



biodiversa

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

Analysis of the outputs of
BiodivERsA
funded projects



Projects completed over 2014 to 2018

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2. Austrian Science Fund, Austria
3. Belgian Science Policy Office, Belgium
4. The Fund for Scientific Research - FNRS - Wallonia-Brussels Federation, Belgium
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36. Swedish Environmental Protection Agency, Sweden
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38. Ministry of Food, Agriculture and Livestock, Turkey
39. Joint Nature Conservation Committee, United Kingdom

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Executive summary

BiodivERsA was built on the opportunity offered by the European Commission to promote the coordination of research on biodiversity, ecosystem services and Nature based solutions across Europe, gathering national Ministries, local governments, agencies and foundations that program and fund biodiversity research, in both mainland Europe and outermost regions and overseas countries and territories.

Since its creation in 2005, BiodivERsA has promoted the development of a specific type of research, at the crossroads of academic excellence and relevance for policy and society. To do so, BiodivERsA Partners have developed innovative approaches for shaping and implementing calls for research proposals and for evaluating research proposals. Yet it is understood that these expectations are high, and that it can often be challenging for the biodiversity research community to ensure both the academic excellence and policy/societal relevance of their work, while efficiently engaging with their non-academic stakeholders. This is why BiodivERsA Partners have also invested in building researchers' skills to engage beyond academia through guidance and capacity building tools.

Logically, BiodivERsA wants to evaluate to what extent these approaches are successful, i.e. to what extent the projects funded by BiodivERsA are actually able to deliver both high-profile academic products and a range of high-quality, society-relevant products through fruitful stakeholder engagement. The present analysis covers outcomes of the 25 BiodivERsA projects that came to an end between 2014 and 2018, corresponding to three BiodivERsA calls, respectively on 'biodiversity, ecosystem services and their valuation' (launched in 2010-11), on 'biodiversity dynamics, resilience and tipping points' (2011-12) and on 'biological invasions and invasive alien species' (2012-13).

The analysis performed here to characterize projects' outputs builds on a mix of approaches, including classical methods to assess academic productions (e.g. with number of publications and journal notorieties) and novel ones (e.g. indicators developed to assess stakeholder engagement and the generation of stakeholder-relevant products – see [parts I and II](#)). It also provides, for each project, a synthetic view and concrete examples of achievements and outcomes, both in terms of scientific breakthroughs and stakeholder engagement, towards a more sustainable conservation and use of biodiversity and ecosystem services (see [part III](#)).

This analysis demonstrates that BiodivERsA's approach is offering tangible results, promoting societally relevant research built on scientific excellence and stakeholder engagement, multidisciplinary approaches and transnational collaborations. Remarkably, we could observe that no trade-off exists between the level of academic excellence reached by the funded projects and their production of society/policy-relevant outputs, or their investment of research teams in stakeholder engagement. We actually observed a tendency for a positive relationship between the excellence of the academic outputs of the projects and the production of stakeholder-relevant outputs.

It will be interesting to pursue the present assessment for projects funded through the following calls launched by BiodivERsA. In particular, the impact of a range of BiodivERsA activities to help researchers engaging with stakeholders and increasing the benefits gained from this engagement, for instance with the production in 2014 of the BiodivERsA stakeholder engagement handbook and in 2018 of the Guide on Policy relevance, will also have to be evaluated on the longer term.

The co-creation of knowledge between researchers from different disciplines and stakeholders is increasingly called for in many arenas, and BiodivERsA has promoted this since 2005. The analysis of the results of the projects funded via BiodivERsA calls clearly demonstrates that our network has been successful in promoting an innovative alliance between academically excellent research and stakeholder engagement, transcending the frontiers assumed between basic and applied research. 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 their research results for society and policy.

INTRODUCTION

BIODIVERSA: PROMOTING BOTH THE ACADEMIC EXCELLENCE AND THE SOCIETAL IMPACT OF BIODIVERSITY RESEARCH

BiodivERsA was built on the opportunity offered by the European Commission to promote the coordination of research on biodiversity and ecosystem services across Europe, which was made under three successive framework programmes since 2005. It currently networks 39 Ministries, local governments, agencies and foundations from 25 countries that program and fund research in Europe and outermost regions and overseas countries and territories to provide new knowledge for better protection and sustainable management of biodiversity and ecosystem services.

Since its creation, BiodivERsA is highly demanding to those who apply to its calls for research proposals. Indeed, BiodivERsA is selecting research projects that are excellent both from an academic point of view (i.e. the selected projects should tackle key scientific questions at the forefront of current knowledge, through high-level and – as needed – interdisciplinary transnational research) and from a societal point of view (i.e. the projects should provide actionable knowledge on how to protect, manage and use biodiversity and ecosystems in a sustainable way). This is thus calling upon synergies between multiple expertise ranging from natural sciences to social sciences and from academic skills to the skills of stakeholders including policy-makers.

To achieve this ambitious objective, BiodivERsA partners have designed specific processes to shape calls for research proposals and evaluate submitted proposals, insisting on the societal and political relevance of projects they support, in addition to their scientific excellence. This is based on a broad range

of BiodivERsA activities, including mapping and foresight activities¹. This is based on the views of top scientific experts but also experts knowledgeable about the policy and societal context, mobilized by BiodivERsA when selecting topics and designing calls for research. In addition to the use of widely accepted criteria for evaluating academic excellence, the partners have developed explicit criteria for the evaluation of policy and societal relevance of the research that BiodivERsA calls for. Finally, evaluation panels established by BiodivERsA to assess research proposals involve experts in environmental policy, conservation and management of biodiversity and ecosystem services, alongside leading scientific experts.

In this context, BiodivERsA recognizes that it is crucial but often challenging for the research community working on biodiversity and ecosystem services to engage with their non-academic stakeholders. Capacity building and the sharing of best practices is thus very important to reach one of BiodivERsA's major goals: reinforce the research community's capacity to efficiently engage with relevant stakeholders. In 2014, the partners therefore published the *BiodivERsA Stakeholder Engagement Handbook*², which is the result of three years of gathering and confronting best practices and consulting BiodivERsA project investigators on their needs regarding approaches to engage stakeholders. Further, the partners published in 2018 the *BiodivERsA Guide on policy relevance and effective science-policy interfacing in research proposals*³ to help researchers increase the quality of their research proposals in terms of policy relevance

1. Blery C., Lemaitre F. & Le Roux X. (2018). BiodivERsA main achievements for research on biodiversity, ecosystem services and Nature-based Solutions over 2008-2018, 52pp (<https://www.biodiversa.org/1557/download>)

2. Durham E., Baker H., Smith M., Moore E. & Morgan V. (2014). The BiodivERsA Stakeholder Engagement Handbook. BiodivERsA, Paris (108 pp). (<http://www.biodiversa.org/stakeholderengagement>)

3. Lemaitre F., Bridgewater P., Eggermont H., Gardner S., Hueso K., Niemelä J., Paloniemi R., Pereira Martins I., Thornton A. & Le Roux X. (2018). BiodivERsA guide on policy relevance of research and on effective science/ policy interfacing in research proposals. BiodivERsA report, 80 pp (<http://www.biodiversa.org/1543>)

in particular, and more generally to understand what is policy relevance of research and learn about the science-policy landscape on biodiversity. More recently, the BiodivERsA Citizen science toolkit for

biodiversity scientists⁴ was published as a resource to help researchers ready to implement citizen science aspects in their proposals.

THE CHALLENGE OF EVALUATING THE QUALITY OF ACADEMIC PRODUCTIONS AND POLICY/SOCIETY RELEVANT PRODUCTS OF RESEARCH, ALONG WITH STAKEHOLDER ENGAGEMENT

Using such innovative approaches calling for both scientific excellence and society and policy relevance of research is not only challenging for applicants, it is also for the research programmers and funders, which explains why the BiodivERsA partners have developed innovative approaches to shape and implement their calls and have promoted capacity building for applicants. It is thus logical that BiodivERsA wants to evaluate to what extent these approaches are successful, i.e. to what extent the projects funded by BiodivERsA are actually able to both deliver high-profile academic products and engage fruitfully with relevant stakeholders for delivering a range of high-quality, society-relevant products.

However, such a comprehensive evaluation of the different facets of the outputs of research projects is particularly challenging and often not done in detail by research programmers and funders. Whether there is a tradeoff between academic excellence of a research project and its investment to engage stakeholders and generate stakeholder-relevant products within this project thus remains unclear. Although important debates exist about the way to evaluate academic quality and excellence (e.g. Garfield and Welljams-Dorof 1992⁵, Donovan 2007⁶), a range of methodologies, tools and metrics are available to evaluate the academic excellence of research productions (Garfield 1979⁷). The most

accessible measurements for a programme such as BiodivERsA include the number of papers produced in peer-reviewed journals, and in particular those published in high-impact journals (as a rule of thumb: excellent research would be published in excellent journals, even if defining what an excellent journal 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 than analysing academic outputs, and no turnkey solution exists for such an assessment.

To analyse the stakeholder-relevant outputs of the first (2008) BiodivERsA call, we developed a methodology based on the typology - presented in the *BiodivERsA Stakeholder Engagement Handbook* - of ways to engage stakeholders in research projects, and the products this can generate⁸. This methodology considers several metrics to characterize the nature and level of stakeholder engagement in each research project, along with the identification of stakeholder-relevant products generated by the project, which can be very diverse. The methodology requires interviews of the Principal Investigator of each funded project, and as needed

4. Goudeseune, L., Eggermont, H., Groom, Q., Le Roux, X., Paleco, C., Roy, H.E., van Noordwijk, C.G.E. (2020). BiodivERsA Citizen Science Toolkit For Biodiversity Scientists. BiodivERsA report, 44 pp. (<https://www.biodiversa.org/1814>)

5. Garfield E and 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.

6. 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

7. Garfield E. 1979. Citation Indexing. Its theory and applications in Science, Technology and Humanities. Wiley, NewYork, 149 pp.

8. 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. (<https://www.biodiversa.org/889/download>)

interactions with a few other key participants, to check the validity and completeness of our assessment of projects' outputs.

This report follows up on the analysis of the outcomes of the 12 projects funded through the first BiodivERsA call⁹. It covers projects that ended between 2014 and 2018, corresponding to the three BiodivERsA calls from 2010-11 (biodiversity and ecosystem services and their valuation), 2011-12 (biodiversity dynamics: developing scenarios, identifying tipping points and improving resilience) and 2012-13 (invasive species and biological invasions). Altogether, these three calls mobilized over 27 million Euro (in cash) from 13 countries, which allowed supporting the 25 transnational projects analysed here. This report 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 academic production of research projects and the excellence of their production of society/policy relevant outputs or their way to engage stakeholders, as some scientists, stakeholders or funders expect there might be such a trade-off.

The first part of this report presents the methodology we used. The second part presents synthetic analyses across all the 25 projects or all the projects funded through a given call. This allows profiling the academic outputs, types of stakeholders engaged and approaches used to engage them, stakeholder-relevant products, along with the collaboration networks promoted through these projects. The third part of the report summarizes in two pages the salient outputs of each project with both academic and societal highlights.

While completing the analysis, we discovered that most projects proved to be very successful, with major advances in terms of both academic outcomes and societal impacts. The presentation of projects' outputs, with concrete figures and facts, demonstrates that research on biodiversity and ecosystem services supported by BiodivERsA is actually linking scientific advancement – with remarkable academic breakthroughs – to policy and practice – with demonstrated impacts – thanks to very efficient links and collaboration with relevant stakeholders. As for the projects funded through the 2008 BiodivERsA call, we also observed that no trade-off exists between academic excellence and the production level of society/policy-relevant outputs, or the investment of research teams in stakeholder engagement. Actually, we even observed a tendency for a positive relationship between the excellence of the academic outputs of the projects and the level of their stakeholder-relevant outputs. In a period increasingly calling for the co-creation of knowledge between a range of scientific expertise and stakeholders, and for a better integration between 'fundamental' and 'applied' research (Mauser et al. 2013⁹; Barot et al. 2015¹⁰; Doran et al. 2017¹¹), this is a clear demonstration that BiodivERsA has developed processes and skills to promote such co-creation and integration. 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 societal impacts.

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

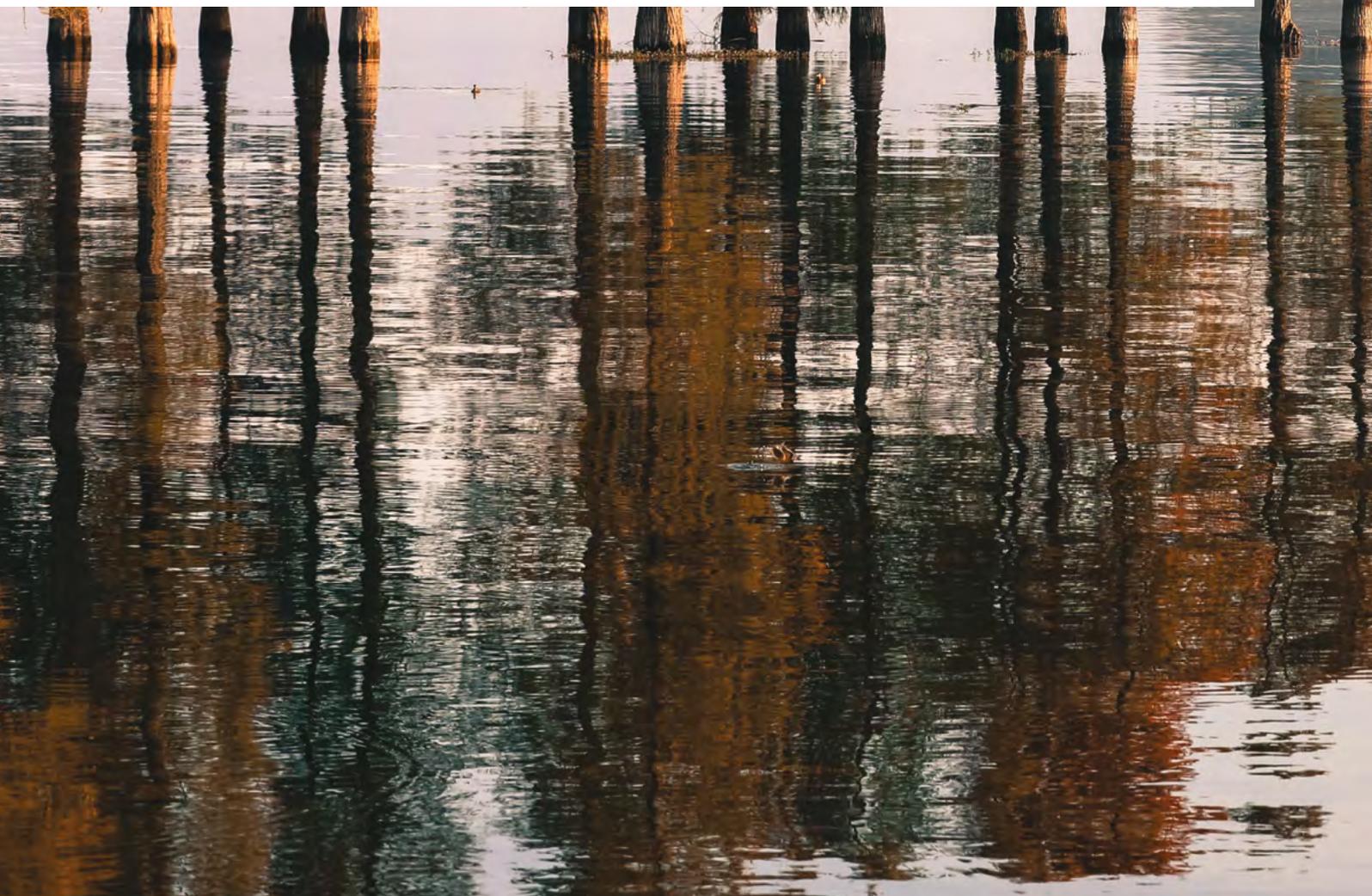
10. Barot S., Abbadie L., Couvet D., Hobbs R.J., Lavorel S., Mace G.M. & Le Roux X. 2015. Evolving away from the linear model of research. *Trends in Ecology & Evolution* 30 : 368-370

11. Doran, Elizabeth M. B.; Golden, Jay S.; Turner, B. L. (2017). From basic research to applied solutions: are two approaches to sustainability science emerging? *Current Opinion in Environmental Sustainability* Volume: 29. Pages: 138-144





PART I: METHODOLOGY





The outputs of funded projects were analysed using the information provided in their final reports required by BiodivERsA, which includes sections for academic and society/policy relevant products, and sections for describing stakeholder engagement. This information was then discussed and completed with project investigators through semi-structured interviews.

The present report analyses the contribution of the BiodivERsA research programme, here through its 2010-11, 2011-12 and 2012-13 calls (as compared to 2008 call), in terms of production of scientific papers and academic breakthroughs along with society/policy-relevant products. The research in general, and more specifically the publication of research results and the delivery of society/policy relevant products from research results is a process that takes time. This is why we completed the present analysis during 2020-2021. Indeed, the last

projects from the above-mentioned calls (i.e. 2012-13) started in 2014 and ran up to 2018 (duration of ca. 4 years). Performing the analysis of research results 2 years after the end of projects seems a minimum delay to assess the productions of research projects, although it might miss additional productions and outputs that the projects can deliver beyond this time frame.

It is often challenging to determine precisely the contribution of a given research programme or project to the production of some papers or other products (and it is even harder to determine the contribution to broader impacts¹²). We also have to recognize that 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 were 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. As far as possible, we ensured papers identified clearly corresponded to a BiodivERsA project and/or acknowledged support from BiodivERsA.

The 2017 impact factors of the journals where these papers were published were obtained from the *Journal Citation Reports* (Thompson Reuters). Because impact factors are known to depend on 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. In this approach, for each subject category, the distribution of journal impact factors is analysed with box plots identifying 5 journal notoriety groups as presented in [Figure 1](#)¹³: outstanding, excellent, good, fair, poor. The groups 'good' and 'fair' correspond to the second and third quartiles of the frequency distribution, respectively ([Figure 1](#)).

12. See https://ec.europa.eu/research/evaluations/pdf/archive/other_reports_studies_and_documents/envti0413167enn_002.pdf_or_https://www.vitae.ac.uk/doing-research/leadership-development-for-principal-investigators-pis/intellectual-leadership/demonstrating-research-impact

13. Désiré M., Magri M.H. & Solari A. 2017. Interpretation of impact factors of the Journal of Citation Reports. INRA 361 pp.

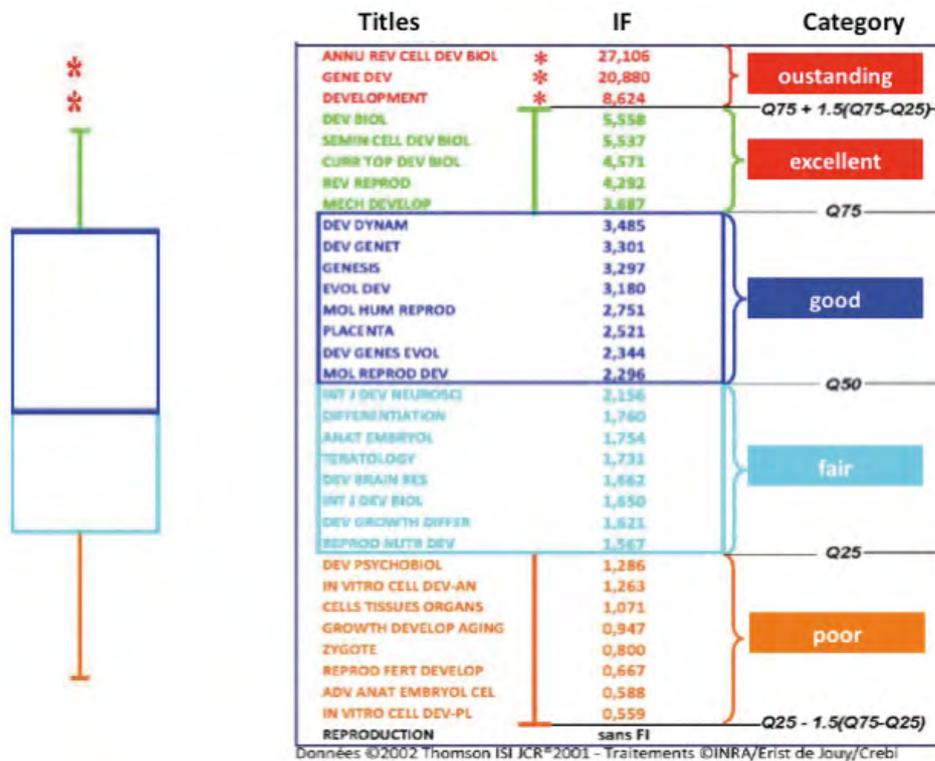


Figure 1: Method used to classify the scientific journals according to the frequency distribution of journal impact factors for each subject category. According to Désiré et al. (2017).

To compute an index of academic excellence of projects based on these journal notoriety groups, we attributed the following grades to each group: poor=1; fair=2; good=4; excellent=6; outstanding=8. We also tested a wider scale for the scoring (poor=1; fair=2; good=4; excellent = 8; outstanding = 10) but this did not change the results obtained.

Overall, we used 3 different indices to assess the academic productivity and excellence of each project:

- the total number of papers published
- the sum of the journal impact factors corresponding to all the publications produced
- the sum of the notoriety grades of the journals corresponding to all the publications produced.

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

The identification of the papers published by BiodivERsA-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 calls studied here. Indeed, adequate methods can analyse and map the collaboration networks revealed by the co-authorships 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 630 papers produced by the 25 projects. For each paper, the list of the countries associated to the authors of the paper was transformed in links between countries

collaborating in this paper. A triangular matrix was then 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 analysed using the Gephi software (<http://gephi.org/>), which allows for a spatial visualisation of the collaboration networks in 2D maps. In a map, the size of a given country (nod) is related to the number of publications including at least one author from that country. It was chosen that the links between countries would disregard the fact that several authors from one country can be co-authors of a given paper, but this did not change the conclusions derived from the results.

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 (excluding academic stakeholders) were derived from the *BiodivERsA Stakeholder Engagement Handbook* (SEH) ([http://](http://www.biodiversa.org/577)

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 involvement and participation in some aspect of a research project.

I.3.1 TYPES OF STAKEHOLDERS ENGAGED

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

Table 1: Classification of stakeholders used in this report

Main type of Stakeholders	Sub-categories (not exhaustive)
International policy-makers or advisors	International policy makers or advisors
	European policy makers or advisors
National and local policy-makers	National governments, policy makers or advisors
	Local policy makers, policy makers or advisors
NGOs	NGOs and associations for nature protection
	Other NGOs
Natural resource managers	Protected area & wildlife managers
Private actors using biodiversity	Farmers / farming organizations
	Foresters
	Fisheries
Other businesses	Other businesses
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

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

Among stakeholders engaged, four levels of engagement were identified. These levels 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 communication activities really specific for stakeholders. Most often the objective for the researchers is 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/website pages specifically intended for stakeholders.

» **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; query to obtain access to study sites or to data without specific interactions, with limited possible influence of stakeholders on the consultation in a mostly one-way interaction

» **INVOLVE:** Middle-level of engagement, with more opportunity for discussions and interactions. Stakeholders are more fully engaged and may provide resources or data, while researchers may also provide feedbacks, in a two-way interaction.

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 consortium, contributing to the suggestion of research directions and perspectives. Researchers are well involved in activities relevant for stakeholders.

Examples: involvement of stakeholders in the project's advisory or steering committee; co-production of a paper co-authored by scientists and engaged stakeholders or of any other product relevant to both scientists and 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' LIVES

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 and promoting outputs beyond the projects' lives.

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 Stakeholder Engagement Handbook* but adapted upon analysis of the methods used in the funded projects, as follows:

Level of engagement	Scores (for index)	Approaches/methods
Inform	1	Information through webtools (regular newsletters, etc.)
	1	Surveys and interviews (responding to)
	2	Forums and workshops (participating to/presentation)
Inform/Consult	3	Training sessions and practical demonstrations
Consult	4	Consultations via interviews, surveys or webtools
	4	Informal consultation
Consult/Involve	5	One to one/small-sized meetings
Involve	6	Forums and workshops (organisers)
Collaborate	7	Steering committee/advisory board
	8	Project partner

Workshops and conferences counted above exclude scientific conferences and account only for 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 were scored for each stakeholder group using the scores

in the table above. The index was the sum of the scores for each stakeholder group computed per project.

I.3.5 TYPES OF RESEARCH PRODUCTS RELEVANT TO STAKEHOLDERS

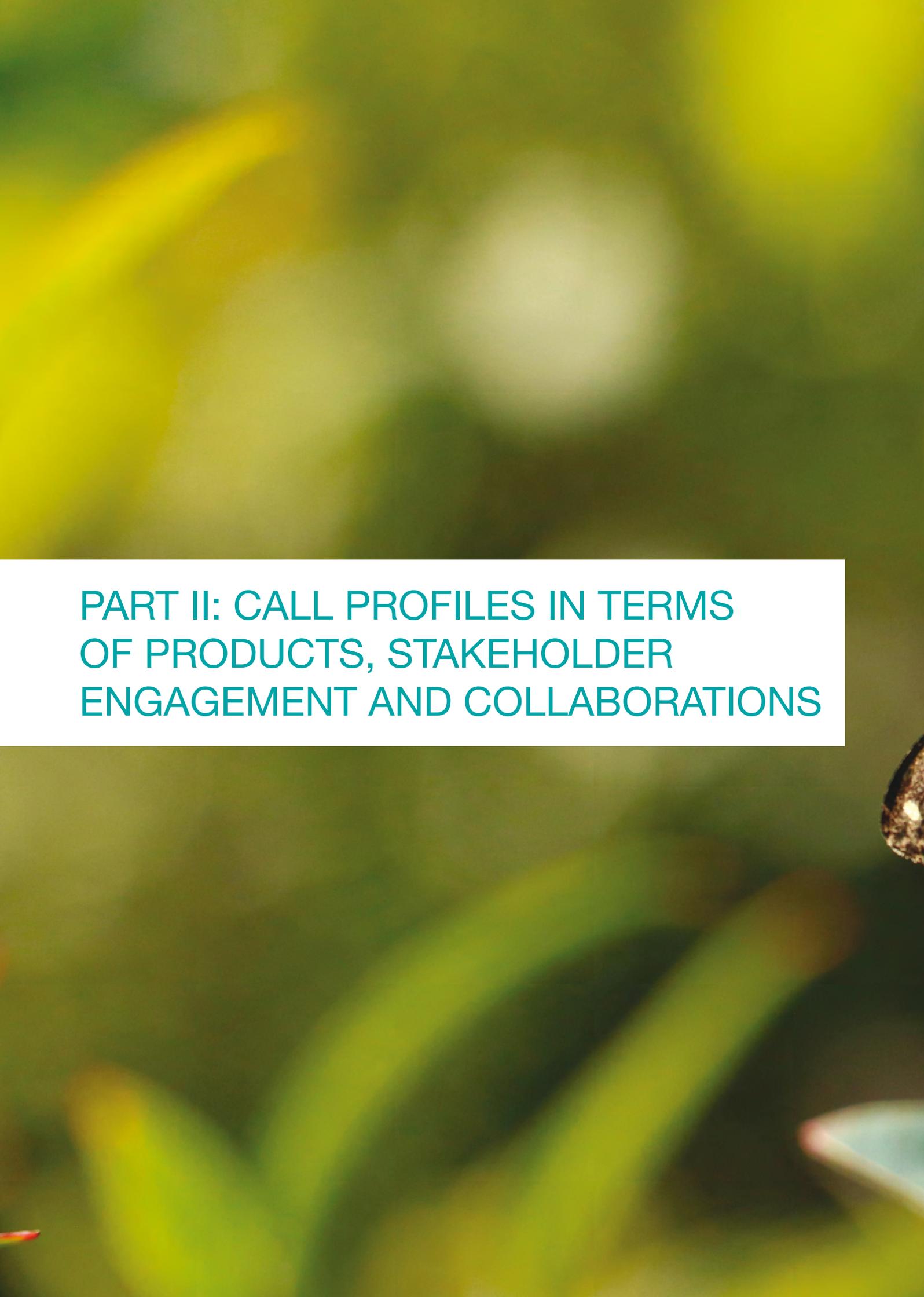
The types of research products relevant for broad stakeholder categories (policy; practice; general public) were identified. They were classified according to the degree to which they are actively targeting and/or involving specific stakeholders:

- » **INFORM (BROAD):** output disseminated towards a large number of stakeholders, without targeting specific people/organisations.
Examples: TV, radio and press interviews, specialized press articles, videos for a general audience
- » **INFORM (TARGETED):** output disseminated to targeted stakeholders, identified specifically
Examples: training sessions, reports to case-study stakeholders, policy briefs, newsletters or videos to specific stakeholders, ,
- » **PROACTIVE (CO-DESIGN):** output involving stakeholders in a proactive manner, through their engagement in co-design and/or co-dissemination

Examples: reports and knowledge-intensive tools co-developed with stakeholders; joint publications between scientists and stakeholders; 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 using the following: inform (broad)=1; inform (targeted)=4; proactive=8 (the scores aim at reflecting the relative intensity of stakeholder engagement). The product-based index computed per project was the sum of the scores for each product.



The background is a soft-focus photograph of green foliage, possibly leaves or grass, with a warm yellow-green color palette. A white rectangular box is centered horizontally and vertically, containing the text.

PART II: CALL PROFILES IN TERMS OF PRODUCTS, STAKEHOLDER ENGAGEMENT AND COLLABORATIONS



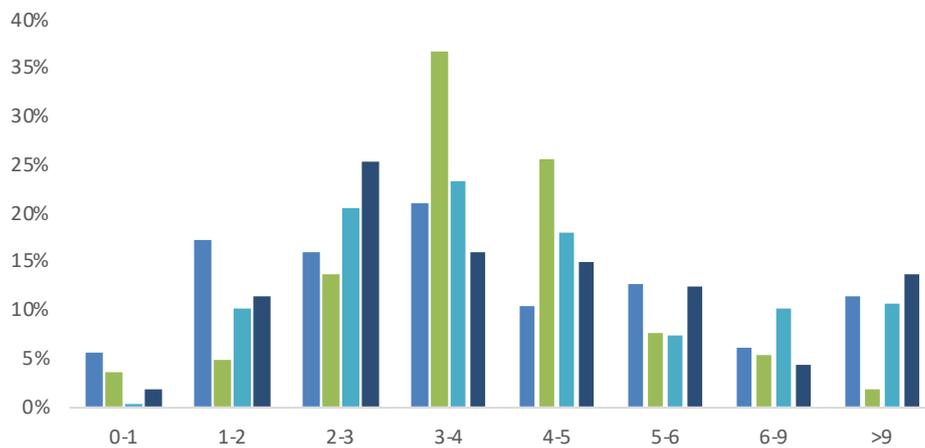
II.1 ACADEMIC PRODUCTIONS

The 25 transnational projects funded through the 3 BiodivERsA joint calls over 2010 to 2013 have contributed – so far – a total of 630 papers published in international peer-reviewed journals, i.e. a mean value of over 25 papers per project.

