EUROPEAN SCIENCE FOUNDATION
SETTING SCIENCE AGENDAS FOR EUROPE

Exploratory Workshop Scheme

Standing Committee for Life, Earth and Environmental Sciences (LESC)

ESF Exploratory Workshop on

Improving Ecological Forecasts by Integrating Feedback Mechanisms

Potsdam (Germany), April 14-17, 2009

SCIENTIFIC REPORT

Main Objectives of the Workshop

The improvement of ecological forecasts through integration of hierarchical feedbacks calls for intensive interdisciplinary collaboration. Evidently, the need to link models and data requires the joint expertise of empiricists, modellers and statisticians. However, we believe that ecological forecasts can be improved not only through collaboration between researchers with different methodological skills, but also through the exchange between different disciplines of biology and the environmental sciences. In a largely independent fashion, both community ecologists and population biologists have accumulated knowledge on hierarchical feedbacks and are starting to develop forecast models that integrate these feedbacks. We believe that the exchange of biological understanding and methodological expertise between community and population biologists holds great potential for improving ecological forecasts. Similarly, pelagic and terrestrial ecology are research fields with largely independent research traditions that lead to different approaches in empirical research and modelling. Exchange of knowledge between these fields will improve their ability to face the challenges posed by environmental change.

Executive summary

Environmental change is a major threat for both biodiversity and ecosystem function and calls for the generation of reliable ecological forecasts. Most models currently used for ecological forecasts ignore hierarchical feedback mechanisms in the response of ecological systems to environmental change. This workshop showed that ecological forecasts can be improved by combining knowledge from community ecology and evolutionary ecology, from terrestrial (i.e. substrate-bound) and pelagic ecology - and from empirical and modeling approaches. We addressed two overarching questions**:**

1. **How can we improve our understanding of the relative importance and generality of hierarchical feedbacks?** In which systems, under which circumstances and at which spatio-temporal scales and for which types of forecasts are which kinds of feedbacks relevant?
2. **How can we incorporate hierarchical feedbacks into forecast models?** Which data and which types of models are necessary for this task? Does including feedbacks change the range of possible behaviours of the models?

To address these questions, the participants divided into three working groups, each of which focused on one topic. These groups addressed how ecological forecasts can be improved through integration/transfer of knowledge between empirical and modeling approaches (Group I), evolutionary and community ecology (Group II), and terrestrial and pelagic ecology (Group III).

Group I addressed the second question in particular. Among others, it asked the pros and cons of including biodiversity (i.e. variation and thus the potential to adapt) in the models by using continuous trait distributions and trade-offs, or by predefining species/genotype-specific trait combinations in multispecies/genotype models, and how these models perform in respect to parameter and forecast uncertainty. Group II and III focused on the first question. Acknowledging that certain models (e.g. Hubbell´s neutral model) have been successfully transferred from evolutionary ecology and population genetics to community ecology Group II evaluated the potential for further cross-fertilization between these disciplines. Similarly, Group III explored if the differences in research approaches between substrate-bound (e.g. terrestrial) and pelagic systems are historical accidents or reflect the differences between habitat and dominant ecological processes.

Scientific content of the event

The following is based on the discussions and on the manuscripts which were initiated during the workshop by each of the three discussion groups.

Group I: Improving ecological forecasts by including feedbacks across scales

Frank M. Schurr, James S. Clark, Francisco de Castro, Thomas Hickler, Christopher Klausmeier, Wolf M. Mooij, Eloy Revilla, David Vasseur, Jacob Weiner

The need to manage and mitigate negative effects of global change on biodiversity, ecosystem functions and services urges us to develop reliable ecological forecasts (e.g. Clark *et al.* 2001, IPCC 2007). The realization that such ecological forecasts require a sound empirical basis has motivated many smaller research projects, and increasingly leads to coordinated efforts to accumulate long-term, spatially extensive data sets (Senkowsky 2005, Scholes *et al.* 2008). Researchers designing both small and large research projects have to confront the difficult question of how maximum learning can be gained from the available resources. Here, we suggest that ecological forecasts can provide answers to this question: in our view, forecasts are not only an ultimate aim of data collection, but they can inform the design of ongoing data collection schemes. To this end, we propose an adaptive research programme that links forecasting and data collection in an iterative manner. Using examples from various fields of ecology, we show how this adaptive programme can be used to address cross-scale feedbacks as a key challenge to ecological understanding and prediction.

