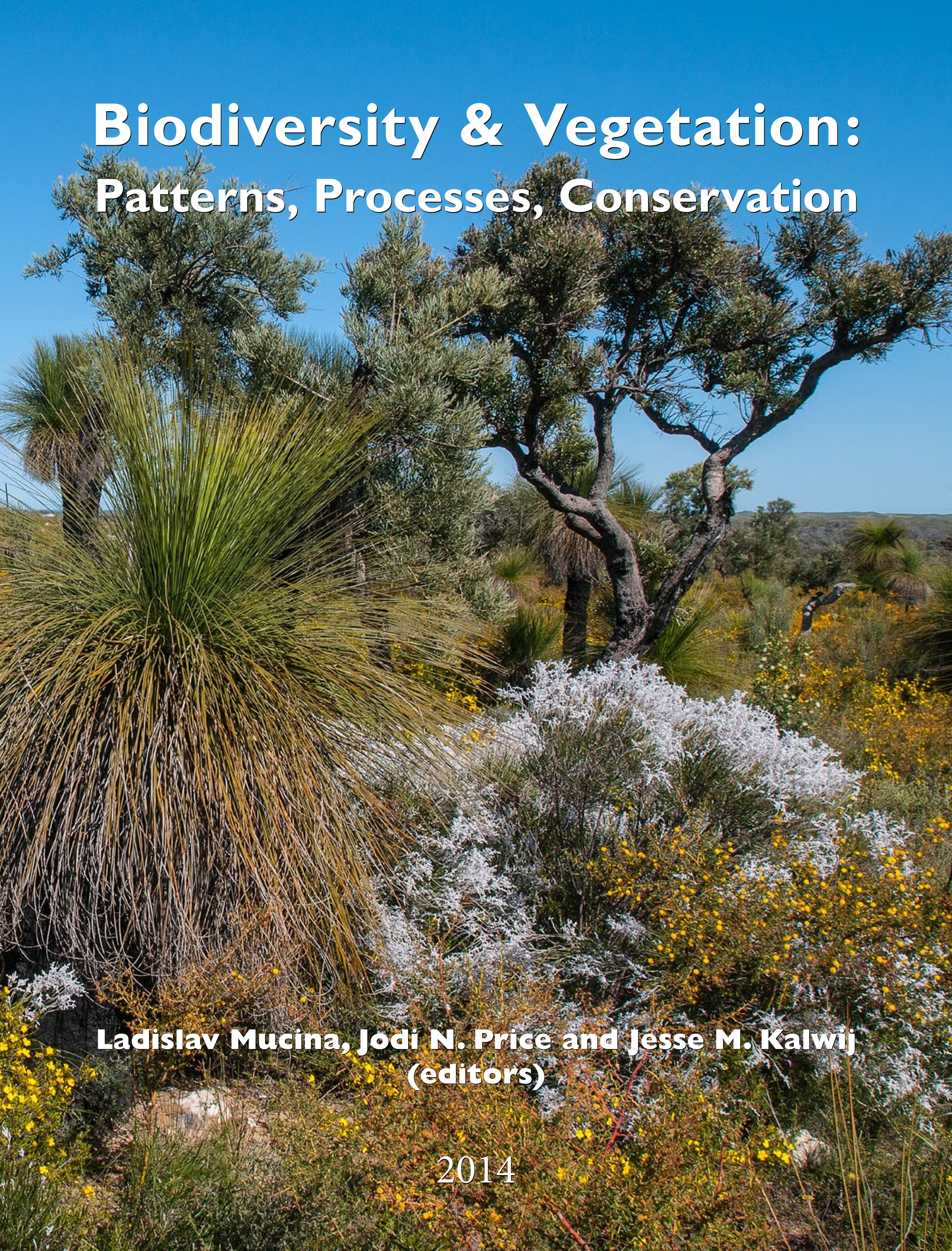

Biodiversity & Vegetation:
Patterns, Processes, Conservation

Ladislav Mucina, Jodi N. Price and Jesse M. Kalwij
(editors)

2014

Biodiversity and Vegetation: Patterns, Processes, Conservation

edited by

Ladislav Mucina,

Jodi N.Price & Jesse M. Kalwij

Kwongan Foundation, Perth, Australia

2014

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Dedicated to life of an ecologist
extraordinnaire

David W. Goodall
4 April 1914 and counting...

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Urodon dasyphyllus (*Fabaceae*) from Kalbarri National Park, Western Australia.
L. Mucina

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Welcome to Perth!

Ladislav Mucina

In 1990 IAVS came for the first time to Australia. Legendary Dr John S. Beard AO had organised an IPE (International Phytogeographical Excursion) in his home of Western Australia. There are many of us (I was not there, unfortunately, since I was just pushing my life reset button in the free West after having escaped communistic Czechoslovakia) that still recall this feat of weird flowers, strange vegetation types, and mesmerising dry landscapes full of eucalypts.

In 2014, IAVS is coming to Australia again – this time to hold its yearly symposium in Perth. For couple of weeks in August and September Australia will become the focus of vegetation-scientific interest as the University Club of The University of Western Australia will host the 57th Annual Symposium of IAVS.

Australia is far from almost everywhere, and the 'tyranny of distance' drives our lives more than national politics. Despite the distance we have been able to attract many colleagues from overseas. We are also committed to make the long trip worthwhile for many young people. We want to be it a 'young' symposium: dominated by young people with fresh ideas and therefore most of the invited key notes will be given by young upcoming star of our science.

We, the Local Organising Committee of the *iavs2014*, welcome you in Australia! We are happy share the floral and vegetation marvels of our country with you not only during the learned talks and poster discussions, but especially during three major excursions flanking the symposium (two in Western Australia, and one into the tropical northern Queensland).

Come and join us – to push the envelopes of scientific theory, to boost the image of our *scientia amabilis*, to make new friends and perhaps find a new job or research partner, and at the same time, just to have a hell of a good time. Vegetation scientists like to meet, value a good drink and something (and lot of it!) nice to eat, and talk shop the whole day long. All that, and more, is guaranteed!

Welcome to Australia, welcome to Western Australia – the home of the black swan and the home of vegetation science for 2014.

Laco Mucina, for the LOC

Our official website: www.iavs2014.com

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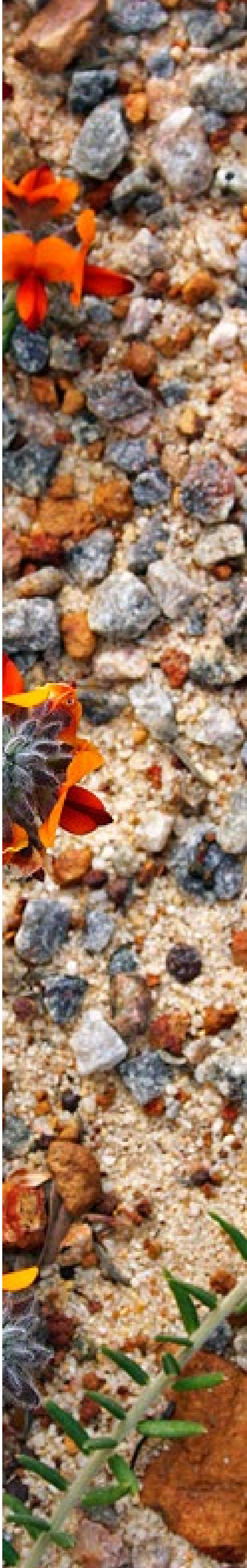

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Kingia australis (*Xanthorrhoeaceae*) from the Stirling Range, Western Australia. Photo: L. Mucina.

Some thoughts about David Goodall's work

Enrico Feoli

Department of Life Sciences,
University of Trieste, I-34127
Trieste, Italy

Correspondence: Enrico Feoli,
feoli@units.it

I am honored to have been invited by my friend Laco Mucina to write this *laudatio* on the occasion of the hundredth birthday of our friend and great mentor David Goodall. It certainly is not an easy task because I am not sure if I will find the right perspective and the right words to make a *laudatio* that is worthy of a person, a scientist of such remarkable versatility. Brief accounts on the life of David Goodall can be found in the Encyclopedia of Australian Science and in Wikipedia, so I will not repeat all of what is written there; I will just mention something that had a great influence on my life and in many respects on my way of thinking about ecology and vegetation science.

I started working with David Goodall many years ago (1986), for me he was already back then a legend, as he was one of the first to introduce multivariate analysis in ecology and wrote programs for computer methods that I began to study and use between 1966 and 1970 – still as a natural sciences student of professors Sandro Pignatti and Duilio Lausi, who introduced me to the fascinating world of quantitative ecology. Thanks to the Working Group of Data Processing of the International Society of Vegetation Sciences and my stay at the University of Nijmegen with Eddy van der Maarel and at the University of London Ontario with Laszlo Orlóci in the seventies and early eighties, I had the opportunity to read many of the David's papers and finally met him at the symposia of the Working Group. I discovered something about the eventful life of David around the world only relatively late, when the University of Trieste (my university) awarded him in 1990 by the title of Doctor *honoris causa* in Natural Sciences, for his innovative contributions to the emerging discipline of quantitative ecology. On that occasion I read his curriculum vitae for the first time. During the periods he spent in Trieste, giving me and Paola Ganis the pleasure of working with him, David Goodall behaved as would be the most diligent of young researchers of the Department. He was always punctual at half past eight in the morning at the Computing Centre of the University and, after a short break for lunch at twelve, resumed work until another short break for the classic English afternoon tea taken around 5 pm as of course any English gentleman would do. After working until about 7 pm we usually had our dinner and then he would be retiring to his room. The times he spent with my family were very enjoyable for all of us. My daughter Lucia, who at that time was a kid, adored him and was amused when he showed to compete with her for the fries. He was a great entertainer by using his experience as a theater actor in his free time.

His life style for us, Italians, was an example of clarity, coherence and organization. When he was in Trieste, his activities were not limited to the development of new applications of his ideas on probabilistic methods in scientific classifications, but he also took part in field excursions to the islands of Dalmatia, he offered seminars and lectures in courses co-organized by the Department of Biology at Ustica (Sicily), in a course organized by ICS-UNIDO (International Centre for Science and Technology of United Industrial Development Organization) at the Academia Sinica in Beijing (China), on the interactions between climate and vegetation and in the International Workshops on Mathematical Ecology organized by the International Centre of Theoretical and Applied Ecology (CETA) in collaboration with the International Centre for Theoretical Physics (ICTP) and much more. He brought a fundamental contribution to the birth of the journal *Coenoses* dedicated to community research. No wonder that the opening article of the journal, entitled "Classification and Ordination: Their nature and role in Taxonomy and community studies", was written by David. *Coenoses* merged with *Abstracta Botanica* in 2000 to become *Community Ecology*, today steered by Janos Podani.

Before the merger of the two journals, David published a paper in Coenoses (1988) and two papers in Abstracta Botanica (1993 and 1994) – results of some new applications and refinements of his well-known probabilistic indices published in the sixties in *Nature, Biometrics* and in *Biometrie-Praximetrie*. The series of his papers on the subject continued in *Community Ecology* where he published in 2002 the paper entitled "Probabilistic classification and its application to vegetation science". David published three papers in 2014 – the year of his 100th birthday – something hardly matched by any ecologist before. The *Plant Biosystems* paper entitled

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"Identification of unknowns within a probabilistic system: The diagnostic value of attributes" found its continuation in this Symposium proceedings ("Probability of similarity and fuzzy sets: should we move to the Jaccard's diversity metrics?" with Paola Ganis and Valerio Pillar.

I am aware that this *laudatio* is a little bit biased by my scientific preference for a particular topic of his work, namely the "probabilistic similarity indices". Nevertheless I cannot avoid recalling the paramount importance of the concept of similarity in all the aspects of scientific activities and the contribution of David Goodall to the development of such a concept. The ontology of the concept includes its "measures" and/or its metrics, and therefore it is impossible to ignore the first historical attempt to associate probability value to similarity between two objects or better to measure similarity by probability of similarity, as it was done successfully by David. I think the importance of the concept is not well understood and many techniques of data analysis that look very "advanced" are still running around such a concept without getting the point. The trivial cause of escaping from the concept of similarity for going to complicate statistical techniques or to the machine learning algorithms, skipping the idea that simple mathematics can help to deal with complex systems, may be due exactly to the mathematical simplicity of the functions of similarity, notwithstanding the implicit elegance of some of them and the philosophical importance of the concept of similarity. In this last aspect I quote the Kant's 'principle of homogeneity' his 'law of affinity' and the 'law of heterogeneity' of Hamilton that today can be found easily in internet.

David was straightforward to the point in the sixties when he proposed to measure similarity directly by the probability that two objects would be more similar than they should be if the attributes by which they were described would be arranged randomly among the objects in the data matrix where they were placed in. With his index, David was leaving the Euclidean metrics and the classical statistics based on sum-of-squares (Euclidean distance) and normal distributions, applicable to well-defined sampling designs, for another metric that we could call 'contextual metric'. In fact in his index, the similarity or dissimilarity between two objects out of n, is not given by the differences (or accordance discordance in case of qualitative characters) between scores of attributes, but by the frequency of the differences, in all the (n-1)n/2 comparisons, higher or lower to the one found between the two objects. It is obvious that in this case the probability of similarity is depending on the data set used and cannot be extrapolated elsewhere. This is viewed as a drawback of the Goodall's approach, but I think it has a particular philosophical value when we consider that in fact a set of objects are always selected or sampled in a particular context and described by the attributes that are specific to answer specific questions related to that context.

I do not want to dwell on philosophical debates on contextual and non-contextual classifications, and I rather continue discussing the impressive David's work in other fields beyond his probabilistic approach in vegetation science and in plant identification.

After having made outstanding contribution in the field of "applied science" related to physiology of tomato, apples, cacao and lettuce in the first phases of his scientific career (1936-1960) and having applied his indices and statistical skills to different areas of biology (microbiology, animal and human biology) between 1960-1970, he started working intensively on modelling of different ecosystem processes publishing several papers between 1967 to 1989, when this series of papers seems to end with the paper "Simulation modelling for ecological application" published in *Coenoses*. In that paper he clearly offered his vision on modelling, a vision that can clarify what modelling is for all those who are not familiar with the topic. He describes the objectives of modelling, explains what the objective functions are, and what are the phases of model construction by explaining well the differences between the stochastic models and the treatment of uncertainty, what is the sensitive testing, and finally he discusses what validation means in the context of ecological research. He makes clear in his paper that modelling is a *pis aller* that has to be seen as an important component of the paraphernalia of mathematical and statistical instruments an ecologist has available.

During his 'modelling period' David also commenced his great journey to be the editor in chief of the famous series "Ecosystems of the World" with Elsevier (Amsterdam). 36 volumes in the series were published since 1974! He also co-edited two of the volumes: Mediterranean-type Shrublands (1981) and Hot Deserts and Arid Shrublands (1986). The Ecosystems of the World is a monumental piece of scientific reviewing – a source of knowledge and inspiration for many generations to come.

In the nineties it looked like his research activity was again more concentrated on data analysis, the main theme of his scientific life, as also witnessed by the "Distinguished Statistical Ecologist Award" He received at the VI International Congress of Ecology (1994).

In these last years he has been again working on his probabilistic methods for classification and identification, but also got busy organizing his philosophical thoughts on human evolution.

I conclude this *laudatio* by mentioning his 2008 paper entitled "Human evolution – Where from here? Without any specific comment, I just invite you to read it as it is written in a very "David Goodall's perspective". I report here just some thoughts out of that paper that may give you an idea about how much David has integrated in his mind biology, human biology and the cultural evolution of Man:

"Before the development of language, mental activity in different individuals remained largely independent. But language provided a mechanism by which different individuals could influence one another's thought processes. This integration of thought processes among individuals who remained physically separate was perhaps a critical event in the development of Homo sapiens. It was based on the physical apparatus which biological evolution had bequeathed to the species, but its development proceeded quite independently of whatever biological changes may have been going on concurrently. The capacity of the individual brain had already been increased considerably through the normal evolutionary processes. But the evolution of language made it possible to go far beyond this; the brains of different individuals united by language could be harnessed together in ways which were not possible without language, thus largely obviating the need for further evolution in the individual brain. Though their brains were physically separate, their mental processes were linked, and the whole group of individuals thus could start to behave and react as a single entity."

I chose this text because I think it could be crucial in stimulating thinking about the importance of language and culture may have had in human history and may have in the Man's future.