Most papers were published in journals with impact factors ranging from 1 to 6 (Figure 2 – Top), but remarkably ca. 10% of the publications were published in journals with an impact factor over 9. The mean impact factor of all the published papers was close to 5. The frequency distribution of papers according to impact factor and the mean impact

factor were consistent with those already observed for the 2008 BiodivERsA call (Figure 2 – Top; with mean impact factor observed for the 2008 call just above 5). The main specificity observed was for the 2010-11 call focused on ‘biodiversity valuation and ecosystem services’, for which only few papers were published in journals with an impact factor higher than 9 (Figure 2 – Top). This is likely due to the disciplines mobilized by this topic from the field of social sciences, policy sciences and economics, for which top journals have overall less high impact factors than journals in natural sciences for instance.

Publications per call and per journal impact factor



Publications per call and per journal notoriety

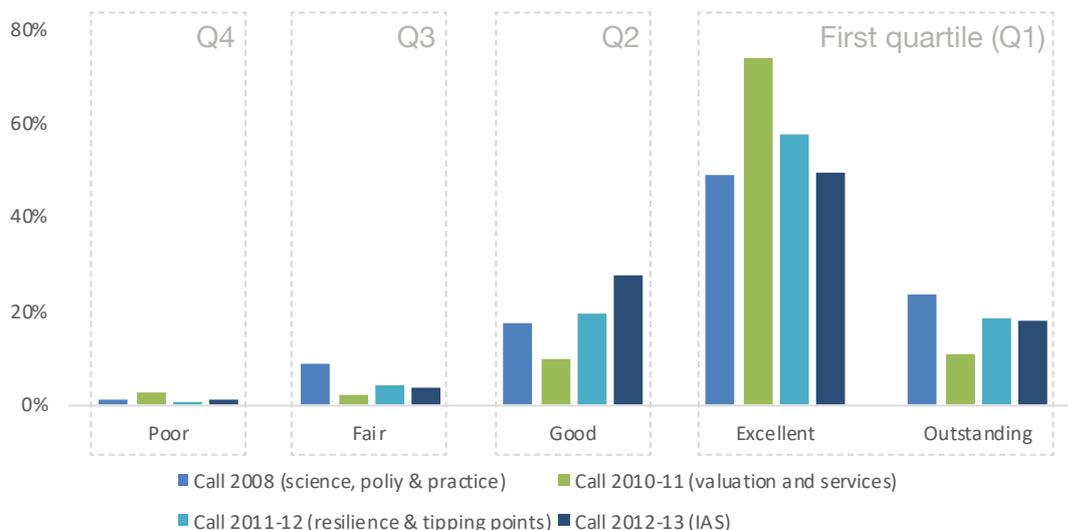


Figure 2: (Top) Percentage of publications per call according to journal impact factor (Bottom) Percentage of publications per call according to journal notoriety (see Figure 1 for methodology). The 2008 BiodivERsA call figures are included for comparison.

This interpretation is largely confirmed by the analysis of journal notorieties. Indeed, 85% of the papers in that call were published in journals with outstanding or excellent notoriety (11% and 74% for outstanding and excellent, respectively) which corresponds to the top-first quartile of scientific journals (Figure 2 – Bottom), and the total percentage was similar between the 3 calls. However, the percentage of papers published in journals with outstanding notoriety was lower for the 2010 call, which could indicate a higher difficulty to reach these journals for highly interdisciplinary projects, but this was ‘compensated’ by a higher proportion of papers in journal with excellent notoriety. Overall, these data are consistent with the figures observed for the 2008 call (72% of the papers were published in journals with outstanding or excellent notoriety).

All these data evidence the overall high academic quality of the research conducted by the

BiodivERsA-funded projects, and the fact that they have produced scientific breakthroughs recognized by their peers.

Multidisciplinary journals were well used to publish by the BiodivERsA-funded researchers, with 24 papers in PLoS ONE and 23 in Ecosystem Services (Figure 3). Also testifying about the multidisciplinary nature of projects’ work, a number of journals in policy and economics ranked high in the list (e.g. *Environmental Science and Policy*, *Ecological Economics*, *Land Use Policy*). Overall, a majority of publications were published in ecology and biological sciences journals, with some specificities linked to call topics, such as the number of publications in *Ecosystem Services* linked to the ‘biodiversity valuation and ecosystem services’ call, and in *Biological Invasions* and *Diversity and Distributions* linked to the ‘Invasive alien species’ call.

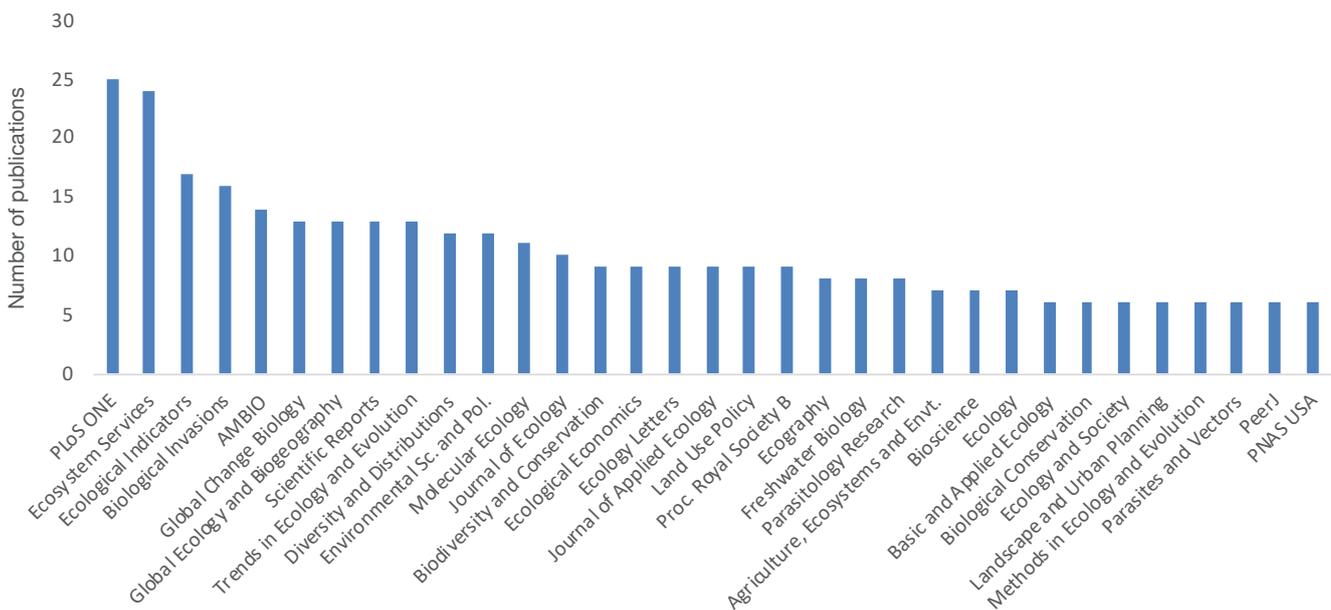


Figure 3: Main journals used for publications produced by the projects of the three BiodivERsA calls studied.

In addition, the number of papers published in journals with high impact factors and recognized as outstanding in their research area (e.g. *Global*

Change Biology, *Trends in Ecology and Evolution*) is another indicator of the high scientific quality of academic outcomes of funded projects.

II.2 COLLABORATIONS BETWEEN COUNTRIES AND BETWEEN SCIENTIFIC DISCIPLINES

The BiodivERsA calls spurred international collaboration between but also beyond the countries participating in each call. Figure 4 shows the

importance and intensity of these collaborations based on an analysis of the countries represented in the 630 papers produced so far.

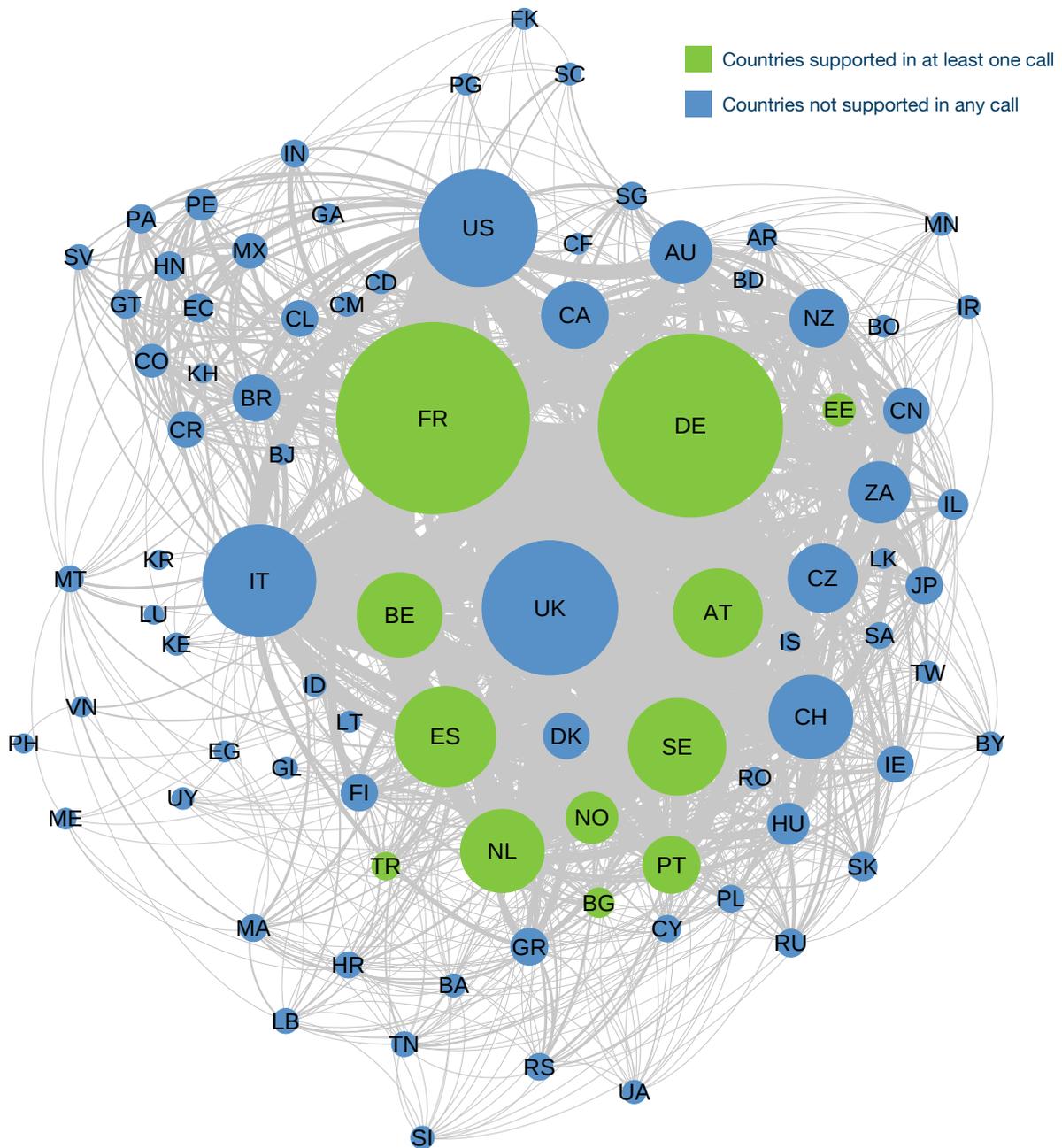


Figure 4: Map of the research collaborations between countries observed in all the projects' publications, for the BiodivERsA calls 2010-11, 2011-12 and 2012-13. Blue nodes (dots) are for countries that did not participate to any call, and green nodes for countries participating to at least one of the calls. The size of the nod for a given country is based on the number of publications involving authors from this country. The size of the links between two nodes/countries depends on the number of publications involving these two countries.

This shows strong collaborations between teams from countries supported in the calls, but also with some other countries. In particular, the size of the nodes for the UK, US and Italy shows an important participation of their research teams to a number of

publications linked to these calls. The centrality of the UK node on the map also shows the importance of the relationships between UK researchers and researchers from many European mainland countries.

II.3 TYPES OF STAKEHOLDERS ENGAGED IN RESEARCH

Close to 320 individually identified stakeholder structures have been engaged by research projects under these three calls (Figure 6), i.e. 12 per project on average. This is a conservative estimate as in some cases, the identification of stakeholder organizations beyond broad groups engaged proved to be quite challenging and was not detailed, thus counting as one.

The research projects engaged with a wide spectrum of stakeholders (Figure 6), depending on their focus and relevance to different stakeholder categories. Overall, the most engaged stakeholders were national and local policy makers and advisors, and private actors using biodiversity (farmers, foresters, fishers). To a lesser extent, the researchers in these calls also engaged with NGOs, businesses, European policy-makers and advisors, and representatives of local people and communities.

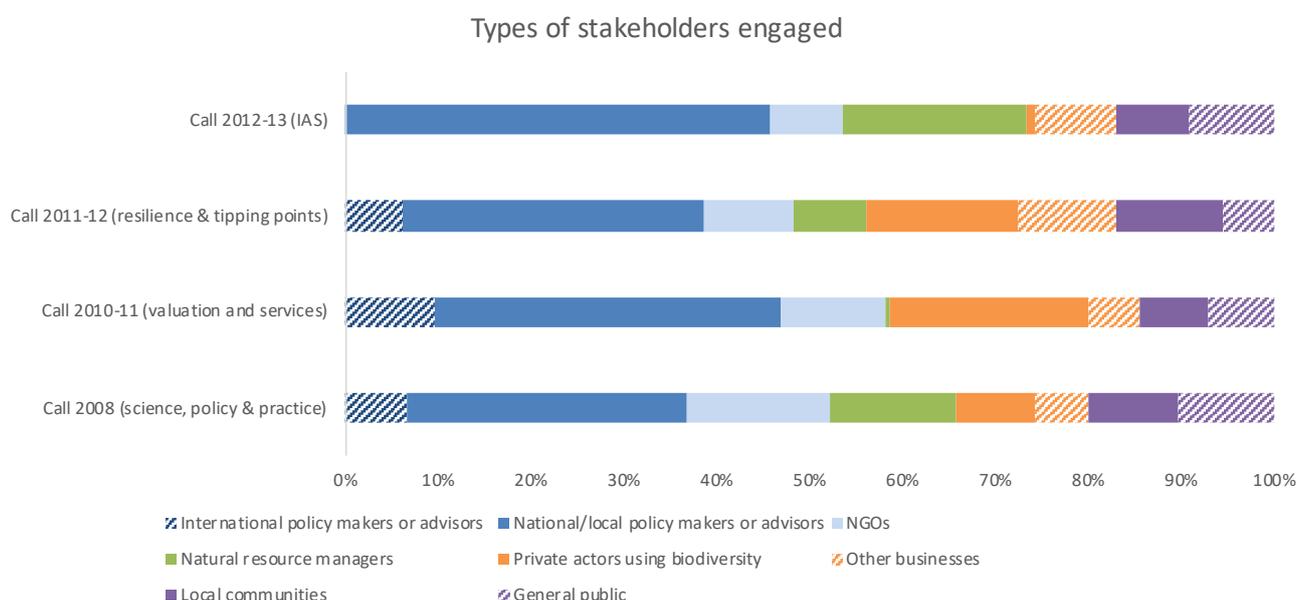


Figure 6: Mean percentage of stakeholder types engaged per project, for each call. Colours refer to the type of stakeholders defined in Table 1. The profile observed for the BiodivERsA 2008 call is included at the bottom for comparison.

The results suggest that call topics influenced the types of stakeholders engaged (Figure 6), with private actors using biodiversity more prominent for research areas where they are direct knowledge holders and/or study objects, would it be for the valuation of biodiversity and ecosystem services (2010-11 call) or the (co-)development of scenarios of biodiversity (call 2011-12). Similarly, the call on invasive alien species (2012-13) has seen projects engage more importantly with national and local policy makers and natural resource managers (e.g. protected areas) who are indeed key stakeholders in relation to biological invasions.

Overall, international and European policy-makers and advisors were less engaged by funded projects

compared to national and local policy-makers (Figure 6), which is to be noticed for pan-European projects. This difficulty for funded projects to engage at the European/international levels has been realised early-on by BiodivERsA partners, as it was already the case in the projects funded through the 2008 call. 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 produce policy briefs mainly targeting European policy makers (<http://www.biodiversa.org/policybriefs>). This observation has also led BiodivERsA Partners to publish a Guide on policy relevance of research proposals (<https://www.biodiversa.org/1543>) to help build capacities of researchers at the science-policy interface, including

their knowledge of European and international (biodiversity) policy landscapes.

Similarly, the engagement with businesses in other sectors than farming, forestry and fishery early appeared to be difficult for researchers, although some progress can be noted across the different calls (Figure 6). Since 2015, BiodivERsA thus eases the engagement with business stakeholders by organisation of workshops devoted to the dialogue and co-construction between business and academic research. In the present calls, it is observed that the engagement of “other businesses” is usually motivated by precise project contexts and topics, for instance environmental consultants, logging or paper

industries, stakeholders from the tourism sector, or biotech and pharmaceutical companies. It is recognized that business-like stakeholders, beyond specific strategic or technical interest in a given projects’ topic, have been more difficult to engage for individual biodiversity projects and researchers.

Finally, a number of projects targeted local communities and the general public, either where research had a direct interest for local livelihoods (e.g. call on tipping points and scenarios) or to make them aware of the research going on and the issues they were attempting to respond to (e.g. in relation to invasive alien species).

II.4 LEVEL OF ENGAGEMENT OF STAKEHOLDERS

As for the types of stakeholders engaged, the main level of engagement varied considerably depending possibly on the call topic (Figure 7).

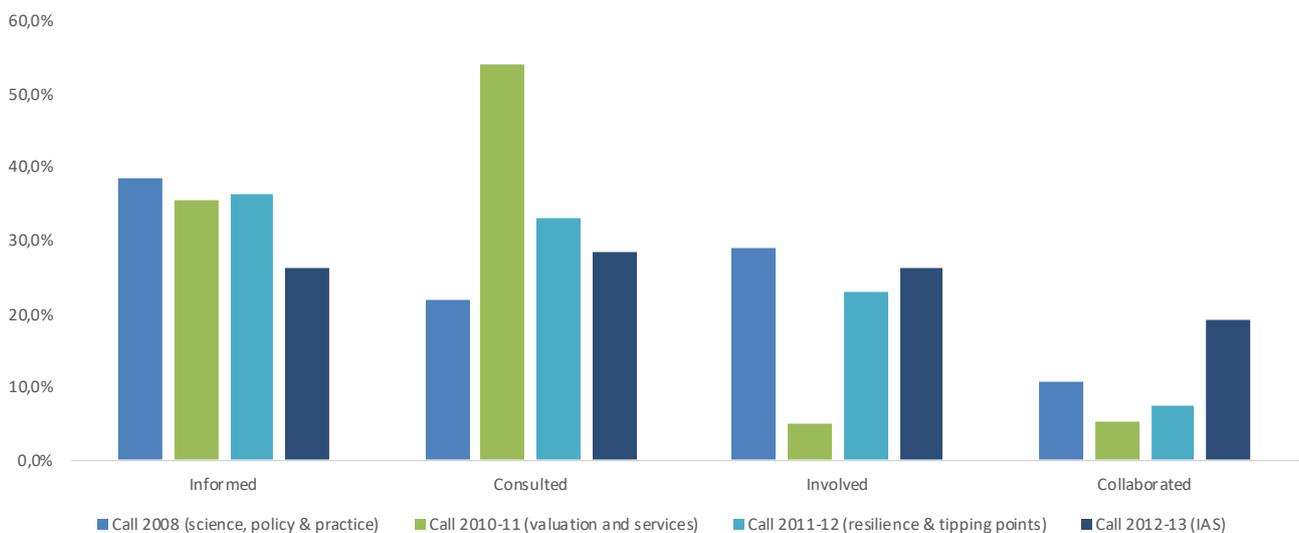


Figure 7: Mean percentages of stakeholders engaged by individual projects, according to the level of engagement, per call. The figures for the BiodivERsA 2008 call are included for reference.

The majority of the stakeholders engaged through the 2010-11 call were “informed” and moreover “consulted”, which highlights efforts to develop valuation methods for biodiversity and ecosystem services that imply consultation of stakeholders without two-way interactions between academia and stakeholders. In contrast, the projects in the 2011-12 call on tipping points and scenarios have largely “consulted” and “involved” stakeholders,

reflecting how these projects often engaged them in the identification of tipping points and the co-development of scenarios. The 2012-13 call on invasive species has a particular profile in terms of level of engagement, with close to 20% of stakeholders engaged to a level of “collaboration”, i.e. either in close and continuous collaboration or directly as project partners. Such collaborations concerned in majority natural area managers,

national and local policy makers and advisors, and NGOs. These stakeholders often had a direct interest in the project topic and expected project outcomes. It should be noted however that, while an important number of stakeholders can have interests in a given project and its outcomes, likely less are interested by, or ready to invest for, more intense collaboration.

Overall, the results of our analysis show a clear trend for an overall decrease in the importance of the low level of engagement, the percentage of stakeholders

just ‘informed’ dropping from 38% to 26% over the 4 first BiodivERsA calls (Figure 7). In contrast, a trend for an increase in the importance of the high level of engagement was found, the percentage of stakeholders ‘collaborated’ being less than 10% for the first three calls but close to 20% for the last call (Figure 7). Though analysing projects from additional BiodivERsA calls will be needed to conclude, this shows a potential trend for the research consortia funded in investing more into more advanced way to engage stakeholders.

II.5 STAGE OF STAKEHOLDER ENGAGEMENT

As expected, a majority of the stakeholders were involved during the research projects’ lives (Figure 8). It is interesting nonetheless to notice that, on

average, over 20% of the stakeholders were engaged actively by a given project during its conception, though this figure decreased with time.

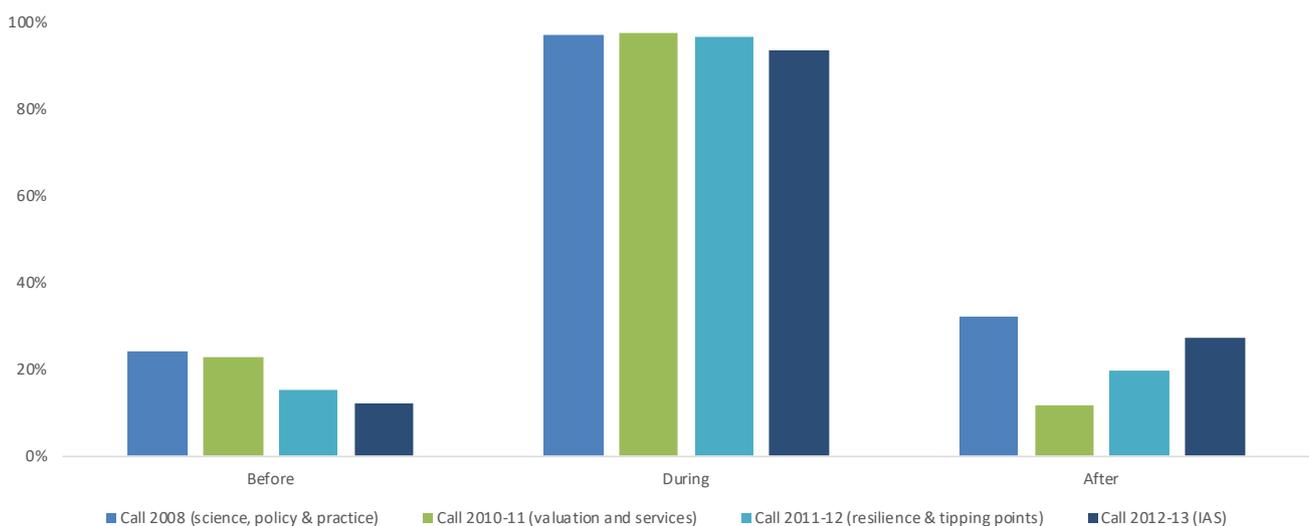


Figure 8: Mean percentage of stakeholders engaged in the funded projects, according to the stage of engagement, per call. The figures for the BiodivERsA 2008 call are included for reference.

Furthermore, the proportion of stakeholders who remained engaged after the life of the projects increased across the 3 calls studied, from 12% for the 2010 call to close to 30% for the 2012 call (a similar figure being observed for the 2008 call). Individual project analyses testified towards the development of long-lasting relationships between

researchers and stakeholders in some projects (see Part III of this report). It was especially noted by several projects that building relationships with their stakeholders allowed them to engage earlier with them in following projects (including Life projects for instance), thus significantly increasing the legacy of BiodivERsA-funded projects.

II.6 METHODS OF STAKEHOLDER ENGAGEMENT USED BY RESEARCHERS

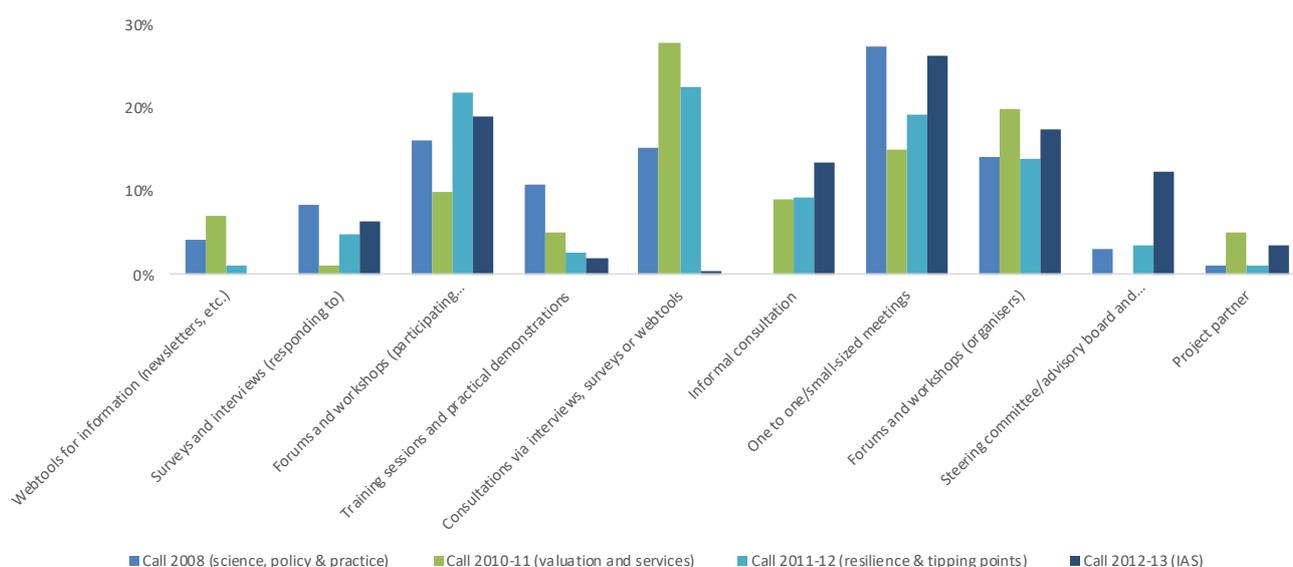


Figure 9: Types of methods used to engage with stakeholders (mean % per project, for each call). The figures for the BiodivERSa 2008 call are included for reference.

In terms of methods used by researchers to engage their stakeholders, Figure 9 shows that these were largely coherent with the engagement levels described above for the different calls, ranging from inform to collaborate. The varying distributions between calls appear coherent with the call themes and type of work performed by the projects. Projects working on biodiversity, ecosystems services and their valuation (call 2010-11) conducted more consultations through surveys and interviews, mostly to identify stakeholders' values and to a lesser extent get feedback on different valuations and market-based schemes. They also relied on the organisations of stakeholder forums and workshops to discuss their work. Projects working on tipping points and scenarios (call 2011-12) relied in majority on methods towards consultation and involvement

(interviews, informal consultations and small sized meetings in particular) linked to the co-development of scenarios. They also notably invested in participation and presentations in stakeholder-organised workshops and forums. Projects working on biological invasions (call 2012-13) stand out in terms of close and continuous stakeholder collaborations through steering committees and advisory boards, likely highlighting a strong interest for this type of research and applicability of results by some stakeholders. These projects have also significantly involved stakeholders via one-to-one or small-sized meetings, which corresponded in particular to close interactions with local stakeholders including natural park managers and local administrations and authorities.

II.7 PRODUCTS INFORMING, TARGETING OR PROACTIVELY ENGAGING STAKEHOLDERS

Figure 10a shows that a relatively important share of the products generated by the projects in the call on 'valuation' and the call on 'tipping points' was intended to inform a specifically targeted audience (47% and 54% respectively). In contrast, under the

call on invasive species, a larger share of products was intended for informing in a broader sense (47%). In addition, the latter had the most significant share of products developed or disseminated with a proactive engagement of stakeholders (22%).

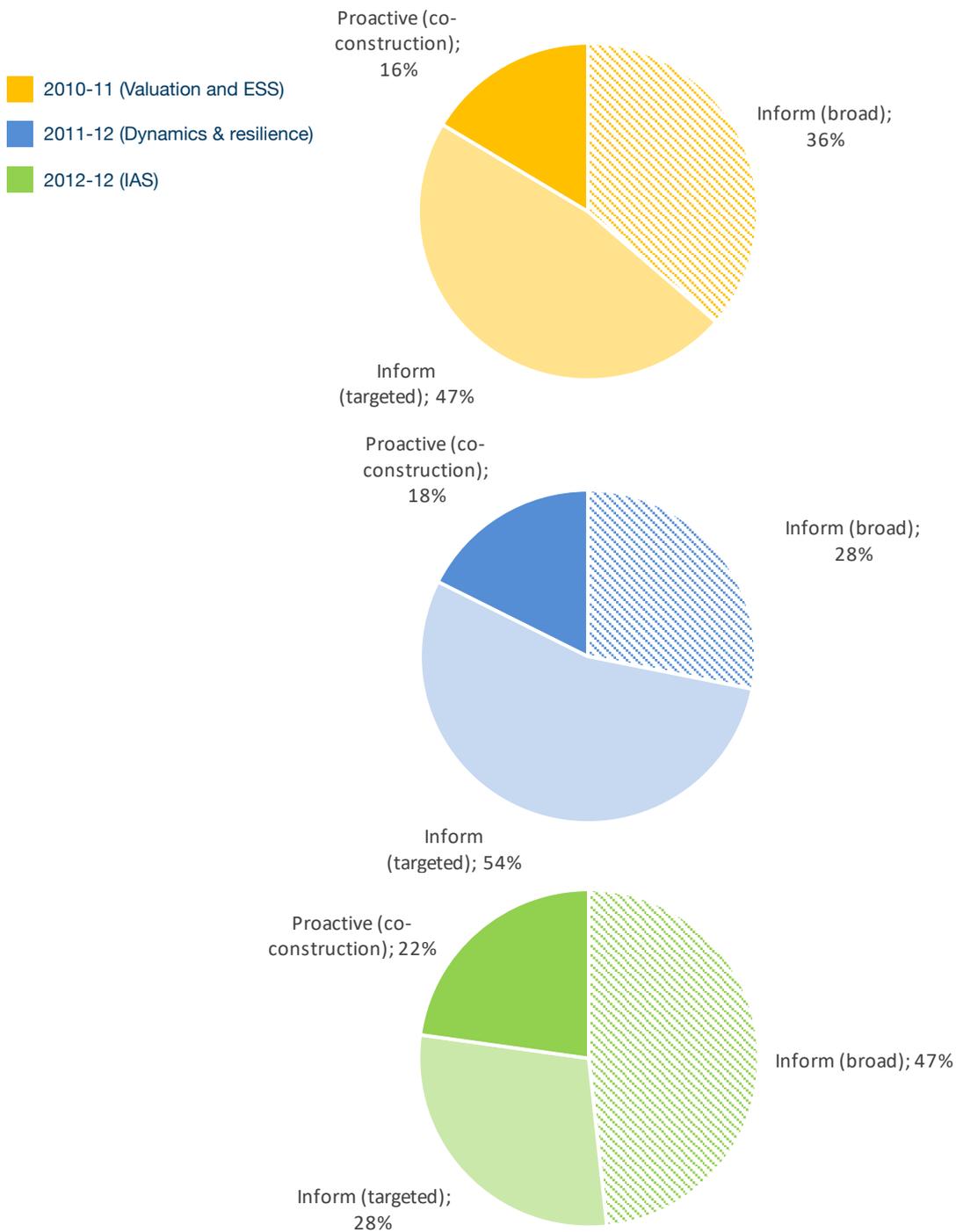


Figure 10 a: Mean percentage of products categorized as “inform (broad)”, “inform (targeted)” or “proactive” in engaging stakeholders, per project. The values obtained are presented for each call, and the profile of the 2008 call is not displayed as these data were not available for this call.