The challenge of cross-scale feedbacks

The cane toad (*Bufo marinus*) was introduced to Australia in 1935 to control insect pests in agriculture. Soon thereafter, negative effects of this introduction became apparent: the rapid expansion of highly toxic cane toads had severe impacts on native predators (Phillips *et al.* 2003). Early forecasts seriously underestimated the future expansion of cane toads in Australia (Freeland *et al.* 1985, Phillips *et al.* 2006). This is because cane toads initially expanded their range at only 10 km per year, whereas they are now invading at more than 55 km per year (Phillips *et al.* 2006, 2008). This unexpected outcome seems to have been brought about by a positive feedback between dynamics at the population and genotype scale: in invading populations there is strong selection for genotypes that rapidly colonize empty habitat, and an increased frequency of such good colonizers further promotes population expansion (Travis & Dytham 2002, Phillips *et al.* 2006, 2008).

The cane toad example demonstrates the challenge cross-scale feedbacks pose to ecological forecasting. Cross-scale feedbacks are not limited to organizational scales, but also occur between spatial and temporal scales, and have long been identified as key to predicting global change impacts (Levin 1992). Nevertheless, cross-scale feedbacks are ignored in most studies investigating ecological responses to environmental change. This probably arises from the fact that most researchers and research groups have expertise at particular organizational, spatial or temporal scales, which is reflected in their modelling and data collection efforts. Thus, calls for more data and improved models are usually directed at the same scale at which an existing model has been built. Our point is that extending models and data collection to scales larger and smaller than those with which a research group is most familiar and comfortable are likely to be more cost effective, because many of the most crucial feedbacks in ecological systems occur across scales (Levin 1992). It has been noted that empirical support for model predictions at larger or smaller scales than modelled is especially strong support for a model (Grimm *et al.* 2005). This also implies that forecast robustness can be greatly enhanced if multiple scales are included in models as well as data collection.

Larger scales often constrain the behaviour of ecological system in ways that are not apparent at smaller scales. For example, total biomass production is limited at the ecosystem scale, but models of individual plant or plant population production may not “see” this limit. Thus, including this ecosystem property within a model will often result in a greater improvement in model realism and forecasting ability than additional information about biomass production of individuals and populations. Looking the other direction, a model of primary production at the ecosystem scale based on climatic variables may produce predictions which are not reasonable given the individuals, populations or successional stage in the region of interest. Technically speaking, single-scale studies may go wrong because they assume smaller-scale variation to be constant and treat larger-scale variation as boundary conditions. This problem can be addressed only by explicit consideration of multiple scales.

An adaptive forecasting programme seems of immediate use for the management of emerging large, distributed and integrated ecological research platforms such as the US National Ecological Observatory Network (NEON, Senkowsky 2005). These platforms are meant to provide multiple data streams of potential value to multiple research questions, pursued by multiple research groups. Due to the extensive and interdisciplinary nature of these platforms, designers have to confront three difficult challenges: 1) What are the important questions to which data from this platform might be applied, now and in the future? 2) What variables can be observed, and which will potentially provide the most insight? 3) What spatial and temporal design would provide the critical information, balanced against data collection costs? Consideration 1 requires creative forethought and can never be completely answered. While Considerations 2 and 3 partly depend on 1, they can in our opinion be guided by considering the cost and utility of different data streams. Hence, a clear communication of 'data value' can help to coordinate the needs of different aims and users.

References

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Group II: The role of evolution in ecological forecasts: a perspective

Neo D. Martinez, Dries Bonte, Anna Kuparinen, Justin Travis, Katja Schiffers, Florian Jeltsch.

Understanding and forecasting changes in the biodiversity and their consequences for ecosystem services and environmental public goods is probably one of the most pressing challenges for maintaining the Earth system and fate of the organisms that depend upon it. While considerable research effort has been directed at discovering the current status of biodiversity in different systems, identifying long term trends in biodiversity as well as the causes and consequences of its loss, our ability to forecast future changes still remains limited.