Understanding vegetation succession process in habitat and vegetation restoration and rehabilitation

Sándor Bartha

Centre for Ecological Research,
Hungarian Academy of Sciences,
Alkotmány út 2-4, H-2163 Vácrátót,
Hungary

Correspondence: Sándor Bartha,
bartha.sandor@okologia.mta.hu

Introduction: State and transition models are traditional tools in restoration ecology. Considerable efforts were paid to describe and classify the related pathways of successions. Although the first syntheses suggested simple pathways, accumulating data from long-term permanent plots studies revealed that succession is highly stochastic and the related mechanisms are far more complex than expected (Pickett & McDonnell 1989). A new non-equilibrium paradigm evolved emphasizing the importance of spatiotemporal neighbourhood effects at various scales. The first methodological consequence of non-equilibrium paradigm was the extension of studies to the landscape scales by analyzing the effects of landscape context and land-use history. However, neighbourhood relationships work along a hierarchy of scales. It means that history and spatial context are vital at finer scales as well. Fine-scale contingencies, i.e. the effects of fine-scale patterns on dynamics are particularly significant in terrestrial plant communities where individuals are sessile and interactions are local.

Methodological consequences of the non-equilibrium vegetation paradigm: Non-equilibrium paradigm conceptualizes vegetation in the form of hierarchic patch dynamics with fuzzy units, where patches are diffuse and the delineation of units is not trivial. Patch dynamics can be modeled by dynamic graphs of state transitions. These models require an operational definition of patches which is able to represent details of dynamic complexity but simple enough to apply to the fields. We proposed that measuring the number of realized species combinations as a function of resolution (sampling unit size) provides this quantitative information about the within-stand vegetation patchwork (Bartha et al. 2004). Recording species combinations in sampling units does not require subjective decisions, i.e. classifications and no artificial boundaries set. Realized species combinations can be considered as microstates in the samples and the graph of state transitions can be created from the temporal transitions of these microstates. The topology of the related dynamic graph changes with scales and according to the dynamical state and differentiation of vegetation (Bartha 2007). This approach provides a unifying framework linking near-equilibrium processes within natural communities with various vegetation pathways representing succession or degradation.

Traditional studies representing patch dynamics of vegetation rarely distinguished more than 20–50 patch types. In contrast, our methods revealed hundreds and thousands of realized microstates (species combinations). This underlines that structural complexity is an inherent feature of vegetation. By ignoring these microstates, i.e. disregarding states and transitions important in the dynamics, our estimations and predictions become inefficient. Evidences from various vegetation types showed that the maximum beta diversities appeared at very fine spatial scales mostly between 0.1 m and 1 m (Bartha et al. 2004). There was an overall positive correlation between diversity components. We demonstrated that beta diversity of dominant matrix species is a sensitive indicator and it can predict alpha and gamma diversity of subordinate species in properly managed grasslands (Fig. 1A). The correlations found suggest that fine-scale structural complexity of dominant species (beta diversity; diversity of potential microhabitats) is important for maintaining diversity of the subordinate species. Dynamical characters of micro-successions depend on the compositional diversity of vegetation. Decreasing fine-scale compositional heterogeneity involves decreasing resilience. In a permanent plot study, we found considerably higher relative interannual variability of coenostate variables in a site with lower fine-scale structural complexity (Fig. 1B). Direct and detailed measurements and analyses of the spatial variation and dependence give considerable more information than the variables referring only to stand-scale averages. Contrary the huge individualistic

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variation of successional pathways, beta diversity showed robust and general trends during regeneration and degradation (Fig. 1C). Case studies proved that beta diversity is a sensitive indicator of vegetation transformations due to restoration treatments. The methodology based on beta diversity provide relatively simple and quick methods for monitoring the fine-scale structural complexity of developing vegetation and able to collect additional information relevant for manipulating the rate and direction of processes.

Dynamic consequences of the non-random spatial dispersion of plant species are well explored by spatial simulation models and by field experiments. From a dynamical point of view, beta diversity refers the deviation of local densities of species combinations from a ‘mean-field approximation’. With the mean-field approximation we assume that the communities are well mixed and individuals interact in proportion to their average population densities. As a consequence of non-random spatial distribution, the behaviour of multi-species combinations and the interaction probability between species cannot be derived from pairwise interactions or from the average abundance of species. Restoration treatments directly modify sizes, architectures, demography and spatial patterns in plant populations, i.e. we are able to modify dynamically relevant traits. By changing these characters it is possible to manipulate the speed and direction of vegetation changes, as well as the diversity and functioning of communities. It is important to underline that fine-scale spatial organization affects vegetation dynamics in the magnitude of few years or few decades, i.e. at the temporal scales where restoration ecology is working.

Perspectives for monitoring restoration measures: Planning restoration requires knowledge about the structure and functioning of target ecosystems, and the processes of spontaneous regeneration. Non-equilibrium conditions typical in restoration practice require specific methodology which able to represent the spatiotemporal variation and dependence at multiple scales. Our knowledge is limited because traditional methods detected oversimplified patterns and underestimated complexity. The underestimated complexity of natural systems implies that we might restore oversimplified versions of target communities.

Restoration treatments directly or indirectly manipulate the fine-scale spatial patterns of populations. By changing size, architecture, demography and composition, they change structural complexity. To understand better the related effects we should collect data at that particular scale where these treatments act. This is why fine-scale spatial analyses are important and useful to follow and evaluate restoration experiments.

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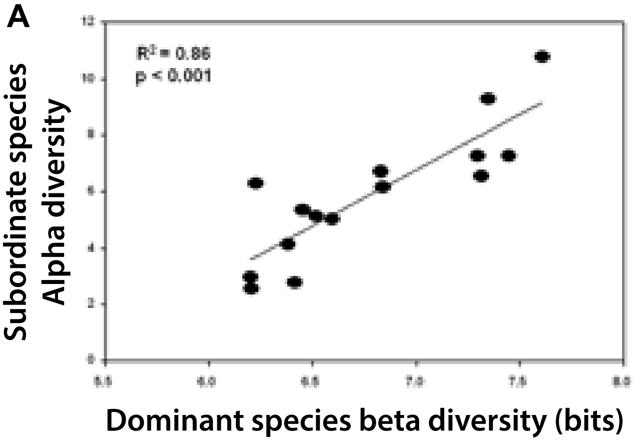

Figure 1A. Relationship between the beta diversity of dominant species and the alpha diversity of subordinate species in natural meadows steppe communities, N=15. (Note: the number of dominant species set as a constant value, S=8 in each vegetation stand, i.e. beta diversity refers differences in fine-scale structures developed from the same number of species.)

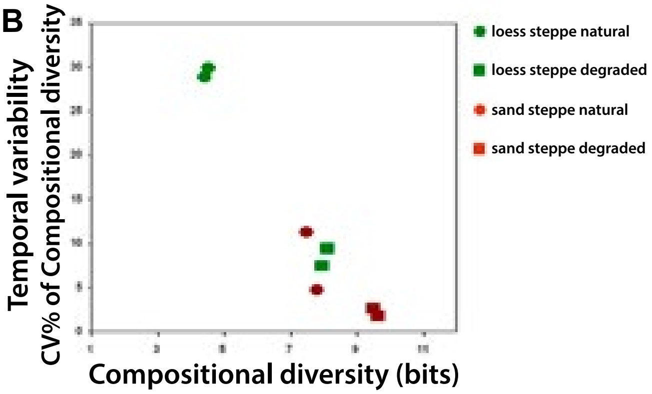

Figure 1B. Interannual relative variability (coefficient of variation) of beta diversity in eight grasslands as function of mean beta diversity during the study periods. (Note: temporal variability was monitored for 4 years in meadows steppes and for 9 years in open sands steppes.)

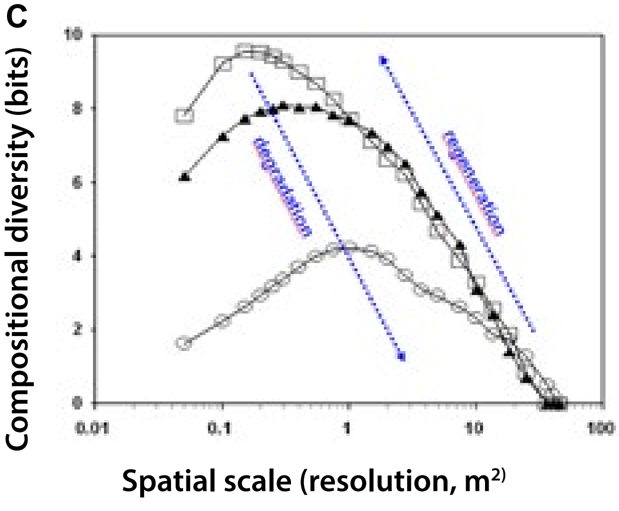

Figure 1C. Trends of beta diversity in degradation and succession. (Note: Beta diversity was represented by the diversity of realized species combinations calculated at increasing sampling unit sizes.)

Starting from scratch – challenges in restoring vegetation when starting from bare earth

Lucy Commander (1,2)

1) Botanic Gardens and Parks Authority, Fraser Avenue, West Perth WA 6005, Perth, Australia

2) School of Plant Biology, The University of Western Australia, 35 Stirling Hwy, Crawley WA 6009, Perth, Australia

Correspondence: Lucy Commander, lucy.commander@bgpa.wa.gov.au

Introduction: In his address to the British Ecological Society in 1982, Bradshaw said that ‘the acid test of our understanding is not whether we can take ecosystems to bits on paper, however scientifically, but whether we can put them together in practice, and make them work’ (Bradshaw 1982). Putting ecosystems back together is the work of restoration ecologists. The ecosystems which restoration ecologists are trying to restore, may have been damaged by overgrazing, desertification, military activity, invasive species or combination of various disturbance regimes. However, some may argue that the most challenging ecosystems to restore are those that have been completely destroyed, such as those that are reconstructed following mining. This presentation will focus on the challenges of restoring ecosystems when vegetation has been completely removed by mining, using examples from Western Australia.

Identifying a reference system: One of the first challenges to restoring ecosystems following mining is to decide which ecosystem to restore. Perhaps the original community is the most appropriate, however, pre-mining surveys may not have been undertaken, so the attributes of the historical ecosystem are not known. On the other hand, the pre-existing ecosystem may have been surveyed, but the physical landscape may have changed so much, that the former ecosystem may not be able to be sustained. For instance, at a gold mine in the Great Sandy Desert, vegetation on sand plains has been cleared to make way for waste rock dumps. Also, at a solar salt facility in Shark Bay, soil has been extracted from borrow pits to be used in infrastructure. The topography and soil characteristics of the formed rock dumps and borrow pits are vastly different from the former conditions (Commander et al. 2013; Golos 2013), leading to the question, should the pre-existing community be restored, or should another reference system be chosen.

The number of species is scale dependent: Once a reference ecosystem has been identified, the attributes of the ecosystem must be defined. One important attribute is the number of species in the ecosystem, as some mines are under strict governmental conditions to replace a certain number of species. For instance, the Western Australian state government has directed that an iron ore mine in the mid-west return 70% of the pre-existing species. Plant species richness is scale-dependent (that is, the species lists increase in size as larger areas are surveyed). Hence, then number of species to be returned after mining depends on the size of the area to be restored. If pre-mining surveys have not been carried out, or are not appropriate, then a survey of an equivalent area in the reference ecosystem can be undertaken to determine the target number of species.

Returning the plants: Understanding the factors that determine species composition, such as seed dispersal, germination and colonisation sequence, is fundamental to theoretical community ecology and of great importance to restoration ecology as it can help determine how to return each species to the site. Ecosystems destroyed by mining can be interesting places in which to study natural colonisation and succession as some species will return to the restoration site spontaneously through wind dispersal of seed. However, in Western Australia, natural colonisation can be very slow, so active restoration is necessary. Forms of active restoration include topsoil replacement, seeding and planting, and different species may require different techniques depending on their reproductive biology. For instance, topsoil replacement is only able to restore species that store their seeds in the topsoil (geosporous), and not seeds that are stored in the canopy (serotinous) seeds. If that topsoil is stored between removal and replacement, seeds of some species will persist (survive), but those that do not persist (as they will either germinate or die) will need to be replaced using another method. Recent research at an

Commander, L. 2014. Starting from scratch – challenges in restoring vegetation when starting from bare earth. In: Mucina, L., Price, J.N. & Kalwij, J.M. (eds.), *Biodiversity and vegetation: patterns, processes, conservation*, pp. 27-28. Kwongan Foundation, Perth, AU.

iron-ore mine in the mid-west has ascertained that only 3% of species return to the site via unaided dispersal (likely wind), and 9% return from the topsoil, resulting in a requirement for seed-based restoration (Commander & Merino-Martín, unpublished data). Seedling recruitment may be limited by seed availability, the availability of suitable microsites, or both (Duncan et al. 2009), and while seed availability is commonly increased by seeding by hand or machinery, current studies are investigating ways to increase the number of suitable microsites. Seed-based restoration should include a thorough investigation of seed quality and germination, as inappropriate seed storage can lead to seed viability loss, and unknown seed fill can result in an underestimation of the number of seeds applied to restoration sites. Analysis of seeds of 21 species in a restoration seed mix used at a Pilbara mine site revealed that seed fill ranged from 9-99%, seed viability ranged from 0–97% and seed germination ranged from 0–86%, hence the number of live seeds in the seed mix was actually far lower than intended. If species are unable to be returned via topsoil and seeds are not available, or are scarce, then plants may be generated through seeds, cuttings, or tissue culture and planted.

Summary: In Western Australia, as in many other parts of the world, the challenges of mine restoration seem to be as big as the areas that we are trying to restore. However, with the help of theoretical ecology, restoration ecologists are doing their best to build ecosystems on bare earth.

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Figure 1. Vegetation recovery 'ground zero': Mining often involves the complete removal of vegetation, and the creation of a new landform. Restoring an ecosystem on this new landform poses many challenges. Photo: L. Commander.

Rehabilitation research in mineral sands mining: the challenge in Eneabba kwongan

Mark P. Dobrowolski (1,2)

1) Iluka Resources Ltd, Perth WA 6000, Australia

2) School of Plant Biology, The University of Western Australia, 35 Stirling Hwy, Crawley WA 6009, Perth, Australia

Correspondence: Mark Dobrowolski, mark.dobrowolski@iluka.com

Rehabilitation context: Iluka Resources is rehabilitating land to native vegetation following mineral sands mining at Eneabba, 250 km north of Perth, Western Australia, with the aim of returning a functioning kwongan ecosystem. Kwongan, meaning "sand-plain" in the indigenous Noongar language, is a term used for the botanically diverse, low heath vegetation occurring on the sand-plains of WA. Rehabilitation of post-mining areas in the Eneabba kwongan began in 1977; since then, approximately 1500 ha has been rehabilitated to native vegetation with 850 ha in planning. Research on rehabilitating the vegetation, soils and fauna has been invaluable to the operational program, but also to increasing our understanding of kwongan vegetation, landscape and ecosystem. This paper will present an historical review of these rehabilitation research themes and how future research, grounded in validated ecological theory, will aid rehabilitation practice.

Historical research themes: Initial research focussed on the immediate methodological difficulties of rehabilitation. These included stabilising the reconstructed soil surface against wind erosion in the hot, dry, windy summers of Eneabba (Bell et al. 1986), sourcing seed for broadcast and propagation, and nutrient allocation and cycling in kwongan vegetation and rehabilitation (Bell & Lamont 1990). Practical solutions have developed although these fundamental challenges remain. For example, harvest of kwongan vegetation shoots and spread of this mulch on rehabilitated ground stabilised the surface against wind erosion, provided niches for seed germination and organic matter to initiate nutrient cycling, and also distributed seeds of key species, many of which are serotinous/bradysporous. This practice ceased due to concerns of the harvesting impact to off-mine path vegetation; there being no new mining activity in kwongan vegetation, which can provide mulch resources from areas destined to be cleared. Surface stabilisation must now be provided by a nurse crop of *Secale cereal* (rye), which although not weedy, shows allelopathic effects on germinating seed. Seed collection and broadcast provides seedling recruitment of serotinous species, although a distance-defined local provenance for seed collection restricts access to this resource. Topsoil seed stores provide complementary species to the rehabilitated vegetation although far fewer seedlings recruit from topsoil compared to the mulch of serotinous species (which are now collected and broadcast). In addition, as topsoil ages in stockpiles it becomes depauperate in both seed (Bellairs & Bell 1993) and beneficial microorganisms (Jasper 1995), and aging selectively favours hard-seeded species such as *Acacia blakelyi*, a woody species that can dominate rehabilitation areas.