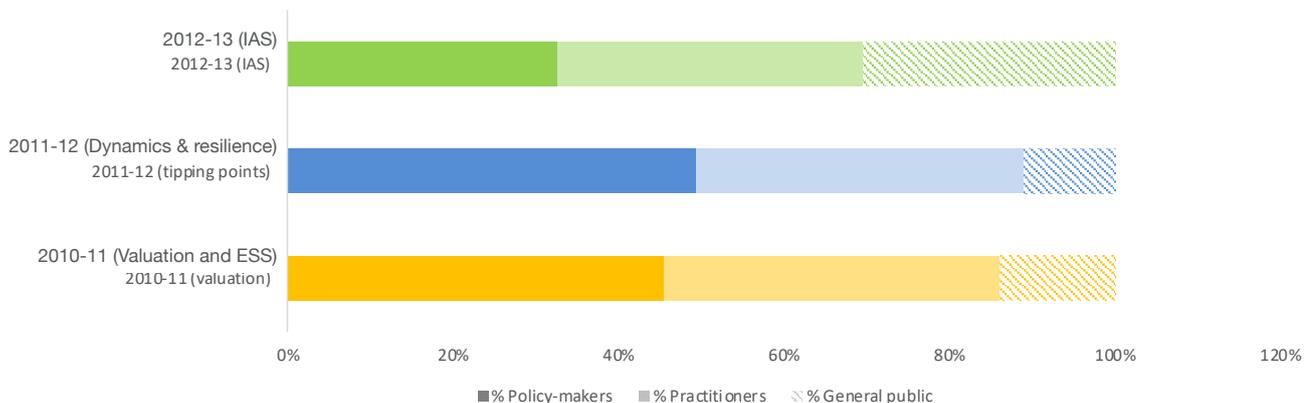
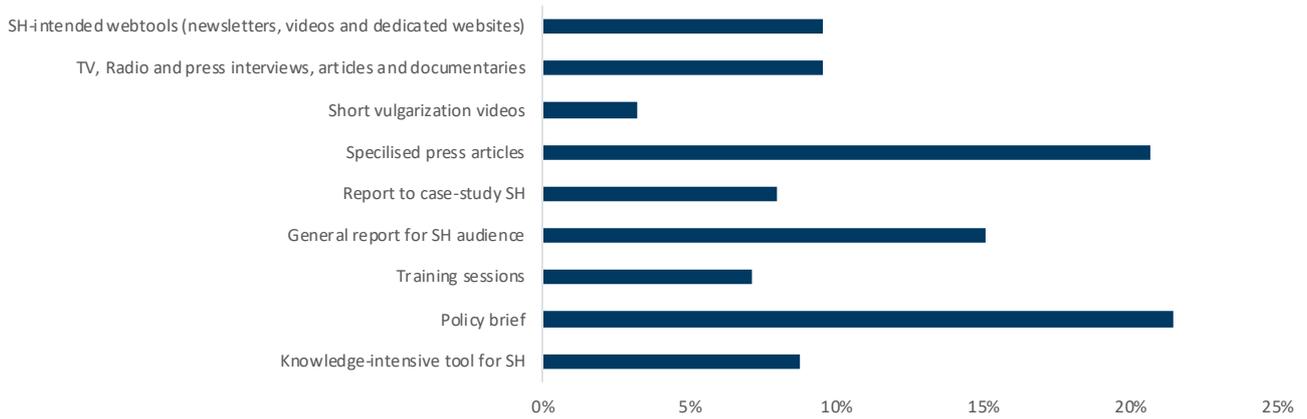


Figure 10 b: Mean percentage of broad stakeholder types for whom products are intended, per project. The profile of the 2008 Call is not displayed as these data were not available for this call.

In addition, [Figure 10b](#) shows a relatively even proportion of products intended for use in policy or practice, and less towards the general public, which can be expected given the R&I nature of the projects. The projects under the invasive alien species call however strike an overall near-to-perfect balance between products intended for these three broad stakeholder types, highlighting particular efforts to

raise awareness in the general public about the risks and implications of biological invasions, especially at local scale.

[Figure 11](#) further shows that the main stakeholder-intended products produced by projects were policy briefs and specialized press/articles.



[Figure 11](#): Overall percentage of project products' nature, across the three calls.

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

It is sometimes 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, our analysis shows an overall lack of correlations between the indices computed to assess the level and quality of academic production from the 25 projects and those computed to evaluate the investment in activities performed with and/or for stakeholders (Figure 12). This demonstrates a lack of trade-off between academic excellence and investments in stakeholder engagement. Moreover,

significant or marginally significant positive correlations were observed between the score for stakeholder-relevant outputs derived from the projects and (i) the journal notoriety score of projects, with $p=0.072$; and (iii) the number of excellent and outstanding publications with $p=0.047$ and $R=0.40$.

This is encouraging as it further demonstrates that investment in the generation of stakeholder-relevant products can be coupled to the level academic excellence of research projects, provided that the research programme has been shaped accordingly.

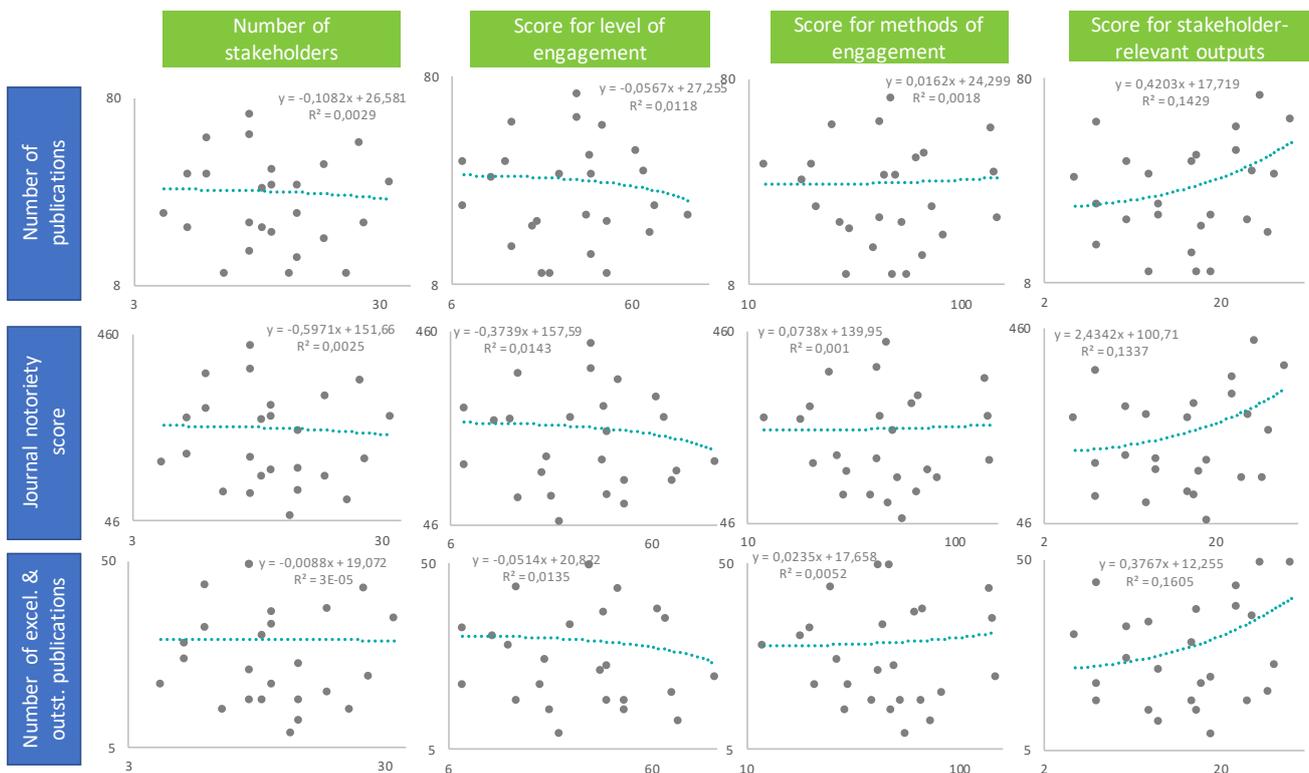


Figure 12: Presentation of the (lack of) correlations between indices of the level and quality of academic production of the 25 research projects (Top to bottom on the right and in blue: number of publications; sum of journal notoriety scores; number of publications in the top quartile in terms of journal notoriety, i.e. excellent or outstanding), and indices of the investment in activities performed with and/or for stakeholders in the same projects (left to right on the top in green: number of stakeholders involved; sum of scores for the level of engagement achieved; sum of scores for the methods of engagement used; sum of scores for the project outputs intended for stakeholders. Each point corresponds to one project. Correlation of the “score for stakeholder-intended outputs” with “number of outstanding and excellent publications” is significant ($p=0,047$). Note that X and Y axes use logarithmic scales.

It should also be noted that projects showed relatively different profiles in terms of academic productions and investment in stakeholder engagement.

The absence of trade-off between academic excellence and stakeholder engagement observed here is of significant importance as, since the establishment of the network, the calls developed by BiodivERsA have aimed to promote research that

could reach excellence for both academic production and society/policy relevance. BiodivERsA thus efficiently covers a particular niche in the landscape of research programming and funding, though we fully recognize that different types of research programmes exist and are all needed, including blue-sky research programmes, to cover all aspects of research.





**PART III: HIGHLIGHTS ON ACADEMIC
FINDINGS, STAKEHOLDER
ENGAGEMENT AND RESEARCH
PRODUCTS RELEVANT TO SOCIETY
GENERATED BY EACH PROJECT**







Projects funded under the BiodivERsA call 2010-11 on
“biodiversity and ecosystem services and
their valuation”



APPEAL

Assessment and valuation of Pest suppression Potential through biological control in European Agricultural Landscapes

CONTEXT

Biological pest control provided by natural enemies is an ecosystem service of immense economic value, threatened by agricultural intensification. It is a service for which great amounts of background information have been gathered and it is, therefore, an excellent study system for exploring generalities of delivery, stability and value of services in relation to land use, biodiversity and society.

While the diversity and abundance of natural enemies and attack rates are generally lower in landscapes dominated by agriculture, little is known about the mechanisms behind landscape-pest control relationships, as well as between enemy diversity and pest control services. This explains our poor predictive understanding of how land-use affects biological pest control.

OBJECTIVES

APPEAL aimed to explore and advance predictive modeling of the relationships between agricultural land-use, biodiversity, food web interactions, and biological pest control of cereal aphids.

APPROACH

- APPEAL used molecular techniques to empirically examine food web interactions under field conditions. It conducted interaction network analyses on how land-use affects trophic linking and biological control.
- These data were used to model biological control of cereal aphids, and facilitate valuations of the biological control service through monetary and non-monetary methods.
- Finally, APPEAL mapped the level of biological control across landscapes in Europe and tested the influence of different future land-use scenarios (i.e. changed agricultural intensity and landscape) structure.

MAIN ACADEMIC FINDINGS

- In both its empirical and modelling work, APPEAL demonstrated a strong effect of landscape complexity (especially composition of small fields and presence of large grasslands) on predator community composition and biological control potential.
- APPEAL showed the consequences of large-scale changes in agricultural policy (e.g. pesticide risk reduction), farming system and crop rotation on predator community composition and functional traits. These traits, especially predator and prey body size relationships, were found to be a strong predictor of biological control.
- Food web analysis highlighted the importance of generalist predators as biological control agents of aphids; it also showed how factors like weed composition can indirectly affect predator community composition and functions through changes in food web interactions.
- APPEAL developed a spatially explicit model to predict the biological control service in agricultural landscapes, which highlighted a reduction of crop damage by aphids varying from 45 to 70% depending on landscape complexity.
- Through an analysis of risks, risk perceptions and cost structures, APPEAL showed that a transition to pest management aiming to improve biological control is best achieved in the context of organic agriculture. In contrast, under the current conditions with low pesticide prices, insecticide use remained a rational decision for conventional farmers.



PROJECT PARTNERS – Swedish University of Agricultural Sciences (SLU), Uppsala, **SWEDEN** (coordinator: Mattias Jonsson); Helmholtz Centre for Environmental Research (UFZ), Halle, **GERMANY**; University of Innsbruck, **AUSTRIA**

DURATION – January 2012 to December 2014

FUNDING – €732,708 under the 2010-11 BiodivERsA call; national funders: Formas and SEPA (SE), PT-DLR/BMBF (DE), FWF (AT).

ACADEMIC RESULT HIGHLIGHT

APPEAL contributed to highlighting contrasting perceptions of ecologists and farmers on values of natural habitat in agricultural production landscapes, seen as providing ecosystem services such as biological pest control by the first or a waste of croplands and source of pests by the second. While natural habitat has been shown to increase pest control in many systems, researchers distinguished five hypotheses for when and why natural habitat can fail to support biological pest control, and showed how the relative importance of natural habitat for biocontrol can vary dramatically depending on type of crop, pest, predator, land management, and landscape structure. These variations can be especially useful to consider under measures to enhance biocontrol services through restoring or maintaining natural habitat.

Tscharntke T. et al (2016), *When natural habitat fails to enhance biological pest control – Five hypotheses*, **Biological Conservation**, volume 204 Part B, 2016 449-458

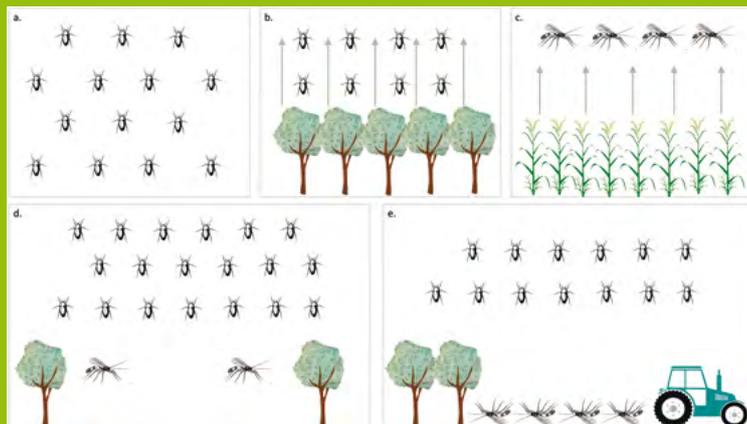


Figure 13: Five hypotheses for when and why natural habitat can fail to support biological pest control: (a) Pest populations have no effective natural enemies in the region, (b) natural habitat is a greater source of pests than natural enemies, (c) crops provide more important resources for natural enemies than does natural habitat, (d) natural habitat is insufficient in amount, proximity, composition, or configuration to provide large enough enemy populations needed for pest control, and (e) agricultural practices counteract enemy establishment and biocontrol provided by natural habitat.

WORKING WITH SOCIETY AND POLICY

APPEAL worked closely with stakeholders, both as sources of information and to provide recommendations:

- APPEAL consulted farmers in Scania about biocontrol, where and how they get their information, the role of monetary concerns, the role the values in their behavior, and how together these factors shape the day-to-day farm management, which directly influenced the research methods and questions of the project. This highlighted key sources of information (Rural Economy and Agricultural Societies, farmers' cooperatives, company advisors) and contrasting patterns of trust in and follow up on provided advice.
- These and overall project results were used to inform policy-makers at European (DG RTD, DG ENV) and national scales (Swedish EPA, Austrian Agency for Health and Food Safety) as well as farming organizations with evidence-based information about agricultural practices and biological pest control useful in defining policies and incentives.

SOCIETAL/POLICY IMPACT HIGHLIGHTS

- ✓ **Two BiodivERsA policy briefs** – APPEAL contributed in two BiodivERsA policy briefs, titled “The CAP can strengthen biodiversity and ecosystem services by diversifying agricultural landscapes” and “Green infrastructure within agricultural landscapes strengthens the supply of ecosystem services”, around EU policy and support to biocontrol and factors facilitating the implementation of measures by farmers.
- ✓ **Contributing to training courses** – the APPEAL team in Sweden contributed to a course for agricultural extension agents organized by Swedish Board of Agriculture, Norrköping, Sweden, based on project results.
- ✓ **Informing the wider public** – APPEAL contributed to national and EU media on several occasions, either on radio (Radio program on plant protection – Swedish National Radio) or in press (EU Public Service Review).

CONNECT

CONNECT

Understanding and mapping the supply and demand of ecosystem services in European landscapes for more effective biodiversity policies

CONTEXT

Biodiversity policy is increasingly influenced by evidence about the role of biodiversity in the provision of ecosystem services to people. Nevertheless, empirical evidence on a direct relationship between biodiversity conservation and ecosystem services delivery is largely missing. This hampers decision-making, especially as there are synergies and trade-offs between conserving land for biodiversity purposes and the provision of single or multiple ecosystem services.

OBJECTIVES

CONNECT aims at improving and integrating existing research methods from natural and social sciences for the analysis of potential synergies, conflicts and associated tradeoffs in support of effective policy and management of biodiversity conservation and ecosystem services at multiple scales in European landscapes, including Natura2000 and High Nature Value areas.

APPROACH

To do so, CONNECT:

- Examined which dimensions of taxonomic, phylogenetic and functional diversity contribute to ecosystem functioning and hence to ecosystem service provision, focusing on services closely related to biodiversity (pollination and wild food provision)
- Assessed synergies and tradeoffs between biodiversity and ecosystem services conservation based on improved spatial modelling and mapping procedures
- Used socio-economic valuation methods that are grounded in a better understanding of the complex interaction between ecosystem functioning and societal demand for ecosystem services
- Translated these improved theoretical and empirical insights into generic understanding to help the development and implementation of policy instruments aimed at biodiversity conservation and the sustainable provision of ecosystem services.

MAIN ACADEMIC FINDINGS

- CONNECT analysed distribution patterns of different terrestrial species groups (amphibians, birds, and mammals) across Europe. Their relationships to identified drivers (energy-related for amphibians and mammals, habitat heterogeneity for birds) varied across groups, explaining the divergent diversity patterns, and highlighting an unequal protection of terrestrial vertebrates' evolution history through Europe.
- New methods for mapping the supply and demand of ecosystem services were developed, focusing on pollination and wild food. The comparison of supply and demand maps highlighted spatial mismatches, and areas where land use planning can optimize matches. Ecosystem services models were used to analyse policies that support an EU scale No Net Loss initiative, revealing scale and scope of implementation as determinant of their impacts and potential challenges under future land-use and climate change.
- Novel methods to quantify the value of ecosystem services were used with the public in five case studies across Europe. Results indicated a general interest and willingness to pay for biodiversity and ecosystem services, with clear preferences for specific services, sometimes synergetic, but often conflicting, e.g. between land managers and general public. This highlighted the need to consider trade-offs in both demand and supply of ecosystem services in landscape planning.



PROJECT PARTNERS – Institute for Environmental Studies, VU University of Amsterdam, **THE NETHERLANDS**, (coordinator: Peter Verburg); Helmholtz Centre for Environmental Research, UFZ, Leipzig, **GERMANY**; LECA, CNRS-Université Grenoble, **FRANCE**; Lund University, **SWEDEN**; Universitat Autònoma de Barcelona, **SPAIN**

DURATION – January 2012 to December 2014

FUNDING – €1,456,118 under the 2010-11 BiodivERsA call; national funders: NWO (NL), PT-DLR (DE), ANR (FR), Formas and SEPA (SE), MINECO (Spain)

ACADEMIC RESULT HIGHLIGHT

To assess the effectiveness of policy options in achieving no net loss in the EU, CONNECT simulated land use changes and their impacts on biodiversity and ecosystem services for three no net loss scenarios compared to business-as-usual. While none achieved the overall no net loss target, all three reduced the overall degree of land cover change at EU level in varying areas, hence reducing impacts on biodiversity and ecosystem services in large parts of the EU and impacting positively services such as pollination and carbon sequestration. The study concludes overall that while achieving no net loss throughout the EU remains challenging given high land use demands, there is room for improvement for certain kinds of biodiversity and ecosystem services in large parts of the EU compared to business-as-usual, while still meeting other land use demands.

Schulp, C.J.E. et al (2016) A quantitative assessment of policy options for no net loss of biodiversity and ecosystem services in the European Union, *Land Use Policy*, Volume 57, pp. 151-163

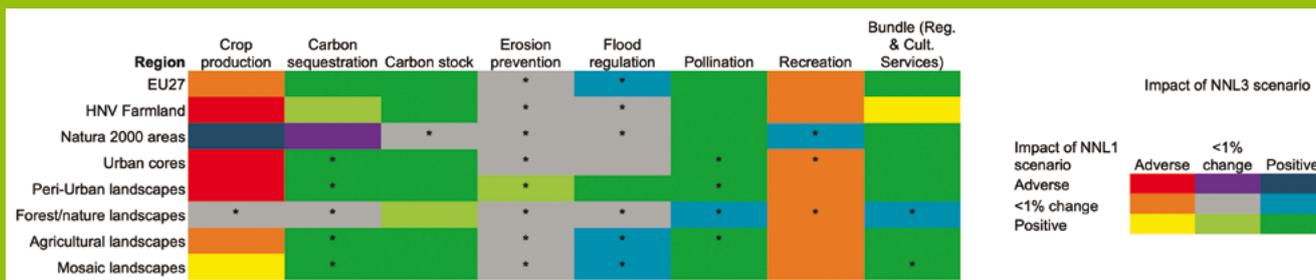


Figure 14: Changes in ecosystem service supply in different landscape types in two no-net-loss scenarios (NNL1 and NNL3) compared to the business-as-usual scenario. Red/Grey/Green correspond to consistent adverse/non-significant/positive changes between both NNL scenarios, while Blue and Yellow represent opposite changes. An asterisk (*) indicates no-net-loss of the service in a specific landscape type in Scenario NNL3 compared to the base year.

WORKING WITH SOCIETY AND POLICY

- CONNECT consulted with a considerable number of national and local stakeholders (citizens, park managers, forestry, agricultural and leisure sectors, NGOs and local and regional authorities) in Sweden, the Netherlands, Germany, Spain and France to advance the understanding of ecosystem service values and management. Focus groups and interviews around case study areas allowed to establish challenges faced, ecosystem services provided, driving forces of landscape change and practices in terms of conservation, use and impacts. This had a direct influence on project plans and follow up on results with these groups.
- French local and national authorities (DREAL, Conseil General Isère, ONCFS, ...), National Park managers, NGOs (WWF France, FRAPNA...) and businesses (EDF, ski resorts, Biotope...) were further involved to explore synergies and trade-offs between ecosystem services and biodiversity and build an influence network, leading to a co-developed proposal for a participatory and science-based development plan in the Mont Blanc region.

SOCIETAL/POLICY IMPACT HIGHLIGHTS

- ✓ **Operational toolbox** – CONNECT developed a modelling toolbox to assess ecosystem services at European regional scale. Uses to date include: i) mapping and simulation of ecosystem services changes under different No Net Loss policy scenarios by consultants for the European Commission, and for analysing targets for a Land Communication; ii) contributing to the Netherlands PBL assessment on visions for European nature in 2050; and iii) in other EU projects (e.g. FP7 HERCULES and OPERAs).
- ✓ **Uptake of results in IPBES work and assessments** – CONNECT’s work to map supply and demand of ecosystem services was used in the IPBES context, with the expert group on policy support tools and methodologies, but also in the IPBES Europe and Central Asia assessment, which among others published maps of game and picking species from the project (fig. 2.42 of the IPBES ECA assessment)
- ✓ **BiodivERsA Policy Briefs** – CONNECT contributed results on the supply of ecosystem services in agricultural landscapes and policy tools to manage synergies and trade-offs into three BiodivERsA policy briefs, accessible here: <http://www.biodiversa.org/policybriefs>



FarmLand

Disentangling the effects of farmland heterogeneity components on biodiversity and ecosystem services for improved agri-environmental policies and rural livelihoods

CONTEXT

Agriculture intensification has resulted in losses in biodiversity and ecosystem services. Agricultural landscapes with significant semi-natural areas being recognised as associated with higher biodiversity and ecosystem services levels, agri-environmental policies have mostly focused on creating or maintaining semi-natural areas (e.g. under the Common Agricultural Policy). However, this implies taking crop area out of production, which can compromise the sustainability of rural livelihoods. In addition to semi-natural areas, the spatial heterogeneity of cropland had been tentatively related to wild plant and animal diversity and the provision of ecosystem services.

OBJECTIVES

FarmLand aimed at testing the role of increased cropland heterogeneity to explore new policy options for agriculture allowing to restore biodiversity and ecosystem services, without reducing crop area.

APPROACH

FarmLand's approach is an unprecedented attempt in terms of scale and integration, working across eight regions of Europe and North America, and with seven taxonomic groups (plants, spiders, carabids, bees, syrphids, butterflies, birds). Specifically, the approach relied on:

- Disentangling the link between farmland heterogeneity and biodiversity, through surveys, experiments and farmer interviews in 453 landscapes located along two independent gradients of cropland heterogeneity, crop diversity and mean field size.
- Assessing species diversity of taxa as well as levels and spatial variability of pollination, biological control and food production potentials.
- Understanding the link between farmland heterogeneity, farming systems and farmers' mental models regarding decision-making in order to propose guidelines for future agricultural policies

MAIN ACADEMIC FINDINGS

- FarmLand showed that decreasing mean field size and increasing crop diversity have significant and positive effects on biodiversity and ecosystem services, independently from the effects of semi-natural areas and the length of semi-natural boundaries.
- Work with farmers revealed how awareness of social-ecological interdependencies influences their practices, and that awareness of relationships between farming practices, landscape, biodiversity, and ecosystem services remained relatively low. Farmers' beliefs and views, as well as market and technical constraints, more significantly influenced practices.
- FarmLand demonstrated that increasing cropland heterogeneity can benefit biodiversity conservation and increase synergies between ecosystem services in agricultural landscapes.
- Findings highlight how agricultural policies should include measures on cropland heterogeneity and better account for farmer constraints influencing cropland patterns.



PROJECT PARTNERS – CEFE, CNRS-Université de Montpellier, **FRANCE** (co-coordinators: Clelia Sirami and Jean-Louis Martin); CEBC, CNRS-La Rochelle University, **FRANCE**; OSUR, CNRS-University of Rennes, **FRANCE**; CTFC, University of Barcelona, **SPAIN**; Fondation Tour du Valat, **FRANCE**; Georg-August University **GERMANY**; DYNAFOR, INRAE-INP Toulouse, **FRANCE**; BTO, **UNITED KINGDOM** (self-financed); Carleton University, **CANADA** (self-financed).

DURATION – October 2012 to March 2016

FUNDING – €1,298,630 under the 2010-11 BiodivERsA call; national funders: ANR (FR), MINECO (ES), PT-DLR/BMBF (DE)

ACADEMIC RESULT HIGHLIGHT

Agricultural landscape homogenization is a major ongoing threat to biodiversity and human well-being. While increasing the amount of semi-natural cover in agricultural landscapes has a positive effect on biodiversity, it can be a challenging to implement. Hypothesizing that increased heterogeneity of the crop mosaic itself can also have positive effects on biodiversity, FarmLand worked in 435 landscapes along independent gradients of crop diversity and mean field size in 8 contrasting regions of Europe and North America. Researchers sampled multiple taxa to calculate an index of multitrophic diversity at the landscape level. Results show that for instance, the effect of decreasing mean field size from 5 to 2.8 ha was as strong as the effect of increasing semi-natural cover from 0.5 to 11%. Overall, the study provides large-scale, multitrophic, cross-regional evidence that increasing crop heterogeneity can be an effective way to increase biodiversity in agricultural landscapes without taking land out of agricultural production.

Sirami et al (2019), *Increasing crop heterogeneity enhances multitrophic diversity across agricultural regions*, *PNAS* 13, 2019 116 (33) 16442-16447

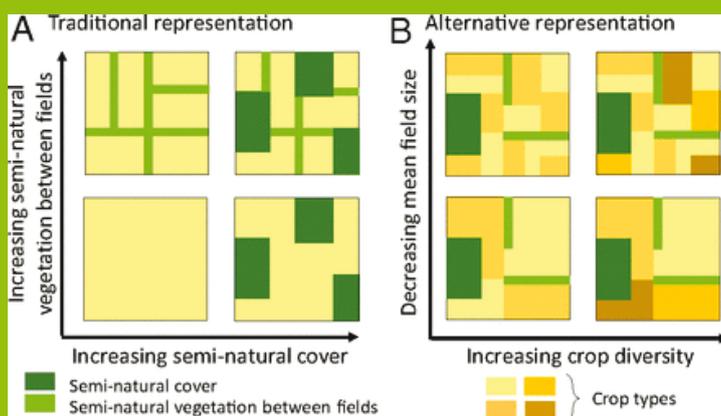


Figure 15: (A) Traditional and (B) alternative representations of agricultural landscape heterogeneity, focusing either on semi-natural heterogeneity or crop heterogeneity, are associated with distinct hypotheses (large squares represent landscapes)

WORKING WITH SOCIETY AND POLICY

Despite some contextual challenges in working with farmers on EU agricultural policy due to the agricultural crisis in 2015/2016, FarmLand closely engaged with agricultural stakeholders throughout the project:

→ Farmers, local authorities (Chambers of Agriculture) and protected area managers in all eight regions of the project were consulted at design stages, to coordinate fieldwork regarding

specific farming practices and provide information on effective farming practices. They further received general and specific results on their fields, either via letters or workshops.

→ Interviews were conducted with farmers in different regions in France and the UK to study farmers' representations, mental models and perceptions of the landscape, and then compare mental models and practices.