We developed a perspective on the role of evolution in ecological forecasts. Such forecasts specify potential fates of ecological systems in the face of largely anthropomorphic changes in the systems environment. We discussed the role of feedbacks as depending on the number of species important to the ecosystem function to be forecasted. If only one species is important (ecosystem function = biodiversity maintenance, single target species is focused on), the function is dependent on the strength of the selection pressure, variation within the population experiencing selection, and rate of environmental change responsible for the selective force. If several species are important (e.g., 1 predator and 1 prey species), then forecasts can be made by focusing on these few species and how each of their response to selective forces influences the other (coevolution). If many species are important (phytoplankton and NPP, soil bacteria and decomposition), then you are back to the one species situation but with high variation to act upon and selection might just increase the abundance of a species rather than a genotype within a species.

Together, the workgroup created a central figure describing a perspective of what the role of evolution is in ecological forecasts. That role critically depends on how populations can respond to selection created by a changing environment. We outlined a paper, assigned writing tasks consisting of a first and second or more authors of each section. Neo Martinez is lead author and responsible for overall coordination and revisions as well as for initial drafts of several sections. We see the paper as an important contribution to focusing more general research on the role of evolution in ecology towards specific consideration of how that role influences what sort of predictions can be made about the response of ecosystems to environmental change. We hope to publish the review in TREE or Conservation Letters.

Group III: Contrasting the role of ecological and evolutionary feedbacks in pelagic and substrate-bound ecosystems

Gaedke, Ursula, Jens Boenigk, Fransisco de Castro, Richard Law, Ophelie Ronce, Peter de Ruiter, Elisa Thebault, Richard Vogt, Matthijs Vos

Habitat properties are known to influence the physiological, ecological and evolutionary properties of the organisms by which they are inhabited, as well as the structure and dynamics of the resulting communities and food webs. We argue that fundamental and systematic differences exist between pelagic and substrate-bound habitats. Pelagic habitats are formed by large open water bodies whereas substrate-bound habitats comprise terrestrial, littoral and benthic ones, including rocky shores, wetlands and stands of submerged macrophytes.

The pelagic realm provides a 3 D habitat without a substrate to settle on. Hence, there is no competition for space, no lasting direct individual neighborhood relationships between sessile organisms, and no large plants structuring the habitat which all play a major role in substrate bound systems. Focusing on such differences allows for a discussion of the ecological and evolutionary processes driving and resulting from them. They also provoked that the focal research questions and modeling approaches differed between the two types of habitats which implies that pelagic and terrestrial ecology may benefit from a mutual transfer of knowledge. For example, ecological research in substrate-bound systems may gain from pelagic research in respect to experiments on evolution and multi-trophic level food webs with multiple generations and replicates since the quantitatively important organisms (plankters) exhibit much faster rates of change, and demand much less space (generation time ca. $1{:}10^4$ between algae and trees, space occupied by an individual ca. $1:10^{11}$). As a consequence, feedback processes between different hierarchical levels are easier to assess experimentally in plankton systems. Furthermore, metabolic rates such as production and respiration are typically easier to measure in the pelagic realm which implies that already more fully quantitative food web studies comprising carbon or another surrogate for energy and the most limiting nutrients are available. Among others, they provide a basis to develop and validate concepts and models on the structure and functioning of food webs. In analogy, a great potential for a transfer of knowledge from substrate-bound to pelagic systems exists in respect to e.g. search strategies for food, mates, shelter, etc., the information flow within food webs less covered by trophic interactions and how to treat individuals as discrete entities and to consider spatial structure & non-trophic feedbacks.

Assessment of the results, contribution to the future direction of the field, outcome

The Workshop was intended to bring together researchers of different backgrounds and who use varied approaches to ecological research, to improve our understanding of the importance and generality of feedbacks in ecological systems and how can they be used to improve forecasts. We achieved this, and the three discussion groups approached the problem from different perspectives, contributing to identify some of the major issues with ecological forecasts, and suggested how these problems could be tackled.

Some of the participants highlighted the fact that, both in the talks and the discussions, there was less about successful forecast examples and more about the problems associated with including them in ecological research, pointing out the gaps in our knowledge and the need to fill them.