In addition to the challenges of obtaining propagules, many species are recalcitrant (cannot be propagated easily from seed or vegetatively) and have been the subject of research on propagation and dormancy breaking (Meney et al. 1990; Dixon & Nielsson 1992; Meney et al. 1993; Scaffidi et al. 2011). Species from the *Cyperaceae, Restionaceae* and *Ericaceae* form the majority of these recalcitrants, with the former two families representing a plant life-form largely absent from rehabilitated vegetation in comparison to undisturbed kwongan. Innovative methods being trialled at Eneabba for transferring largely intact vegetation within topsoil profiles could address recalcitrant species loss from rehabilitated vegetation. Once established, rehabilitated vegetation should be resilient and responsive to periodic disturbance that a functional kwongan ecosystem encounters. Wildfire is the key disturbance. The vegetation dynamics after fire (purposefully lit) have been investigated in rehabilitation and adjacent kwongan vegetation (Herath et al. 2009). More recent wildfires at Eneabba will allow further research on this resilience.

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The research focus at Eneabba has not been exclusively on vegetation and its ecology. Invertebrate fauna studies using ants as bio-indicators revealed rapid return of species, with comparable species richness in rehabilitated and control sites, although functional group profiles of ants were not equivalent (Bisevac & Majer 1999). Soil investigations have also featured in research at Eneabba, including assessment of the soil structural development in tailings, and soil water modelling to estimate profile depth to support kwongan vegetation through periodic drought. Soil factors, given their importance to species filtering in vegetation community assembly, deserve greater research attention.

Future research for rehabilitation practice: Future research at Eneabba will necessarily include the practical aspects of rehabilitation, for example, trialling alternative stabilisation methods prior to their broad-scale adoption, and the long-term effectiveness of the delivery method of plant propagules for field recruitment and survival of seedlings. As well as this applied research that can be quickly implemented to solve the immediately obvious and practical problems, successful rehabilitation practice requires a foundation in fundamental ecological theory. Future research on this theme at Eneabba will test models of plant community assembly using a plant functional trait perspective, and an understanding of the key environmental drivers. Such research will help inform plant species selection for rehabilitation, particularly in historically backfilled areas with greater alteration of soil conditions. Research in ecological theory will also allow a more realistic appreciation of the likely outcomes of rehabilitation, and assist in setting achievable targets for re-instating a functional ecosystem.

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Construction of the vegetation direct transfer (VDT) trial at Eneabba, Western Australia. Excavator cut **(A)** and direct placement **(B)** of ~30 cm soil with largely intact kwongan vegetation. Photos: C. Payne.

Fire-climate interactions and their biodiversity implications for SW Australian shrublands

Neal J. Enright

School of Veterinary and Life
Sciences, Murdoch University,
Murdoch WA 6150, Perth, Australia

Correspondence: Neal Enright,
N.Enright@murdoch.edu.au

Global importance of fire: Disturbance regime is a fundamental driver of plant community composition and structure, and of species coexistence. Fire is one of the most common causes of recurrent landscape scale disturbance, and has shaped evolution and adaptation in many taxa globally (Bond & Keeley 2005). Altered fire regimes are a significant component of global environmental change and have been implicated in species losses and invasions. Climate change is predicted to result in decreased precipitation and increased temperature across many fire-prone regions, resulting in longer fire seasons and increased fire likelihood, while reduced productivity may lead to increased fuel limitation and less fire in other situations (Moritz et al. 2012).

Fire and climate change in the mediterranean-type ecosystems: Mediterranean-type climate regions are projected to be among the most 'at risk' to the future impacts of climate change worldwide. Thomas et al. (2004) identify shrublands as the global structural vegetation type likely to lose the largest fraction of species, with the Southwest Australian Floristic Region (SWAFR) and the Cape of South Africa potentially losing the most (Malcolm et al. 2006). The mediterranean-type climate region of SWAFR covers an area of 300 000 km2 and contains more than 7200 plant species, of which ~79% are endemic (Beard et al. 2000; Hopper & Gioia 2004; Mucina et al. 2014). Mean maximum temperature in the region has increased by 0.15–0.20o C per decade over the period 1900–2007, and annual rainfall has decreased by 20% since the 1970's. Climate change projections infer a continuing temperature increase and rainfall decrease, implying a climate with longer fire seasons, and more extreme fire danger days.

Fire and population dynamics: Different plant taxa, and plant functional groups, may respond to shortened disturbance intervals and their interaction with changing climate in different ways, leading to potential shifts in plant community composition, diversity, structure and function. The biota of fire prone ecosystems have key traits that enable population persistence under a given fire regime. In plants, a fundamental dichotomy exists in fire response, with some species able to resprout after fire, while others rely exclusively on seeds for regeneration. These traits result in populations that are multi-aged and long lived on the one hand, and generally single-aged and shorter lived on the other. A second factor potentially affecting plant response to fire is the mode of seed storage, either in a serotinous (canopy) or in a soil-stored seed bank (SSB). Seed banks may confer resilience in species responses to changing environmental conditions, but there could be differences in response to changing climate-fire regimes between serotinous and SSB species: While some fraction of the seed bank in SSB species may be carried over between fires, all seeds of serotinous species are released, and either germinate or perish after each fire. Populations of serotinous species, particularly prevalent in SW Australia and South Africa, may therefore be especially vulnerable to extinction under a regime of more frequent fire.

Changes in three key plant population dynamics drivers associated with changing climate and fire regimes (demography, post-fire recruitment, fire interval) will likely combine to drive perennial plant species losses and ecosystem state changes more quickly than is currently proposed based on climate envelope or fire regime shifts alone, and must be taken into account in order to more fully assess potential climate change impacts. Species in regions subject to a warming and drying climate will suffer the cumulative impacts of changes to all of these drivers, with lower post-fire population densities, slower seed bank accumulation rates and shortened fire intervals combining to exacerbate immaturity risk and drive population declines. A conceptual model is presented – the interval squeeze

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model – that provides a framework for understanding potential change impacts. Using experimental fires, and including year to year variations in rainfall, we have partly quantified the implications of interval squeeze for the biodiverse shrub species flora of SWAFR.

Outlook: Adaptive approaches to fire management to increase the probability of *in situ* persistence will be required as climate changes, and may include heightened wildfire suppression, lengthened fire intervals between prescribed fires, and targeted vegetation and climate monitoring (measuring seed stores, using seasonal rainfall projections) to better predict potential fire-climate impacts, and better meet biodiversity conservation objectives.

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Figure 1. Fire sweeping through the kwongan shrubland in SW Australia.

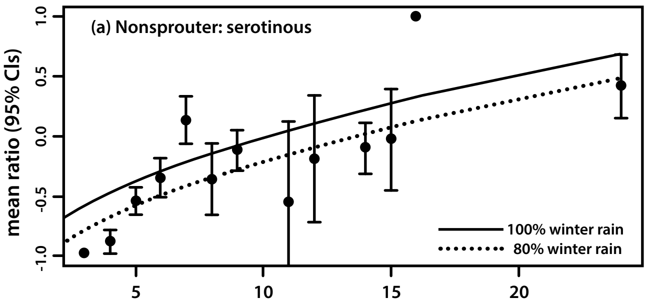
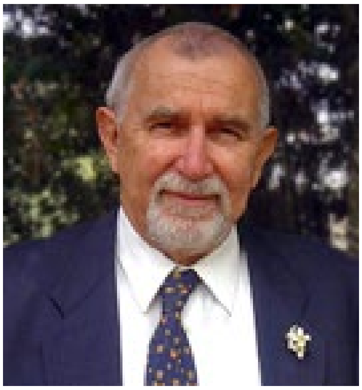


Figure 2. For species regenerating solely from seed, a 20% reduction in post-fire winter rainfall could increase the fire interval required for self-replacement by >50%.

Theory and practice in gradient-based vegetation survey

Andrew N. Gillison



Center for Biodiversity Management,
Yungaburra, QLD 4884, Australia

Correpondence: Andy Gillison, www.cbmglobe.org; andygillison@gmail.com; andyg@cbmglobe.org

Background: Living things are rarely distributed either uniformly or at random, their performance and dispersion in time and space being governed mainly by environmental gradients. Although most life scientists intuitively sample along gradients, methodology is commonly constrained by a statistical demand for random or systematic (e.g. grid-based) survey design. Such limitations can have profound logistical consequences and rarely capture the desired range of environmental gradients and because of spatial auto-correlation, may overestimate the true value of a particular variable (Gillison & Brewer 1985; Legendre & Fortin 1989). In order to maximize information gain about the distribution of biota and their functional attributes, a different kind of statistical model is required that better facilitates environmental representation and logistic efficiency.

Types of gradients: *Exogenous* gradients consist of abiotic elements such as climate and substrate, or naturally occurring or induced disturbances such as fire, grazing, agriculture, pathogens and pollutants. These elements frequently exhibit temporal as well as spatial aspects where seasonality and other cyclic or episodic events play a significant role in ecosystem performance. *Endogenous* gradients arise from within the plant, where survival and establishment are manifested through reproductive and vegetative regenerative strategies. Here combinations of plant functional traits and types can reflect differential physiological response gradients to exogenous influences expressed through slow-to-fast, functional cascades. The challenge is to select the most readily observable, gradient-based variables that are best suited to survey purpose and scale.

Gradient hierarchies: Across multiple scales, hierarchies of exogenous environmental gradients influence the capacity of variables to predict vegetation response to environmental change. The predictive value of mean annual temperature at global scale for example, is likely to be much less than that of soil nutrient availability along a local land use intensity gradient. Recent studies at multiple scales have also improved our understanding of endogenous gradients and the role of functional traits in species performance (Gillison 2013; de Bello et al. 2013). Consequently there is a clear need for a tiered or nested approach to survey that incorporates macro-scale exogenous gradients, meso-scale endo- and exogenous gradients of vegetation structure and micro-scale endogenous functional traits that can reflect whole-plant syndromes of functional elemental gradients from life form to stomata (Gillison 2013) or combined elements of the leaf economic spectrum (Pollock et al. 2012).

Review of methods: *History*: Advances in data capture and analysis have led to wide-ranging gradient-based sampling methods that owe much of their ecological underpinning to Robert Whittaker (e.g. 1973) despite some methodological issues (Wilson et al. 2004). *Sample placement*: Empirical studies indicate that regular spacing of samples along gradients as indicated by Whittaker and others may not capture as much information as those that also target gradient extremes (Mohler 1983) or spatially compressed habitats such as forest margins (Gillison 2013). *Plot size*: While criteria in defining plot size will continue to exercise debate, survey methods must inevitably address the fact that the performance of biota is influenced by interacting environmental gradients at multiple scales (Murray et al. 2008) where plot size can play a major role (May et al. 2013; Münkemüller et al. 2014). *Gradsect directed transects*: In an attempt to reconcile the tension between random *versus* subjective sampling (cf. Whittaker 1973; Cottam & Curtis 1995) a formal statistical model for purposive sampling using gradient-directed transects or 'gradsects' was put forward by Gillison and Brewer (1985). 'Gradsect' is defined here as *a purposive, gradient-directed transect that is designed to maximize information about species distribution and performance.* Gradsect design is based on a hierarchy of environmental

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factors arranged according to descending levels of perceived ecological importance (e.g. thermal, moisture, hydrology, geology, soil and land use). The statistical model avoids the need for random sampling, supporting instead, the purposive location of sample sites along pre-defined environmental gradients with the aim of improving information return and logistic efficiency. An underlying assumption of gradsect theory is that the gradients selected represent the key drivers of species and ecosystem performance. Gradient identification and location are usually determined via a combination of institutional and local information assisted by reconnaissance survey and an intuitive appraisal of site factors. Empirical evidence suggests that site location based on optimal search algorithms or decision trees is less effective than an intuitive approach, preferably coupled with iterative spatial modelling. Because gradsect design is not based on probability theory it cannot be used to generate area-based estimates of taxonomic or other biological entities – for which random sampling is necessary. Steeper gradients compress environmental niche space thereby indicating logistic advantages in sampling and improvements in detecting variation in taxa and functional traits and syndromes. However, access to the steepest gradients frequently presents difficulties requiring logistic trade-offs and site offsets. Hierarchical modelling using gradsects and combinations of leaf-height-seed size (LES) traits is providing more useful theoretical insights about the ecology of functional traits than standard statistical (multi-step) models (Pollock et al. 2012) while gradsect sampling of functional traits and vegetation structure show convergence in biodiversity indicators along similar environmental gradients in different continents (Gillison et al. 2013).

Perspectives: Many of the key elements and aims of gradient-based theory and practice are embodied in gradsects where the likelihood of locating rarities is enhanced and spatial modelling of species distribution and performance is facilitated through a more comprehensive environmental context than is normally acquired through random or purely systematic sampling. Gradsects outperform traditional statistically based designs in all known cases (cf. Wessels et al. 1998; Parker et al. 2011) and the methodology is being increasingly applied in ground-based and remotely sensed surveys world-wide especially in the USA for example in national park management and in developing metrics for biodiversity offsets.

Case studies: Examples of gradsect applications at local, regional and global scales are presented.

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Plant types and vegetation responses to climate manipulation at the Buxton hub

J. Phillip Grime

Buxton Climate Change Impacts
Laboratory (BCCIL), Department of
Animal and Plant Sciences, University
of Sheffield, Sheffield S10 2TN,
United Kingdom

Correspondence: Phil Grime,
j.p.grime@sheffield.ac.uk

Introduction: In present circumstances of rapidly-changing world conditions it is essential that we develop as fast as possible a common understanding of how communities and ecosystems in different parts of the world have assembled and will respond in future to impacts of changing climate and human exploitation. This presentation addresses these objectives under two headings. Part 1 draws heavily on a recent publication (Grime & Pierce 2012) and is concerned with recognition of primary functional types of plants and the mechanisms controlling their admission and persistence in communities. Part 2 describes a collaborative effort to measure responses to long-term manipulations of rainfall and temperature in an ancient grassland ecosystem in Northern England.

Plant traits, plant types and community assembly: In the 1960's a small group of plant ecologists known as the Unit of Comparative Plant Ecology (UCPE) was created in Sheffield. The UCPE was dedicated to a systematic "Big Data" research programme with two main components—extensive field surveys of herbaceous vegetation and standardised screening of plant traits in controlled laboratory conditions. These were explicit searches for pattern and mechanism inspired by the philosophies of J.T. Curtis and Robert MacArthur. Our founding hypothesis (Grime 1965) identified the search for recurring constraints in life history and physiology as the key to recognizing primary plant functional types. The plan was to engage with a large number of contrasted species and habitats of the British Flora and to persist long enough to establish, on a statistical and mechanistic basis, how and why trait values varied across species and habitats and in relation to variation in other trait values. We suspected that by this approach we could take some first steps in defining the major ecological factors and patterns of trait variation involved in the autecology of species and the assembly and functioning of plant communities and ecosystems. The outcome of this long and demanding programme has been the development of a comprehensive database with records of the composition of approximately 10,000 vegetation samples over an area of 3000 km^2 in North-Central UK and species trait values (Figure 1) corresponding to the same geographical area.

In 1974 a connection was established between the results of the laboratory experiments and the field survey data collected by UCPE. Inherently slow-growing species were found to be consistently associated with various kinds of infertile, unproductive habitats and fast-growers were restricted to fertile soils. A further synergy between lab and field data was apparent. The fast-growers fell into two categories: the first consisted of ephemerals of disturbed habitats and the second was made up of robust, perennial and clonal species. Recognition of this widespread pattern in the inland flora of UK led directly to the CSR theory of primary functional types (Grime 1974) and my main purpose in this meeting is to review recent testing, and extended application of the theory. Particular attention will be given to the role of plant functional types and individual traits during the assembly of plant communities and as determinants of the relative abundance of coexisting species.

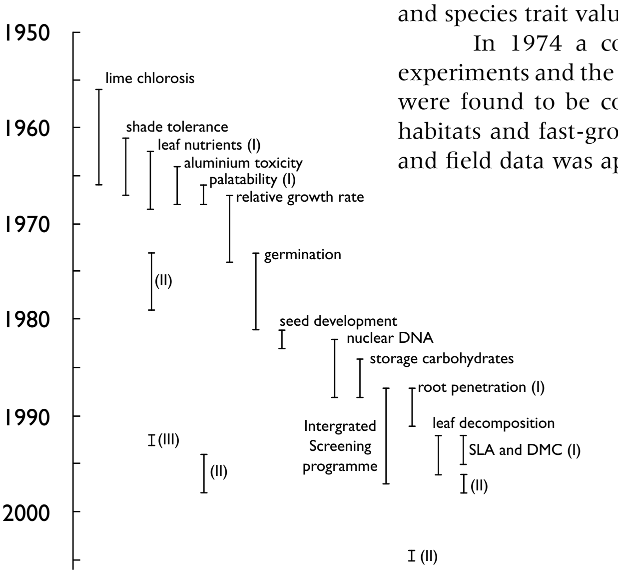

Figure 1. The chronology of the UCPE screening experiments. The numerals in brackets indicate screening experiments conducted in two or more phases.