SOCIETAL/POLICY IMPACT HIGHLIGHTS

- ✓ **Post-2020 CAP sustainability** – FarmLand analyzed the 2018 plans for updating the EU Common Agricultural Policy in terms of capacity to support Sustainable Development Goals, identifying key levers and available knowledge to support the CAP's potential for meeting the public demands on sustainability and the environment (see [Pe-er G.K et al \(2019\), A greener path for the EU Common Agricultural Policy, Science](#))
- ✓ **Several policy briefs** – FarmLand contributed key EU-scale results and recommendations for improving agri-environmental policies, developing a policy brief on "[Making the greening greener to the benefit of nature and farmers](#)" and contributing two BiodivERsA policy briefs on "The Common Agricultural Policy can strengthen biodiversity and ecosystem services by diversifying agricultural landscapes" and "Green infrastructure within agricultural landscapes strengthens the supply of ecosystem services" (accessible here: www.biodiversa.org/policybriefs)
- ✓ **Cartoon on ecological solidarity** – FarmLand contributed results of its analysis of farmer mental models to develop a cartoon for the general public on ecological solidarity, accessible here: http://www.cen-paca.org/images/upload/therville_mathevet_2014_la_solidarite_ecologique_illustree.pdf

INVALUABLE

Understanding and mobilizing Market Based Instruments for conservation policy and financing

CONTEXT

While the use of market-based instruments (MBIs, e.g. environmentally related taxes, trade schemes, etc.) for the management of biodiversity and ecosystem services is booming, their definition and underpinning theory is still quite debated. Payments for Ecosystem Services and Biodiversity Offsetting in particular are regarded as promising tools. However, evidence on their performance at the time of INVALUABLE was still inconclusive, with little understanding of success and failure factors linked to policy and legal frameworks, despite a need for economic valuations to help setting standards in e.g. offset schemes.

OBJECTIVES

The overall goal of INVALUABLE was to clarify the potential of MBIs to better integrate biodiversity and ecosystem services into society, based on appropriate institutional arrangements for relevant public policies and an improved use of economic valuation approaches.

APPROACH

Working across case studies in Belgium, Germany, France, Indonesia, Cambodia, Guatemala, Costa Rica, Mexico, Brazil, Madagascar, INVALUABLE:

- Analyzed the emergence of MBIs in societal discourses, to clarify their theoretical foundations, natures and heterogeneous meanings;
- Researched the impacts of payments for ecosystem services and biodiversity offsetting in terms of environmental efficiency, institutions, social equity and legitimacy, and agents' motivations;
- Investigated the use of scientific information and traditional knowledge for decision-making through existing science-policy interface bodies;
- Studied the role of legal and institutional frameworks in improving the use of scientific and traditional knowledge for designing MBIs.

MAIN ACADEMIC FINDINGS

- INVALUABLE showed how the concept of market-based instruments (MBIs) emerged in the biodiversity sector in the mid-2000s through an advocacy effort of international NGOs, environmental institutions and the private sector. However, studying their use in the context of payments for ecosystem services and biodiversity offsets showed diverse contracts, subsidies and legal approaches, far from "market" supply and demand characteristics.
- Institutional design and involved actors in studied cases varied largely, but results suggest that NGOs and intermediaries play a key role by promoting or hindering procedural equity.
- Beyond evidencing better environmental outcomes with greater involvement, INVALUABLE found that the additionality of most payment for ecosystem services schemes, compared to a baseline scenario, was limited, in particular where farmers with the most harmful activities were not enrolled.
- INVALUABLE further identified successful approaches for the participatory design of market-based instruments, by evaluating a spatial decision support system ([QUICKScan](#)), also highlighting the complementary role of legal approaches to promote dialogue and public participation.

PROJECT PARTNERS – IDDRI, Paris, **FRANCE** (coordinator: Renaud Lapeyre); IRD, GRED, Montpellier, **FRANCE**; CIRAD, ECOFOR, Montpellier, **FRANCE**; Radboud University Nijmegen / CIDIN, **THE NETHERLANDS**; Universitat Autònoma de Barcelona, **SPAIN**; University of Freiburg, Germany; Wageningen University, **THE NETHERLANDS**; Université Catholique de Louvain, **BELGIUM**; Institute for European Environmental Policy, Brussels, **BELGIUM**; Matthieu Wemaëre Association d'Avocats, Brussels, **BELGIUM**

DURATION – January 2012 to January 2015

FUNDING – €1,174,596 under the 2010-11 BiodivERsA call; national funders: ANR (FR), NWO (NL), MINECO (ES), PT-DLR/BMBF (DE), BelSPO (BE)

ACADEMIC RESULT HIGHLIGHT

Modern impact evaluation designs can help understand why conservation programs succeed or fail, which is essential for designing initiatives. Despite a critical need for empirical evidence, conservation science has been slow to adopt these impact evaluation designs, and lags behind other sectors in doing so. Building on a participative workshop on evaluating forest conservation initiatives, INVALUABLE explored the reasons why nature conservation policy has been slow to adopt more rigorous impact evaluation designs. Building on a workshop with international policy-makers and NGOs, they characterized the current barriers and proposed elements for a strategy to build a systematic body of evidence on the effectiveness of conservation initiatives (see figure).

Baylis K. et al (2016), Mainstreaming Impact Evaluation in Nature Conservation. Conservation Letters, 9: 58-64.

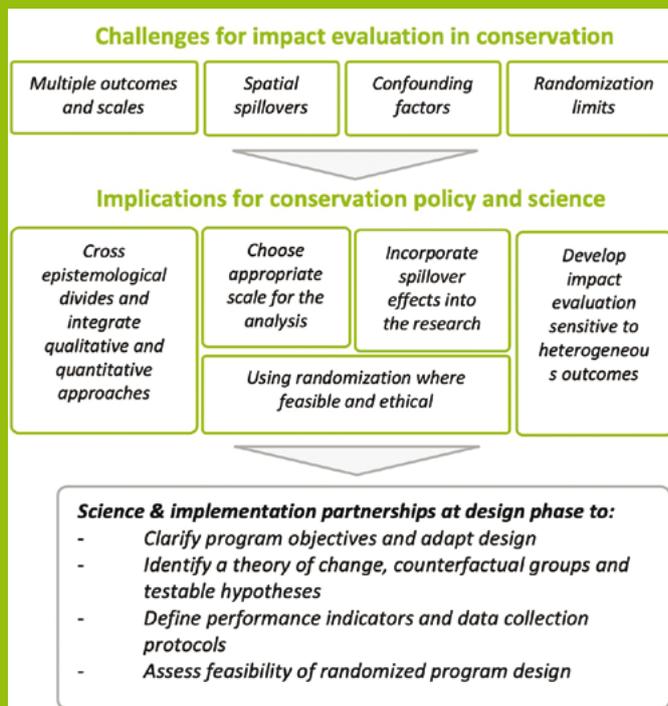


Figure 16: identified challenges for impact evaluation of conservation programs, implications for science and policy, and key features of partnerships between scientists and implementors to advance impact evaluation of conservation initiatives (drawn after Baylis et al 2016).

WORKING WITH SOCIETY AND POLICY

INVALUABLE closely worked with its stakeholders to review and test project results, in particular:

- Policy-makers and advisors from national to international levels, including national Ministries, DGs of the European Commission and international organisations such as the OECD or the World Bank, were informed and discussed project results during devoted workshops
- International NGOs, including WWF, The Nature Conservancy and Conservation International, supported fieldwork, were associated in interpreting results, and applied these in designing follow up conservation work (e.g. WWF in Uganda; TNC in Indonesia)

- National and international delegations of policy-makers (Brazil France, Malaysia, Norway and the EU) and multi-national businesses (EDF, Asian Pulp&Paper) confronted results in INVALUABLE side-events organised at the COP12 of the Convention on Biological Diversity and the IUCN World Parks Congress, leading to joint publications (see highlights).

SOCIETAL/POLICY IMPACT HIGHLIGHTS

- ✓ **Co-developed publication on potential for market-based instruments** – following up on its side-event at CBD COP12, INVALUABLE gathered inputs in a publication titled “Can MBIs make a difference?”
- ✓ **INVALUABLE Policy briefs** – the project produced several policy briefs on market-based instruments, payments for ecosystem services and biodiversity off-sets in the context of international conventions on biodiversity available here. One brief on French biodiversity law saw its recommendations included in the national law text in relation to the Nagoya protocol, so that retrocessions from resource users to state are actually allocated to conservation measures.
- ✓ **Direct transfer of competencies in civil society** – the engagement with international NGOs in the project led to several follow up projects and also direct transfers of competence, including two Postdocs that have had subsequent contracts with The Nature Conservancy and Conservation International, and the project coordinator who became Programme Director at WWF France.

SCIN

Advancing knowledge of biological soil crusts functioning for local conservation and management

CONTEXT

Bare ground is not just bare ground; in fact, the soil surface in areas free of vegetation is often covered with a 'skin' made up of a complex community of microorganisms, like cyanobacteria (bluegreen algae), lichens and bryophytes – the biological soil crust (BSC). BSCs can be the only living cover in arid and semi-arid regions such as hot and cold deserts or warm and dry steppe. They are also the first colonizers of disturbed soils and have major impacts on the soil properties through stabilization, erosion limitation, and facilitation of colonization by higher plants. Despite these important properties that provide protection to large, particularly marginal areas, soil crusts are not well understood, and conservation authorities are missing knowledge for improved policies and actions in the area of land protection.

OBJECTIVES

SCIN aimed to achieve much better appreciation of the functioning and importance of BSCs from severest deserts to alpine ecosystems in Europe, and contribute to the development of better and simpler soil protection practices and policies.

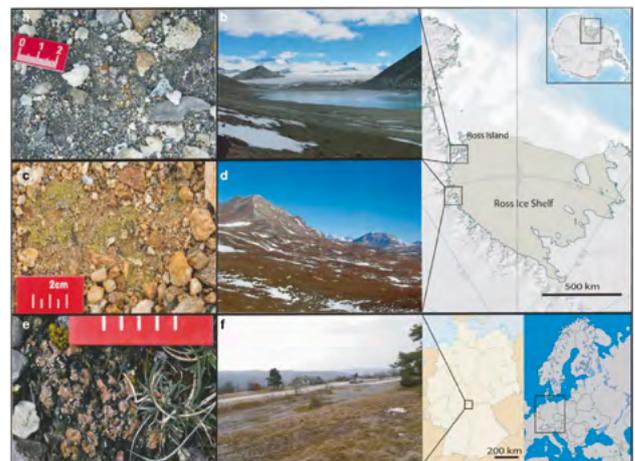
APPROACH

To advance knowledge and raise awareness of BSCs, SCIN worked around BSCs in Sweden, Germany, Austria and Spain to:

- Estimate annual productivity through continual in situ monitoring of soil crust activity linked to detailed photosynthetic measurements, determining rates of change and recovery and sensitivity indices.
- Back functional studies with detailed biodiversity assessments to reveal the key organisms in soil crust functioning over a wide latitudinal, altitudinal and climatic range.
- Identify the possible importance of local adaptations in crust physiology and genetics potential for restoration projects
- Raise awareness of BSCs and identify conservation options with local conservation and land management authorities

MAIN ACADEMIC FINDINGS

- Identifying 255 species of cyanobacteria, algae, lichens and bryophytes in sites along a European latitudinal gradient, SCIN results highlighted similar species composition in sites close to human activities, while others were distinct, also between each other.
- SCIN showed how BSCs have a high regeneration potential for soil stability, chlorophyll content and properties (nitrogen content), occurring within two years at all sites as long as the disturbed plots are surrounded by natural BSC populations.
- Monitoring the soil crust activity and the microclimate at all sites allowed SCIN to significantly advance the understanding of BSCs relationships with rainfall, air temperature, incident light and minimum temperature.
- Observing similar behaviour of BSCs in terms activity periods (growth) and CO₂-fixation in response to environmental factors at all sites, SCIN results suggest that BSCs can be treated as one functional type and are valuable indicators for climate change.



PROJECT PARTNERS – University of Kaiserslautern, **GERMANY** (coordinator: Burkhard Büdel); Complutense University Madrid, **SPAIN**; CSIC, **SPAIN**; Swedish Museum of Natural History, Stockholm, **SWEDEN**; University of Graz, **AUSTRIA**; University of Kiel, **GERMANY**; University of Salzburg, **AUSTRIA**

DURATION – October 2011 to September 2014

FUNDING – €1,025,756 under the 2010-11 BiodivERsA call ; national funders: DFG (DE), FWF (AT), Formas (SE), MINECO (ES)

ACADEMIC RESULT HIGHLIGHT

Biological soil crusts are the dominant functional vegetation unit in some of the harshest habitats in the world but are largely understudied. SCIN contributed to understanding lichen-dominated BSC response to stress by comparing several sites differing in stress level, looking at changes in biotic composition, CO₂ gas exchange and carbon allocation. Results showed that soil crusts under very stressful environments, like in the Antarctic, had similar maximum net photosynthetic rates as compared to BSC of less stressful environments, but allocated fixed carbon mostly to the alcohol soluble pool, which has an important role in desiccation and freezing resistance and antioxidant protection. In contrast, BSC in less stressful sites as in Germany showed greater carbon allocation into the polysaccharide pool, with a tendency of C allocation towards growth. The SCIN researchers identified benefits and risks attached to changing life traits, describing the ecophysiological mechanisms that underlie them.

Colesie C. et al (2014). *Habitat stress initiates changes in composition, CO₂ gas exchange and C-allocation as life traits in biological soil crusts. The ISME journal*, 8(10), 2104–2115



Figure 17: Cardinal points of photosynthesis of BSC from sites in Antarctica (Darwin – D and Garwood – GW) and in Germany (Homburg – H) for mean maximum net photosynthesis under optimal conditions (left) and mean carbon use efficiency (right). Observed differences between the two Antarctic sites and the German site are related to environmental stress levels and highlight the adaptive changes of BSCs in harsh environments.

WORKING WITH SOCIETY AND POLICY

SCIN's activities in terms of stakeholder engagement included starting a dialogue with local stakeholders on biological soil crusts, forming and maintaining successful links to transfer results and raising the awareness and appreciation of BSCs as an important component of the landscape

- Round table discussions were organised on BSCs with the Landschaftspflegeverband of Lower Francony in Northern Bavaria
- SCIN followed up yearly with the nature conservancy and land management agencies at all sites to inform on ongoing experimentations, results and to discuss maintenance measures inferred by SCIN results

SOCIETAL/POLICY IMPACT HIGHLIGHTS

- ✓ **Field visits and local media articles** – SCIN organised field visits with local administrations, public and press at sites in Germany and Sweden, leading to articles in local press around case-study sites

SmallFOREST

Biodiversity, ecosystem services and values of small forest patches in agricultural landscapes to guide management, planning and policy

CONTEXT

In many parts of Europe, the original forest cover has strongly reduced and forests now occur as small fragments, often embedded in an intensively managed agricultural landscape. Despite their small size, these forest patches often act as refugia for biodiversity and provide ecosystem services. However, the delivery of services varies depending on ecological factors (e.g. taxonomic group and ecosystem service considered, surrounding land-use and history) but also in terms of values perceived by stakeholders across regions. The lack of understanding of these variations and their effects hampers decisions about management, planning and policy regarding forest remnants in agricultural landscapes.

OBJECTIVES

SmallFOREST aimed at better understanding the relationship between biodiversity, ecosystem services and the drivers behind this relationship at various spatial scales, for small forest patches embedded in agricultural landscapes along a SW-NE transect across temperate Europe.

APPROACH

To do so, SmallFOREST:

- Compiled field data for 708 deciduous forest patches distributed among 8 regions from South-West France to Central Sweden and Estonia;
- Quantified the diversity of vascular plant species, fungi, carabids, ground-dwelling spiders, millipedes, centipedes, woodlice, harvestmen and dung beetles;
- Valued ecosystem (dis)services through data collected and benefit transfer approaches, from local (carabid density) to global scales (biomass carbon stocks);
- Assessed qualitatively perceived impacts of policies and policy instruments affecting the biodiversity and ecosystem services of studied areas, through consultations with relevant stakeholders.

MAIN ACADEMIC FINDINGS

- SmallFOREST was able to highlight predictors of local diversity for different taxa (e.g. habitat features for herbaceous diversity, macroclimate for carabid beetle diversity). But at a regional scale these communities could be viewed as random assemblages of mostly non-forest species that are typically patterned by dispersal filters and chance.
- The strong edge effect (the smaller the size, the greater the change in community composition between the core and edge of patches) was detrimental to forest species, highlighting the importance of conserving old and large enough forest patches as refugia for forest specialists.
- Merging biodiversity variables and ecosystem services into single indices, SmallFOREST found that patch size was the best predictor of diversity and multifunctionality. The > 3 ha patches with diverse structural woody layers have the strongest potential contribution to reaching conservation and ecosystem services objectives.
- The socio-economic valuation work in SmallFOREST showed that local populations are sensitive to structural changes in forest patches and their effects on biodiversity. SmallFOREST found preferences for increasing the area covered by these patches. The cognitive mapping approach further uncovered distorted spatial perceptions of small forest patches, the existence of small and/or poorly accessible ones being even ignored.



PROJECT PARTNERS – Jules Verne University of Picardie, Amiens, **FRANCE** (coordinator: Guillaume Decocq); Bremen University, **GERMANY**; Centre Tecnologic Forestal de Catalunya, Solsona, **SPAIN**; INRAE, Toulouse, **FRANCE**; SLU Alnarp, Lund, **SWEDEN**; Stockholm University, **SWEDEN**; Swedish Environmental Research Institute Ltd., Stockholm, **SWEDEN**; Tartu University, **ESTONIA**; University of Freiburg, **GERMANY**; ZALF Müncheberg, **GERMANY**; KU Leuven, **BELGIUM**; University of Ghent, **BELGIUM**.

DURATION – January 2012 to December 2014

FUNDING – €1,103,888 under the 2011-12 BiodivERSa call; national funders: ANR (FR), DFG (DE), MINECO (ES), Formas (SE), ETAg (EE), BelSPO (BE)

ACADEMIC RESULT HIGHLIGHT

Global forest loss and fragmentation have strongly increased the frequency of forest patches smaller than a few hectares. Little is known about the biodiversity and ecosystem service supply potential of such small woodlands in comparison to larger forests. SmallFOREST quantified the diversity of six taxonomic groups and the supply potential of six ecosystem (dis)services across temperate Europe. Large, ancient woodlands host high levels of biodiversity and can therefore deliver a number of ecosystem services. Despite their lower multidiversity, smaller woodlands in agricultural landscapes, especially ancient ones, had the potential to deliver multiple services at higher performance levels per area than larger woodlands of similar age, probably due to positive edge effects on the supply potential of several ecosystem services. There is thus an urgent need for targeted policy instruments to ensure their adequate management and future conservation.

Valdès, A. et al. (2020), High ecosystem service delivery potential of small woodlands in agricultural landscapes. *Journal of Applied Ecology*, 57: 4-16. DOI: 10.1111/1365-2664.13537

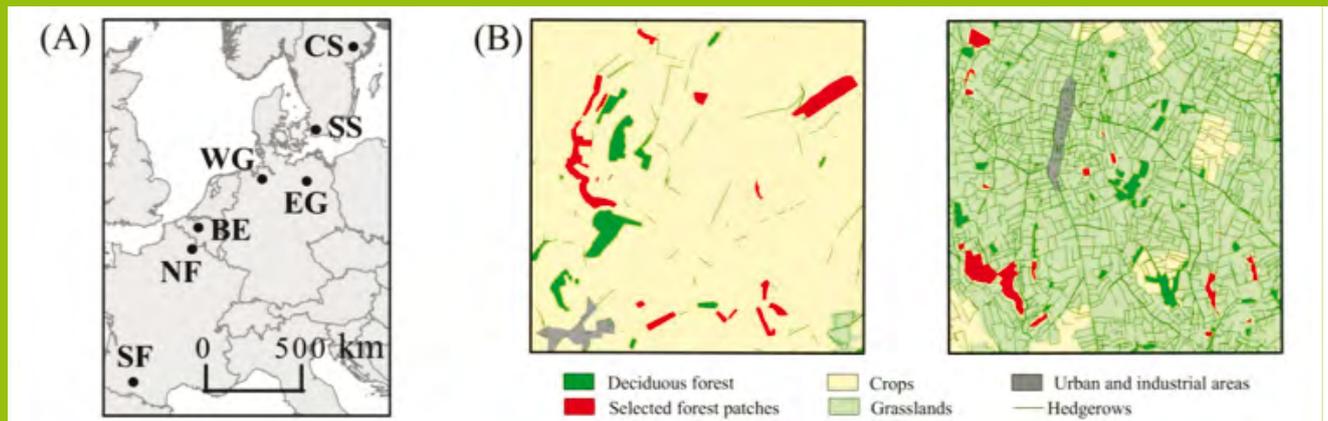


Figure 18: Sampling locations along the 2500-km latitudinal 490 gradient in Europe. (B) Detail of two of the 14 studied landscapes (low vs. high connectivity) in North France, showing the distribution of land uses and the selected forest patches in red. Each landscape is 5 × 5 km²

WORKING WITH SOCIETY AND POLICY

SmallFOREST engaged with a diverse range of stakeholders from project design to implementation and interpretation of results. Over 40 individual organisations or stakeholder groups were involved across the countries harbouring study sites, including national governments (e.g. Ministries of rural affairs, environment protection agencies, national forest offices), local authorities (e.g. regional councils, chambers of agriculture), national and local NGOs, users of natural resources (local foresters and farmers, and associations) and forest owners. In particular, the project:

- Refined the research questions, study design and questionnaires at the start of their work
- Consulted these groups on ecosystem service valuation, social preferences and perceived impacts of policy instruments
- Informed and on occasions discussed project results and implications through meetings with organisations (e.g. Natuurpunt in Belgium) or conference presentations at national science-policy events in the case-study countries (e.g. Estonian Ministry of Rural Affairs conference on grassy margins and natural landscape elements).

SOCIETAL/POLICY IMPACT HIGHLIGHTS

- ✓ **Article in EFI newsletter** – SmallFOREST results on the provision of forest services were the object of an article on European forest governance in the European Forest Institute’s newsletter of March 2014
- ✓ **Contributions to a training seminar** – SmallFOREST results were included in a training seminar for experts and managers of Estonian Environmental Agency on “How to consider large-scale mosaic ecology of species in conservation planning of contemporary rural landscapes”
- ✓ **Local press articles** – the SmallFOREST results were advertised in local professional press, e.g. in the Estonian journal of private forestry, or in local public press in [France](#)

URBES

Pioneering ecosystem services thinking in urban planning and management

CONTEXT

The majority of the human population lives in cities and more than 75% in Europe. Cities are facing enormous challenges, such as climate change and transformation to a future beyond fossil fuels. Ecosystems may play an important role in facilitating this transformation. Understanding how urban ecosystems work, change, and can be enabled to best perform is a basis to provide flexibility in urban landscapes and build adaptive capacity to cope with problems such as increased risk of heat waves and flooding. At the time URBES started, urban socio-ecological systems analysis was an emerging field seeking to address these challenges, with significant knowledge gaps hindering potential contributions to developing a sustainable planet that is increasingly urban.

OBJECTIVES

In this context, the URBES project aimed to increase the scientific knowledge and bridge the gap between scientists, policy-makers, experts and practitioners on the role of urban biodiversity and ecosystem services for human well-being.

APPROACH

To do so, URBES worked across four cities in Europe and one in the USA, as well as with Urban Atlas, in a cross-disciplinary way to:

- Understand relationships between urban biodiversity, ecosystem services and land use;
- Advance valuation of urban biodiversity and ecosystem services through monetary and non-monetary approaches for separate ecosystem services, developed and integrated in a multi-criteria analysis;
- Develop ecosystem thinking for the policy and management of urban biodiversity and ecosystem services;
- Implement communications and trainings with local authorities based on project findings

MAIN ACADEMIC FINDINGS

- Mapping urban green spaces across Europe from 1990 to 2006, URBES revealed an overall increase starting in 2000, yet contrasting trends between Western/Southern Europe and East European. Further work showed the heterogeneity of ecosystem services provision across these, and their potential for service delivery.
- Cross-city analyses in the projects' case-studies showed no typical rural-urban gradient. Results did demonstrate that core cities do not necessarily provide fewer services compared to their surrounding regions, potentially linked to the amount of mature trees in the urban structure.
- Comparing demand and supply of regulating ecosystem services from green infrastructure in five cities revealed significant spatial mismatches between service provision and demand, pointing to a minor or complementary role of green spaces to abate air pollution and GHG emissions at city scale.
- Valuation of ecosystem services in URBES further showed that in cities, the high density of beneficiaries leads to a surprisingly high socio-economic value of locally provided ecosystem services, and illustrated the long-term economic costs and severe impacts on social, cultural, and insurance values, including in resilience-related values.



PROJECT PARTNERS – Stockholm Resilience Centre, **SWEDEN** (coordinator: Thomas Emqvist); Beijer Institute of Ecological Economics, **SWEDEN**; Erasmus University Rotterdam, **THE NETHERLANDS**; Humboldt-University, Berlin, **GERMANY**; Kiel Institute for the World Economy, **GERMANY**; Mistra Urban Futures, Göteborg, **SWEDEN**; Universitat Autònoma de Barcelona, **SPAIN**; University of Kiel, **GERMANY**; University of Salzburg, **AUSTRIA**; The New School, New York, **UNITED STATES**; University of Helsinki, **FINLAND**

DURATION – September 2011 to August 2014

FUNDING – €2,662,281 under the 2010-11 BiodivERsa call; national funders: Formas (SE), MINECO (ES), NWO (NL), PT-DLR/BMBF (DE) and FWF (AT).

ACADEMIC RESULT HIGHLIGHT

URBES conducted the first analysis of the diversity of regulating ecosystem services across European cities. Researchers used the Urban Atlas database to develop a mapping of patterns of regulating ecosystem services in urban core areas and their hinterlands across 300 cities. They analyzed results in relation to each city's land-use development history and planning culture. Results show a heterogeneous distribution across cities and European regions, and considerable differences between core cities and the hinterland (see figure). Finally, this study clustered European regions according to their potential for urban ecosystem service provisioning and ranked cities in terms ecosystem services supply. These results provided the first overall picture of regulating services in urban Europe to inform decisions on the key aspects of future European policy and strategies involving urban nature, green spaces and health.

Larondelle N. et al (2014) *Mapping the diversity of regulating ecosystem services in European cities*. *Global Environmental Change*, 26, 119-129

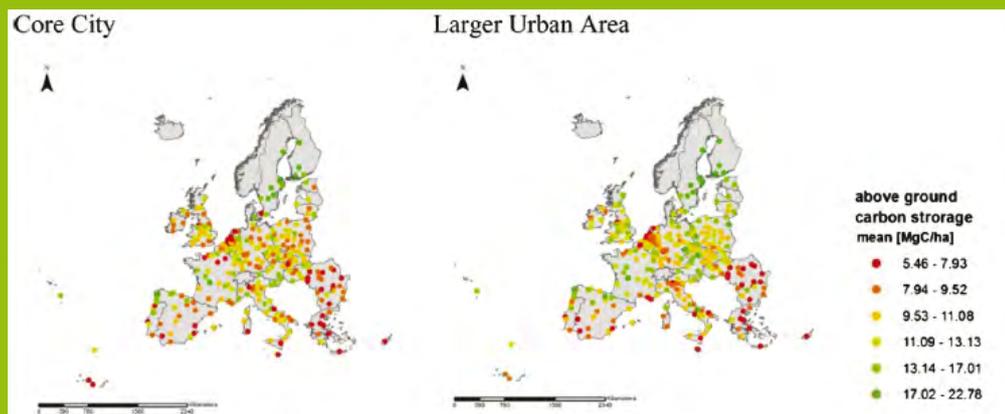


Figure 19: Ecosystem services (here above ground carbon storage) values in European cities divided into the core city and the larger urban area (Urban Atlas data). This highlights considerable variations in provisioning services between core cities and their hinterlands, as well as between European regions.

WORKING WITH SOCIETY AND POLICY

URBES integrated stakeholders at the core of the project with considerable concrete outcomes.

- IUCN Europe and ICLEI were project partners in charge of the uptake and dissemination of project results
- Urban planners, consultants and local authorities in Barcelona, Berlin, Rotterdam and Stockholm were interviewed part of the research and involved in discussing results and implications for urban governance. They had concrete contributions to pioneering ecosystem service thinking in urban planning and governance.

- On the European and International arena, URBES engaged with international policy-makers and advisors (e.g. European Commission's DG ENV and DG RTD) contributing to shifting narratives from ecosystem conservation in cities to thinking of cities as urban ecosystems, especially through its contributions to the [Cities and Biodiversity Outlook](#) and dialogues on the concept of nature-based solutions.

SOCIETAL/POLICY IMPACT HIGHLIGHTS

- ✓ **Policy workshops in Rotterdam** – 5 workshops were organized in Rotterdam with local authorities to co-develop guidelines and actions on green infrastructure at city-scale, leading to contributions to the [International Architecture Biennale Rotterdam 2014](#) and collaborations on the city's strategic planning.
- ✓ **Technical reports and trainings for policy-makers** – URBES organized trainings for the ICLEI Cities Biodiversity Center on monetary and non-monetary valuation of urban biodiversity and ecosystem services. They contributed a [brief on assessing urban ecosystem services for the European Commission](#), and a [report on ecosystem services in the Stockholm region for the County's Council](#).
- ✓ **URBES Factsheets, videos and case studies** – URBES widely shared results, through [thematic factsheets](#), videos involving local authorities and urban planners in [Barcelona](#), [Berlin](#) and [Rotterdam](#), and advertising [case studies](#). It further contributed to the production of an [animated movie on the project](#) as laureate of BiodivERsA's Prize for Excellence and Impact for this call.





**Projects funded under the BiodivERsA call 2011-12 on
“biodiversity dynamics: developing
scenarios, identifying tipping points and
improving resilience”**



BUFFER

Assessing socio-ecological resilience and effectiveness of varying protection levels to guide the planning and management of Marine Protected Areas

CONTEXT

Coastal zones are complex socio-ecological systems, providing considerable goods and services but also under high pressures. Marine Protected Areas, from fully to partially protected areas, are a well-established tool for the conservation and management of biodiversity and related services. But their levels of protection differ. Fully protected areas may better restore ecological resilience but allow no socio-economic uses, while partially protected areas allow for a wider range of uses but may result in lower ecological outcomes and resilience. This had never been comprehensively investigated.

OBJECTIVES

- Understand the link between different levels of protection and drivers of resilience for (Partially) Protected Areas, and implications for sustaining coupled socio-ecological benefits;
- Derive and integrate functional indicators of coupled social-ecological resilience as tools for decision, enabling better governance and management of multiple uses in coastal areas.

APPROACH

- Compare socio-ecological effectiveness of over 100 MPAs distributed globally, based on a meta-analysis of existing data on underwater visual census, acoustic telemetry, experimental fishing, social surveys, interviews of key informant and institutional analyses of governance systems
- Create a typology of Partially Protected Areas, looking at their size, age, socio-cultural characteristics, uses and regulations, but also at the presence of nearby Fully Protected Areas;
- Assess the differences between partially protected and completely open areas, looking at natural dimensions (functional diversity and redundancy, phenotypic diversity and selection pressures) and human dimensions (uses, users and management adaptability and transformability);
- Use this new knowledge to co-develop socio-ecological tools for MPA planning and management.

MAIN ACADEMIC FINDINGS

- Fully and highly protected areas are always ecologically effective; moderately protected areas are effective only when adjacent to a fully protected area, and can then buffer impacts of human pressure on fish populations; other classes of partially protected areas are never ecologically effective;
- This notably highlights that networks of MPAs need network-specific assessment design, indicators and success criteria. When evaluating MPAs, conservation targets need to be more explicitly linked to ecological performance such as fish abundance or biomass;
- Socio-ecologically effectiveness of partially protected areas highly depends on their approach being multi-sectoral, accounting to a wide range of stakeholders and therefore managing trade-offs
- Partially protected areas contribute more positively to broader socio-economic aims where ecological goals are achieved, which are best achieved where proper process management, overall institutional embedding and resources are in place;
- A novel regulation-based classification system of MPAs was developed based on these findings, with each MPA class related to different levels of ecological effectiveness.