The feedback from the participants was excellent, many commenting that it was very interesting and highly productive. Each of the groups is preparing a manuscript centered around the themes discussed. These manuscripts will be submitted to high-ranking journals hopefully during this year.

Final programme

Tuesday 14 April	
	Arrival
19:00	Dinner and get-together (Best Western Park Hotel)
Wednesday 15 April	
9:00-9:15	Conveners' Welcome
9:15-10:00	Talk "Improving ecological forecasts" (conveners)
	plus Discussion
10:00-10:45	Brief self introduction of all participants
10:45-11:30	Coffee break and "**SHOW AND TELL**" space (posters, papers, etc.)
11:30-12:30	Talk "Combining models and data for ecological forecasts" (James Clark). Plus Discussion
12:30-13:45	Lunch
13:45-14:15	Talk "Hierarchical feedbacks in population dynamics: can evolution prevent extinction?" (Ophélie Ronce). Plus Discussion
14:15-15:00	General discussion: Formation of subgroups on specific topics
15:00-15:30	Coffee break
15:30-17:00	Discussion/Work in subgroups
17:00-17:30	General meeting
	Reports from subgroups
	General discussion
19:00	Dinner in the historical city centre of Potsdam
	India Haus restaurant (Lindenstr. 65)
Thursday 16 April	
9:00-10:00	Talk "Forecasting community and evolutionary dynamics" (Richard Law). Plus Discussion
10.00-12.00	Discussion/Work in subgroups
12:00-12:15	Brief general meeting
12:15-13:30	Lunch
13:30-14:00	Talk "Trait-based approaches for ecological forecasting" (Chris Klausmeier). Plus Discussion
14:00-15:15	Discussion/Work in subgroups
15:15-15:40	Coffee break

15:40-16:10	General meeting
	Reports from subgroups
	General discussion
16:10-18:30	Excursion: tour of the Park and Sanssouci Palace
	(***Bus at 16:18. Last entry to the palace:16.30***)
18:30	Dinner (Mövenpick restaurant close to Sanssouci Palace. Zur Historischen Mühle 2)

Friday 17 April

9:00-10:00	Talk "Ecological forecasts in pelagic and terrestrial systems" (Matthijs Vos). Plus Discussion
10:00-12:15	Discussion/Work in subgroups
12:15-13:30	Lunch
13:30-14:00	Talk "Ecology meets biosphere modelling" (Thomas Hickler). Plus Discussion
14:00-15:15	General meeting Reports from subgroups Workshop products (publications, future collaborations, grant applications, etc.)
15:15-15:45	Coffee break
15:45-17:15	Workshop products (cont.)
17:15-17:30	Final round-up of the workshop by conveners
18:00	Dinner (Best Western Park Hotel)

Saturday 18 April

	Departure

Final list of participants (names and affiliations)

Ursula GAEDKE (University of Potsdam, DE)
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Dries BONTE (Ghent University, BE)
Katja SCHIFFERS (University of Aberdeen, UK)
James CLARK (Duke University, USA)
Peter DE RUITER (Wageningen University, NL)
Thomas HICKLER (University of Lund, SE)
Christopher KLAUSMEIER (Michigan State University, USA)
Anna KUPARINEN (University of Helsinki, FI)
Richard LAW (University of York, UK)
Neo MARTINEZ (Pacific Ecoinformatics and Computational Ecology Lab, USA)
Wolf MOOIJ (NIOO-KNAW, NL)
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Justin TRAVIS (University of Aberdeen, UK)
David VASSEUR (Yale University, USA)
Richard VOGT (Université du Québec à Montréal, CA)
Matthijs VOS (NIOO-KNAW, NL)
Jacob WEINER (University of Copenhagen, DK)

Statistical information on participants

In total 25 people attended the meeting. Of the 24 invitees who could attend, 5 (21%) were women. Participants were classified, with respect to age, as Junior (5, 21%), Middle (12, 48%) or Senior (7, 28%).

The distribution per country was as follows:

Germany: 5
Netherlands: 4
USA: 4
Great Britain: 3
Austria: 1
Belgium: 1
Sweden: 1
Finland: 1
Spain: 1
France: 1
Canada: 1
Denmark: 1