Collaborative research involving long-term climate manipulation at Buxton: Commencing in 1987, UCPE enlisted the support of engineers to design and test techniques by which to apply identical continuous manipulations of temperature and rainfall to large plots (6 treatments, each replicated x5) at grassland sites at Buxton in North Derbyshire (an ancient unfertilized sheep pasture) and at Wytham in Oxfordshire (an abandoned wheat field). The results, after

Grime, J.P. 2014. Plant types and vegetation responses to climate manipulation at the Buxton hub. In: Mucina, L., Price, J.N. & Kalwij, J.M. (eds.), *Biodiversity and vegetation: patterns, processes, conservatio*n, pp. 35-36. Kwongan Foundation, Perth, AU.

Figure 2. Overall view of the Buxton site. Photo: A.P. Askew

five years, confirmed the strong differences between the two sites, (predicted from CSR theory) in responsiveness to the climate manipulations. With initially severe financial difficulty and slow scientific returns the experimental treatments and recording at Buxton has been sustained. The main experiment reached its 20th birthday in 2013 and has now achieved the status of an "Experimental Hub" providing a source of climate-treated and control materials (organisms and soil samples) for colleagues in Europe and further afield. Figure 3 identifies some of our current collaborations.

Fridley, Grime and Askew maintain the plots and record vegetation cover. Askew is responsible for maintaining the climate manipulation treatments. Soto has compared rates of carbon capture under contrasted climatic treatments. Wei-Ming He and Grime have compared the effects winter, spring summer and autumn warming on the composition of the Buxton grassland. Frank, Fridley, Askew and Mills are examining the effects of climate treatments on the chemistry of soil carbon. Stevens has examined the availability of soil mineral nutrients under contrasted climate treatments. Ravenscroft, Whitlock and Buckland are describing genetic responses of plant populations to climate manipulation. Vergeer is seeking evidence of epigenetic responses to climate in *Scabiosa columbaria*. Buckland and Evans have examined the effects of five climate treatments applied over 20 years on the timing and intensity of flowering in17 herbaceous species. Moser, Fridley and Askew are examining the effects of climate on the capacity of southern grasses to invade the Buxton plots. Hodgson, Stevens, Pierce and Cerabolini are seeking evidence of climate change on the distribution and abundance of native plant species in Northern England and Northern Italy. Schmidtlein is using CSR theory to detect the functional significance the composition of light reflected by leaf canopies. The National Science Foundation (USA) and the Ecological Continuity Trust (UK) support the activities at Buxton.

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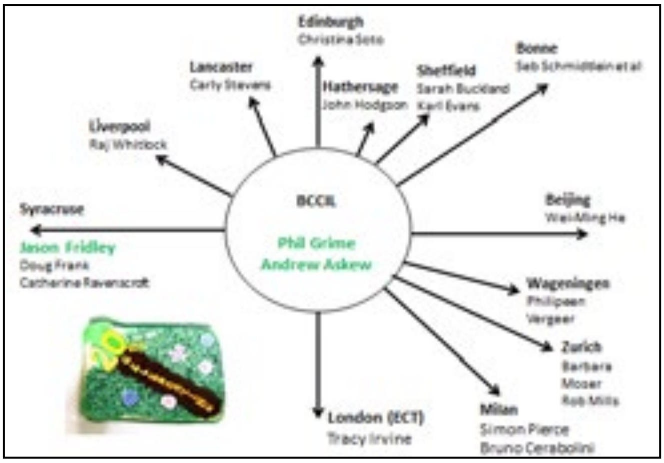

Figure 3. Major links and research partners of the Buxton Climate Change Impacts Laboratory (BCCIL).

Vegetation and flora survey in Western Australia

Greg Keighery

Science and Conservation Division,
WA Department of Parks and Wildlife,
Keiran McNamara Conservation
Science Centre, Locked Bag 104,
Bentley Delivery Centre WA 6983,
Australia

Correspondence: Greg Keighery,
greg.keighery@dpaw.wa.gov.au

Our playground: Western Australia with an area of 2 525 500 km2 is a continental sized state stretching 2391 kilometres from the Tropics through the arid zone to the warm-temperate Southwest Australian Floristic Region (SWAFR) characterized by mediterranean-like climate. The flora is correspondingly highly diverse with around 12 000 named taxa and another 1000 unnamed. This flora is highly endemic, especially in the SWAFR where 79% of the known 7239 taxa are endemic.

Vegetation mapping: Survey to catalogue, classify and map the vegetation in Western Australia began in the early 1900s. Most early studies were of necessity broad scale with few sampling points and focused on a structural/dominance approach. Ludwig Diels (Diels 1906) pioneered this work in classic study of the plant geography of southwest. Charles Gardner (Gardner 1944) continued with a statewide review in 1944. In the 1970s John Beard (Beard 1990) travelled the state using available mapping and aerial photography to prepare a 1:1 000 000 map of the state and a 1:250 000 for the southwest. The vegetation descriptions for these maps have been standardized and the maps digitized. On the basis of this work Beard established a set of 24 phytogeographic regions, these regions were pivotal to the development of the 53 regions identified in the Interim Biogeographical Regionalisation of Australia (IBRA areas). These maps remain the only state wide tool to appraise the broad adequacy of reservation and vegetation change. While they continue to be used at an Australia wide level for adequacy of 'ecosystem' level reservation status, they have been superseded in many areas by larger more comprehensive datasets. However with the advent of computer databases (especially GIS), detailed geological maps, satellite imagery the need for accessible computer based maps to guide management of fire especially in the vast outback regions of Western Australia remains acute. Small scale (ranging from 1:5000 to 1:25 000) vegetation mapping of specific reserves and bushland areas continues to be undertaken at for conservation planning, management and Environmental Impact Assessment. Many hundreds of these maps have been produced but the vast majority of these exist as a few paper copies. There is a considerable need to digitize and update these maps to the common standard and recent taxonomies. This mapping of vegetation units documents what vegetation is actually present within the reserve network, most reserves containing multiple vegetation units. Such a compilation has been done for the Avon Wheatbelt IBRA and Great Western Woodlands IBRA.

Point Based Surveys: A major shift from the structural/dominance approach to a quadrat based survey system occurred in the late 1970's. The issues responsible for this change included: homogeneity, repeatability, scale and improved computer capacity and analysis tools. Point based surveys are useful, whereas vegetation and land systems maps are quantitatively 'noisy', not uniform and have many assumptions with regard to species and community boundaries.

Regional Surveys: Regional surveys are multidisciplinary, usually focused on a major natural region (IBRA region or sub region) with the aim to inventory as wide a range of biota as possible to guide the establishment of a Comprehensive, adequate and representative reserve (CAR) network. Regional Surveys have taken place on the Nullarbor, Kimberley Rainforest, Carnarvon Basin, Pilbara and the Agricultural region of Western Australia (see Keighery et al. 2007). With this large faunal component they have less botanical quadrats, as the two need to correspond for modeling. Despite a focus on the common and widespread, regional surveys have contributed substantially to knowledge of the flora of Western Australia. They have greatly aided knowledge of the distribution of numerous plant taxa (common, rare and weeds) and new WA records. All of these data tied to geo-referenced habitats are suitable for monitoring.

Keighery, G. 2014. Vegetation and flora survey in Western Australia. In: Mucina, L., Price, J.N. & Kalwij, J.M. (eds.), *Biodiversity and vegetation: patterns, processes, conservation*, pp. 37-38. Kwongan Foundation, Perth, AU.

Subregional and local surveys: This level survey is principally flora based with a larger number of point-based surveys informing both vegetation maps and species lists. These surveys have uncovered numerous new taxa, demonstrated that species richness is a common feature of the southwest and that rarity (number of singletons recorded) is also common at many scales from the quadrat, habitat, and reserve to the region. These surveys have greatly added to knowledge of the distribution of weeds in native vegetation and new populations of threatened and near threatened taxa are routinely encountered.

In many of the above examples biological survey has consistently shown that structural vegetation mapping is generally a poor surrogate for composition, even at very broad scales. For example, the Biological Survey of the Agricultural zone demonstrated that the flora composition gradients were not congruent with the IBRA regionalisation of the southwest that was based on broad scale vegetation mapping.

Despite these successes over the past 30 years, there are still many outstanding issues. Distribution data on the major clades is now well understood, but at the species/genotypes level the flora is still poorly known. We are consistently recording new unknown taxa and presumed extinct taxa, some only 50 km from Perth. Currently we do not know how to address adequacy of conservation of the rare component of the flora (~30% across all scales), let alone at the population level. This obviously requires a much larger area than the normal 10% of land area to be set-aside as reserves. For example the Warren bioregion has over 40% of its area as conservation estate, yet 17% of its vascular flora is still unreserved.

Conclusions and outlook: The flora of Western Australia is still incompletely known and systematic survey at any scale (both floristic and structural) captures both expected and unexpected communities and species records. Vegetation maps are still needed at a range of scales to address prioritizing conservation and management actions. However, ready access and standardisation remain major issues that require resourcing. Integration of floristic communities, geological surfaces and mapped structural communities needs to be addressed, especially where land use conflicts occur. To ensure these data are widely available these surveys and much of the underpinning data are published. Now a looming challenge is how to maintain the large complex survey datasets through time in relation to funding, taxonomic and personnel change?

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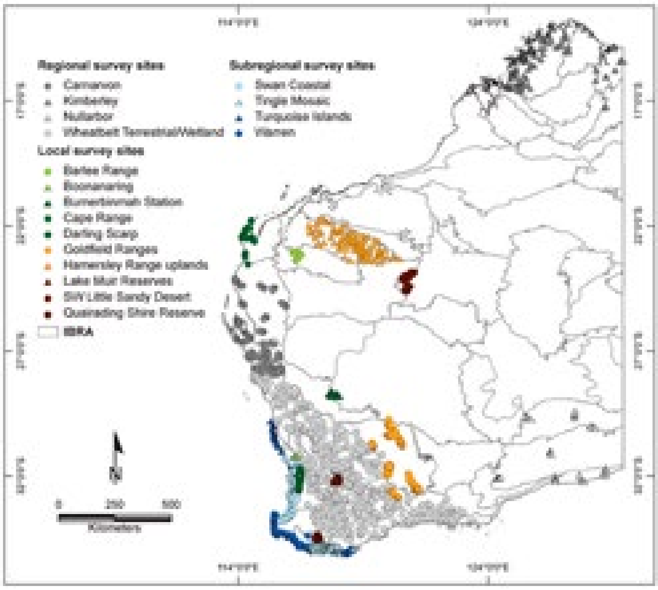
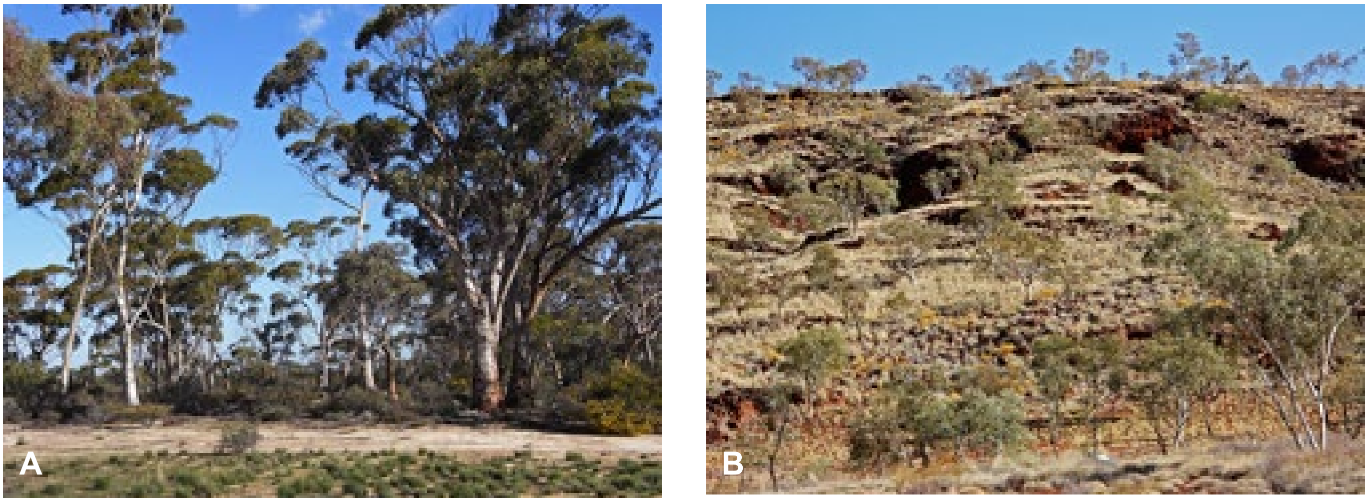


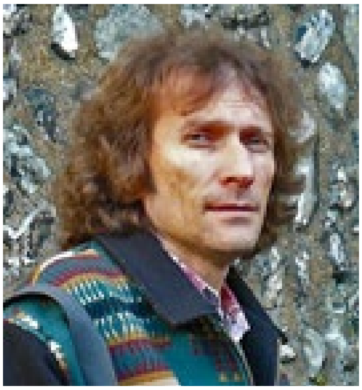
Extent of the flora and vegetation surveys of lead by the WA Department of Parks & Wildlife (formerly Department of Environment & Conservation) Biogeography Program. IBRA subregions are shown. From: Keighery et al. (2007).



Vegetation images form two representative regions that have been extensively surveyed: **A**: Wheatbelt: remnant *Eucalyptus salmonophloia* woodland at the feet of the Sandford Rock NR (N of Westonia). **B**: sparse dry savannah woodlands with snappy gum (*Eucalyptus leucophloia*) in Karijini National Park near Newman. Photos: L. Mucina.

The sunburnt country: an introduction to Australian native vegetation

David A. Keith (1,2,3)



1) Centre for Ecosystem Science, University of NSW, Sydney NSW 2052, Australia

2) Ecosystems Processes Team, NSW Office of Environment and Heritage, PO Box 1967 Hurstville NSW 2220, Australia

3) Long Term Ecological Research Network, Terrestrial Ecosystem Research Network, Fenner School of the Environment, Australian National University, Canberra ACT 0200, Australia

Correspondence: David Keith, david.keith@unsw.edu.au

Introduction: Often earmarked as the world's flattest and second driest continent, Australia is dominated by deserts, but also has a surprising diversity of forests, woodlands, heathlands, grasslands and wetlands. In this paper I aim to provide a synopsis of continental vegetation patterns and the ecological processes that maintain them. I will use a classification of major vegetation formations based on previous work (Keith 2004) as a framework for description. Although there is very substantial variation within these units, they are strongly distinguished by physiognomic, structural and compositional features and also reflect key differences in governing ecological processes. I contrast these features between two of the formations and then review recent thinking on evolutionary legacies, ecological processes and conservation issues that shape Australian vegetation.

Contrasting vegetation features: Australian rainforests are dense (closed) evergreen forests that exhibit strong beta diversity along latitudinal, elevation and rainfall gradients along the entire east coast and associated mountain ranges and across the tropical north. These gradients reflects turnover and transitions from structurally complex, highly diverse communities in the tropical lowlands of northeast Queensland, to structurally simple forests at high latitudes and altitudes characterised by one or a few tree species, abundant bryophyte epiphytes and understorey ferns. Along rainfall gradients in northern and eastern Australia, the stature of forests becomes shorter, and the abundance of epiphytes and ground-layer vegetation declines. Forests do not exist in the driest parts of the continent, but some forest taxa (e.g. *Ficus, Flindersia*) extend to very dry climates, a relict signature of Tertiary forests that were eliminated from vast areas of central, western and southern Australia during Miocene aridification. High floristic diversity at the familial and ordinal levels, especially in the tropics, reflects a deep evolutionary history. Gap dynamics is a dominant renewal process within Australian rainforests, although tropical cyclones and marginal fires entering from adjacent vegetation can initiate successional pathways over larger spatial scales. Zoochory and anemochory are major mechanisms of diaspore dispersal and the majority of plant species are likely to have non-dormant seeds, with seedlings and saplings exhibiting shade-tolerant features. These often persist in arrested states of development for some years until perishing or accelerating their growth when gaps are initiated.