PROJECT PARTNERS – CRIOBE, National Centre for Scientific Research (CNRS), **FRANCE** (coordinator: J. Claudet); Centre of Marine Sciences of the University of Algarve, CCMAR, **PORTUGAL**; University of Luleå, ETS, **SWEDEN**; Institute of Marine Research (IMR), **NORWAY**; Instituto Superior de Psicologia Aplicada (ISPA), **PORTUGAL**; Institute of Marine Research, Swedish University of Agricultural Sciences, Lysekil, **SWEDEN**; Centre for the Law and Economics of the Sea (AMURE), CNRS, **FRANCE**

DURATION – February 2013 to July 2016

FUNDING – €1,125,316 under the 2011-12 BiodivERsA call; national funders: ANR (FR), RCN (NO), FCT (PT) and Formas (SE)

ACADEMIC RESULT HIGHLIGHT

BUFFER researchers carried out the first global meta-analysis of partially protected areas (PPAs), using a regulation-based classification system to assess their ecological effectiveness. Unambiguous differentiation was found between areas according to allowed use, which is the key feature determining PPA performance. Highly and moderately regulated areas exhibited higher biomass and abundance of commercial fish species, whereas fish abundance and biomass in weakly regulated areas differed little from unprotected areas (see figure). Notably, the effectiveness of moderately regulated areas can be enhanced by the presence of an adjacent fully protected area. Limited and well-regulated uses in PPAs and the presence of an adjacent fully protected area thus confer ecological benefits, from which socio-economic advantages are derived.

Zupan M, Fragkopoulou E, Claudet J, Erzini K, Horta e Costa B, Gonçalves E (2018). *Marine partially protected areas: drivers of ecological effectiveness*. *Frontiers in Ecology and the Environment* 16: 381-387

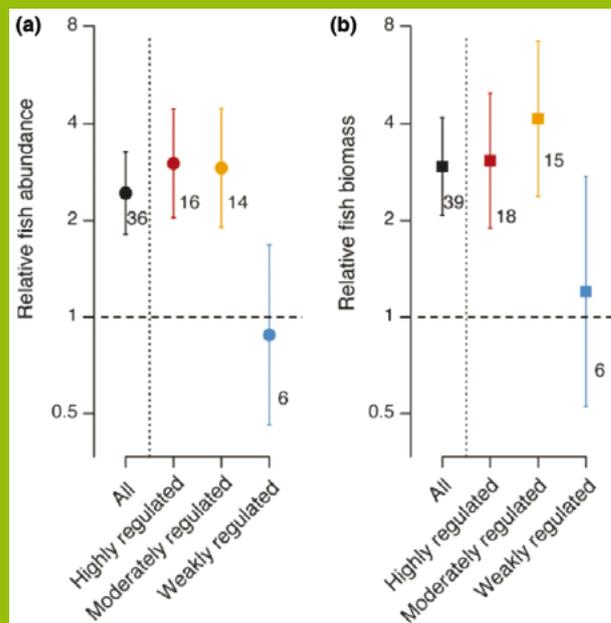


Figure 20: Ecological effectiveness of partially protected areas (PPAs) in terms of (a) abundance and (b) biomass of targeted fish species for all PPAs combined and types of PPAs differing in regulation level (sensu Horta e Costa et al. 2016). The value 1 corresponds to the status of unprotected areas.

WORKING WITH SOCIETY AND POLICY

BUFFER researchers collaborated closely with MPA managers who carried out significant efforts to disseminate their results to broader audiences of policy, international organisations and practitioners, and now actively use the tools produced.

→ A tight collaboration (co-design of field studies, interpretation and dissemination of results) was implemented with MPA managers in the field sites. This led to direct uptake of BUFFER results, for instance in the revision of the Portuguese Arabida Marine Park's management plan.

→ Engaging with national and international MPA organisations and policy advisors allowed for a strong uptake of the novel classification system developed by BUFFER. It is notably used as a criterion of the Blue Parks international MPA label. Further, MedPAN, the network of MPA managers in the Mediterranean, asked all its members to apply the BUFFER classification part of their 4-year review of the status of MPAs 2020.

SOCIAL/POLICY IMPACT HIGHLIGHTS

- ✓ **ClassifyMPAs** – BUFFER developed a web-based tool and easy-to-follow decision tree for managers to classify MPAs, backed by the classification developed in the project: <http://www.classifympas.org/>
- ✓ **Video to ease the use of the new classification** – Laureate of the BiodivERsA Prize for Excellence and Impact, BUFFER developed a video on how to use the classification system in under three minutes. See: <https://www.youtube.com/watch?v=Ryj-yfA3aMM>
- ✓ **Follow up work** – The SafeNET project (DG MARE, European Commission) builds on BUFFER results to identify coherent network(s) of MPAs that can help achieve fisheries maximum sustainable yield and maximize long-term ecological and socio-economic benefits in the Mediterranean Sea: (<http://www.criobe.pf/recherche/recherche-projets/safenet/>)



CoForTips

Identifying tipping points and co-developing scenarios of change for decision-support in the Congo Basin

CONTEXT

The future of the forests of the Congo Basin is constrained by two processes: climate change and land use change (agriculture conversion, infrastructure development and logging). CoForTips' starting point was the question of the resilience of the forests of Central Africa in the coming decades.

OBJECTIVE

To foster a better management of Central African forests through:

- a better understanding of the dynamics, regime shifts and tipping points of biodiversity, and
- a better definition of the conditions of resilience of the social and ecological systems in the region.

APPROACH

- Identify tipping points, using remote sensing to measure the resilience of species assemblages (tree communities and keystone wildlife species), and mapping potential future forest states and management scenarios
- Develop models that integrate social, economic, governance, ecological and geophysical processes and engage expert, local and scientific knowledge to represent, predict and explain regional trajectories of landscape change over the 5 to 10 next decades
- Foster resilience by engaging local and regional stakeholders in scenario development and highlight how their decisions influence the overall pressures and land-use management responses that will shape tomorrow's forests in the region

MAIN ACADEMIC FINDINGS

- Using forest inventory data of 140,000 plots spread over 4 countries in central Africa, CoForTips defined major functional forest types in the region and modelled their environmental and anthropogenic determinants. Expected functional shifts were characterized for the Congo basin forests under the combined effect of an increasing climate dryness and anthropogenic pressure;
- Based on three sites considered at the three main stages of a forest socio-ecosystem transition, CoForTips analyzed drivers and barriers of change at the local, national and regional levels. It identified key drivers of change (i) the direct and indirect influence of industrial sectors, (ii) interactions between changes to biodiversity and livelihood strategies, and (iii) legal frameworks and enforcement on land tenure and social justice.
- CoForTips identified regional trajectories of deforestation and land use change, demography, agriculture and bioenergy production and carbon sequestration.
- Using the results above and the Companion Modeling approach, CoForTips developed and tested science-based role-playing games to engage local and regional stakeholders in the development of scenarios, highlighting the ways they have or could have influenced different socio-ecological outcomes at the simulated landscape scale.



Villagers from Ampel (Mindourou, Cameroun) negotiate access to land between migrants and locals, over the AgriForest game developed by CoForTips

PROJECT PARTNERS – Centre for International Cooperation in Agronomic Research for Development (CIRAD), Montpellier, **FRANCE** (coordinator: C. Garcia); International Institute for Applied Systems Analysis (IIASA), Laxenburg, **AUSTRIA**; Université de Liège, **BELGIUM**; Institut de Recherche pour le Développement (IRD), Montpellier, **FRANCE**;

DURATION – January 2013 to December 2015

FUNDING – € 835,118 under the 2011-12 BiodivERSA call; national funders: ANR (France), FWF (Austria), BelSPO (France)

ACADEMIC RESULT HIGHLIGHT

CoForTips contributed to increasing the understanding of the compositional heterogeneity of Central African forests, the environmental drivers of forest composition and their vulnerability to future changes. Using a dataset of 6 million trees in more than 180,000 field plots, this study jointly modeled the distribution in abundance of dominant tree taxa and produced maps of the floristic and functional composition of central African forests. Results reveal highly deterministic assemblages and highlight functional convergences among types of forest that are floristically dissimilar. Combining these spatial predictions with scenarios of climatic and anthropogenic change further suggests a high vulnerability of the northern and southern forest margins, the Atlantic forests and most forests in the Democratic Republic of the Congo. These results constitute key quantitative benchmarks for scientists and policymakers to shape transnational conservation and management strategies that aim to provide a sustainable future for central African forests.

Réjou-Méchain, M. et al. Unveiling African rainforest composition and vulnerability to global change. *Nature* 593, 90–94 (2021). <https://doi.org/10.1038/s41586-021-03483-6>

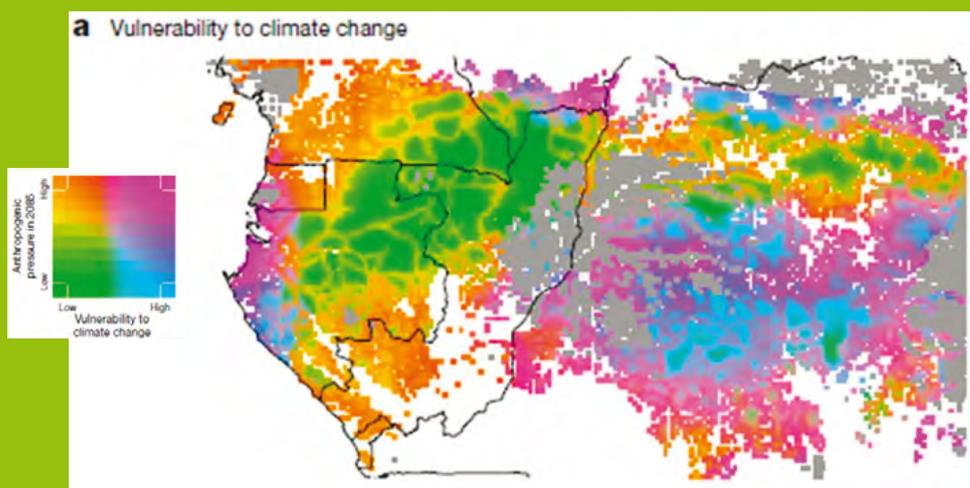


Figure 21: analysis of the expected changes for the forests of the Congo Basin on the basis of climatic scenarios, on the analysis of the sensitivity of the forest formations identified in the article and on human development scenarios.

WORKING WITH SOCIETY AND POLICY

CoForTips engaged with:

- National and international policy makers (Cameroon Ministry of Forests, COMIFAC, ...) to help validate results and guide research questions;
- Local stakeholders to provide data (e.g. logging companies) and join the companion modelling approach, where questions were defined with the villagers of the three sites. This led to a debate and revision of how scenarios were developed in the project.
- During and after the project, CoForTips' social and ecological models were presented to the local

and then regional stakeholders as strategy board games to be played collectively, allowing them to freely elaborate scenarios based on their own decisions and highlighting their consequences at the landscape scale.

- In particular, the Forest Stewardship Council solicited the CoForTips game approach in 2017, leading to the development of a collective agreement of all parties involved for the management of Intact Forest Landscapes in the FSC-certified concessions of the Congo Basin, after several years of difficult discussions due to the complexity of the topic and the apparent diverging positions.

SOCIAL/POLICY IMPACT HIGHLIGHTS

- ✓ **Policy brief with the different participatory scenarios**, the identification of the opportunities and bottlenecks, and strategic recommendations to policy makers and practitioners (Industrial investments in agriculture in Central Africa – Establishing the conditions for sustainability and equity (http://publications.cirad.fr/une_notice.php?dk=587486))
- ✓ **A TEDx talk by C. Garcia** on “Wicked games: using games to resolve environmental conflicts” (www.youtube.com/watch?reload=9&v=v362bMWL0Yw&feature=youtu.be)
- ✓ **Several follow-up projects** allowing applications of the game approach and CoForTips results, including CoForSet funded by FRB/FFEM (www.cofortips.org/en/le-projet-coforset) and in the OPAL project funded by SNSF (www.opal-project.org/our-games/)



REGARDS

Understanding mechanisms of environmental and social change in European marginal grasslands to enhance socio-ecological resilience

CONTEXT

European marginal grasslands are biodiversity hot spots and socio-ecosystems currently ongoing environmental, socio-economic and political changes. Their vulnerability or resilience to such changes is however largely unclear, due to a lack of knowledge on mechanisms of their ecological and human sub-systems, and of the role of land management decisions and ecosystem service delivery to foster resilience or vulnerability.

OBJECTIVES

REGARDS aimed to unravel the resilience mechanisms of marginal grasslands to climate and social changes to enhance socio-ecological resilience, from farm to regional level.

APPROACH

Working in three mountain grassland sites with contrasted biophysical and human situations (Austria, France, Norway), REGARDS sought to:

- Identify dangerous thresholds for these socio-ecosystems regarding their responses to climate change and management, and use field experiments to assess how coupled plant-soil biodiversity can determine such responses
- Understand how landscape structures affect the resilience of ecosystem services through a historical analysis, and understand how multi-level (regional, national, EU) governance and programmes influence farmer responses and delivery of these services
- Assess how regional integration and globalization modify resilience, by reconstructing flows of goods and ecosystem services, people and information with other regions at each site.
- Combine studied ecological and human processes through participative scenarios to evaluate likely resilience thresholds in terms of biodiversity, ecosystem services and material well-being

MAIN ACADEMIC FINDINGS

- REGARDS demonstrated a resistance/recovery trade-off in response to extreme climate events, with lower resistance but faster recovery in intensively managed grasslands, and inversely in less managed ones, reflecting plant drought adaptation and stronger association with arbuscular mycorrhizae. Management practices that effect functional composition can thus mitigate yield reductions caused by extreme climate events.
- REGARDS also highlighted how resilience varies across ecosystem services, and showed that managing provisioning services has consequences for other important regulating or cultural services.
- Historical analyses revealed spatial trade-offs in ecosystem services across land uses as key for landscape planning and policy to foster resilience of multifunctionality at regional level.
- Analysis of mountain farming governance systems showed that participatory processes with farmers to design regulatory institutions can address complex dynamics of ecosystems and practices, enabling farms to adapt and transform while maintaining traditional practices.
- REGARDS showed that higher altitude grasslands are less likely to be abandoned, social and psychological factors playing a role beyond economic and environmental constraints.
- The participatory design of scenarios to 2040 at each site confirmed the high potential of local community resilience with regard to grassland management, through diversification of agricultural and tourism activities, but conditional to supporting institutions and values.

PROJECT PARTNERS – National Centre for Scientific Research (CNRS)/University J Fourier, Grenoble, **FRANCE** (coordinator: S. Lavorel); Max Planck Institute for Biogeochemistry, Jena, **GERMANY**; University of Science and Technology Trondheim, **NORWAY**; Université Catholique de Louvain, **BELGIUM**; University of Innsbruck, **AUSTRIA**

DURATION – December 2012 to November 2015

FUNDING – €1,198,929 under the 2011-12 BiodivERSa call; national funders: ANR (FR), PT-DLR (DE), RCN (NO), BelSPO (BE) and FWF (AT)

ACADEMIC RESULT HIGHLIGHT

REGARDS contributed to developing a flexible comparative framework to assess resilience across ecosystems. Resilience is a key concept in ecology but numerous metrics are applied to quantify it over a range of ecosystems. This affects the degree to which different trajectories of ecosystem recovery from disturbance are represented as 'resilient', precluding a comparison of disturbance responses across ecosystems and their properties and functions. To approach a broadly comparable assessment of resilience, REGARDS researchers developed a bivariate framework that jointly considers the disturbance impact and the recovery rate, both normalized to the undisturbed state of a system. Building on a set of 12 case studies that represent all possible combinations of systems differing in their resistance and recovery rates, they demonstrated the potential of the framework for integrating the various components underlying resilience.

Ingrisch, J. et al. (2018) Towards a comparable quantification of resilience. Trends in Ecology and Evolution. 2357: 1–9

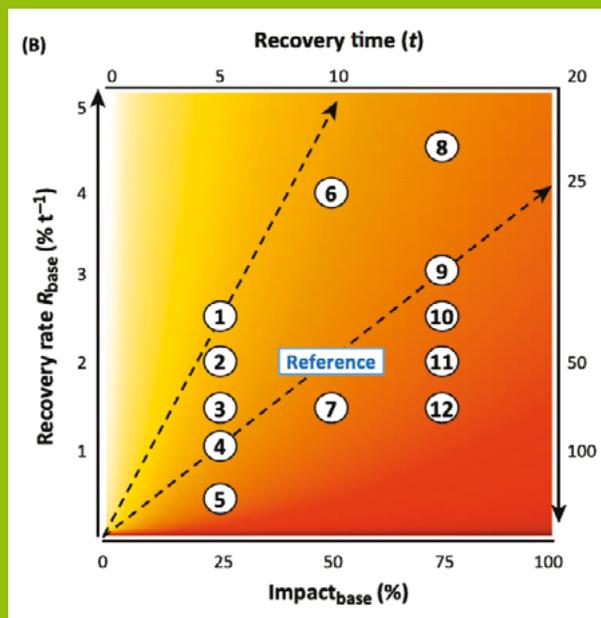


Figure 22: Bivariate scheme for comparing resilience based on disturbance impact and recovery rate for grassland ecosystems, both normalized to the pre-disturbance state of each system (reference: pre-disturbance state of respective system); 1–12 depict the resilience of the 12 cases

WORKING WITH SOCIETY AND POLICY

Questions addressed by REGARDS reflect a co-construction with key local (in particular farmers) and regional experts based on previous collaborations. They thus actively took part in the project:

- Local farmers at the study sites were tightly involved, from providing inputs on the study and interpretation of mountain farming governance and farming systems analysis, to taking part in participative scenarios development and adapting scenarios to expectations at each site.
- Analyses of institutional governance and farm-level impacts in terms of resilience were developed

with the contributions of a wide range of experts in agriculture, tourism, planning, conservation and policy and administration.

- The construction of the 2040 visions developed in REGARDS involved other key sectors in activity at each site, from tourism actors to agricultural extension experts and national park managers (in particular the Ecrins National Park in France, involved throughout the project)
- Final REGARDS workshops were held with stakeholders at each site, to review the results of the projects but also kick off follow up collaborations adaptation to climate change.

SOCIETAL/POLICY IMPACT HIGHLIGHTS

- ✓ **Case-study reports on governance impacts on resilience** – REGARDS provided stakeholder reports for each case study based on its analysis of institutional impacts on the resilience of these grasslands (see www.sciencedirect.com/science/article/abs/pii/S0264837715300934)
- ✓ **MtnPaths** – A follow up collaboration (funded by SNSF and ANR) on participative scenarios for the adaptation to climate change in the Swiss and French Alps to co-develop and implement visions for sustainable futures in these regions, based on adaptation pathways through participatory modelling (<https://plus.ethz.ch/research/forschungsprojekte/mtnpaths/project.html>)
- ✓ **CIFOR info brief on Adapting to the Anthropocene** – Building on REGARDS results and subsequent projects (SINCERE, MtnPaths), this brief summarizes key messages on how policy and management can help socio-ecosystems to respond to change (www.cifor.org/knowledge/publication/7588/)

EC21C

Simulating land-use and climate change effects on European biodiversity to assess the effectiveness of the EU's Green infrastructure measures

CONTEXT

Changes to climate and habitat threaten European biodiversity. One of the main ways wildlife will survive climate change is to move to new areas when climate conditions become intolerable. However, intensifying usage of landscapes by humans can cause barriers to wildlife trying to move to new locations. As a result, European ecosystems we are accustomed to, as well as the vital services they provide, are likely to be significantly disrupted. Predicting when and where the shifts in the distributions of animal and plant species will disrupt European ecosystems can serve as a basis to guide and evaluate policy and management measures including Green Infrastructure, i.e. strategically planned networks of natural and semi-natural areas delivering a wide range of ecosystem services, both in rural and urban areas.

OBJECTIVES

EC21C studied how plants, mammals, birds, and some insects in Europe could be affected under future trajectories of climate and land-use change, and how land-management can assist wildlife.

APPROACH

To do so, EC21C:

- Studied how individual plants and animals will move through European landscapes as climate changes;
- Simulated changes in European species' distributions under predicted 21st century climate and land-use changes (almost all vertebrates, 20% of plant species, and a representative sample of insects);
- Projected when and where European ecosystems and the services they provide might change drastically;
- Evaluated the potential and limitations of green infrastructure for biodiversity conservation and adaptation to environmental change.

MAIN ACADEMIC FINDINGS

- EC21C found land use change is by far the biggest driver of expected habitat change, yet both climate change and CO₂ increase will profoundly affect future habitat distributions. In addition, both agricultural yields and nitrogen leakage are expected to increase in the future as a result of CO₂ increase, climate change and land use intensity change.
- While tree diversity in European temperate and alpine forests enhances the stability of forest productivity, EC21C showed that it may strongly decline in Central Europe under climate change by causing tree species to go locally extinct.
- Beyond how far individuals can move, EC21C highlighted how wildlife survival to climate and land-use change depends on what they eat, how fast they breed and how well they survive in different habitats.
- Semi-natural areas were found to considerably mitigate the effects of warmer temperatures on species within their current landscape, in particular for pollinators in agricultural settings.
- When making decisions about land-use for conservation, farmers were influenced by the degree of knowledge they have, but also by social pressures, while their consultation revealed local ecological, social and economic factors useful to set up effective measures.
- EC21C found that Green Infrastructure could maintain habitat diversity and minimise the effects of land-use change, particularly if adopted by farmers. Adoption was found to depend on the information available to farmers and the social pressures they experience.

PROJECT PARTNERS – University of Évora, **PORTUGAL** (coordinator: Regan Early); University of Montpellier, CNRS, **FRANCE**; Helmholtz Centre for Environmental Research, UFZ, **GERMANY**; University of Linköping, **SWEDEN**; University of Lund, **SWEDEN**; Museo Nacional de Ciencias Naturales, Madrid, **SPAIN**

DURATION – October 2012 to September 2015

FUNDING – €1,217,686 under the 2011-12 BiodivERsA call; national funders: FCT (PT), ANR (FR), PT-DLR/BMBF (DE), Formas (SE) and MINECO (ES)

ACADEMIC RESULT HIGHLIGHT

Information on the ecological traits of species might improve predictions of climate-driven range shifts. However, the usefulness of traits is usually assumed rather than quantified. Here, EC21C presents a framework to identify the most informative traits, based on four key range-shift processes: emigration of individuals away from the natal location; the distance a species can move; establishment of self-sustaining populations; and proliferation following establishment. This framework categorizes traits according to their contribution to range-shift processes and enables the predictive value of traits to be evaluated empirically. Results also show that the framework can be used to better understand range-shift processes and improve estimates (see figure).

Estrada et al, (2016). Usefulness of Species Traits in Predicting Range Shifts. Trends in Ecology and Evolution, 31(3), 190–203

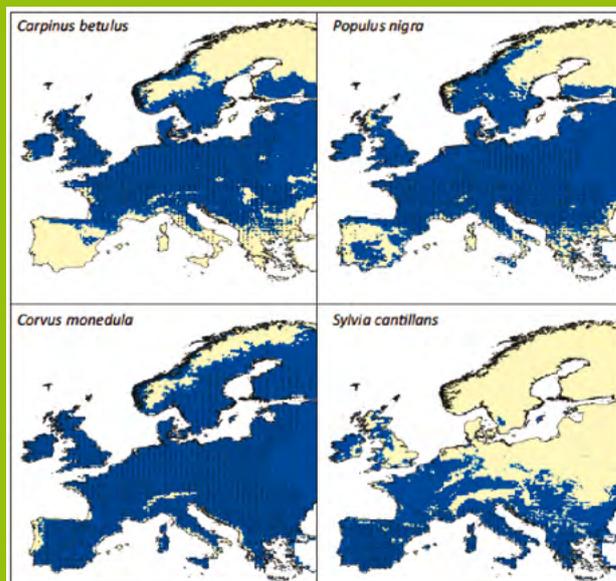


Figure 23: Current Distributions and Areas Predicted Climatically Suitable for Case Study Species in 2071–2100. Black dots are currently occupied, blue areas will be climatically suitable in the future, and yellow areas are climatically unsuitable

WORKING WITH SOCIETY AND POLICY

EC21C research directly relates to European policy planning and evaluation, and principally engaged with stakeholders through interviews and participation in the scenarios development, consulting with farmers and farming organisations, local policy makers, authorities and landscape planners, as well as agricultural consultants.

- EC21C's work directly relates to knowledge needs from policy, responding to a request by the European Commission formulated in the context of a previous work ([PRESS](#) project).
- EC21C conducted an in-depth stakeholder analysis at study sites using interviews and the Net-Map tool, while interviewees themselves took part in deciding which stakeholders should be included in the research.

- Local stakeholders were engaged in scenario development through a regional participatory workshop to define storylines in relation to green infrastructure, and to identify spatially explicit consequences of the scenarios in terms of green infrastructure
- Members of the Commission's DG Environment, which prepared the EU strategy on Green Infrastructure, were informed on EC21C results relating to the ecological, economic and social consequences of studied implementation options at local and regional level.

SOCIETAL/POLICY IMPACT HIGHLIGHTS

- ✓ **BiodivERsA policy briefs** – EC21C contributed to [three BiodivERsA policy briefs](#) with key results on EU and national agricultural policies' performance in supporting green infrastructure implementation in Member States, and how heterogeneous landscapes, characterized by a significant proportion of semi-natural habitats enhance and stabilize pollination and decrease sensitivity to climate change.
- ✓ **Feedbacks to local stakeholders** – EC21C provided local stakeholders with adapted information on the projects' results, e.g. [this brochure](#) explaining research and respective results to stakeholders in the German case study

FISHCON

Advancing freshwater scenarios to guide EU and local scale strategies for managing connectivity and conservation

CONTEXT

Freshwater ecosystems provide numerous essential ecosystem goods and services. They host ~10% of the world's fauna and one third of all vertebrates, while covering only 0.8% of the earth's surface. However, their diverse and increasing use impacts their functioning. Flood protection by levees for instance had cut off most of the historic floodplains and caused significant drop in freshwater fisheries productivity. At the start of FISHCON, most predictions on biodiversity resilience to environmental change ignored how organisms are able to spread between different habitats. The role of habitat connectivity is particularly evident for organisms living in freshwater. Dispersal barriers are imposed by the network structure of freshwater rivers and lakes, impacting species differently, with negative (e.g. capacity of organisms to (re-)colonize areas) and positive consequences (e.g. hindering invasive species' dispersal).

OBJECTIVES

FISHCON aimed to integrate for the first time habitat connectivity into scenarios of biodiversity maintenance, management and resilience.

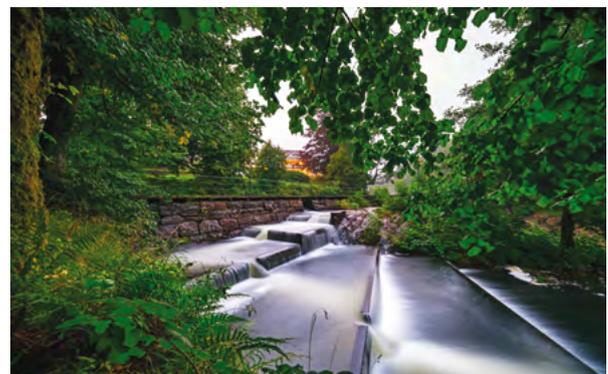
APPROACH

Combining detailed lake and stream data sets across Germany, Norway and Sweden, FISHCON:

- Built models of fish dispersal, land use and climate change impacts on the spatial distribution of freshwater fish species of the EU Water Framework Directive;
- Explicitly linked present-day management of habitat connectivity to future biodiversity scenarios going beyond the catchment scale;
- Predicted future fish distributions, both at large scale across Europe and at small scales covering specific catchments that are relevant for local management;
- Involved local stakeholders to identify relevant strategies for managing habitat connectivity within focal catchments and investigate how management actions affect the fate of biodiversity.

MAIN ACADEMIC FINDINGS

- FISHCON built models integrating direction and extent of predicted habitat shifts under coupled climate and land use change scenarios, along with associated changes in fragmentation of river, fish distributions and the species-specific dispersal abilities of fishes. Future changes in fish biodiversity and consequences were found to depend on landscape configuration, land-use and composition of resident fish communities.
- FISHCON detected the greatest effects of land use change on community assemblages (e.g. species richness) for areas predicted to shift from agricultural to forest areas. They found that in many systems the upstream range limit of fish species is set by man-made dams or weirs.
- FISHCON's scenarios including moderate climate change effect with no land use change still led to significant changes of fish species richness, as some species are already in sites close to their environmental tolerance levels.
- FISHCON showed that fish communities are hierarchically organized, species being either strong or weak performers in terms of invasion potential and resilience to invasions. Thus managing man-made barriers is critical for the future of many populations.
- Building on local knowledge of species composition and possible invaders, FISHCON demonstrated it is possible to identify situations where invasions and range expansions driven by environmental changes will be most detrimental to biodiversity conservation.



PROJECT PARTNERS – Institute for Nature Research, Trondheim, **NORWAY** (coordinator: Anders Finstad); Forschungsverbund Berlin e.V., **GERMANY**; University of Umeå, **SWEDEN**

DURATION – December 2012 to August 2015

FUNDING – €677,097 under the 2011-12 BiodivERsA call ; national funders: RCN (NO), PT-DLR (DE) and Formas (SE)

ACADEMIC RESULT HIGHLIGHT

FISHCON revealed interactions of future changes in land use and climatic conditions by modelling single and interacting impacts on the spatial distribution of 33 fish species in the Elbe River. They identified synergistic, additive and antagonistic interaction effects on species losses, gains, diversity indices and spatial distribution under moderate and extreme scenarios. Results revealed species richness would increase by 0.7–2.9 species by 2050 across the river network, with significant changes for 56–85% of the network. Evidence shows that future land use and climate change effects are highly interactive, and emphasizes the role of adaptive river management and spatially connected conservation areas to compensate for high species turnovers and range shifts.

Radinger J. et al (2016) Synergistic and antagonistic interactions of future land use and climate change on river fish assemblages, *Global Change Biology*, 22(4):1505-1522

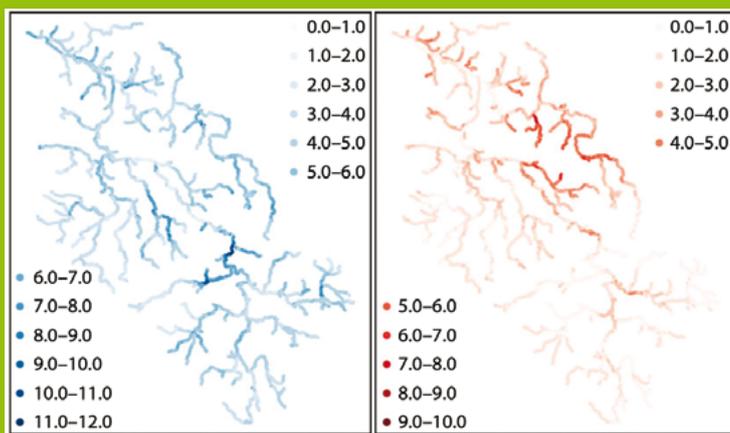


Figure 24: Species gain and species loss (number of species) for the River Elbe network. Comparisons between baseline scenario (climate: Current, land use: Current) and one of the three moderate future scenarios used in the study (here moderate future changes in both climate and land use).

