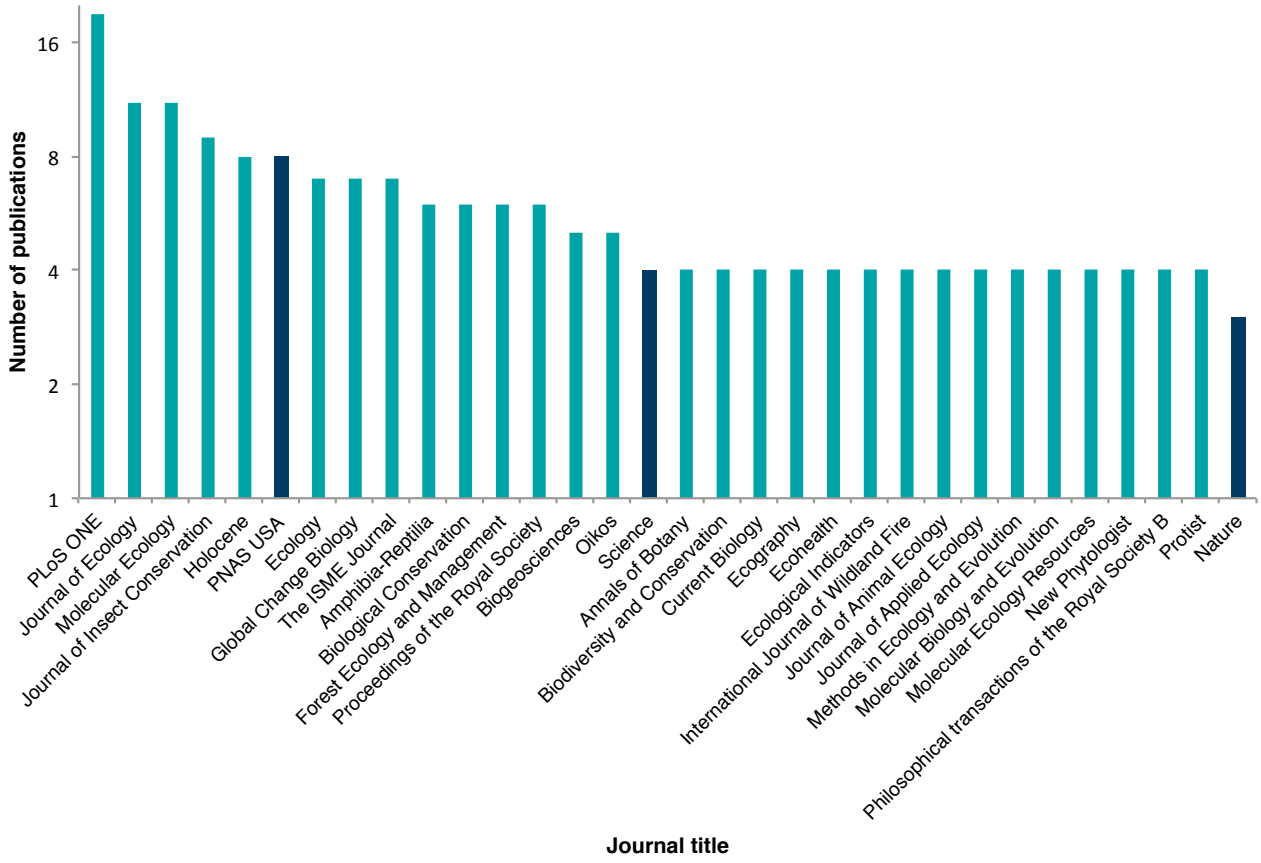
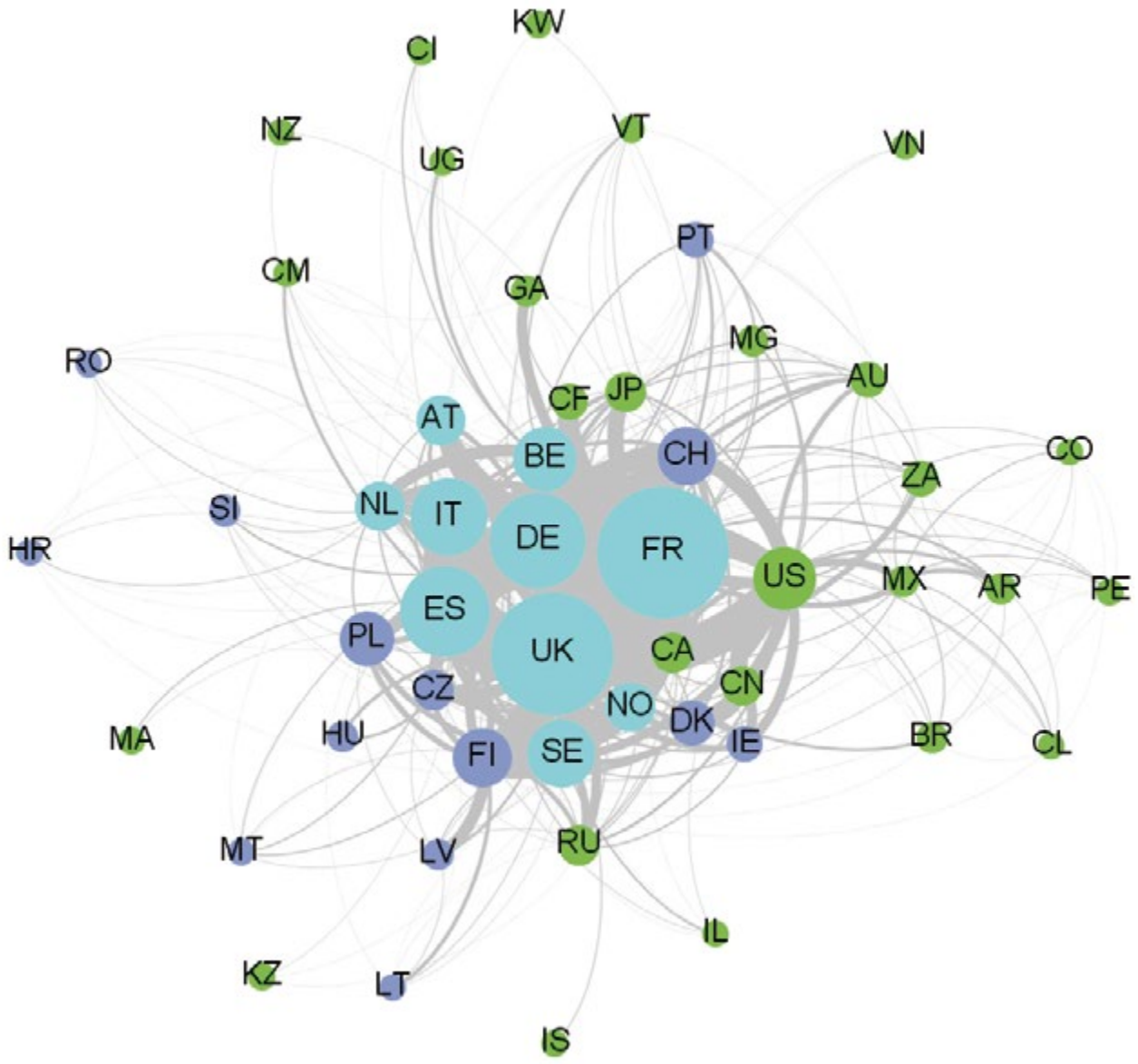
APPENDIX 1

Journals mostly used to publish the results from projects of the 2008 BiodivERsA call. Note that the Y axis has a logarithmic scale. Journals corresponding to less than 4 papers published do not appear, except for Nature. Top generalist journals are indicated in darker blue.



APPENDIX 2

Map of the research collaborations between countries observed in all the projects' publications (see fig. 4 for first map). Light blue dots are for countries geographically in Europe and participating to the call (including sub-contracted teams); purple dots are for countries geographically in Europe but not participating to the call; and green dots correspond to countries not in Europe and not participating to the call. The size of the nod for a given country is based on the number of authors from this country in all the publications linked to the call (scale from 1 to 3), while the links between nodes/countries are based on the number of authors from these two countries involved in joint publications



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BiodivERsA is supported by the European Commission within the Horizon 2020 Programme