Australian heathlands are dominated by shrubs with small sclerophyllous leaves with a variable component of sclerophyllous graminoids. Some are punctuated by emergent eucalypts. Their distribution is predominantly in the temperate southeast and southwest, although heathlands also occur in isolated parts of the tropics. Oligotrophic substrates such as podsolised sands, sandstone and acid volcanics are a unifying environmental feature of heathland systems, and there is strong compositional turnover in relation to regional rainfall gradients and local soil moisture gradients. Many heathlands are typified by high floristic diversity and local endemism, but unlike rainforests this is expressed primarily at the species level within relatively few plant families, suggesting more recent radiation of heathland flora. Nutritional impoverishment is widely held as a major evolutionary force, with traits such as sclerophylly, cluster roots, mycorrhizal associations, N-fixation and carnivory well represented in most Australian heathland systems. Fire regimes are primary drivers of ecosystem dynamics and evolution, with life history syndromes characterised by traits such as primordial tissue insulation and post-fire sprouting, serotiny, seed dormancy, myrmecochory and pyrogenic flowering. The interactions between these traits and characteristics of fire regimes determine the pathways and outcomes of vegetation dynamics in heathland systems.

Interpretation: Australia's flammable eucalypt forests and woodlands, acacia shrublands and hummock grasslands have no analogons worldwide, completely lacks

Keith, D.A. 2014. The sunburnt country: an introduction to Australian native vegetation. In: Mucina, L., Price, J.N. & Kalwij, J.M. (eds.), *Biodiversity and vegetation: patterns, processes, conservation*, pp. 39-40. Kwongan Foundation, Perth, AU.a

true deciduous forests and coniferous forests which are so dominant in temperate, boreal and montane environments of the northern hemisphere. The continent is also marked by high levels of floristic endemism at the species and generic levels, especially in certain hotspots of the humid tropical and temperate zones. While this is traditionally attributed to a long isolation and vicariant evolution of terrestrial biota since Australia separated from Gondwanaland, recent molecular phylogenies suggest a surprising frequency of intercontinental dispersal events over evolutionary time (Weston & Hill 2013). These apparently vary between biomes, but the current state of knowledge suggests that vicariance and dispersal both have significant roles in shaping Australian vegetation.

Recent theories propose that landscape history and productivity are central determinants of terrestrial vegetation (e.g. Orians & Milewski 2007). Eutrophic landscapes are relatively rare in Australia, whereas oligotrophic landscapes, limited by nutrients, and sometimes water, are widespread. The latter are characterised by sclerophyllous vegetation, slow plant growth rates and low specific leaf area, propagule dormancy and localised dispersal, high endemism, relatively simple trophic networks, and highly stochastic dynamics driven by boom/bust resource cycles and fire regimes. Oligotrophic environments limited by nutrients but not water or light include sclerophyllous forests and shrublands that are among the most fire-prone systems worldwide.

An overview of the factors that influence the conservation status and management of Australian vegetation identifies eight interacting groups of threatening processes: land clearing and associated fragmentation; soil degradation through erosion and eutrophication; landscape-scale changes in hydrology; invasions by exotic plants; trophic disruption by introduced herbivores and predators; invasive plant pathogens; altered fire regimes; and climate change. Their effects vary markedly between different vegetation formations, with temperate grasslands and grassy woodlands most affected by land clearing, semi-arid woodlands and arid shrublands affected by soil degradation and mammal introductions and heathlands affected by plant pathogens and fire regimes.

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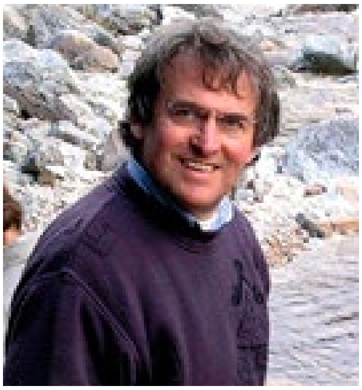
A: Tall moist temperate forest with *Eucalyptus jacksonii* (red tingle) and *E. guilfoylei* (yellow tingle) in the Warren region of SW Australia (Tree Top Walk in the Valley of the Giants by Walpole). **B:** Species rich sandstone kwongan shrublands of the Stirling Range National Park, Western Australia. Grass tree *Xanthorrhoea* sp. (*Xanthorrhoeaceae*) is in foreground. **C:** Open temperate eucalyptus woodland with sparse shrubby understorey (grey shrub: *Cratystylis conocephala*, *Asteraceae*) near Norseman, Western Australia. **D:** Spinifex (*Triodia* sp.) sparse spiny grassland on sandy dunes of the Little Sandy Desert south of Newman, Western Australia. **E:** Tropical seasonal savannah woodland dominated by *Eucalyptus tetrodonta* on the Mitchell Plateau, Northern Kimberley, Western Australia. The palm is *Livistona eastonii*. **F:** Coastal heath on the Kangaroo Island, South Australia. **G:** A unique cloud forest with many endemic plants occurs only on the southern mountains of Lord Howe Island 200 km east of the Australian mainland. **H:** Tropical freshwater swamp forest on Cape Tribulation in the Wet Tropics of northern Queensland, dominated by fan palm (*Licuala ramsayi*). Photos: A-F, H: L. Mucina; G: I. Hutton.

The role of phosphorus in explaining plant biodiversity patterns and processes in a global biodiversity hotspot

Hans Lambers (1), Patrick E. Hayes (1), Etienne Laliberté (1), Rafael S. Oliveira (1,2) & Graham Zemunik (1)



1) School of Plant Biology, The University of Western Australia, 35 Stirling Hwy, Crawley WA 6009, Perth, Australia

2) Departamento de Botânica, Instituto de Biologia, Universidade Estadual de Campinas, Campinas, 13083-970, São Paulo, Brazil

Correspondence: Hans Lambers, Hans.Lambers@uwa.edu.au

Introduction: South-western Australia is recognised as a global biodiversity hotspot (Myers et al. 2000), where the greatest plant diversity is found on the most severely phosphorus (P)-impoverished soils in kwongan (also spelled as kwongkan) (Lambers et al. 2010; Lambers et al. 2013), the term used for south-western Australian sandplain vegetation (Hopper 2014). Mycorrhizas are known to enhance plant P acquisition but, paradoxically, non-mycorrhizal plant families (e.g., *Proteaceae*) feature most prominently on the poorest soils, and these families are uncommon on soils containing more phosphorus (Lambers et al. 2014). Almost all *Proteaceae* produce carboxylate-releasing cluster roots, which are capable of mobilising scarcely available P and micronutrients, including manganese (Mn). They effectively 'mine' these nutrients, as opposed to 'scavenging' them from the soil solution further away from the root surface, as mycorrhizas do (Lambers et al. 2008). In addition to efficient acquisition of P from soil, south-western Australian *Proteaceae* species also use the acquired P very efficiently in photosynthesis. They achieve this high efficiency by (1) extensively replacing phospholipids in their membranes by galactolipids and sulfolipids during leaf development (Lambers et al. 2012), (2) functioning at very low levels of ribosomal RNA (Sulpice et al. 2014), which is the major organic P fraction in leaves (Veneklaas et al. 2012), and (3) allocating P preferentially to photosynthetic mesophyll cells (Shane et al. 2004), rather than to epidermal cells, as is common in other dicots (Conn & Gilliham 2010). South-western Australian *Proteaceae* also show a tremendous capacity to remobilise P from senescing leaves (Denton et al. 2007; Hayes et al. 2014) and contain a large amount of P in their seeds (Lambers et al. 2015). Non-mycorrhizal *Cyperaceae* produce dauciform roots, which function in a similar manner to cluster roots (Shane & Lambers 2005). There is evidence that sand-binding roots, *e.g.*, in *Anarthriaceae* (Shane et al. 2010) and *Haemodoraceae* (Smith et al. 2011), also function in a similar manner (Hayes et al. 2014; Lambers et al. 2014). The traits referred to here help explain the ecological success of non-mycorrhizal species on severely P-impoverished soils in south-western Australia. These same traits may also have allowed non-mycorrhizal families to diversify in these severely nutrient-impoverished environments.

Patterns in other severely nutrient-impoverished regions: In south-western Australia, there are about 700 *Proteaceae* species, and they are also a prominent non-mycorrhizal plant family in the P-impoverished fynbos, in the biodiversity hotspot of south-western South Africa, with >350 species (Lambers et al. 2015). In strong contrast, the *Proteaceae* are a poorly represented plant family, but *Cyperaceae* are common in the P-impoverished campos rupestres of the cerrado in Brazil (de Campos 2012), another global biodiversity hotspot (Myers et al. 2000). Most intriguingly, the pattern of non-mycorrhizal species featuring prominently on the most severely P-impoverished soils is very similar to that in kwongan. The non-mycorrhizal, 'P-mining' role played by *Proteaceae* is taken over by other families, including *Xyridaceae*, *Cactaceae*, *Velloziaceae* and *Eriocaulaceae*.

Interpretation: Non-mycorrhizal species with carboxylate-releasing P-mining strategies feature prominently on the wold's most P-impoverished soils. They coexist with mycorrhizal species and may even facilitate their growth (Muler et al. 2014). Since carboxylates not only mobilise P, but also Mn, leaf Mn concentrations might be used as a proxy for the carboxylate-releasing strategy (Abrahão et al. 2014; Hayes et al. 2014).

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Representatives of three enigmatic families typical of the Southwest Australian Floristic Region: **A:** phosphorus mining *Banksia coccinea* (*Proteaceae*) from Stirling Range; **B:** sedge-like ancient *Anarthria scabra* (*Anarthriaceae*) from Denmark area and; **C:** *Anigozanthos manglesii* (*Haemodoraceae*) from Perth metropolitan area – the latter two families contain species having sand-binding roots. Photos: L. Mucina.

Embedding vegetation science in conservation: getting the message across

Rob H. Marrs

School of Environmental Sciences,
University of Liverpool, Liverpool
L69 3GP, United Kingdom

Correspondence: Rob Marrs,
calluna@liv.ac.uk

Norman Moore in his classic textbook Moore (1987) put forward some very important viewpoints about his view of the future status of conservation declaring "conservation was both a subject and an aim" and thereafter that "it provided one of the most potent political ideas since Marxism, and that it is an idea that will tend to untie rather than divide mankind, but that time has not yet come". Implicit in this was the obvious issue that conservation was a science in its own right but that to implement any action required the co-operation of a series of stakeholders, including politicians, policy-makers and the general public. Well assuming this is the case how do vegetation scientists fare in bridging the gap between applied vegetation science and those who implement our findings. One of the crucial differences between vegetation scientists and the other two disciplines of applied biology (agriculture and medicine) is that we tend to think in terms of multivariate objectives as mostly we deal with plant communities, whereas in agriculture the objectives are usually mono-specific. Here I will outline three areas where I think vegetation science could, and perhaps should, provide a greater contribution (1) Involvement in the evidence base, (2) Translating science into practice, and (3) the Future importance of vegetation science in biodiversity offsetting.

Involvement in the evidence base: Increasingly, managers and policy-makers are attempting to implement "evidence-based" conservation. Partly, this is a fashion statement and partly there is a genuine attempt to try and develop conservation strategies that are likely to work. However, this is difficult for non-experts to do. Until recently, most applied end-users would not pay for access to the scientific literature and whilst increasing open-access has removed some of this barrier there is still the problem of (a) "Where do I look?" and perhaps more importantly: "How do I mediate between conflicting results/conclusions". Two recent advances in conservation science help here – the translational work by Bill Sutherland's www.conservationevidence.com that provides summary versions of scientific papers and a vehicle for reporting" conservation failures", and the development of Systematic Reviews *sensu stricto* within environmental science. The latter approach was originally developed for conservation but has been expanded to a wider environmental remit through the development of what is now essentially the Collaboration for Environmental Evidence that operates worldwide. This Collaboration was created following the success of the Cochrane Collaboration in medical science. Central to the Systematic Review approach is the minimization of bias within the literature searching and assessment period and subsequent use of meta-analysis (Fig. 1a). I will explore some examples where vegetation science data have been used and describe some of the highs and lows of this approach.

Translating science into simple models and action: Information flow between vegetation scientists and end-users is much easier if the results can be placed in a simple context. I will use three examples:

(a) Watt's original model of cyclic regeneration (Watt 1947) – this classic descriptive study of pattern and process bases on autogenesis has been used to develop management strategies for heaths and moors for decades. However, Watt's original model was not all-encompassing and there are several improvements that have provided scope for using this as a tool for improving information flow to end-users.

(b) Grime's hump-back curve relating species diversity to productivity – this in itself is interesting but coupled with long-term surveillance data provides a potential mechanism for the reduction in species diversity at the country-wide scale in Great Britain and the biotic homogenization of the flora.

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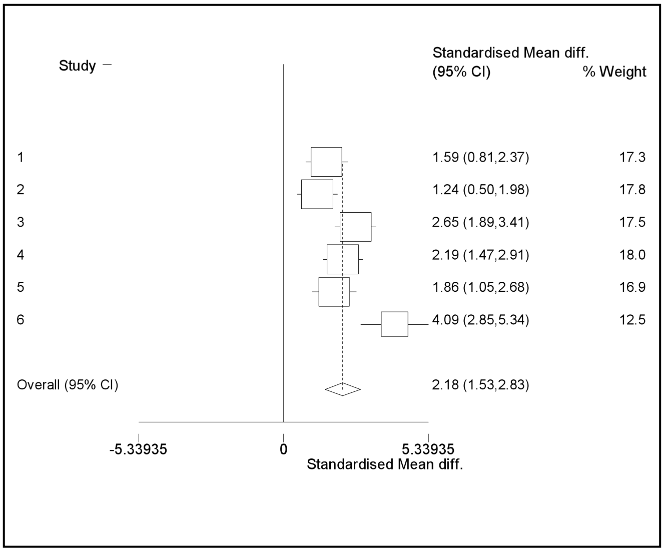

Figure 1. (a) Example of a use of formal meta-analysis to test for treatment success in six different experiments –in this case cutting bracken twice per year for 10 years –: response variable bracken cover (%) (Stewart et al. 2007).

(c) Experimental tests of management practices – testing old-wives tales versus more modern approaches. I will illustrate this part using data from a recently completed 8-year experiment testing traditional versus modern vegetation management techniques. The old-fashioned techniques are much championed by our conservation agencies but they don't work(Fig. 1b)!

Future importance of vegetation science in biodiversity offsetting and mitigation: Whether we like it or not, this is going to be an increasing issue in the future. I will, therefore, end on an approach I have pioneered for the UK for putting vegetation science at the heart of this issue.

Twenty-seven years on has conservation become the general idea uniting rather than dividing mankind, not yet but hopefully we are moving further in that direction.

Figure 1. (b) Applying traditional management treatments.

Acknowledgements: The ideas in this reflect discussions with many colleagues including: M. Le Duc, R. Lewis, R Pakeman and S. Smart.

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Can plant trait research become a serious science?

Norman Mason

Landcare Research, Private Bag 3127
Hamilton, New Zealand

Correspondence: Norm Mason,
MasonN@landcareresearch.co.nz

Background: The last decade has seen a surge in the volume of plant functional trait literature. However, trait research has, in many ways, yet to mature into a serious science. Usually, studies do not go beyond demonstrating trait-based relationships, and we are left with only the suggestion of what mechanisms might be driving observed patterns. Worse, most studies make little or no effort to extricate trait effects from the effects of species identity, so that we can't even be sure whether the observed patterns are 'real'. Overall, it remains difficult to assess whether functional trait studies tell us as much as they claim about the mechanisms driving species turnover and variation in ecosystem processes between communities. This presentation examines some of the potential pitfalls in taking trait-based relationships at face value and provides some suggestions for turning trait research into a serious science. In doing this I look to examples from the existing literature in three major areas of research where functional traits have been applied: 1) revealing co-existence mechanisms 2) predicting species responses to environmental gradients and disturbance, and 3) predicting ecosystem-level properties.

Epistemology 101: Correlation is not causality: This basic message seems to be often forgotten in trait research. Trait-based relationships have a role both at the start and the end of the scientific process. Firstly, they are a tool for generating hypotheses. Real plant communities are horrendously complex, and ecologists need a way to make sense of the jumble of species and individuals they find in the field. Traits, by allowing the search for consistent patterns across different assemblages and even different biomes, cut through this complexity, reducing the range of possible explanations for observed vegetation dynamics. However, the traits plant ecologists use are invariably linked to multiple aspects of function, so that multiple mechanisms could be driving any trait-based pattern. Trait research often fails to derive testable hypotheses for choosing between these competing mechanisms. Ideally, such hypotheses could be tested using manipulative experiments, although this is not always possible given the complexity of plant communities and the long time-scales over which they develop. Still astronomers manage to test hypotheses in galaxies light years away, so we should be able to manage something similar for plant communities.