WORKING WITH SOCIETY AND POLICY

FISHCON directly addressed issues of national policy makers on the implementation of the Water Framework Directive (WFD) while also building local management strategies. For instance:

- National policy-makers in charge of implementing the WFD (e.g. Norwegian Environment Agency) were engaged to frame the project
- FISHCON engaged with over 1,000 individual managers of local and regional fisheries in the studied sites, to collect data, but also create a network of contacts that were informed of results

- Results were presented and discussed through interactive workshops at case study sites with local managers, recreative and professional fishermen, tourism industry representatives and local authorities
- In the Elbe River case study, FISHCON results were highlighted in working groups on the large rivers and connectivity of navigable rivers in Germany, organised by an environmental consultancy. This allowed providing policy support to Federal advisors on hydrology and waterways engineering.

SOCIETAL/POLICY IMPACT HIGHLIGHTS

- ✓ **Use of FISHCON results for implementing the WFD in Norway** – intended since the project design, FISHCON results helped guide the Norwegian Environment Agency in using information on relative performance of freshwater fish in relation to invasions and range expansions driven by environmental changes, thus helping the implementation of the EU Water Framework Directive.
- ✓ **Sustained collaborations** - the institutions involved in FISHCON have become regular consultants for local and national authorities with regard to questions related to fish migration, dispersal and population dynamics, particularly in Germany.
- ✓ **Results transfer for developing competences** – FISHCON results and materials are now taught in the lecture “protection of Endangered Species” within the International Master Course “Fisheries Science and Aquaculture” at Humboldt University, Berlin, Germany

LIMNOTIP

Social-ecological scenarios for European freshwater ecosystems in support of decision-making and local management

CONTEXT

Freshwater ecosystems provide a wide array of ecosystem services, but have been heavily affected by human activities during the last century. Eutrophication, where overly enriched water bodies suffer from excessive growth of algae, is a major threat to these ecosystems and may become increasingly problematic as a result of climate change. In shallow lakes, eutrophication can cause abrupt regime shifts: lakes reach a “tipping point” and change from a clear-water with submerged plants to turbid conditions with dense algal blooms. This generally results in a dramatic decline in biodiversity and in the provision of goods and services. Improved knowledge on the socio-ecological mechanisms behind regime shifts in freshwater ecosystems, especially linked to future climate change, is decisive to prevent and handle them.

OBJECTIVES

LIMNOTIP aimed to assess the ecological and social mechanisms behind tipping points in freshwater ecosystems under different climate change scenarios, to identify early warning signals and investigate how society may handle a shift in ecosystem services as a system is tipping over.

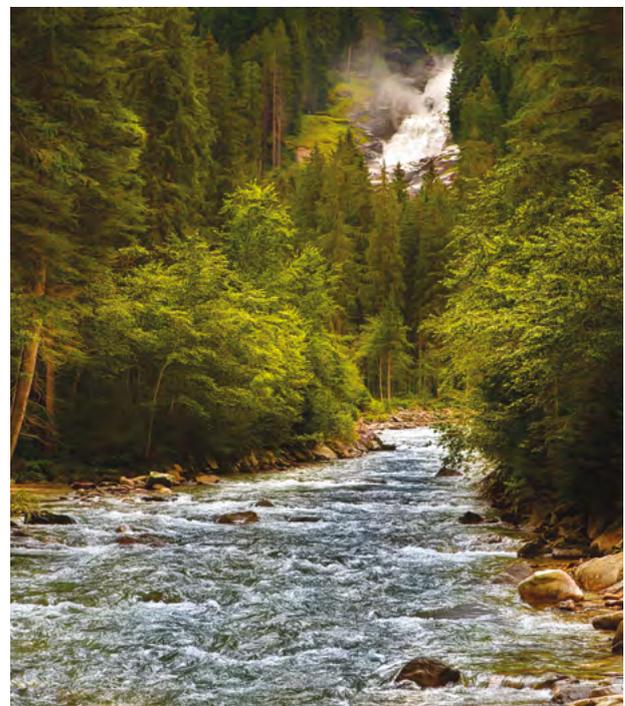
APPROACH

To do so, LIMNOTIP:

- Analysed decadal time series of freshwater ecosystems along a latitudinal gradient of Europe from Norway to Austria to identify patterns, structure and early warning signals of European freshwaters serving as a basis for future scenarios
- Conducted standardized large-scale mesocosm studies to develop a mechanistic understanding of biodiversity changes and levels where tipping points put ecosystems at risk.
- Integrated results into social-ecological modelling and built on climate scenarios to assess differences in resilience and rate of changes between regions and between pristine/strongly affected lakes.
- Developed social-ecological scenarios for decision-support, and identified regional recommendations based on critically and empirically validated knowledge

MAIN ACADEMIC FINDINGS

- Using long-term data sets from diverse ecosystems, LIMNOTIP showed that resilience is affected by system specific drivers and processes (like nutrients and water color, but that large-scale multiplier effects (like climate warming) can override these, synchronising shifts across large geographical scales.
- It revealed that increased temperature favours smaller sized plankton species, and that climate warming will likely induce earlier establishments of many organisms groups in spring, in some cases causing mismatches in trophic interactions.
- LIMNOTIP developed a social-ecological model representing direct interactions of actors with a shallow lake and its potential resources. This highlighted the importance of integrating stakeholders and accounting for policy responses and time scales to sufficiently address drivers or restore lakes to a desirable state.
- LIMNOTIP results further show how local-scale food web management has the potential to increase resilience against effects from climate warming, and offer possibilities to reverse from tipping points



PROJECT PARTNERS – University of Lund, **SWEDEN** (coordinator: Lars-Anders Hansson); Forschungsverbund Berlin e.V., **GERMANY**; Leibniz-Institute of Freshwater Ecology and Inland Fisheries, **GERMANY**; University of Oslo, **NORWAY**; Wasserkluster-Lunz, **AUSTRIA**.

DURATION – October 2012 to September 2015

FUNDING – €720,242 under the 2011-12 BiodivERSa call ; national funders: Formas (SE), PT-DLR (DE), RCN (NO) and FWF (AT)

ACADEMIC RESULT HIGHLIGHT

Synergies between large-scale environmental changes, will have a considerable impact on future aquatic ecosystems. LIMNOTIP studies demonstrate, for the first time, that community responses to global change are determined by food-chain length, suggesting that phytoplankton, and thereby algal blooms, will benefit from climate change in three-, but not in two-trophic-level systems. These results provide a powerful framework for predicting and understanding future aquatic ecosystems and their provision of ecosystem services and water resources.

Hansson, L-A, et al. (2013) Food chain length alters community response to global change in aquatic systems. *Nature Climate Change* 3: 228-233.

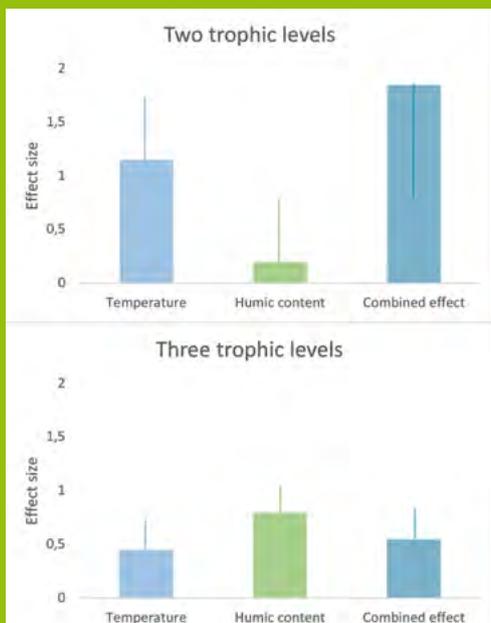


Figure 25: Temporal mean effect sizes (± 1 s.e.m.) of elevated temperature (T), humic content (B) and the combined effect (TB) on the abundance of cyanobacteria *Microcystis* spp., without and with fish, that is at two and three trophic levels, respectively. Note that the histograms show how *Microcystis* spp. will benefit from a future scenario irrespective of the food-chain composition.

WORKING WITH SOCIETY AND POLICY

LIMNOTIP interacted closely with local stakeholders to develop insights into the future of freshwater resource management, in particular:

→ Local authorities, NGOs and SMEs (e.g. Sydvatten) contributed with knowledge and data on case-study sites, to identify key ecosystem services and benefits as well as social drivers that affect lake water quality. This was achieved through focus groups

- In Sweden, local authorities (Water district Rönne å) were also involved in designing data collection and in contributing to the development of a conceptual model representing the main social-ecological interactions and processes identified for lake restoration
- Lake users were consulted on perceptions of provided services and water quality to qualitatively inform the model development

SOCIETAL/POLICY IMPACT HIGHLIGHTS

- ✓ **Support to local restoration actions** – LIMNOTIP was strongly involved in the evaluation of the restoration of Lake Ringsjön, southern Sweden, ongoing during the project, showing that biomanipulation is an efficient tool for reversing tipping points and effects of climate warming
- ✓ **Decision-support for local authorities on climate mitigation** – LIMNOTIP has directly contributed results in the “Vattenråd” (Water district Rönne å, Sweden) and affected decisions made, highlighting the role of local-scale management to reduce the effects of climate warming. making regarding water resources and management action

SIGNAL

Managing European grassland's resilience to climate extremes and biological invasions through biodiversity

CONTEXT

Meadows and pastures encountered in Europe are an important part of the cultural landscape, harbor unique biodiversity and are essential for agricultural production (meat, milk and dairy products). However, they are under the triple threat of climate change, land use change and biotic invasions. Their joint effects threaten biodiversity, resilience and ecosystem services of semi-natural grasslands and can suddenly drive them beyond thresholds of system integrity (tipping points and regime shift). At the start of SIGNAL, evidence suggested biodiversity itself may buffer against change, through potential stabilizing mechanisms involving species richness, presence of key species, and within species genetic diversity, which can be promoted by conservation management and political decisions.

OBJECTIVES

SIGNAL set out to analyse the role of biodiversity for grassland resilience, identify early warning signals of thresholds and regime shifts in European grasslands and provide new instruments for their conservation and management.

APPROACH

SIGNAL investigated mechanisms of resilience in European grassland prone to novel climate extremes, linking for the first time the interaction of biodiversity experiments, climate impact research, and invasion research, based on two main approaches:

- A drought-simulation experiment in 10 sites ranging from Belgium and France to Turkey and Israel, combining two levels of warming, three levels of land-use and three levels of invasion, with some add on experiments, e.g. on assembly rules and decomposition

- A mesocosm experiment installed at 5 sites and looking at the role of species richness, presence of key players (legumes and invasive species) and within species richness, regarding response to drought

This was completed by literature reviews and meta-analyses.

MAIN ACADEMIC FINDINGS

- Ecosystem responses to climate extremes of similar magnitude can vary significantly between climates and regions: productivity of grasslands in drier climates was more strongly reduced by drought than in more mesic climates. However, grasslands in dry climates show better recovery potential to drought.
- Increased trait variation through higher plant species diversity can alleviate negative drought effects, suggesting that biodiversity loss may especially threaten resilience of ecosystems exposed to climate extremes.
- SIGNAL further showed through a meta-analysis on mowing techniques that their adjustment in frequency and cutting height are effective tools for maintaining or increasing biodiversity, i.e. by cutting at least once per year, and not too high above the ground level.
- Survival and establishment of non-native invasive species after drought vary between climates and regions, with non-native species sometimes showing superior competitive performance under drought compared to native species.
- The richness of functional groups such as forbs, grasses and annuals and presence of legumes did not affect resistance to extreme drought, but can predict dynamics in the years following it, based on the prior presence of given dominant functional groups.

PROJECT PARTNERS – University of Bayreuth, **GERMANY** (coordinator: A. Jentsch); University of Antwerpen, **BELGIUM**; Bulgarian Academy of Sciences, Sofia, **BULGARIA**; Institut National de la Recherche Agronomique (INRAe), Clermont-Ferrand, **FRANCE**; Hungarian Academy of Sciences, Vácrátót, **HUNGARY**; University of Camerino, **ITALY**; University of Bern, **SWITZERLAND**; University of Selal Bayar, Manisa, **TURKEY**

DURATION – March 2013 to December 2016

FUNDING – €1,271,145 under the 2011-12 BiodivERsA call ; national funders: PT-DLR/BMBF (DE), BelSPO (BE), BNSF (BG), ANR (FR), and RCL (LT).

ACADEMIC RESULT HIGHLIGHT

The relationship between plant diversity and productivity has stimulated a long-running debate. A classic hypothesis, the humped-back model (HBM), states that plant species richness peaks at intermediate productivity, taking above-ground biomass as a proxy for annual net primary productivity. Indeed, at low productivity, few species can tolerate the environmental stresses, whereas at high productivity a few highly competitive species dominate. Over time the HBM has become increasingly controversial, and recent studies claimed to have refuted it. SIGNAL substantially contributed to provide evidence in support of the HBM pattern at both global and regional scales, based on data from coordinated surveys conducted in grasslands located across the world and comprising a wide range of site productivities.

Fraser, L. H. et al (2015) *Worldwide evidence of a unimodal relationship between productivity and plant species richness. Science*, 349(6245), 302–305

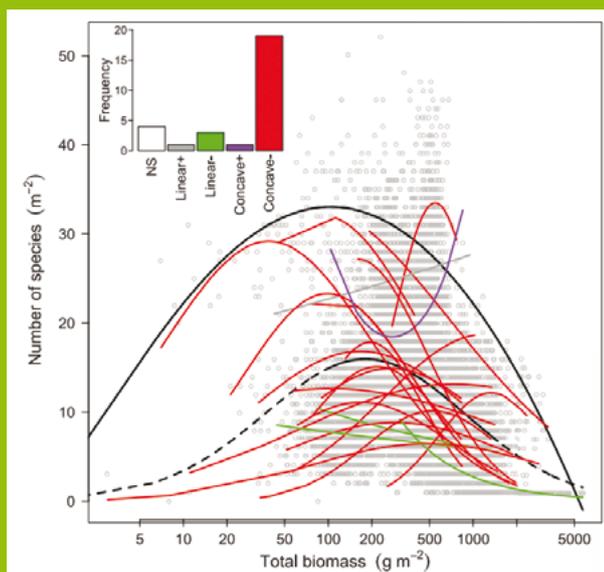


Figure 26: Biomass production-species richness relationships for 28 study sites. Solid black line indicates the significant regression for the overall relationship between number of species and total biomass. Colored lines correspond to relations for individual sites. The color refers to the form of relationship, as presented in the inset (in particular red = concave-, corresponding to the humped-back model).

WORKING WITH SOCIETY AND POLICY

SIGNAL aimed to strengthen the science-society/policy interface by delivering timely, relevant, evidence-based and understandable knowledge to managers and policy-makers about the resilience capacity of European grasslands in the face of unknown future climate extremes. To do so, it performed analyses of how SIGNAL project results inform specific national and EU policies, and engaged both at supra- and sub-national levels, targeting in particular:

- National biodiversity strategies, by engaging with national government representatives, as well as with national Natura2000 managers in the four project countries, which were contacted during the proposal design phase.
- European policy-makers, in particular by informing the services of the European Commission on the implementation of the 2020 Biodiversity Strategy, but also on Agro-Environmental Payment in the European Common Agricultural Policy.

SOCIETAL/POLICY IMPACT HIGHLIGHTS

- ✓ **SIGNAL policy brief** – The project produced its own policy brief on European Gradients of resilience in the face of climate extremes, highlighting project findings and their concrete implications for EU policy-making (<http://www.biodiversa.org/1123/download>)
- ✓ **Articles in EU policy reviews** – Two interviews of the SIGNAL project coordinator resulted in publications disseminated among EU politicians in 2017 (Research Media EU and PEN Science and Technology)
- ✓ **Field trip on sustainability and science-policy interface** – A secondary school (45 students from Markgrafen Wilhelmine Gymnasium Bayreuth, Germany) visited the SIGNAL experimental site in summer 2017, discovering SIGNAL results and their practical implications for policy.

TIPPINGPOND

Identifying tipping points, early warning signs and management options in ponds and lakes in a changing climate

CONTEXT

Ponds and shallow lakes are very important for regional biodiversity and strongly contribute to ecosystem services such as carbon storage, recreation and fish production. They are also excellent model systems for the theory on regime shifts in ecosystems, where initial resilience to environmental change is lost upon reaching a disturbance threshold. Ponds and lakes can show clear shifts from a clear-water to a turbid state upon eutrophication (excessive algal growth and biomass accumulation, occurring naturally or because of excessive nutrient loads) or with temperature increase, resulting in lower biodiversity at different trophic levels and declines in ecosystem services.

OBJECTIVES

Focusing on ponds and shallow lakes, TIPPINGPOND explored whether ecosystem characteristics can predict resilience and tipping points in relation to eutrophication and climate change, and translate these into policy and management recommendations for preserving of ecosystem integrity.

APPROACH

Through a combination of experimental approaches and field survey data, and engaging with local stakeholder groups at each step, TIPPINGPOND:

- Sampled in i) natural lakes to identify potential tipping points along gradients of brownification and nutrient concentrations in particular in Sweden, and ii) farmland ponds along an eutrophication gradient in Belgium to identify links between ecosystem structure, environmental conditions and biodiversity;
- Completed existing datasets on fish culture ponds in France and Belgium to quantify stability in ecosystem characteristics and tipping points;
- Conducted a series of field and controlled indoor mesocosm experiments in Sweden and Germany, to identify i) thresholds in brownification and nutrient contents for shifting lakes, ii) the links between the diversity and composition of zooplankton communities and the resilience of lakes to nutrient and temperature increases and iii) the effects of oligotrophication (partial reversal of eutrophication) and increasing temperature stress on phytoplankton communities.

MAIN ACADEMIC FINDINGS

- TIPPINGPOND identified tipping points for multiple aquatic organism groups along a gradient of eutrophication.
- Analyzing variability in environmental conditions and zooplankton community characteristics in fish ponds revealed that ecosystem characteristics are most significantly affected by pond management practices.
- Field surveys in farmland ponds also showed that high initial diversity stabilizes resource use efficiency of plankton communities.
- TIPPINGPOND showed that brownification altered the composition of communities, but had little impact on plankton functioning in boreal lakes, and that functional recovery was faster and more complete than compositional recovery.
- Outdoor experiments showed that gradual environmental change allows for adaptation of zooplankton communities. Genetic adaptation in response to environmental stressors had marginal effects on population structure and community composition, but significantly influenced ecosystem functioning.
- Based on these findings and collaboration with local managers, TIPPINGPOND developed a framework for optimizing biodiversity conservation in large fish pond complexes.

PROJECT PARTNERS – Katholieke Universiteit Leuven, **BELGIUM** (coordinator: L. De Meester); ISARA, Lyon, **FRANCE**; Carl-von-Ossietzky University, Oldenburg, **GERMANY**; University of Uppsala, **SWEDEN**

DURATION – May 2013 to April 2016

FUNDING – €860,817 under the 2011-12 BiodivERsa call ; national funders: BelSPO (BE), ANR (FR), PT-DLR (DE), Formas (SE)

ACADEMIC RESULT HIGHLIGHT

Climate is changing rapidly, and natural populations' capacity to adapt genetically is key to predict responses. TIPPINGPOND demonstrated genetic change in the capacity of the water flea *Daphnia* to tolerate higher temperatures using both a selection experiment and the reconstruction of evolution over a period of forty years derived from a layered dormant egg bank. They observed a genetic increase in thermal tolerance in response to a two-year ambient +4° C selection treatment (fig. a.) and in the genotypes of natural populations from the 1960s and 2000s hatched from lake sediments (fig. b.). This study is the first to demonstrate both the capacity for rapid evolution of thermal tolerance and actual genetic change over recent decades associated with climate change in natural populations.

Geerts, A. et al (2015) *Rapid evolution of thermal tolerance in the water flea Daphnia*. *Nature Climate Change* 5, 665–668

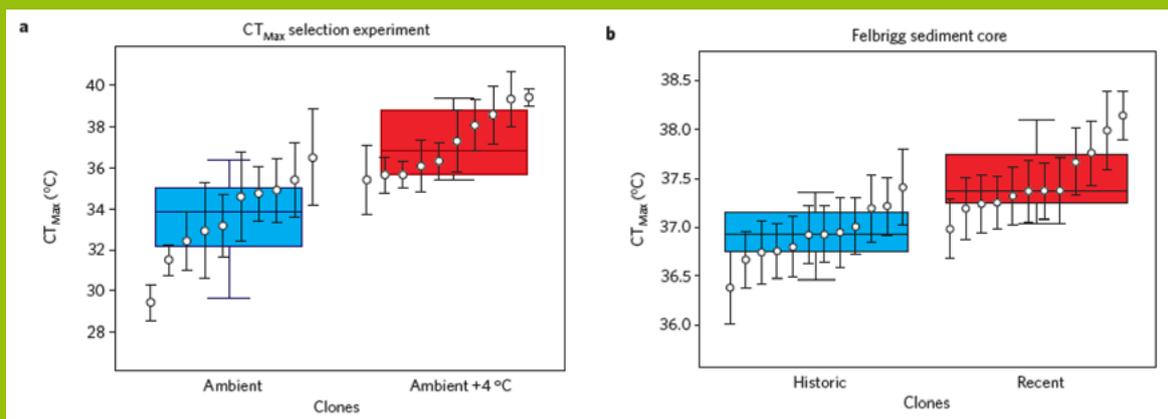


Figure 27: Average critical thermal maxima (CT_{max}) for *Daphnia* clones from a selection experiment (plot a, grouped by selection temperature, 'ambient' or 'ambient+4° C') and from Felbrigg Hall Lake (plot b, Historic clones from sediment dated 1955–1965 and recent clones from sediment dated to 1995–2005). In both panels, results clearly show the potential of *Daphnia* populations to evolve higher heat tolerances.

WORKING WITH SOCIETY AND POLICY

TIPPINGPOND involved stakeholders at every step of the project design and implementation:

- Fishpond managers and private owners from the study sites, as well as local authorities (e.g. Belgian Agency of Nature and Forests) and local NGOs were involved in the design of the project and case-study selection, and attended regular local meetings to discuss implementation and results.
- Local fishpond managers also provided data on fish stocks and management practices, while TIPPINGPOND organised a workshop with French, Belgian and German managers to discuss project findings and a field visit of the French case-study.
- Local policy-makers, commercial users and the general public at case-study sites were interviewed on perceptions of biodiversity and ecosystem services, informing the development of recommendations (see highlights).

SOCIETAL/POLICY IMPACT HIGHLIGHTS

- ✓ **Fishpond toolkit and brochures** – TIPPINGPOND co-developed a toolkit of fish pond practices promoting extensive and sustainable fish production based on natural resources. It is addressed to local fishpond managers and accompanied by a series of practical context notes (available here: <http://www.biodiversa.org/525>)
- ✓ **BiodivERsA policy brief** – TIPPINGPOND contributed key results in relation to pond systems for a brief on “**Measures to increase ecosystem resilience and avoid tipping points**”, presenting how their work allows characterization of tipping points for ponds (see: <http://www.biodiversa.org/1355>)
- ✓ **Local press articles** – TIPPINGPOND results were shared in local press articles, notably in the EOS Maanblad Over Wetenschap magazine (Nov. 2014) and in the DeBoomklever local magazine (Dec. 2015)

TIPTREE

Predicting potential for successful genetic adaptation of tree populations on the decline in a changing environment

CONTEXT

Forests provide a bundle of key ecosystem services, including wood production, carbon sequestration, freshwater availability and biodiversity sustainability. Impacts of climate and land-use changes on forests are expected to be acute, but the adaptive potential could nonetheless be high in tree populations. Indeed, besides spatial migration (without adapting), tree populations could adapt through plasticity (short term, individual physiological tolerance) or evolutionary response (longer term). However, observed and predicted rates of environmental changes raise the issue of how quickly tree species can adapt.

OBJECTIVES

The TipTree project investigated to what extent trees have the potential to adapt to ongoing climate change, and the array of roles human actions can play in this adaptation.

APPROACH

TipTree used a predictive ecology approach combining:

- genomic and genetic estimates of population adaptive potential for six alpine, temperate, Mediterranean and tropical tree species,
- modelling of tree population eco-evolutionary dynamics, investigating in particular tree abilities of rapid adaptation (in 1 to 10 generations), in different parts of the species range and particularly in warm margins where tipping points are most expected, and
- dialogue between researchers and stakeholders to identify challenges and adaptive solutions for forests under climate change.

MAIN ACADEMIC FINDINGS

- Genomic approaches allowed to identify genes under divergent selection in nearby populations, confirming landscape-scale patterns of local adaptation in mountain and tropical forests. TipTree demonstrated how physiological process-based models can be used promisingly to assess the mortality risk of forest trees under a given climatic scenario.
- TipTree produced new scientific knowledge for the response to climate change of 5 major tree species of European forests (*A. alba*, *F. sylvatica*, *P. abies*, *P. halepensis* and *Q. robur*) and one major tropical species from South America (*E. falcata*). Results showed that the studied tree populations harbor much genetic variation, and that genetic diversity for stress responses is structured along environmental (e.g. temperature and water stress) gradients as the result of past selection.
- Using both genomic and quantitative genetics approaches, TipTree confirmed the high adaptive potential of tree populations, that they can evolve over a few generations, and that phenotypic change contributes to mitigate population decline.
- Based on a co-identification of challenges with their stakeholders, TipTree produced scenarios for mixed *A. alba*/*F. sylvatica* mountain forests along altitudinal gradient, in face of increasing temperature/decreasing precipitations.



PROJECT PARTNERS – French Research Institute for Agriculture, Food and Environment (INRAe), **FRANCE** (coordinator : S. Oddou); Office National des Forêts, **FRANCE**; University of Montpellier, **FRANCE**; University of Marburg, **GERMANY**; University of Uppsala, **SWEDEN**; Fed. Of Swedish Family Forest Owners, LRF, **SWEDEN**; CNR, **ITALY**; CIFOR-INIA, **SPAIN**; European Forest Institute, **SPAIN**; University of Akdeniz, **TURKEY**

DURATION – December 2012 to December 2015

FUNDING – €1,015,278 under the 2011-12 BiodivERsA call ; national funders: ANR (FR), Formas (SE) and PT-DLR (DE)

ACADEMIC RESULT HIGHLIGHT

TipTree researchers contributed to integrate knowledge on adaptive capacity and exposure to climate change and provided tools to support conservation management of forest trees. This is illustrated with the maritime (*Pinus pinaster* Ait.) and Aleppo (*Pinus halepensis* Mill.) pines. In a study case they identified areas suitable for in situ conservation of most genetic groups of these species, to the exception of central–eastern–southern Iberian genetic groups of maritime pine and the Moroccan genetic group of Aleppo pine which required ex situ conservation. They also proposed a framework to increase the efficiency of the European conservation network (EUFORGEN and EUFGIS programmes)

Serra-Varela MJ, Alía R, Daniels RR, et al. (2017) Assessing vulnerability of two Mediterranean conifers to support genetic conservation management in the face of climate change. *Diversity and Distributions* 23:507–516. <https://doi.org/10.1111/ddi.12544>

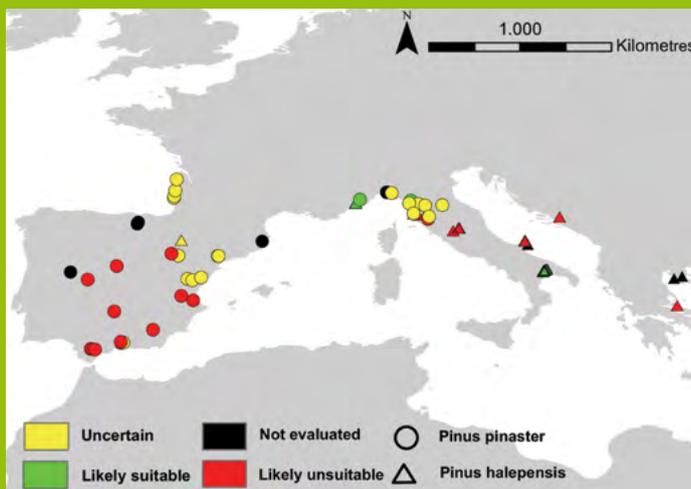


Figure 28: Exposure to climate change assessed for the EUFGIS dynamic conservation units of *Pinus pinaster* and *Pinus halepensis* along their natural distribution

WORKING WITH SOCIETY AND POLICY

TipTree was designed together with stakeholders with a specific interest in identifying adaptation levels that could be operated in forest management. During the projects' life:

- TipTree directly involved national and European policy advisors as partners (ONF in France, LRF in Sweden, EFIMED for Mediterranean areas) in project framing and the identification of management responses to climate change for model forcing during the project.
- A joint prospective workshop on adaptation of Mediterranean forests to climate change was co-organised with ONF, targeting various stakeholder groups
- Local stakeholders like the Bavarian Office for Forest Seeding and Planting and Bavarian Forest National Park supported field work
- TipTree worked with a broad range of national and European stakeholders (UN organisation, national ministries and NGOs) to synthesize the major challenges imposed by climate change –and more generally global change– to forests in Europe in the 21st century, for which genetics and vulnerability assessments can contribute to the development of appropriate practical solutions.

SOCIETAL/POLICY IMPACT HIGHLIGHTS

- ✓ **BiodivERsA policy brief** – TipTree contributed key results supporting a brief on “Measures to increase ecosystem resilience and avoid tipping points”, in relation to the characterisation of tipping points and indicators for the management of European forest ecosystems in the face climate change (<http://www.biodiversa.org/1355>).
- ✓ **Co-written report** – Based on a workshop organised in 2014 and involving 26 stakeholders (national and International; including forest managers, forest owners' representative, conservationists, policy makers, forest agencies and researchers), this report focuses on “realistic” management scenarios, including soft and hard options: *From science to practice: the contribution of projects TipTree and AMTools to guiding better forest survival and regeneration under Global Change scenarios*
- ✓ **GenTREE H2020 follow up project** – Seeking to optimize the sustainable use and management of forest genetic resources in Europe, this project involves the TipTree researchers and the European Forest Institute. It integrates tools developed in TipTree (models) and generalises the approach used in TipTree in several locations to the European scale (<http://www.gentree-h2020.eu/>)





Projects funded under the BiodivERsA call 2012-13 on
“invasive species and biological invasions”



DIARS

Advancing the use of remote sensing in tackling the huge problem of Invasive Alien Species

CONTEXT

Invasive alien species have become a major threat to biodiversity, human health and economic development. The development of warning and rapid response systems, called upon by biodiversity conservation policy of the European Commission, has been limited by abilities to detect, monitor and assess the impact of invasive species from the ground. However, recent advances in remote sensing and the increasing availability of free open-source software provided a powerful opportunity to tackle this challenge and generate relevant tools to monitor invasions and their impacts combining field and remote sensing observations.

OBJECTIVES

DIARS aimed to advance the use of remote sensing in tackling invasive species, pioneering the use of such techniques in the context of biological invasions in Europe.