Traits as predictors: Can we avoid black swans or are we empirical turkeys? The role of traits at the end of the scientific process is as a pathway to application. Traits have the potential to act as a common currency, allowing observations made on a subset of species to be used in predicting outcomes for a larger species pool. But are we really justified in using trait-based relationships to make predictions in the absence of a sound mechanistic understanding? Without it we increase the risk of being blindsided by "black swan" events. These extreme, but often predictable, events are having an increased influence on plant communities as climate change intensifies weather extremes and eruptions of invasive species disrupt existing vegetation processes. Trait-research is still largely the realm of empirical turkeys (who don't anticipate the butcher coming at Christmas, because she didn't come any of the 364 preceding days of the year). Thus, it is currently of little use in predicting and mitigating the impacts of the extreme events which have such a marked influence on vegetation.

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Can we trust observed trait patterns? The need for taxonomic generality:

A particular challenge for applying trait research is the potential for trait-based relationships to be driven by one, or several, dominant species (i.e. lack of taxonomic generality). This is potentially a problem both for traits as indicators of processes and traits as a means of extrapolation. If a trait-based relationship is driven by a single species, then we can't be sure which, if any, of the traits that we have measured are responsible for the observed patterns or processes. This severely limits our ability to draw conclusions about what mechanisms might be behind our observations. In such instances, metrics for different traits will usually be highly correlated, so that there will be no way to tell which traits have the strongest influence. This also increases the risk that the observed patterns could be due to "dark traits" - attributes of the species driving observed relationships that were not measured as part of the study.

Case study 1: Plant traits as predictors of tree climatic response: Laughlin et al. (2012), in their seminal paper propose a novel model, 'traitspace' for making trait-based predictions of plant species abundances along climatic gradients. They use tree distributions in the south-western USA to demonstrate their model. I consider how this work could be extended to a) test the taxonomic generality of the trait-climate relationships presented and b) generate hypotheses that need to be satisfied for these relationships to be useful in predicting species responses to climate change. I show that taxonomic generality could be tested with a very simple additional analysis of their data. I also propose a series of testable hypotheses and additional data required for predicting the impacts of increased frequency and severity of drought expected due to climate change.

Case study 2: Trait trade-offs and co-existence amongst desert annuals: Angert et al. (2009) found that Sonoran desert annual species separated along a trade-off based on relative growth rate (RGR) and water use efficiency (WUE). They also showed that species trait differences are correlated with differences in performance between species within years. Subsequent work has shown that the apparent RGR-WUE trade-off is driven by differences between species in germination and growth in response to temperature following rainfall events (Kimball 2011). This is thought to promote co-existence because the timing of precipitation varies between years, meaning that no species has a consistent advantage over its competitors. This body of work provides a good example of trait-based patterns being used to generate testable hypotheses for species co-existence mechanisms. However, there is apparently no assessment of taxonomic generality in any. I suggest some simple analyses for testing the taxonomic generality of several key relationships underpinning our current understanding of desert annual communities.

Case study 3: Community trait metrics as predictors of productivity in experimental grasslands: Mouillot et al. (2011) show that a combination of functional composition (community weighted mean: CWM trait values) and functional diversity provides very accurate predictions of variation in productivity across experimental grassland communities. They suggest that species differences in seasonal growth phenology and leaf inclination enhance productivity by increasing spatial and temporal resource use differentiation between species. However, they offer no suggestions for how these suppositions might be tested. Also, they make no effort to test the taxonomic generality of their trait-productivity relationships. I show that there while there are no existing statistical methods for testing the taxonomic generality of functional diversity-ecosystem function relationships, it shouldn't be hard to develop new methods. I also propose several hypotheses for testing the mechanisms Mouillot et al. (2011) proffer to explain their findings.

Conclusions: Functional traits are a tool for hypothesis generation. Too often trait studies treat demonstration of trait-based patterns as the end point, rather than the start of the scientific process. For trait research to become a serious science, trait-based patterns need to be explicitly embedded in a larger theoretical framework, from which hypotheses for testing proposed mechanisms can be derived. There are existing examples of this (e.g. co-existence amongst Sonoran Desert annuals) and future trait research should follow these. We also need more robust tests of whether observed patterns are really driven by the traits we have measured rather than the identity of the species in our studies. Trait research is an exciting, rapidly-developing field of plant ecology, but in embracing new approaches, we must not forget the basics of the scientific method.

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The role of vegetation science in the assessment of rehabilitation areas in Western Australia over some 30 years: a review

Elizabeth M. Mattiske

Mattiske Consulting Pty Ltd, P.O. Box 437, Kalamunda WA 6926, Australia

Correspondence: Elizabeth Mattiske, libby@mattiske.com.au

Introduction: After 35 years of assessing baseline flora and vegetation values and assessing rehabilitation areas in a range of post mining and cleared areas in Western Australia it is timely to undertake a review on the applicability of science in assessing the rehabilitation processes on disturbed environments. As areas of the global ecosystems come under increasing pressures, the application of science to understanding native ecosystems and their functioning processes becomes critical to the rehabilitation of disturbed systems. It is critical to review the history of past practices, current practices and current gaps so that future options can be placed into context. To illustrate these aspects, a range of examples from different baseline and rehabilitation studies in various bioregions in Western Australia will be utilized to illustrate the relevance of vegetation science in the assessment of rehabilitation areas. Vegetation scientists have a key role in applying science to assist in bridging gaps between key stakeholders such as community expectations, the regulators, the policy makers, the developers and the underlying need to maintain resilient and sustainable ecosystems on rehabilitated areas. The latter can be achieved through (1) the clearer presentation of data, (2) the translation of technical data into user friendly information based on science, (3) the review of past and current trends to increase efficiencies and outcomes on local, regional, national and global scales. The timing of the review is critical as the cumulative impacts increase on ecosystems and the allocation of resources to managing sustainable systems becomes more competitive at a global scale.

Translating science into action: The translation of relevant science can assist in allocating and prioritising resources to rehabilitating sustainable systems. On the basis of a range of studies in different bioregions there are some similar patterns on past and current practices that can inform gaps and future needs. There is an awareness that an understanding that the supporting environments in less disturbed and in rehabilitation areas are critical determinants in the resulting progress of rehabilitation of sustainable ecosystems. As indicated by Hobbs & Norton (1996) and Powell (1992) one of the critical sampling needs is the selection of baseline sites that are similar to those of the post disturbance site in relation to landforms, soil, biota and climatic conditions. In the 35 years of studies, the assessments have been influenced in many ways by the stakeholders, the changes in ecological terms and vegetation science (Allen 1990; Asher & Bell 1999; Walker 1999; Wilson 1999; Grant & Loneragan 2003). The review will cover these various influences to enable a critical review of potential options for the future. Through an understanding of the strengths and weaknesses of past and current practices and policies there is an opportunity to illustrate the broader capability of the involvement of vegetation science to challenges in the regional, national and global context. The interactions between supporting site conditions, seasonal conditions, site treatments, species selection, establishment and persistence characteristic of different taxa, management strategies, end land uses, cultural use of taxa and external processes influence the potential efficiencies and outcomes in rehabilitated areas.

Options for data review: The approach in assessing rehabilitated areas since the 1980's has shifted from a narrow and relatively simple data collection and interpretation process into a wider and more complex use of data collection and data analyses in both spatial and temporal vegetation techniques. The data in recent years includes more complex data on site parameters, floristic and structural components. In addition, overarching shifts in seasonal conditions and extreme events in some areas have the potential to influence the progress of many rehabilitation projects. Along with this complexity it has been possible to undertake more complex data analyses using a range of software

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packages. These vegetation science tools have assisted in summarizing the spatial and temporal patterns in and between less disturbed environment and rehabilitated areas. In recent years there has also been increasing expectations from wide community groups and different stakeholders. The types of data and the resulting outputs have assisted in the refinement of expectations and approaches to rehabilitation of disturbed areas as well as assisting in delineating key gaps and the development of options for future practices. Whilst there are some consistencies between practices and outcomes there remain many challenges to science. This review provides some options for such a critical review.

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James Tsakalos (PhD student at the UWA) fascinated by the complexity of kwongan at the Iluka Resources mining site at Eneabba. Photo: L. Mucina.

Rehabilitation practitioner Mark Dobrowolski (right) and vegetation scientist Sanyi Bartha (left) discussing the intricacies of post-rehab vegetation dynamics at the Iluka Resources mining site at Eneabba. Photo: L. Mucina.

Progress and challenges in ‘underground ecology’

Mari Moora

Department of Botany, Institute of Ecology and Earth Sciences, University of Tartu, EE-51005 Tartu, Estonia

Correspondence: Mari Moora, mari.moora@ut.ee

Shifting our attention under the ground: Classical plant community ecology relies on recording visible, well-recognizable features, processes and patterns. For example, different plant species are determined using morphological characteristics and their abundance is measured or estimated visually. Similarly, when we study the ecological interactions, such as herbivory, that underlie vegetation patterns, we rely on visible evidence: who is eating what. This remains an agreeable and irreplaceable way to study nature. However, it has its obvious important limitations. A major one for the study of vegetation is that with such an approach we often ignore at least a half of the community – the belowground part and its contribution to community richness and composition. Furthermore, associations between plants and other important members of the soil community, including the mutualists and antagonists of plants in the rhizosphere, are overlooked. While the importance of belowground parts of communities have been acknowledged for several decades, there has been a reluctance in (vegetation) ecology to change our approaches. One reason for this is that the tools required to effectively study belowground community ecology (i.e. powerful molecular methods) have been widely available for less than a decade and are still developing rapidly. However, there also seems to be a reluctance to consider things that we cannot see. That said, I believe that we are witnessing a conceptual shift in community ecology in general and vegetation ecology in particular that will lift ‘underground ecology’ up from its ‘shady status’ and tie it together with processes that we are able to see aboveground.

‘Underground’ contribution to community ecology: The application of molecular tools in parallel with classical vegetation analyses has recently challenged the prevailing understanding of processes that shape patterns in plant communities in space and time. Studies of roots in grasslands have revealed that the total small-scale diversity of plant communities is much higher than one would expect if only the aboveground part were studied (Hiiesalu et al. 2012, 2014). In addition, these findings have challenged longstanding theory about the relationship between diversity and productivity (Hiiesalu et al. 2012). Moreover, the soil environment retains a historical footprint (i.e. it preserves the structures and hence the DNA of the organisms that have inhabited it). Therefore, it is possible to describe past ecological communities with a precision and spatio-temporal scale never before achieved. Willerslev et al. (2014) presented 50 000 years of Arctic vegetation history, derived from ancient DNA metabarcoding of circumpolar plant diversity. They found that forbs were the most dominant group of vascular plants in the late Quaternary arctic vegetation, which contradicts the prevailing view that a graminoid-dominated ‘mammoth steppe’ existed in the Arctics at that time.

Soil microorganisms and plant community patterns: As they do aboveground, plants interact with other organisms belowground. The most widespread soil microbial group involved in these interactions are mycorrhizal fungi. As the majority of plant species are mycorrhizal, these fungi are intimately involved in the processes that regulate plant-environment relationships and hence the development of local and global plant diversity patterns. Depending on the partners involved and the morphological and functional characteristics of mycorrhiza, several types of mycorrhizal association are distinguished. Among angiosperm species, about 82 % form arbuscular mycorrhiza (AM), 9% orchid mycorrhiza (ORM), 2% ectomycorrhiza (EcM), 1% ericoid mycorrhiza (ERM) and 6 % are nonmycorrhizal (NM) (Brundrett 2009). AM fungi (phylum *Glomeromycota*) are ecologically obligate symbionts and depend on recent photosynthate supplied by a host plant. Fungal partners of other mycorrhizal types (ORM, EcM, ERM; taxa in phyla *Basidiomycota* and *Ascomycota* have developed alternative strategies for carbon gain (e.g. saprotrophic abilities) in addition to symbiosis with autotrophs.

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Coexistence, species pools and community assembly: Taking a simplified view, one may consider that in a given habitat (physio-chemical space) plant communities are assembled from those available and suitable plant species present in a region (i.e. the plant species pool) and their biotic interactions with one another and with available mutualistic and antagonistic counterparts (i.e. the 'interactors' species pool). Therefore, processes at both large (dispersal of the species) and small scales (interactions between coexisting species) act concurrently. While the distribution of plant species (and richness) along environmental gradients is relatively well described, the biogeography of microorganisms including soil fungi is in its infancy. Due to the cryptic lifestyle of soil fungi, knowledge about the global patterns of fungal species remains scarce, though new information is constantly accumulating thanks to the rapid development of molecular tools. This provides the potential to study variation in the richness of plants and their symbiotic fungi along environmental gradients. At the local community scale, plant coexistence is often explained either by stabilizing mechanisms that increase negative intraspecific interactions relative to interspecific interactions, thereby preventing monodominance of stronger competitors and extinction of weaker competitors, and equalizing mechanisms (which minimise average fitness differences between species, thus slowing the competitive exclusion of inferior competitors. It has been shown empirically that soil microbes can modify plant resource competition, accelerating intraspecific more than interspecific competition. There is also some evidence that negative plant–soil community feedback – a mechanism that modifies plant-to-plant interactions, not by altering competition for resources, but rather through the dynamics of soil microbes (changes in density and composition), and hence contributes to plant coexistence. Coexisting plants (often from different species) are linked via common mycorrhizal networks (CMN). Therefore, it has been suggested that resource sharing through CMN represents a mechanism for minimizing fitness differences between plant species (an equalizing mechanism). However, there is not yet convincing evidence for ecologically meaningful resource transfer via CMN.

Outlook: The studies of belowground plant and fungal communities have the potential to challenge prevailing ecological theories in vegetation science because current theories are based on the responses of aboveground vegetation. At the same time, studies of plant-associated soil microorganisms complement and improve prevailing coexistence theories in plant ecology. Future research should seek to translate the findings of small-scale laboratory studies to the community and ecosystem level so that the contribution of belowground processes to plant coexistence and diversity at different environmental scales can be revealed.

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Digging in the dirt. Final harvesting of experimental plots in the forest understorey where the influence of soil fertility and AM fungal activity on coexistence of plants above- and belowground was addressed (Koorem et al. 2012). Photos: M. Moora.

The metabolic theory of ecology: advances and retreats in formulating a general theory for ecology

Charles A. Price

School of Plant Biology, The University of Western Australia, 35 Stirling Hwy, Crawley WA 6009, Perth, Australia

Correspondence: Chuck Price, chuck.price@uwa.edu.au

Background: Plant ecology encompasses a vast array of factors and processes. The survival and reproduction of the individual depend on its ability to acquire resources through photosynthesis and nutrient uptake, and to transform those resources into biomass for growth, survival, and reproduction, all the while maintaining a homeostatic environment that differs markedly from its surroundings. Add to this the combined dynamics of intra- and interspecific interactions, and spatial and temporal heterogeneity in environmental variables, and the high dimensional nature of ecology soon confounds most attempts at synthesis. Any theoretical effort that begins to distil this vast array of factors into a unifying framework would help ecology to become a more predictive science.

The metabolic theory of ecology (MTE) is an attempt to provide a general, synthetic theory for the structure and function of plants and animals that integrates across scales from cells to ecosystems (Brown et al. 2004). MTE is grounded in the premise that the flux of energy at the organismal level can be predicted using basic biophysical principles of mass balance, hydrodynamics, biomechanics, and thermodynamics (West et al. 1999; Gillooly et al. 2001). Also central to the theory is the principle that organisms have evolved via natural selection to use resources efficiently. Applications of MTE to the plant sciences have been used to predict individual-level biological rates (e.g. primary production) and states (i.e. leaf mass, nutrient content), and the consequences of such phenomena at lower and higher levels of biological organization (Brown et al. 2004). The scope of the theory continues to expand and now encompasses a large array of biological phenomena – from the dynamics of cellular organelles to global patterns in biodiversity – and sub-disciplines, including plant physiology, community ecology, and ecosystem science.

Challenges to and for a general theory: Since its inception, MTE has generated considerable enthusiasm and controversy in the form of elaborations, extensions, and challenges to its theoretical precepts and empirical predictions. Theoretical and empirical evaluations point to both successes and failures of the assumptions and predictions of the many interrelated models that comprise the theory. Consequently, there has been a vigorous debate about its merits and limitations, a debate filled with claims and counter-claims that have served to both obfuscate and clarify what MTE is and what it is not (Price et al. 2012).