APPROACH

DIARS focused on three different invasive alien plant species: a bryophyte species (*Campylopus introflexus*); a shrub species (*Rosa rugosa* – serving as a benchmark for the project methods); and a tree species (*Prunus serotina*) in two different ecosystems: dune habitats (Belgium and Germany) and forest stands (France) in order to:

- Characterize invasions and their impacts on ecosystem and validate novel approaches, combining high density LiDAR and airborne hyperspectral APEX imagery with high quality field datasets, evaluating the potential and limits of these new approaches
- Create accurate fine scale maps and predictive models of the distribution of invasive plant species at the landscape scale, and assess potential generalization of the approach across ecosystems and species
- Support monitoring, prediction of spread and risk assessment for non-native invasive plant species in support of management measures, through the development of decision-support tools and trainings.

MAIN ACADEMIC FINDINGS

- DIARS validated the ability of airborne hyperspectral remote sensing data to generate reliable distribution maps of *C. introflexus*, suggesting that such data can provide reliable information about invasion degrees as an alternative to field approaches over large areas.
- It successfully showed that the project's mapping methodology can be transferred to other areas, limiting the need to collect additional field data.
- DIARS developed a novel sampling design for invasive species to collect presence-absence data which allows for robust estimates of their realized distributions and projections of potential distributions.
- DIARS also quantified the impact of *Prunus serotina* on structural and leaf chemical vegetation traits, suggesting that it changes biochemical cycles to its own advantage and alters the photosynthetic capacity of the long-lived indigenous broadleaved species, with consequences for the climate change mitigation potential of these forests in the long term.



C. Introflexus

PROJECT PARTNERS – Flemish Institute for Technological Research - **BELGIUM** (coordinator: R. Van De Kerchove); Katholieke Universiteit Leuven – **BELGIUM**; CNRS/University of Picardie Jules Verne– **FRANCE**; Friedrich-Alexander-Universität Erlangen, Nürnberg – **GERMANY**; Karlsruhe Institute of Technology – **GERMANY**; Fondazione Edmund Mach, Research and Innovation Centre – **ITALY**; Carnegie Institution for Science – **USA**

DURATION – January 2014 to December 2016

FUNDING – € 1,107,399 under the 2012-13 BiodivERSa call; national funders: BelSPO (BE), ANR (FR), DFG (DE).

ACADEMIC RESULT HIGHLIGHT

The uneven distribution of invasive species within the invaded ranges introduces uncertainty in species presence–absence data collected from the field, as these may either reflect unsuitable sites or be incidental. DIARS researchers contributed to an environmental systematic sampling design to collect presence–absence data and a probability index to sort dispersal-limited absences and unsuitable sites. Applying their framework to the non-native tree species *Prunus serotina* which is invasive in Europe, they demonstrated high model performances. This enabled to provide managers with robust estimates of both realized and potential distributions of invasive species.

Hattab T. et al. (2017). A unified framework to model the potential and realized distributions of invasive species within the invaded range. *Diversity and Distribution*, 23: 806-819

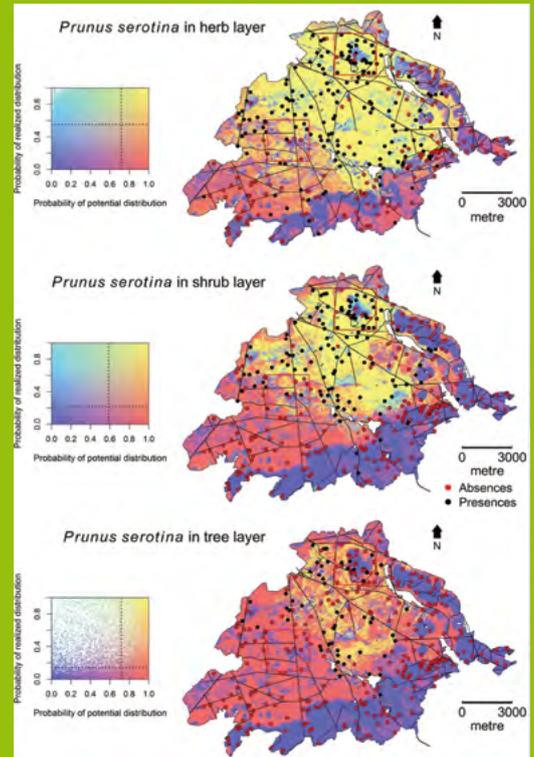


Figure 29: Maps of potential versus realized distributions, with areas likely already invaded (yellow), areas not yet invaded but with a high risk (red), areas with a low risk of invasion (dark blue) and areas likely to be invaded but which should not be, given environmental conditions (i.e. due to habitat quality and source–sink dynamics (light blue))

WORKING WITH SOCIETY AND POLICY

DIARS engaged in particular with local to national authorities and NGOs, as well as with protected area managers. In particular they

- Worked with nature conservation and management authorities to collect data, conduct sampling and/or analyse data at local sites, sometimes leading to joint publications (e.g. State agency for coastal protection, national parks and sea protection of Schleswig-Holstein, French Office for Forests ONF)
- Set up a steering committee involving the Belgian Biodiversity Platform, the LUP (Luftbild, Umwelt,

Planung and the Conservatoire Botanique National de Bailleul to provide expertise on alien and native invasive plants as well as in remote sensing, providing progress reviews and recommendations for focus and adjustments.

- Conducted training workshops at local sites. Work with the Nature Conservation Agency in the Sylt case study (Germany) in particular helped them realize that *C. introflexus* was invading the dunes of the Sylt island, which was unnoticed previously. See a workshop [video here](#).

SOCIETAL/POLICY IMPACT HIGHLIGHTS

DIARS toolbox – It was developed in collaboration with the steering committee and intended for engaging and educating stakeholders and end-users such as ecologists, nature conservation agencies and land managers. It is a series of walk through tutorials on the DIARS remote sensing-based framework for mapping, modelling and assessing the impact of biological invasions. Developed as a free and open source software, it has been used for students and at the different case-study sites to map species, model distributions and assess impacts of biological invasions (see: <http://diarsproject.github.io/DIARS/HomeDIARS.html>). DIARS also provided a hands-on training session with the toolbox, organised within the EUFAR training course [RS4FOREST EBV](#) in the Bavarian Forest National Park and at the German Aerospace Centre (DLR).

EXOTIC

Understanding genetic mechanisms at play behind the adaptation of biological invaders to inspire novel management strategies

CONTEXT

Invasive species cause important ecological and economic problems. Evolutionary forces can lead alien species to a better adaptation in the introduced environment, but often too little is known about the specific genetic mechanisms underlying them. The example of the Asiatic ladybird *Harmonia axyridis* is edifying: originating from Southeast Asia and used as a biological control agent in North America and Europe, it is now considered as an invasive species in these areas. Although introduced into new areas since 1916, established populations were observed only recently (since 1988 in the USA and 2001 in Europe). The main negative impacts include the loss of biodiversity through intraguild predation, infestation of homes resulting in allergies, and deterioration of fruit and wine quality. Yet the underlying genetic mechanisms for the adaptation of the Asiatic ladybird were not well established, hindering management and policy responses.

OBJECTIVES

EXOTIC aimed at understanding the adaptive changes that have taken place during *H. axyridis* invasions through genome-wide comparison of native, biocontrol and invasive populations.

APPROACH

Building on an interdisciplinary approach integrating ecology, evolution, analytical chemistry and genomics at several levels (genes, phenotypes, individuals and populations), EXOTIC:

- Identified most important genomic regions of *H. axyridis* adaptations linked to life-history traits (e.g. timing of reproduction, age and size at maturity and growth pattern, longevity, etc.) that affect its invasion success;
- Conducted experimental studies and population genomics analyses, with particular attention to the contemporary shifts of identified life-history traits.
- Deciphered the main adaptive pathways behind the global invasive success of *H. axyridis* and assessed the negative impacts on native ladybird species, in view of pre-identifying novel management strategies.

MAIN ACADEMIC FINDINGS

- EXOTIC generated a large amount of genomic information on *H. axyridis* (transcriptome, genome and population data) and developed three new inferential methods to optimize the statistical treatments of the next-generation sequencing data produced.
- EXOTIC uncovered crucial genomic information to better understand why non-melanic and melanic morphs are present on the native area of the species, whereas the non-melanic one is fixed in the vast majority of invasive populations.
- Investigating traits linked to invasiveness (body mass and generation time), EXOTIC results indicate that genetic responses to natural selection can be very quick. Testing natural selection based on body mass had only a minor impact on other traits. However, testing natural selection based on shorter generation time lines revealed shifts on other traits such as fecundity, at least partly explaining the evolved phenotypes displayed by invasive populations.
- EXOTIC also advanced the understanding of this invader's biology with direct implications for management. The project demonstrated for the first time in the Coccinellidae family that female *H. axyridis* produce a volatile sex pheromone, and confirmed that microsporidia associated with the specie can be lethally transferred to some indigenous ladybird species, explaining their early and significant declines upon colonization by the invasive ladybird.
- Using Chromatography-Mass Spectrometry and bioassays, EXOTIC found differences in both induction patterns and induction levels for antimicrobial effector genes, highlighting a clear advantage of introduced invasive *H. axyridis*.

PROJECT PARTNERS – INRAE, Montpellier, **FRANCE** (Coordinator: B. Facon); Université de Liège – **BELGIUM**; Justus Liebig University of Giessen, **GERMANY**; Max Planck Institute for Chemical Ecology, Jena, **GERMANY**

DURATION – December 2013 to November 2017

FUNDING – € 675,350 under the 2011-12 BiodivERsA call ; national funders: ANR (FR), BelSPO (BE) and DFG (DE)

ACADEMIC RESULT HIGHLIGHT

Biological invaders have long been hypothesized to correspond to the fast end of the life history spectrum, with early reproduction and a short lifespan. EXOTIC contributed to examine the rapid evolution of life history within the ladybird *H. axyridis*. Results show that biocontrol populations have evolved a classic fast life history during their maintenance in laboratories, while invasive populations also reproduce earlier than native populations, but later than biocontrol ones, and allocate more resources to reproduction. Overall, invasiveness was not explained only by faster life histories: the rapid evolution of life history actually allowed invasive populations to converge to a fine match between the invaded environment and the invader.

Tayeh, A. et al. (2015) *Biological invasion and biological control select for different life histories*. *Nature Communications*, 6, 7268

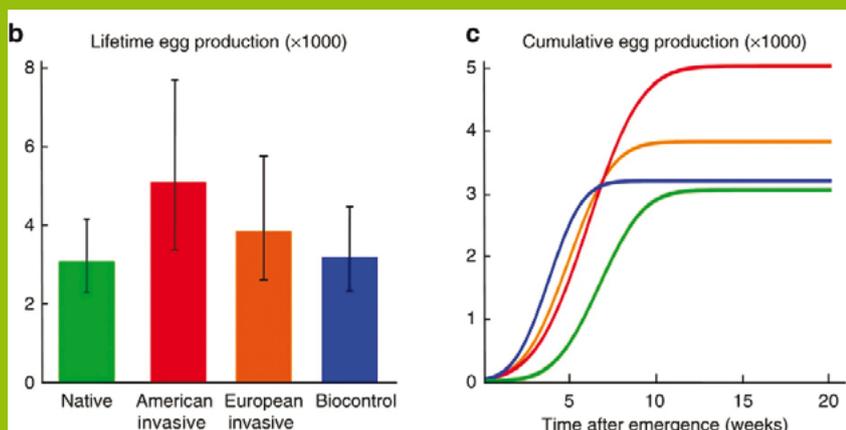


Figure 30: (a) Lifetime egg production (mean with 95% confidence intervals) per type of population. and (b) Cumulative egg production along lifetime within each type of population. These results highlight the specific strategies that include more resource allocation to reproduction by invasive populations.

WORKING WITH SOCIETY AND POLICY

EXOTIC worked with a variety of stakeholders, including both public and private sectors and policy and practice:

- National and local policy makers were engaged during the project, including contributions of project results to the French national group on invasive species when elaborating management recommendations, and presentations on invasive potential threats to mayors in Thuringia (Germany).
- EXOTIC also interacted with pharmaceutical and biotech companies in Germany, in particular with Sanofi part of a collaboration between Sanofi and

the Fraunhofer project group Bioresources. This related to the biological profiling of selected antimicrobial effector genes from *H. axyridis* against human pathogens. *H. axyridis* and other ladybirds have been suggested on this occasion as a source for natural products to the Federal Association of Pharmaceutical Companies.

- Results of the project have used in the context of a successive French project (BIOFIS) dealing with academic and applied research actions on invasive species, involving protected areas and wildlife managers confronted with invasive species.

SOCIETAL/POLICY IMPACT HIGHLIGHTS

- ✓ **General public documentary** – EXOTIC partners actively contributed to the production of a general public documentary film on biotechnologies applied to insects entitled “Bugs - Nature’s Little Superheroes”. It was produced by French, German and Swedish media and broadcasted in May 2017. It received several awards across Europe and Asia (<https://javafilms.fr/film/bugs-natures-little-superheroes/>).
- ✓ **Contributions to a French biology school book** – EXOTIC contributed to writing a chapter in the next ‘Life & Earth Sciences-SVT’ book for the French high school students, focusing on the genetics of color polymorphism in *Harmonia axyridis* (see <https://planet-vie.ens.fr/thematiques/genetique/expression-genetique/du-genotype-au-phenotype-les-motifs-des-coccinelles>).

FFII

Forecasting Future Invasions and their Impacts for preventive management

CONTEXT

It is widely accepted that prevention and early responses are the best strategies to mitigate the impacts of invasive alien species. Consequently, research efforts must focus on prediction, both of the likely distribution of invasions and their impact in newly invaded areas. Global environmental changes are crucial for these predictions. It is also important to combine a better understanding of robust, general outcomes from global studies with a more detailed understanding of mechanisms from specific communities locally.

OBJECTIVES

FFII aimed at better forecasting the future of invasions and their impacts worldwide. To reach this goal, particular attention was paid to patterns, processes and the impacts of biological invasions globally, combined with a specific study on ant species as biological invaders in New Caledonia.

APPROACH

To do so, FFII:

- Studied large-scale patterns of biological invasions to predict invasion risks, combining invasive species' databases (e.g. the "100 worst invader" species), distribution models and species niches regarding climate to determine which areas are at greatest future risk of invasion by which species.
- Studied processes of invasion by ants, looking at functional traits of over 2,200 ant species to derive a 'profile' for invasive ants, screen species for potential invasiveness and guide preventative management.
- Linked global databases of invasive and endangered species to study invasive species' impacts (including socio-economic), allowing development of an impact classification scheme and prediction of 'worst invaders' and areas at greatest risk through synthesis of available data.
- Conducted field studies at the local scale to support global studies with a finer understanding of ecosystem impacts of the invasive little fire ant (*Wasmannia auropunctata*) in New Caledonia.

MAIN ACADEMIC FINDINGS

- Studying a large number of species, FFII showed that biological invasions are amongst the second most serious threats to biodiversity, both currently and in the near future.
- FFII connected the IUCN Red List with the IUCN Global Invasive Species Database, allowing to see which invaders threaten which red-listed species worldwide. Results show the chytrid fungus *Batrachochytrium dendrobatidis* threatens the greatest number of vertebrates globally, followed by six invasive mammals that also have huge impacts on biodiversity.
- FFII demonstrated that a few of the world's current biodiversity hotspots, such as Polynesia-Micronesia and Mesoamerica, will be especially vulnerable to at least some of the currently worst invaders.
- FFII showed which ant species are likely to invade which regions (including dominance in case of simultaneous invaders) and which ones may become invaders in the coming decades.
- A large-scale analysis of invasion pathways across taxonomic groups, based on the largest currently existing pathway dataset with >8,000 non-native species, allowed to develop models predicting future ranges of currently problematic ant invaders and identifying 'invasive ant hotspots' useful for preventive management of invasions.
- At the local scale, FFII demonstrated significant cascading effects of the invasive little fire ant *W. auropunctata* on the native biodiversity and ecosystem processes in New Caledonia



W. auropunctata

PROJECT PARTNERS – Swedish University of Agricultural Sciences, Umeå, **SWEDEN** (Coordinator: D. Wardle); CNRS - University of Paris Sud, **FRANCE**; IRD - University of Marseille, **FRANCE**; Institute of Freshwater Ecology and Inland Fisheries, Berlin, **GERMANY**

DURATION – December 2013 to November 2017

FUNDING – €906,153 under the 2012-13 BiodivERsA call; national funders: Formas (SE), ANR (FR) and DFG (DE)

ACADEMIC RESULT HIGHLIGHT

FFII contributed to knowing where species that are threatened by invasive species live, and the degree to which they are threatened. This global study links for the first time 1372 vertebrates threatened by more than 200 invasive species from the Global Invasive Species Database. The novel maps of threatened vertebrates' vulnerability to invasive species allow for risk assessments for biodiversity, identifying which taxonomic groups are threatened and where. They show that most threatened vertebrates are concentrated in the Americas, India, Indonesia, Australia and New Zealand, not fully matching the current hotspots of invasions, or the current hotspots of threatened species. The differences highlighted in invasive alien species threats between regions and taxa can help efficiently target response and management plans, and achieve related targets such as those of the Convention on Biological Diversity.

*Bellard C, Genovesi P, Jeschke JM. 2016 Global patterns in threats to vertebrates by biological invasions. **Proceedings of the Royal Society B** 283: 20152454.*

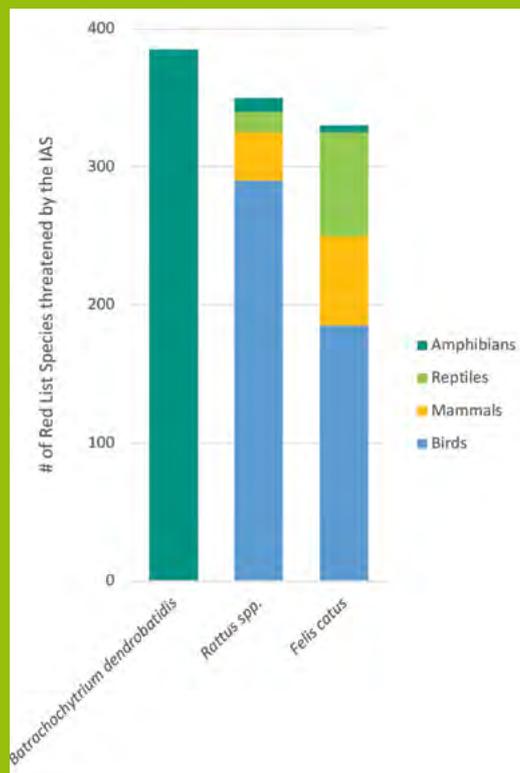


Figure 31: Top three of the invasive alien species that globally threaten the highest numbers of mammals, birds, reptiles and amphibians.

WORKING WITH SOCIETY AND POLICY

FFII engaged with stakeholders from local to international scale:

- The IUCN was closely involved throughout the project, in particular, through its Invasive Species Specialist Group, collaborating on project design and implementation, especially on the connection of Red List and GISD, defining 'impacts' and contributing to the large-scale analysis of invasion pathways.
- North and South Provincial Directories of Environment in New Caledonia, as well as local

authorities in Germany, were involved in the project design. Natural area managers in New Caledonia and a larger spectrum of New Caledonian authorities were also engaged during the project in various meetings to develop a national strategic plan against invasive species (authority in charge: Conservatoire du Patrimoine Naturel).

- The [Aspectize](#) IT start-up was involved from project start to design and realize a new generation multi-component database to study ecological characteristics of invasive ants.

SOCIETAL/POLICY IMPACT HIGHLIGHTS

- ✓ **Contributions to IUCN and CBD information document** – FFII participated in developing the IUCN *Environmental Impact Classification for Alien Taxa (EICAT)* and the complementary *Socio-Economic Impact Classification for Alien Taxa (SEICAT)*. It also co-produced with IUCN an information document for the Convention on Biological Diversity's SBSTTA 20th meeting ([Progress toward pathways prioritization in compliance to Aichi Target 9 – UNEP/CBD/SBSTTA/20/INF/5](#)).
- ✓ **Contributing to national and local strategies** – FFII contributed to several invasive species management strategies (eradication program against *W. auropunctata* in 3 valleys in Tahiti, French Polynesia; invasive ant biosecurity analysis for Tetiaroa Atoll, French Polynesia). Most importantly, it contributed to writing and implementing the [New Caledonian national strategy against invasive species](#), with special action plan against invasive ants from 2015 onwards.
- ✓ **Local and national TV documentaries and interviews** – FFII contributed to a large number of local and national documentaries (e.g. [documentary](#) on ant invasions aired on national TV, and two interviews about the projects' work on national New Caledonian evening news).

CONTEXT

Xenopus laevis, or the African clawed frog, is one of the world's most widely distributed amphibians with invasive populations that have become established on four continents. Invasions are due to both accidental escape and voluntary release of laboratory animals in many cases, with severe consequences on native populations of amphibians and fish. This species has also been implicated in the transmission of diseases severely contributing to the global decline of amphibians.

OBJECTIVES

In a context where landscape data on the presence and invasion potential of *X. laevis* in Europe was lacking, INVAXEN aimed at better understanding the biology, dispersal patterns, physiology, and invasive potential of *X. laevis* along with its impact on local amphibian populations, to guide future management and eradication efforts.

APPROACH

- Study the biology of *X. laevis*, through a comparative analysis of the native and invasive populations, evaluating the impact on local populations of *X. laevis*, dispersal patterns and the genetic diversity and gene-flow within and between populations.
- Model the future distribution of the species, through the integration of the data on movement patterns, gene flow and physiology, to model potential future distribution of the species outside of its current range under different scenarios of global change
- Contribute to reinforced eradication programs and provide support at the local, national and European levels in deciding how to restrict the ongoing, and prevent future invasions.

MAIN ACADEMIC FINDINGS

- INVAXEN conducted a first of a kind comparison of the ecology, physiology, and population genetics of both native *X. laevis* populations in South-Africa and invasive populations in Portugal and France. It allowed to understand how animals have adapted to novel environments, key to predicting their invasive success. It demonstrated invasive populations in France have greater adaptive plasticity, being issued from diverse native populations, and that the species' temperature niche has evolved post-invasion suggesting strong adaptive potential.
- The project conducted the first evaluation of the impact of *X. laevis* on both local vertebrate and invertebrate communities, looking at its diet and its role as a vector of amphibian parasites and amphibian pathogens.
- Combining their results on the adaptive potential of environmental niches in *X. laevis*, population genetic information and physiology with distribution models, regional climate models and IPCC scenarios, INVAXEN generated novel predictive maps indicating the future invasion potential of *X. laevis* at landscape scale that differed sensibly from previous work, allowing to identify areas of priority concern outside the current invasion range.



A female African-clawed frog (*Xenopus laevis*) caught at the Barcarena Stream, Oeiras, Portugal. Photo by F. Ihlow.

PROJECT PARTNERS – MNHN - CNRS Paris – **FRANCE** (Coordinator: A. Herrel); Royal Belgian Institute of Natural Sciences – **BELGIUM**; Zoologisches Forschungsmuseum Alexander Koenig – **GERMANY**; Fundação da Faculdade de Ciências da Universidade de Lisboa – **PORTUGAL**; Stellenbosch University – **SOUTH AFRICA**

DURATION – June 2014 to June 2018

FUNDING – €746,010 under the 2012-13 BiodivERSa call; national funders: ANR (FR), BelSPO (BE), DFG (DE), and FCT (PT)

ACADEMIC RESULT HIGHLIGHT

INVAXEN contributed to a global assessment of invasive amphibians in term of environmental and socio-economic impacts in comparison to other groups. Using an impact scoring system and comparing results to other previously assessed taxonomic groups (mammals, birds, freshwater fish, invertebrates, and plants), they found overall relatively similar impacts to other groups although less documented, with a few amphibian species having serious socio-economic impacts.

Measey, G.J., Vimercati, G., de Villiers, F.A., Mokhatla, M.M., Davies, S.J., Thorp, C.J., Rebelo, A.D. & Kumschick, S. 2016. A global assessment of alien amphibian impacts in a formal framework. *Diversity and Distributions* 1-12. DOI: 10.1111/ddi.12462

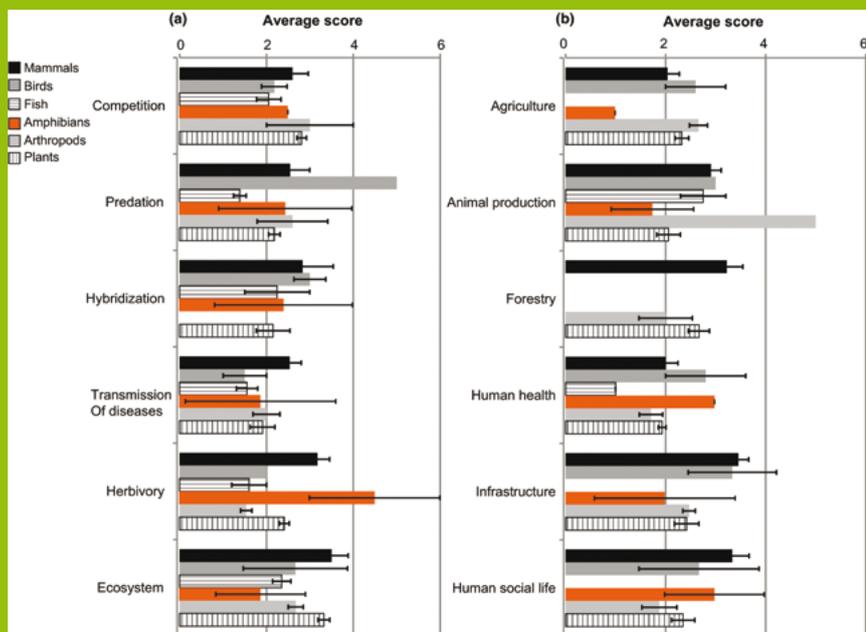


Figure 32: Average impact scores of alien amphibians (in orange) compared to other taxa already assessed (Kumschick et al., 2015a). (a) Environmental impacts and (b) socio-economic impacts

WORKING WITH SOCIETY AND POLICY

INVAXEN researchers actively engaged with local stakeholders who contributed to project development and implementation. In particular:

- Local authorities in France and Portugal, communities and land managers involved in *X. laevis* eradication were involved from the start, providing technical staff support and equipment for fieldwork.
- A specific collaboration contributed to a successful eradication programme of the Oeiras municipality (Portugal). Work in collaboration with the Governmental Institute for the Conservation of Nature and Forests allowed providing advice and

gaining insights on alterations of population size and structure of native freshwater species that are preyed upon by *X. laevis* as the abundance and distribution area of the invasive *X. laevis* decreased. This information was used to propose eradication programmes in France.

- INVAXEN models, allowing for better predictions of the invasion potential and the identification of areas of priority concern, were transferred into eradication and management efforts part of the follow-up CROAA project funded by the European Commission's LIFE programme (<https://www.life-croaa.eu/en/home/>).

SOCIETAL/POLICY IMPACT HIGHLIGHTS

- ✓ **BiodivERsA policy brief** – INVAXEN contributed key supporting results for a policy brief on the use of distribution modelling tools under different climate scenarios to inform invasive alien species risk assessment and to focus and prioritise global and national efforts against biological invasions (Action on invasive alien species should better anticipate climate change effects on biological invasions in Europe, <http://www.biodiversa.org/1307>)
- ✓ **INVAXEN animated video** – This animated movie shows the results of the project, in terms of scientific research, but also how relevant they are at societal level, and how they can help with management practices in the field (https://www.youtube.com/watch?v=m1gVZHO_L80)

PROBIS

Identifying genetic and phenotypic traits of invasive populations and their influence on invasion success to improve predictions and management

CONTEXT

Biological invasions occur when barriers limiting the spread of some species are broken-down, allowing these species to extend beyond their natural range areas. In the last century, rates of biological invasions severely increased due to human activities, and are major components of global changes, sometimes generating severe environmental, economical and societal impacts. However, the ecological and evolutionary dynamics over the course of invasion remain to be elucidated to predict future patterns of invasion.

OBJECTIVE

PROBIS aimed at identifying relevant phenotypic and genetic traits that underpin a species ability to invade a new environment. PROBIS innovatively scaled down to the intraspecific level to identify these relevant biological traits.

APPROACH

- Combine field surveys, genomic tools, large-scale semi-natural experiments and computational modeling on three model organisms (a fish, a crustacean parasite and a dragonfly) that have high ecological and socio-economic impacts
- Identify a suite of phenotypic traits, in each species, differing between recent and older populations, the mechanisms underlying these differences and their consequences for invasion on a large spatio-temporal scale
- Engage stakeholders around the development of predictive scenarios to better forecast potential invasions and provide recommendations to develop mitigation strategies accordingly.

MAIN ACADEMIC FINDINGS

- PROBIS characterized phenotypic variation along gradients of invasion for all three species. Variations concerned key life-history traits (e.g. growth rate, ability to cope with climate) and functional traits (e.g. feeding rate) that directly impact the functioning of ecosystems. They showed that the slight changes in these species' traits along the invasion gradient can impact ecosystem functioning as strongly as climate warming.
- Using novel sequencing technologies, PROBIS showed that the species' genomic diversity was highly structured along the invasion gradient, the degree of structuring strongly depending upon invasion history.
- This allowed developing a modelling framework taking into account the within-species variation observed for genetic and phenotypic characteristics. Given the low level of generality observed across the studied species, PROBIS highlighted the need to account for specificities of biological models to improve predictions in invasion rates.



PROJECT PARTNERS – CNRS /Université Paul Sabatier de Toulouse, Moulis Centre – **FRANCE** (coordinator : J. Colbert); IRD, Montpellier – **FRANCE**; GEOMAR/Helmholtz Centre for Ocean Research, Kiel – **GERMANY**; Umea University – **SWEDEN**; Mugla University – **TURKEY**; University of Aberdeen – **UNITED KINGDOM**; Bournemouth University – **UNITED KINGDOM**

DURATION – December 2013 to December 2016

FUNDING – € 675,350 under the 2011-12 BiodivERsA call ; national funders: ONEMA (FR), DFG (DE), Formas (SE)

ACADEMIC RESULT HIGHLIGHT

Facilitated by the intensification of global trade, invasions are now both common and paradoxical from an evolutionary standpoint: not only non-native environments could be different from native ones and introduced individuals ill-adapted, but also small founding population size should be associated with reduced adaptive potential. As such, biological invasions are considered valuable realtime evolutionary experiments. Here, PROBIS investigated the population structure and adaptive potential of the highly invasive topmouth gudgeon (*Pseudorasbora parva*) across Europe and East Asia. The study provides conclusive evidence for a genome-wide signature of two distinct invasion events, in Slovakia and Turkey, each originating from a specific area in the native range. A third invaded area, in France, appears to be the result of dispersal within the invasive range. Results also suggest that faster early stage development, resistance to pollution and immunocompetence contribute to the invasion success. By showing that invasive populations have different evolutionary histories, this study reinforces the idea that populations, rather than species, are the units to consider in invasion biology

Baltazar-Soares M et al. Genomic footprints of a biological invasion: Introduction from Asia and dispersal in Europe of the topmouth gudgeon (*Pseudorasbora parva*). *Molecular Ecology*. 2019;00:1–15. <https://doi.org/10.1111/mec.15313>

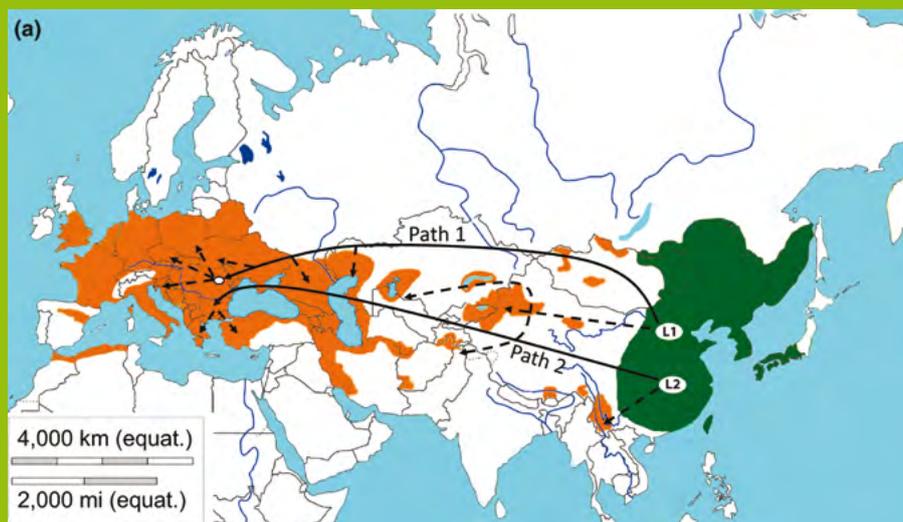


Figure 33: Geographic distribution of *Pseudorasbora parva* in native and invasive range. Identified mitochondrial lineages are represented by L1 and L2. Solid lines indicated the major introduction pathways and dashed the other introductions.