Here, I will consider those aspects of MTE that are most relevant to plant biologists, one that focuses on current applications of the theory, and the prospects and challenges for future applications. In doing so, I do not argue that the theory as a whole is entirely 'correct' or incorrect', but rather, I identify ways in which the theory is useful and areas in need of further refinement. Like all general theories, MTE is an imperfect representation of reality. As such, I evaluate the utility of MTE for both the questions it answers and the questions it raises, and show multiple examples in which MTE has provoked new empirical tests of plant biology, an undoubtedly useful outcome. In this way, I emphasize that MTE offers a coarse-grained view of the world that is insightful for understanding relationships between plant form and function, and relationships between individuals, populations, communities and ecosystems. With this objective in mind, I begin by reviewing the conceptual framework of MTE to clarify its major assumptions and mechanistic underpinnings with respect to plants. Next, I address what we perceive to be the strengths and weaknesses of MTE and of its key foundational predecessor, namely the model of West, Brown, and Enquist (WBE) (West et al. 1997, 1999), which offers a derivation for the body-mass scaling of metabolic rate and related traits in plants.

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Following this, I discuss some of the major predictions and applications of MTE regarding the structure and function of plants at different levels of biological organization, from individuals to populations to ecosystems. In doing so, I examine the utility of this framework for explaining particular biological phenomena and discuss promising new applications of MTE, as well as prospects and challenges for extending the theory.

Prospects for the future: The insight of MTE was to build on earlier foundations and to propose a unified theoretical framework, with roots in the theory of evolution by natural selection as well as physical principles. The promise of MTE was that a model with relatively few parameters, that are also biologically intuitive, could explain a substantial amount of variability in biological rates and states. Has this promise come to fruition? At the very least, MTE has served to energise the field and to refocus efforts on the use of biological scaling as a theoretical and empirical methodology. At the most, it provides a coarse-grained theory for the origin of metabolic scaling phenomena across disparate taxa, the impacts of which are potentially far reaching as evidenced by the numerous extensions that have been developed thus far. For example, MTE has recently been combined with information theory, life-history theory, the neutral theory of biodiversity, resource limitation models, Kimura's and Hubbell's neutral theory, food web theory, predator–prey models, and models of forest structure and dynamics to yield predictions on a suite of additional processes ranging from molecular evolution to food web structure.

Although these extensions are exciting, several lines of evidence suggest that some may reach beyond the foundations on which they rest, and represent, in some cases, new bodies of theory rather than confirmations of MTE. First and foremost, greater efforts have been expended in testing the predictions of MTE than in rigorous examination of its basic assumptions and structure. The available evidence indicates that many of the core MTE predictions, such as ¾ scaling of metabolic rate with mass, are not universal as previously believed and considerable variation across mammals and plants in network geometry remains unexplained. The reasons for these differences in predictions may have, at their root, the fact that structural and physiological assumptions of MTE differ from those in the biological system of interest. Moreover, some principles likely need to be modified or added to accurately capture the primary drivers behind the evolution of vascular networks and organismal metabolism.

Summary: I argue that there does not yet exist a complete, universal and causal theory that builds from network geometry and energy minimisation to individual, species, community, ecosystem and global level patterns. Whilst all models are necessarily incomplete approximations of reality, I believe the time is ripe for a new wave of empirical tests and the development of theories that emphasise the central role of body size, metabolism and temperature as highlighted by MTE and others.

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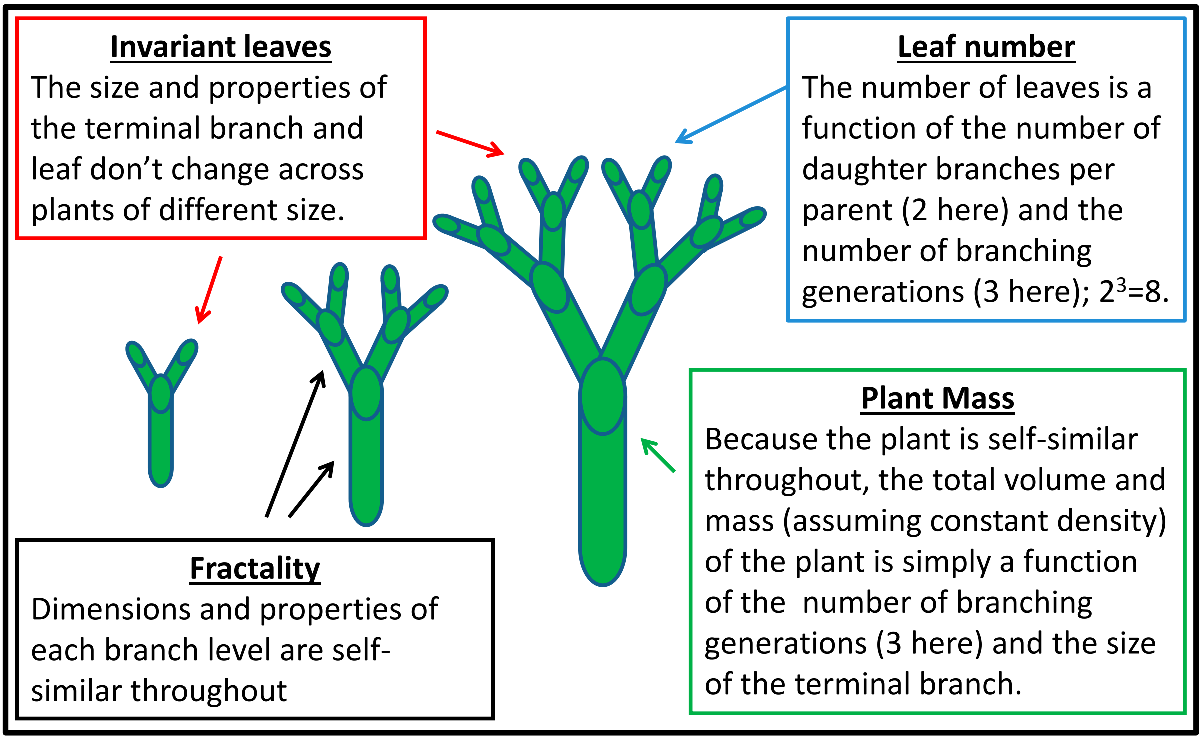

Invariant leaves
The size and properties of the terminal branch and leaf don't change across plants of different size.

Leaf number
The number of leaves is a function of the number of daughter branches per parent (2 here) and the number of branching generations (3 here); 2^3=8.

Plant Mass
Because the plant is self-similar throughout, the total volume and mass (assuming constant density) of the plant is simply a function of the number of branching generations (3 here) and the size of the terminal branch.

Fractality
Dimensions and properties of each branch level are self-similar throughout

The search for generalities in community assembly

Jodi N. Price

School of Plant Biology, The
University of Western Australia, 35
Stirling Hwy, Crawley WA 6009, Perth,
Australia

Correspondence: Jodi Price,
Jodi.Price@uwa.edu.au

Introduction: Identifying general 'rules' of community assembly has been a central goal in ecology for a long time. Broadly speaking, community assembly includes all the processes (e.g. dispersal, abiotic, and biotic filters) that govern species co-occurrences. Here I am focussing specifically on processes that govern small-scale patterns. Recently, there has been a surge in the numbers of studies examining dispersion of trait values among co-occurring species in order to understand community assembly processes. The usual method in trait dispersion studies is to compare the observed functional diversity (FD) among co-occurring species to that expected at random (based on species that occur within a sampling region, i.e. species pool), to determine if observed FD is greater or less than expected (showing trait divergence or convergence, respectively). Patterns in FD have been used to test long-standing ecological theories, such as limiting similarity – which predicts that co-occurring species should be more different than expected by chance due to competitive exclusion of species that overlap in niche space. In contrast, trait convergence has generally been attributed to habitat filtering for its role in increasing similarity among co-occurring species. There have been several recent developments in functional community ecology that I suggest have greatly advanced our understanding of community assembly, and should continue to be a focus for future trait-based research. These are: (1) moving beyond the simplistic dichotomy of assigning convergence to habitat filtering, and divergence to limiting similarity, (2) taking into account scale and within-community environmental variation, and (3) incorporating large-scale environmental gradients and if possible, a global perspective, in order to determine what generalities may exist, as well as their potential contingencies.

(1) Inferring process from trait patterns: Multiple processes can produce identical trait patterns, and more caution needs to be taken in assigning process to pattern (Mayfield & Levine 2010; de Bello et al. 2012). For instance, trait convergence can be competition-driven; where fitness differences are more important than niche differences (Chesson 2000) species with trait values associated with strong competitive ability can outcompete species with trait values associated with low competitive ability (de Bello et al. 2012). In this case, examining single traits expected to be associated with competitive ability (Herben & Goldberg 2014), and reducing the scale of observations to match that of plant-plant interactions may better inform process (de Bello et al. 2013). One approach to separate biotic convergence from abiotic convergence is to use a species pool that contains only those species that can persist under the prevailing environmental conditions (i.e. habitat-specific species pool), then any detected convergence is more likely to be due to biotic processes because habitat filters have been taken into account. Using this approach in grassland communities in Estonia, we found evidence for biotic convergence in plant height and seed weight (de Bello et al. 2012). Environmental heterogeneity can also produce patterns of trait divergence if species are filtered according to microhabitats (Price et al. 2014). Hence, scale, and the scale of environmental variation in particular, needs to be taken into account, which I discuss below.

(2) Scale and heterogeneity: The processes inferred from trait patterns are, to a large degree, due to *a priori* decisions about 'appropriate' scales of observation (Adler et al. 2013; Münkemüller et al. 2014). Broadly, it is expected that environmental filtering occurs at large spatial scales, whereas competition-driven divergence or convergence is expected to occur at small-spatial scales (e.g., de Bello et al. 2013). However, scale is used as a surrogate for direct measures of environmental variability, when in reality it is environmental variation *per se*, rather than scale that drives these processes (Willis et al. 2010). Few trait dispersion studies have directly measured within-community

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environmental heterogeneity, and this area has been highlighted as a key direction for future research (Adler et al. 2013). In my work, together with my colleagues, we have examined the influence of small-scale environmental heterogeneity on functional diversity in experimental as well as natural grassland communities. In experimental communities, we found species became more similar in plant height and leaf area in heterogeneous soil treatments compared with homogenous treatments of the same overall soil fertility (Price et al. 2014). In this case, we concluded that species that were better able to access patchily distributed resources (larger species) were able to outcompete smaller species thereby increasing similarity among the abundant species. Hence, small-scale environmental heterogeneity produced competition-driven convergence. In dry calcareous grasslands in Estonia, we found evidence that small-scale trait convergence was partly due to micro-environmental filtering.

(3) Gradients and multiple study sites: Whether there exists some general 'assembly rules' for plant ecology has been the subject of some conflict in ecology (e.g., Wilson 2009), but to date most studies have been from single sites and are therefore limited in their ability to test for generalities. Götzenberger and others (2012) reviewed the trait dispersion literature for plant communities, and found little support for deviations from random expectations. However, they highlighted that methodological improvements were needed before drawing strong conclusions. Since 2012, a number of large scale studies incorporating environmental gradients, and disturbances have been published (e.g. Bernard-Verdier et al. 2012), and these have improved our ability to make predictions about the conditions under which can we expect to find trait divergence and convergence. However, it is still unclear what patterns can be predicted under a particular set of environmental conditions. Additionally, experimental studies have tested if species are more likely to colonise sites where resident species are more different, to the colonising species, and I have used a meta-analysis approach to determine if resident species do reduce colonisation success of functionally similar species (Price & Pärtel 2013). We found the results were highly contingent on the experimental approach, with evidence for limiting similarity only found in synthetic assembled communities. Another approach to seek generalities is to use a co-ordinated survey design to collect data from multiple study sites using the same sampling protocol. Together with colleagues from the University of Tartu (TartuNetwork), we have been collecting small-scale plant community data, species traits, and environmental variables from ecologically similar, but evolutionary different temperate grasslands around the globe to determine if similar patterns (and processes) can be identified.

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Key contributions of restoration ecology to ecological theory

Rachel J. Standish

School of Plant Biology, The University of Western Australia, 35 Stirling Hwy, Crawley WA 6009, Perth, Australia

Correspondence: Rachel Standish, rachel.standish@uwa.edu.au

Introduction: While the practice of ecological restoration is probably hundreds if not thousands of years old, and the discipline of ecology at least 140 years old, the idea to use restoration to advance ecological theory has only been emphasized in the last three decades (Jordan & Lubick 2012). The practice of returning species, structure and function to degraded ecosystems requires answers to some basic ecological questions about how systems work— What prevents degraded ecosystems from recovering? How do communities assemble? What makes systems resistant to invasion? How does species diversity contribute to ecosystem functions? The answers to these and other questions pertinent to restoration draw on numerous ecological theories and require input from multiple disciplines. At the same time, restoration has helped to define the agenda for ecological research because it has been used as a basis for deciding which questions are worth answering and which are less relevant. Indeed, the demand for ecological theory to inform restoration efforts has rapidly increased as society has become progressively more motivated to reverse environmental degradation and to mitigate anticipated future environmental change. Here, I discuss key conceptual advances in community ecology that have occurred through the development of restoration science. Progress has been made because the restoration setting has proved to be an ideal place to test these particular ecological concepts.

Community assembly: With its emphasis on describing the rules that govern the assembly of communities through time, community assembly theory has long been a focus of restoration ecology and is all the richer for it. Assembly theory is often conceptualized as a series of ecological filters that operate on the regional species pool to determine community membership (Keddy 1992). The specific contributions of restoration ecology to the theory have been to emphasize the importance of dispersal limitation (i.e., dispersal filter), abiotic filters (e.g., soil conditions, microclimate), the potential role of facilitation (e.g., nurse plants) and that filters can be dynamic in that their importance can vary through time and influence species differently depending on their age (e.g., Zobel et al. 1998; Temperton et al. 2004). I present evidence from my own research to illustrate some of these contributions including the importance of abiotic filters (Daws et al. 2013), dynamic filters (Hallett et al. 2014) and facilitation among neighbouring plants in restoration settings.

Ecological thresholds: Nested within the broader conceptual framework of community assembly is the concept of ecological thresholds. Thresholds are defined as the point at which a small change in environmental conditions leads to a switch between ecosystem states (Suding & Hobbs 2009). The idea of thresholds first emerged in the 1970s, and has since become a major concept in restoration ecology given its relevance to understanding the dynamics of ecosystems that exhibit multiple stable states. In this context, the stable states are commonly the degraded state and the historical ecosystem state that is used as a benchmark for restoration efforts. In my own work, my colleagues and I have applied the thresholds concept to understand the dynamics of eucalypt woodlands in south-western Australia (Standish et al. 2009). In this system, threshold dynamics were evident for multiple environmental conditions and for more than one ecosystem state. Data supported the notion of an irreversible threshold associated with the switch from healthy to salt-affected woodland, another with the development of degraded ecosystem states after long-term grazing by livestock and lastly, data supported the idea of thresholds preventing the recovery of York gum woodland on abandoned farmland. The latter study in particular, contributed to an emerging reality of 'stuck' ecosystem states on old-fields elsewhere and to the development of additional models of vegetation succession

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to accompany the classic model (Cramer et al. 2008). More broadly, ecological thresholds have been described for a great variety of ecosystems including coral reefs, grasslands, and freshwater lakes. The threshold concept is now firmly entrenched in ecological theory, which is due, at least in part, to its now widespread application in the field of restoration ecology.

Link between biodiversity and ecosystem function: The ability to manipulate the diversity of restoration plantings creates an ideal opportunity to further explore the link between biodiversity and ecosystem function. Perhaps the greatest contribution of restoration ecology has been to expand understanding beyond grassland ecosystems to woody ecosystems. In particular, there is emerging interest in exploring the link between biodiversity and carbon sequestration. I describe a field experiment my colleagues and I have established in south-western Australia where we planted assemblages of 1, 2, 4 and 8 species to measure the link between plant diversity, carbon sequestration and other ecosystem functions (Perring et al. 2012). This experiment is still maturing and so I present data from an older restoration planting to explore the link between biological diversity and carbon sequestration in this biodiversity hotspot.

Outlook: There are other ecological concepts that are likely to be informed by restoration ecology in the future. Changed species interactions due to shifts in phenology associated with climate change have renewed interest in understanding the consequence of species losses and gains on ecosystem functions such as pollination. Synthetic ecosystems offer potential as model systems for the opportunity they provide for manipulation of species interactions within relatively simple networks. Additionally, now that the tools for large-scale restoration have become more widely utilized, there is the opportunity to test emerging ideas such as the role of connectivity and scale in determining ecosystem recovery from disturbance (Standish et al. 2014).

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Jonathan Anderson and Georg Wiehl planting trees at Peniup, Gondwana Link, southwestern Australia. The Stirling Ranges are visible on the horizon. Photo: R.J. Standish.