WORKING WITH SOCIETY AND POLICY

PROBIS worked with local and national stakeholders around data acquisition and the development and uptake of model predictions. In particular:

→ Natural park managers in Belgium, France, Germany, Sweden and Turkey contributed to the sampling of species in the case study sites. This allowed for efficient sampling based on their observations of the species and knowledge of the areas, and for managers to gain knowledge about ongoing invasions.

→ The National Angling Federation in France supported the uptake of the project's results by coordinating exchanges between local federations and the researchers on management of the invasive fish *Pseudorasbora parva*

→ Local and national authorities like Kalmar in Sweden and the French Agency for Biodiversity were engaged in the uptake of PROBIS results, leading to the development of policy positions and subsequent applied projects.

SOCIETAL/POLICY IMPACT HIGHLIGHTS

- ✓ **General public article in The Conversation** – PROBIS researchers were interviewed to highlight their work, building around the example of the topmouth gudgeon, its paths of invasion and socio-economic consequences (<https://theconversation.com/pathogen-carrying-invasive-fish-from-china-threatens-us-waterways-48795>)
- ✓ **Policy recommendations** – Building on the PROBIS work, the team provided a follow up report at the request of the French Biodiversity Agency to prepare policy positions in 2014 and 2015 on the invasion of studied species under the National Working Group on Invasive Species in Aquatic Environments

GC-INVAMOFECT

Uncovering the microbiome and vector competence in invasive mosquitoes in support of disease control policy

CONTEXT

Invasive, non-indigenous mosquitoes are of world-wide concern as vectors of a large range of viral and parasitic pathogens, affecting both humans and animals. Understanding current distribution and possible future expansion of invasive and native mosquito species, along with the diseases they carry, is essential to control these disease vectors and guide coherent policy and management articulating human and animal health with biodiversity conservation. Mosquitoes have proven capabilities to adapt rapidly to local environments. While their genome plays a strong role, it was suspected that microbial symbionts (and more generally insects' microbiome) likely also are a key factor in their successful adaptation to novel environments.

OBJECTIVES

In this context, GC-INVAMOFECT aimed at clarifying genomic, microbiological and ecological bases of the rapid adaptive capacities of mosquitoes, and thus their strong invasion potential and risk of pathogen transmission in colonized territories.

APPROACH

To do so, GC-INVAMOFECT:

- Investigated the role of genome and microbiome in mosquito invasions and capacity to vector diseases by comparing native, founder and colonizing populations of *Aedes albopictus* and *A. japonicus* collected worldwide, in natural to man-made environments. This accounted for both anthropogenic activities (pollution, land use etc.) and global changes (climate, trade, etc.).
- Performed experimental evolution in innovative research infrastructure, to simulate particular ecological perturbations at “semi-field” conditions and test hypotheses on genetic and ecological forces driving evolution and biological invasion and adaptation with high impact on disease transmission potential
- Studies the correlations between mosquito spreading, its microbiota content, and human activities to guide coherent policy on disease vector control articulated with biodiversity conservation.

MAIN ACADEMIC FINDINGS

- GC_INVAMOFECT allowed sampling of 50,000 specimens of mosquitoes of target invasive species and co-occurring species in Austria, France and Germany. Visual phenotyping, barcoding and genotyping confirmed the presence of *A. albopictus* in the three countries as well as *A. japonicus* in Austria and Germany.
- Modelling allowed to characterize the range of potential habitats suitable for both *A. albopictus* and *A. japonicus* in Europe, suggesting an overall range expansion and reduction for the first and the second, respectively, due to climate warming.
- The researchers showed that increasingly intensive rainfall and flooding clearly favor arbovirus transmission by mosquitoes.
- The microbiota hosted by the mosquitoes were characterized, including the presence of various mosquito-borne diseases such as flaviviruses and filarioid helminthes. Results show that the genetic diversities of both hosts and their bacterial microbiota were significantly reduced in recently established populations, suggesting a link between the microbiota shift and the vector competence of invading hematophagous insects.



Tiger mosquito (*Aedes albopictus*) known to transmit viruses such as dengue, chikungunya and Zika to humans.

PROJECT PARTNERS – CNRS, University of Lyon, **FRANCE** (Coordinator: P. Mavingui); University of Veterinary Medicine, Vienna, **AUSTRIA**; IRD, Université de Montpellier, **FRANCE**; Goethe University, Frankfurt am Mein, **GERMANY**

DURATION – December 2013 to November 2016

FUNDING – €1,034,434 under the 2011-12 BiodivERsA call ; national funders: ANR (FR), FWF (AT) and DFG (DE)

ACADEMIC RESULT HIGHLIGHT

The global emergence and re-emergence of mosquito-borne diseases has led many researchers to conduct studies of both the mosquito hosts and their microbiota, leading to a broad description of the bacterial communities hosted by mosquito populations. GC_INVAMOFECT conducted a review describing key advances in the field of the mosquito microbiota research while also encompassing other microbes and the environmental factors driving their composition and diversity. Recent findings on the microbiota functional roles underline their interactions with the host biology and pathogen transmission. This led the researchers to show how applying the holobiont concept (originally used in coral research and which describes the assemblage of a host and the many other species living in or around it, forming together an ecological unit) to mosquitoes and their microbiota is useful to get a comprehensive understanding of the vector pathosystem functioning. This can also help developing innovative and efficient novel vector control strategies.

Guégan, M. et al (2018) *The mosquito holobiont: fresh insight into mosquito-microbiota interactions*. *Microbiome* 6, 49

Pathogen		Mosquito	Microorganism	Interference
Arboviruses	Dengue virus	<i>Aedes aegypti</i>	<i>Serratia odorifera</i>	Enhances susceptibility to the virus
			<i>Chromobacterium</i>	Increases infection resistance Antiviral activity Immune elicitor
			Enterobacteriaceae, Esp_jvi isolate, alternatively <i>Salmonella</i> , <i>Escherichia</i> or <i>Shigella</i>	Decreases antibacterial activity Reduces virus dissemination titer
			<i>Wolbachia</i>	Reduces susceptibility to the virus

Figure 34: Examples of microbial interference between microbiota and vector-borne pathogens, as synthesized in this review. This highlights how multipartite interactions between the pathogen, the mosquito and its bacterial microbiota have become a major target for developing new control strategies in order to stop pathogen transmission and related epidemics.

WORKING WITH SOCIETY AND POLICY

GC-INVAMOFECT sought to lay grounds for innovative disease vector control techniques, and worked with local and national stakeholders to do so during and in the follow-up of the project:

→ Sampling design was developed collaboratively with local and national authorities in charge of mosquito management (e.g. Entente Interdépartementale pour la Démoustication, in France; Austrian Agency for Health and Food Safety) which were informed of presence of invaders and then more generally of project results

→ National policy-makers were informed of project work and results, leading to the support of follow-up work on innovative vector control strategies based on project results at national level. These policy-makers included the French National Agency for Food, Environment and Work safety (ANSES) and the German Federal Office for Agriculture and Food (BLE)

SOCIETAL/POLICY IMPACT HIGHLIGHTS

- ✓ **Technology transfer** – GC-INVAMOFECT developed novel carbon dioxide based mosquito capture methods during its sampling work, which drew the attention of a French start-up company and of the German company Biogents (<https://eu.biogents.com/>), leading to a [co-produced publication](#).
- ✓ **Interviews and articles for the general public** – GC-INVAMOFECT researchers received media attention, including on local television and in national press (e.g. Krone der Wissenschaft in Austria, [Die Presse](#) in Germany)

Understanding responses of European forests and societies to invasive pathogens

TO DEVELOP EFFECTIVE COUNTERACTIONS

CONTEXT

Several European tree species are currently under attack by different invasive pathogens, with generally large-scale invasions affecting trees with a widespread distribution. These species are an integral part of ecosystems; they are also economically important and supply crucial environmental services such as biodiversity, watershed protection, stabilization of river banks, and recreational and cultural benefits. Although widespread, different invasive pathogens have not yet affected their entire populations in Europe, unveiling an opportunity to study invasions at different stages and along different European gradients. This can allow us to deepen our understanding of their different pathways of introduction and spread, and advance early detection and warning of invasions.

OBJECTIVES

RESIPATH aimed at studying how European forest communities are affected by and respond to invasive pathogens, and at developing means to mitigate their impacts.

APPROACH

Working in nine countries from Norway to Turkey, RESIPATH focussed on elm attacked by the Dutch Elm Disease, ash attacked by the ash dieback, alder attacked by *Phytophthora alni*, and oak affected by both *Erysiphe alphitoides* and *P. cinnamomic* to:

- Investigate how the pathogens are introduced and spread
- Study the mechanisms involved in the adaptation of forest tree populations to new pathogens and those of hybridisation of invading organisms in Europe
- Assess whether the selected pathogens threaten the sustainability of tree populations in Europe
- Develop an early detection system for invasive fungal and oomycete pathogens
- Advance knowledge on how public perception is related to objective data and how mass media messages influence citizen opinions about pathogens invasion.

MAIN ACADEMIC FINDINGS

- RESIPATH uncovered a large number of species hybrids in the genus *Phytophthora*, several likely posing novel threats to European forest due to new host ranges and aggressive characters. The researchers also revealed the main environmental drivers of the aquatic and terrestrial *Phytophthora* species.
- Studying the species' spreading pathways showed a strong human role, with a strong presence in nurseries compared to natural woodlands
- RESIPATH detected the effect of natural selection on populations of Oak and Alders under attack, indicating that the degree of variation in resistance –an heritable feature– plays a key role in adaptation speed, while hybridization between closely related species may affect the evolution of these traits.
- Surveying 3,500 citizens in nine countries showed strong variations in knowledge between countries, yet awareness of the potential problems and acceptance for counteractions were comparable. Specifically, actions such as education, label of plant origin and regulation for plant production were positively received, while restrictions in trade or access to infected areas less so. National and local media coverage of ongoing attacks increased acceptance of actions.



PROJECT PARTNERS – Swedish University of Agricultural Sciences, Uppsala, **SWEDEN** (Coordinator : J. Stenlid); AgroBiolInstitute, Sofia, **BULGARIA**; ANSES Plant Health Laboratory, Malzeville, **FRANCE**; Austrian Research Centre for Forests, Vienna, **AUSTRIA**; INRAE Bordeaux; **FRANCE**; INRAE Nancy, **FRANCE**; Institute for Agricultural and Fisheries Research, Merelbeke, **BELGIUM**; Julius Kühn Institute, Braunschweig, **GERMANY**; Norwegian Forest and landscape institute, Ås, **NORWAY**; Norwegian Institute for Agricultural and Environmental Research, Ås, **NORWAY**; Plant Protection Central Research Institute, Ankara, **TURKEY**; University of Algarve, Faro, **PORTUGAL**; Centre Tecnològic Forestal de Catalunya, Solsona, **SPAIN**;

DURATION – January 2014 to December 2016

FUNDING – €1,890,394 under the 2011-12 BiodivERsA call; national funders: Formas (SE), BNSF (BG), ANR (FR), FWF (AT), BelSPO (BE), DFG (DE), RCN (NO), MFAL (TK), FCT (PT) and MINECO (ES)

ACADEMIC RESULT HIGHLIGHT

Gremmeniella abietina outbreaks in Sweden were used to exemplify how host–pathogen phenotypic interactions can help to predict the impacts of specific invasive and emergent diseases in forests. More precisely, RESIPATH demonstrated the roles of the environment and the phenotype in addition to the influence of lack of co-evolution, which explains invasive pathogens' ability to bypass the defense and/or recognition systems in the host. Results show that the lack of host-pathogen coevolution (i.e. pathogens getting in contact with hosts without any prior co-evolution) is driven by globalization. Similarly, the lack of environmental coevolution (i.e. pathogens facing new environments without prior pathogen-environment coevolution) is aligned with climate change. Both global processes are currently driving forest damage. Results suggest that globalization and climate change act synergistically, increasing the chances of both genotypic and phenotypic imbalances, and that short moves on the same continent are more in balance than if the move is from another part of the world.

Stenlid J & Oliva J. (2016) *Phenotypic interactions between tree hosts and invasive forest pathogens in the light of globalization and climate change. Philosophical Transactions of the Royal Society B* 371: 20150455

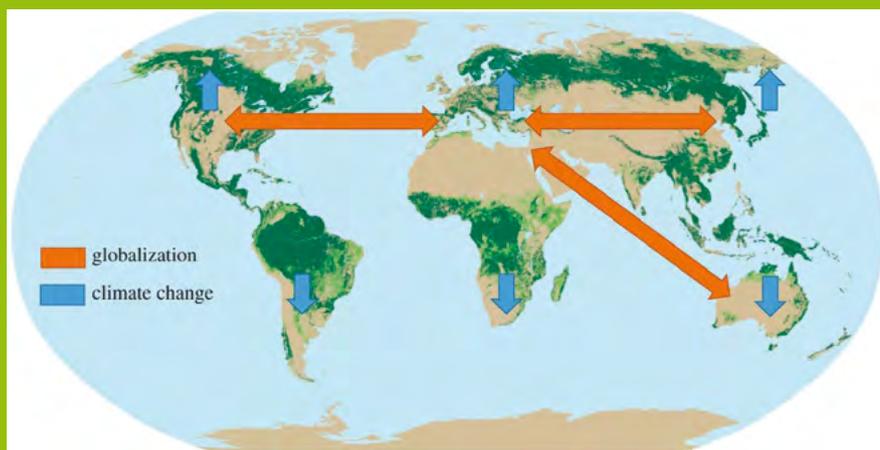


Figure 35: Map of global forest distribution highlighting how globalization and international trade can potentially bring plants from geographically distant but climatically similar locations into contact with new pathogens (orange arrows), and how predicted climate changes could enable pathogens to move short distances along climatic gradients, bringing them into contact with new host trees (blue arrows).

WORKING WITH SOCIETY AND POLICY

RESIPATH directly involved a laboratory of the French Agency for Health and Safety (ANSES) part of the consortium. In addition, researchers conducted successful engagement with various stakeholders at key steps of the project:

→ Specific activities were co-developed with local stakeholders, for instance a public survey questionnaire and sampling campaigns were co-designed with chambers and boards of agriculture in Sweden, France and Belgium.

→ Forest owners and a wide spectrum of local and national authorities were informed through regular meetings on project development and results (e.g. Bulgarian Ministry of Agriculture and Forests and the national executive forest agency), as well as NGOs (e.g. Global Water Partnership) and state businesses (e.g. Southwest State Enterprise – Blagoevgrad, Bulgaria)

SOCIETAL/POLICY IMPACT HIGHLIGHTS

- ✓ **Professional press articles** – RESIPATH published results through several specialized and professional press articles in national languages (e.g. ‘Forêts-Entreprise’ and ‘Revue Forestière Française’ in France or ‘Gartneryrket’ in Norway).
- ✓ **General press article** – RESIPATH researchers in France were interviewed by [The Conversation](#) for an article on invasive pathogens, focussing on the ash dieback.
- ✓ **Follow-up business collaboration** – as a result of the RESIPATH investigation and engagement, AgroBioInstitute and Southwest State Enterprise (Blagoevgrad) developed an applied research project testing the use of sludges of the Municipality of Pernic (Bulgaria) for recultivation of forest regions and application in forest nurseries.
- ✓ **Capacity building at the science-policy interface** – contacts established in RESIPATH led one member to be recruited in a new position as pest risk assessor at the National Board of Agriculture in Sweden.

SalmInvade

Exploring the ecological effects of salmonid invasions and their socio-economic conditions to develop their sustainable management in Europe

CONTEXT

Millions of non-native fishes (both species and genotypes) are regularly released into the wild in Europe, either intentionally by stocking or non-intentionally by escapes from aquaculture, where they can become invasive. Salmonids (salmon and trout family) are of great socio-economic and cultural importance. Widely distributed in European marine, coastal and freshwater ecosystems, they are grown and released in large numbers into the wild. Non-native genotypes are often transferred across catchments, creating an ongoing ecological and genetic burden on wild fish. For scientists, salmonids constitute an excellent model system to better understand and address the causes and consequences of freshwater invasions, integrating ecological, evolutionary, and socio-economic dimensions.

OBJECTIVES

SalmInvade aimed to study potential invasive species/genotypes of salmonids, and understand the psychological, economic and governance conditions and pathways by which society relates to these fish to ultimately develop the foundation for sustainable salmonid management in Europe.

APPROACH

SalmInvade brought together teams from Sweden, Germany, Norway, France and Canada to:

- Investigate the invasion potential of non-native salmonids in Europe, including genetically modified and non-native genotypes, and the ecological and evolutionary impacts of salmonid invasions.
- Understand the social, economic and ecological mechanisms behind the establishment of non-native salmonids, and evaluate current releases of non-native salmonids in Europe.
- Evaluate how salmonid invasions are perceived by the public and by key stakeholders in various European cultures, and how these perceptions play a role in the spread of non-native salmonids.

MAIN ACADEMIC FINDINGS

- Meta-analyses of the global ecological impacts of introduced salmonids revealed substantial negative effects. In particular, results show that the release of native individuals from a given species (intraspecific invasions) can have stronger effects than the release of non-native species (interspecific invasions).
- Comparing native Atlantic salmon performance under different invasion scenarios, SalmInvade showed that the introduction of growth-enhanced salmonids causes cascading and more diverse ecological effects than previously recognized. Combined field and laboratory studies also showed that non-native brook trout reduced the fitness of co-existing native brown trout.
- Experiments on the effect of angling on invasive salmonid phenotypes and species revealed a high vulnerability of domesticated non-native fish due to 'bolder' behaviors, indicating they could potentially be controlled by intensive fishing.
- A large-scale online survey of citizens' views on non-native salmonids showed overall low awareness, yet the majority intuitively tend to prefer salmonid-friendly river conditions.
- SalmInvade also found strong differences in governance approaches for salmonid stock and transfer, with angling clubs acting as major vectors of salmonid introductions. Overall, contextual factors (economic, social norm) drove stocking practices, with no consideration for biological effects.



PROJECT PARTNERS – University of Gothenburg, **SWEDEN** (Coordinator: J. Johnsson); Leibniz Institute of Freshwater Ecology and Inland Fisheries, Berlin, **GERMANY**; Norwegian Institute for Nature Research, Trondheim, **NORWAY**; Université Paul Sabatier/CNRS, Toulouse, **FRANCE**; Memorial University, St. Johns, **CANADA**

DURATION – December 2013 to March 2017

FUNDING – € 1,100,388 under the 2012-13 BiodivERsA call ; national funders: Formas (SE), DFG (DE), RCN (NO) and ANR (FR)

ACADEMIC RESULT HIGHLIGHT

Knowledge on the temporal dynamic of the ecological impacts of biological invasions remains extremely limited. Using a meta-analytic approach, Salmolnvaade researchers investigated how the ecological impacts of non-native brown trout (*Salmo Trutta*) vary with time since introduction, over a 170-year-long period. Results show significant negative ecological impacts shortly after the species introduction, and a decrease with time, becoming nonsignificant over a century after introduction. The decreasing pattern was consistent across ecological, geographical, and methodological contexts. Overall negative ecological impacts were more pronounced at the individual and population levels and in experimental studies. These results further indicate that rapid response of native organisms (e.g. adaptation, local extinction) likely play an important role in the decline of the negative ecological impacts, yet the time-lapse and resulting magnitude of effects in absolute terms cannot lead to neglect the negative impacts of biological invasions.

Závorka, L. et al (2018) *The negative ecological impacts of a globally introduced species decrease with time since introduction*. *Global Change Biology*; 24: 4428– 4437

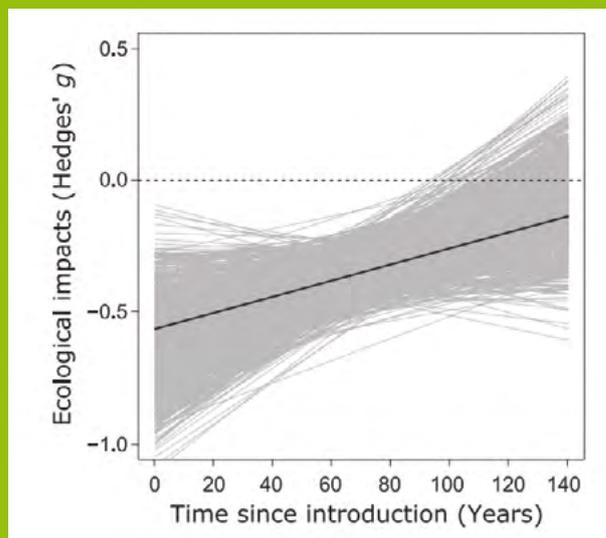


Figure 36: Ecological impacts of non-native brown trout according to time since introduction, showing that impacts were significantly negative just after introductions and became on average nonsignificant where the species was introduced more than one century ago.

WORKING WITH SOCIETY AND POLICY

Salmolnvaade significantly invested in engaging diverse stakeholders at all project stages, using different levels of engagement. In particular:

- A stakeholder reference group helped frame the project, review its implementation and interpret project results, as well as support the further engagement. The group involved national authorities (e.g. French office for biodiversity and Swedish Directory for the environment), a private company (Vattenfall AB), angling and fisheries associations from Sweden and Germany, and the IUCN Freshwater Fish Specialist Group.
- National stakeholder workshops were organised to inform on draft results and co-develop policy

recommendations, involving national and local authorities, national professional and recreational angling federations, companies (e.g. Electricité de France), NGOs (e.g. WWF Germany) and natural area managers.

- Hundreds of local angling clubs in France and Germany were engaged with support of their federations, in helping to frame consultations, providing data on views and practices. In Sweden clubs also took part in the angling experiments. All responding angling clubs in particular received an adapted synthesis of project results.

SOCIETAL/POLICY IMPACT HIGHLIGHTS

- ✓ **Salmolnvaade Policy Brief** – Based on project results, [Salmolnvaade policy recommendations](#) argue for an adaptation in the international and local legislative frameworks to better respond to potential and effective salmonid invasions, as well as in local management practices to limit the risk of such invasions.
- ✓ **Training workshops and a management software** – A series of training workshops were organized for anglers based on project results, with over 600 attendees across Germany. A [software to plan fisheries management actions](#) was developed and made available to the general angling public.
- ✓ **Information to the general public** – Salmolnvaade engaged significantly with local and national media to inform on salmonid invasions, angling and management (stocking) practices, including on national [Norwegian radio](#), through a [documentary](#) in Germany, and [recreational fishing events](#) in Sweden.

WholsNext

Anticipating and preventing invasions of ornamental plants under future climate change

CONTEXT

Most naturalized and harmful invasive alien plant species in Europe have once been intentionally introduced for ornamental purposes. Thus, it is likely that also future plant invaders will be recruited from those currently growing in our gardens. In addition, climate change could potentially trigger new invasions by formerly unproblematic ornamental plants, due to increasingly suitable conditions, particularly for those with origins in warmer regions with more variable rainfall. Early identification of such “sleeping” invaders would give invasive-plant managers and the ornamental plant industry a head start in preventing future invasions.

OBJECTIVES

WholsNext aimed to assess which ornamental plant species will most likely establish and become invasive under climate change, and which regions of Europe will most likely be affected by invasions.

APPROACH

Modelling studies and experiments were combined to assess invasion potential of a large number of ornamental plants under different scenarios of future climate change, specifically by:

- Developing a comprehensive overview of ornamental alien species that are currently frequently grown in Europe as garden plants, testing species characteristics associated with naturalization success in Europe and worldwide. This allowed selection of a core set of 50 ornamental alien plants to be included in the experimental and modelling studies.
- Developing an invasion-simulation model, and implementing landscape-simulation modelling and spread-modelling approaches to understand how ornamental alien plants respond to warming and changes in precipitation, and in turn assess landscape- and Europe-wide probabilities of establishment and vulnerabilities per type of habitats and regions.
- Testing results of the modelling work through experimental studies, while using experiments to feedback parameters for the modelling studies and ground truth the model findings.

MAIN ACADEMIC FINDINGS

- WholsNext climate-warming experiments revealed that native herbaceous species will suffer more than alien plants. In particular, drought and increased water variability promoted the growth of most exotic ornamentals relative to natives, which confirmed that many alien ornamental plants have an increased invasion potential under climate change.
- Analysing thousands of alien species in the European garden flora showed that their naturalization successes are mainly determined by climate suitability and nursery availability, allowing to derive a list of species that have an increased future naturalization potential.
- By overlaying these species’ climatically suitable areas with future climate, WholsNext showed that hotspot areas at risk of plant naturalization are increasing across Europe.
- For a subset of these species, researchers coupled niche and demographic modelling to simulate their spread across Europe in the 21st century, and assess the effectiveness of mitigation measures. Results show that reducing cultivation frequency strongly reduces spread of the species across all climate change scenarios.
- WholsNext used simulations to assess invasion risks in a protected mountain area in the Alps under future climate change. Results predicted more than doubling in the range-size of woody aliens, and herbaceous species to occupy up to 20% of the park area under future conditions. The challenge however remains to detect which garden species will naturalize and where, comforting that curbing nursery availability of the risky species can significantly help to reduce risks.

PROJECT PARTNERS – University of Konstanz, **GERMANY** (coordinator: M. van Kleunen); University of Vienna, **AUSTRIA**; CNRS - University Joseph Fourier, Grenoble, **FRANCE**; University of Tübingen, **GERMANY**

DURATION – January 2014 to December 2017

FUNDING – € 792,943 under the 2012-13 BiodivERSA call; national funders: DFG (DE), FWF (AT) and ANR (FR)

ACADEMIC RESULT HIGHLIGHT

The number of alien plants escaping from cultivation into native ecosystems is increasing steadily. WholsNext provided an overview of the historical, contemporary and potential future roles of ornamental horticulture in plant invasions. Results show that currently at least 75% and 93% of the global naturalized alien flora is grown in domestic and botanical gardens, respectively. Species grown in gardens also have a larger naturalized range than those that are not. Building on historical analyses of the development of global plant trade networks, the study highlighted the increasing monetary value of live-plant imports and the key role of commercial nurseries as plant sources. Results also showed that plant characteristics promoted through horticulture, such as fast growth, promote invasion. The study finally highlighted the role that horticulture could play in mediating socio-economical, technological and environmental changes that may otherwise lead to novel patterns of plant introductions and invasion opportunities for those already cultivated.

van Kleunen M. et al (2018) *The changing role of ornamental horticulture in alien plant invasions*. **Biological Reviews**, 93: 1421-1437

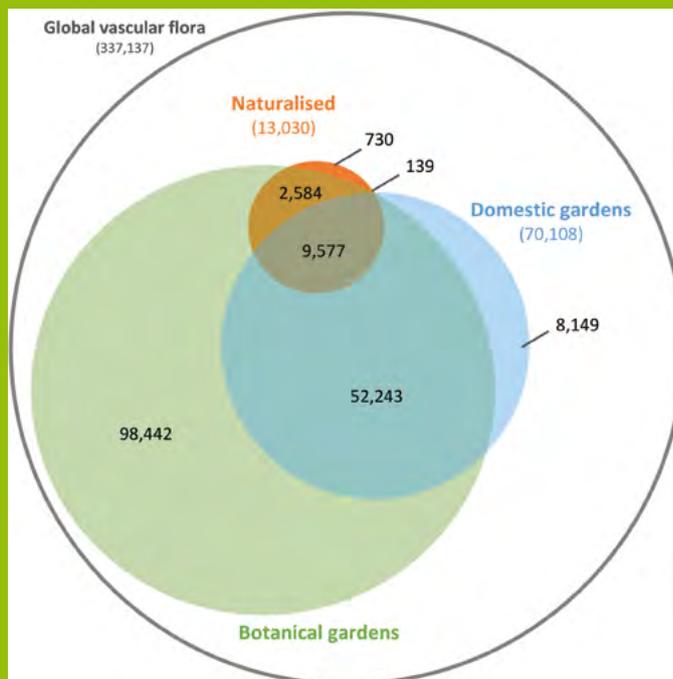


Figure 37: Venn diagram illustrating that most of the species that have become naturalized somewhere in the world (in orange) are grown in domestic gardens (in blue) and/or in botanical gardens (in brown). A black circle illustrating the size of the global vascular plant flora has been added for comparison.

WORKING WITH SOCIETY AND POLICY

WholsNext worked with stakeholders from project planning to implementation, and led to follow up studies at local scale. In particular:

- Natural resource managers (e.g. Ecrin National Park and alpine national botanical conservatory in France) contributed to framing the research questions and the different scenarios of changes in climate, land use and tourism. They also provided data on land use and species distributions for the spatially explicit simulation model to forecast invasion risks, and contributed to parameterizing the model.

- In Germany, workshops were conducted with landscape architects and planners around plants, peoples' perceptions and invasions, but also with private gardeners and the general public to raise awareness about potential threats of ornamental plant naturalization.

SOCIETAL/POLICY IMPACT HIGHLIGHTS

- ✓ **BiodivERsA Policy Brief** – WholsNext contributed central results to a [BiodivERsA brief on anticipating climate change effects on biological invasions in Europe](#), in particular demonstrating the importance of distribution modelling tools and climate scenarios to focus and prioritize global and national efforts against biological invasions.
- ✓ **Spin-off study** – WholsNext led to a follow up collaboration with the NGO Deutsche Umwelthilfe, the City of Radolfzell and private gardeners for an inventory of the alien plants grown in the public green spaces and private gardens of the city, allowing to [assess their current and future naturalization risk](#).
- ✓ **Articles in specialized and general press** – WholsNext researchers contributed articles to both specialized press (e.g. [Natur & Garten](#) for private gardeners) and towards the general public (Nodium botanic magazine).

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... and many more facts and figures!



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