Back to basics with more complexity: trends in belowground ecology

François P. Teste

School of Plant Biology, The University of Western Australia, 35 Stirling Hwy, Crawley WA 6009, Perth, Australia

Correspondence: François Teste, francois.teste@uwa.edu.au

Background: Conducting research on what drives the structure of plant communities is of great interest in order to restore and conserve biodiversity. There are numerous interacting forces that appear to shape plant communities yet there remains important gaps in our understanding of the role of the belowground, the 'hidden-half' (Eshel & Beeckman 2013), in this quest to better predict plant community composition. For instance, mycorrhizal fungi, key root symbionts involved in improving nutrient acquisition in plants, have been demonstrated to have large effects on plant growth and are capable of altering the strength of plant-plant interactions (van der Heijden et al. 2008). This body of evidence should be adequate proof that mycorrhizal fungi can have large effects on the structure of plant communities. However, basic quantification of the colonisation of root and soil by mycorrhizal fungi, rhizosphere interactions with bacteria, and their functioning require more in-depth analyses to improve on replicability and precision. So-called rare root symbionts such as dual colonisers, tripartite root symbioses, and endophytes were originally viewed as simple scientific curiosities; only recently are we becoming more aware of their ubiquity in ecosystems where we know little about their functions. Furthermore, more complex biotic and abiotic interactions from a greater number of ecosystems need to be included in future ecological research to gain a better grasp at the importance of belowground symbionts. I also suggest some simple yet powerful approaches and tools that can enable us to shed more light on the 'hidden half' (Eshel & Beeckman 2013).

Back to basic biology

Colonisation by mycorrhizal fungi: quantifying the WHOLE 'hidden-half': Determining the level of mycorrhizal colonisation (i.e., the frequency of occupancy) on plant roots and in particular in native plant communities has been a staple variable to measure in belowground ecology. Much research has been conducted to support the view that mycorrhizal colonisation levels on fine roots can be misleading when interpreting the potential importance of mycorrhizal fungi on plant nutrient uptake, growth, and plant-plant interactions (Wallander 2006). There is a clear need to also quantity the extent of occupancy or scavenging potential of these fungi in the soil (Wallander 2006; Baldrian et al. 2013). Determining the frequency of occupancy and ideally the functioning of mycorrhizal fungi in the soil has been found to be of greater relevance in understanding how plants interact belowground. For instance, certain fungal species appear unimportant based on localised or patchy root colonisation. Yet they can occupy large volumes of soil and are involved in rapid exchange of nutrients between plants thus making them potentially as important as fungal species with high levels of root colonisation. Future ecological research that quantifies the level of colonisation by mycorrhizal fungi should now be required to include the extent of occupancy in the soil via density or biomass measurements.

The diversity of mycorrhizal types, structures, and functions: The refinement of our classification of mycorrhizal symbioses beyond the simplistic endo- and ectomycorrhizas remains understudied. The belowground ecology in ecosystems such as Australia's Mediterranean and tropical ecoystems have been understudied compared to forest and grassland ecosystems of the Northern hemisphere. In these ecosystems there is a high diversity of plant community assemblages that harbour an even more diverse set of belowground interactions and mycorrhizal types (Lambers et al. 2014). Evidence of diverse forms and functions of mycorrhizal types are continually being unravelled (Lambers et al. 2014) as we look more closely and identify the symbiotic structures on plant roots. Of relevance to hyperdiverse ecosystems is the occurrence of often seen 'ectomycorrhizal-like' roots and dark septate endophytes. Determining the function and taxonomy of these atypical root symbionts is needed since researchers globally are in agreement on their ubiquitous nature and potential ecological relevance (Kernaghan 2013).

'Switch-hitters': the Mickey Mantles of the belowground: Understudied systems are likely to harbour undiscovered fungal-fungal interactions. The colonisation of fine root tips by two different species of ectomycorrhizal fungi has been frequently observed as an interesting curiosity without much evidence for any relevance to plant community ecology. Similarly, the dual colonisation of the same fine roots by completely different mycorrhizal types (e.g., arbuscular mycorrhiza and ectomycorrhiza) has been seen in one woody plant species globally (these plants are sometimes referred to as 'switch-hitters') but needs more thorough investigation. However, there are findings from recent studies in Australia that these 'switch-hitters' may gain more nitrogen (N) and

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phosphorus (P) when growing alongside plants with other nutrient-acquisition strategies (Teste et al. 2014a, b). I suggest 'switch-hitters' represent an optimal nutrient-acquisition strategy for growing in nutrient-poor soils with a wide pH range amongst closely interacting plant species.

Realistic experimental designs and tools

Microcosms and complex experimental designs: More realistic and complex experiments have always been possible yet we still often restrict studies to simple one or two factor experiments. There is a need to improve on the realism of belowground studies attempting to demonstrate the influence of mycorrhizal fungi on plant community structure. The findings from glasshouse experiments can more easily be extrapolated to natural plant communities if larger pot sizes are used and if plants are allowed to interact as they do in natural plant communities. It is critical to understand the environmental context of the response in root growth studies but often mycorrhizas are ignored (Hodge 2012). These recommendations are important to bolster the relevance and realism of studies on long-lived plants in particular. It has become clear that experimental complexity is required via multifactorial design to better determine the contribution of mycorrhizal fungi relative to other biotic and abiotic factors (Klironomos et al. 2011). For example, manipulating the composition of the plant and mycorrhizal fungi along with abiotic factors is advocated.

Quantum dots as nutrient tracers: The use of quantum dots in nutrient tracing in soil is cutting-edge (Whiteside et al. 2012) and permits the convenient tracing of complex molecules belowground. Traditional isotope tracing remains a good alternative for determining transfer of simple elements in plant to soil systems. However, different size quantum dots emit different colours enabling simultaneous diagnosis of, for example, nitrate and organic N movement *in situ*. To do this, samples can be UV irradiated and high-resolution digital images taken and quantified to show nutrient movement and differential accumulation in plants, fungi, and soil. Furthermore, quantum dots offer the possibility of capturing *in situ* images of continuous mycorrhizal network links in the field something only previously possible in controlled environments using autoradiography.

High resolution isotope tracing: High resolution nano-scale Secondary Ion Mass Spectrometry (nanoSIMS) is the latest isotope imaging instrument capable of determining the concentration and sub-cellular fate of key nutrients in plants, mycorrhiza, mycelium, associated soil bacteria. The nanoSIMS allows to link structural features of mycorhizal fungi such as the mantle of ectomycorrhizas or symbiotic bacteria found on roots, to their isotopic composition with high sensitivity, precision, and resolution (60 nm) as never done before (Herrmann et al. 2007; Clode et al. 2009). Carbon (C) and N pools can be very small and dynamic in the rhizosphere and have escaped quantification in the past. Further detailed isotope tracing with Chip-stable isotope probing (Chip-Staple Isotope Probing (Radajewski et al. 2000; Mayali et al. 2013) is a logical extension of the nanoSIMS and can be done in conjunction with well-established microsatellite analyses, to help untangle the major sources of nutrients for unseen soil biota and their relative importance at a fine taxonomic level. Furthermore, the nanoSIMS can easily distinguish, for example, if more inorganic N ($^{15}NH_4$) was taken up by ectomycorrhizal fungi, compared to organic N (e.g. dual labelled ^{13}C and ^{15}N-amino acids, peptides etc.), and accumulated in the Hartig net structure.

Conclusion: A better understanding of belowground interactions, in particular plant interactions with key fungal root symbionts will enable us to gain more predictive power in determining what shapes plant communities. I first propose to take 'one step back' approach to allow us to take 'two steps forward' by improving on our basic quantification and classification of root symbionts. I then advocate for more complex experiments, especially if conducted in 'controlled environments' and demonstrate the advantage of using microcosms in glasshouse studies. Finally, I mention how the use of cutting-edge tools and technologies can better assist ecologists striving to acquire a clearer picture of the interactions in the 'hidden-half'.

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The role of the species pool in the study of diversity patterns and plant community assemblages

Martin Zobel

Department of Botany, Institute of Ecology and Earth Sciences, University of Tartu, EE-51005 Tartu, Estonia

Correspondence: Martin Zobel, martin.zobel@ut.ee

Concept of the species pool: Plant community ecology aims to describe and understand vegetation patterns. During the last decades in particular, explaining variation in plant diversity has been one of the major challenges. Classical coexistence theory addresses the coexistence of species within the same spatial region and is able to explain and predict local extinctions. It is insufficient to understand diversity patterns; a broader approach is needed. Species diversity of local plant assemblages is balanced by the regional processes of species *formation* and geographic *dispersal*, which add species to communities, against processes of predation, competitive exclusion, adaptation, and stochastic variation, which may promote local *extinction*. The species pool hypothesis was initially introduced to incorporate evolutionary diversification in the explanation of local (within region) diversity patterns. The hypothesis states that the number of species that occupy a given point would be determined to a large extent by the commonness of that particular habitat type. All else being equal, the larger the local and/or global area of a habitat type and the older its geological age, the greater the past opportunity for speciation and hence, the greater the number of available species that are adapted to that particular habitat type. The role of dispersal in landscapes was subsequently addressed as well. The general species pool hypothesis holds that local variation in species diversity is primarily dependent on the availability of species. Later authors added the idea of hierarchical filters – any member of the regional species pool should pass through a 'dispersal filter' and 'filter of biotic interactions' in order to establish and regenerate.

Towards an operational species pool hypothesis: In order to operationalize the species pool hypothesis, we still need to address two specific working hypotheses: (1) Local variation in species diversity is dependent on historical diversification (speciation minus extinction); (2) Local variation in species diversity is dependent on dispersal limitation of species. A number of studies demonstrate the significance of dispersal limitation in determining local diversity patterns. The shifting limitation hypothesis claims that the relative significance of dispersal limitation declines along productivity gradients. We need more evidence to determine how the significance of dispersal limitation as a driver of diversity patterns varies across ecological and geographic gradients. There is much less evidence with respect to the role of evolutionary history in determining local diversity patterns because the evolutionary and historical context of the current vegetation is an extremely complex issue to address. Contemporary landscapes, especially those in formerly glaciated areas, have been subject to local immigration and extinction events and the speciation centres and particular migration histories of currently coexisting species are hardly known. In most cases, it is virtually impossible to recognize the size and composition of historical species pools. Suitable model systems, notably sufficiently large areas with endemic flora and negligible human impact, are needed to disentangle the role and character of evolutionary processes. There is a handful of evidence demonstrating that current diversity patterns can be explained by historical factors like the size and ecological character of the historic habitat area.

Empirical measurement of species richness is important both for improving our understanding of nature, and for biodiversity conservation purposes. The species pool concept may become helpful in this context as well, because it may provide a general framework for comparative studies. Plant community diversity differs greatly for natural reasons, so comparing absolute richness may be uninformative when we would like, for instance, to evaluate the impact of anthropogenic factors on vegetation. It sounds quite natural to apply a relative measure of richness. For instance, one may calculate

Zobel, M. 2014. The role of the species pool in the study of diversity patterns and plant community assemblages. In: Mucina, L., Price, J.N. & Kalwij, J.M. (eds.), *Biodiversity and vegetation: patterns, processes, conservation*, pp. 59-60. Kwongan Foundation, Perth, AU.

what proportion of the local or regional species pool is present *in situ*. This approach has some analogies with the classical concept of community completeness, developed by Ramensky (1924).

Species pool and assembly rules: During recent decades, assembly rules of plant communities have commanded much attention, especially trait dispersion relative to random expectation. In order to assess habitat filtering, randomization tests need to incorporate landscape or regional flora and to include traits related to resource use and to tolerance of abiotic conditions. To reveal dispersal limitation, one needs to incorporate landscape or regional species pool in the randomization test and to address variation in dispersal distances. To reveal niche differentiation and equivalent competition, one needs to incorporate the community species pool in the randomization test and to address either traits indicating resource use or competitive ability.

Challenges: I conclude that the role of dispersal limitation in driving plant communities is quite well demonstrated. Further research has to find ecological patterns like changes in the rate of dispersal limitation along ecological gradients, as well as differences among biomes. It becomes more and more important to address dispersal limitation in a landscape context, taking the land use intensity and landscape structure into account. Knowledge of how dispersal limitation is related to human activities is also a key for restoring biodiversity.

More studies are needed to address the role of evolutionary processes in shaping local diversity patterns as we see them nowadays. It is not a trivial task and good model systems are inevitably needed for improving our understanding. Such model systems are expected to be sufficiently large areas with endemic flora under minimal human impact. Given the increasing human impact on vegetation worldwide, as well as poor knowledge of the flora of many tropical regions, finding appropriate model systems is a difficult task.

Species pools have to be taken into account when addressing assembly rules. By carefully defining the set of samples used for randomization (either local community species pool, regional species pool or local flora including all species regardless of their ecological requirements), as well as reasonable choice of plant traits (addressing separately resource use, abiotic tolerance, competitive ability (competitive effect in particular), other interactions like pollination, mycorrhiza or diseases, dispersal ability) would allow distinguishing the possible mechanisms of assembly like niche differentiation, equivalent competition, dispersal limitation, and habitat filtering.

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Species rich calcareous alvar grassland in Estonia. Discussion why European calcareous grassland harbour much more species than grasslands on acidic soils has facilitated development of the species pool concept. Photos: M. Zobel.

Oral Presentations

Anarthria scabra in the region of Augusta to Walpole.
Photo: L. Mucina.

Standardising vegetation mapping in Queensland, Australia: The Queensland Herbarium Regional Ecosystem and Survey Mapping Program

Eda Addicott (1,2,3)

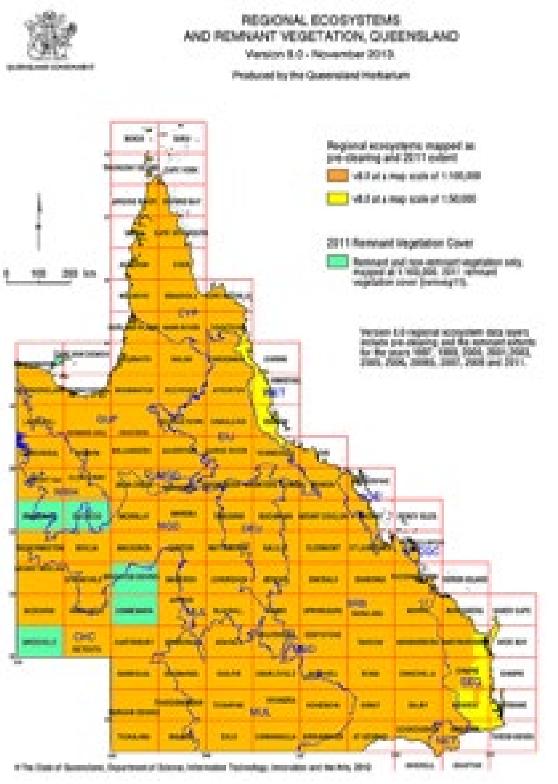
1) Queensland Herbarium, Department of Science, Information Technology, Innovation and the Arts, Brisbane Botanic Gardens, Mt Coot-tha Road, Toowong, Brisbane QLD 4066, Australia
2) Australian Tropical Herbarium, James Cook University, P.O. Box 6811, Cairns QLD 4870, Australia
3) Centre for Tropical Environmental and Sustainability Studies (TESS), School of Marine and Tropical Biology, James Cook University, P.O. Box 6811, Cairns QLD 4870, Australia

Correspondence: Eda Addicott, Eda.Addicott@science.dsitia.qld.gov.au

Background: Classification of landscapes is used globally as a tool for conservation planning, and, in Australia has been largely undertaken by regional scale mapping (for example Galloway et al. (1970). 'Regional ecosystems' (RE) were adopted as the state-wide landscape classification scheme in Queensland in 1999 with the assumption they were surrogates for biodiversity (Sattler & Williams 1999). The RE classification scheme is a triple-tiered hierarchy. The first division is based on IBRA biogeographic regions (Thackway & Cresswell 1995), the second on broad geological divisions, with consideration of geomorphological processes and soils, and the third on vegetation types. An RE is defined as 'a vegetation type in a bioregion that is consistently associated with a particular combination of geology, landform and soil' (Sattler & Williams 1999).

Approach: The State is divided into areas based on 1:250 000 scale map sheets. A team of botanists use remote sensing imagery to delineate imagery patterns on each map sheet at a scale of 1:100 000. Stratified sampling is used to comprehensively collect vegetation site data of the different imagery patterns and vegetation types across the whole map sheet. GIS is used to create final mapping layers. Experts describe vegetation types and RE based on the imagery patterns and hand-sorting of the vegetation site data.

Current State & Outlook: A state-wide mapping program commenced in 1999 with the aim of producing consistent and standardised RE mapping across the whole state. Approximately 95% of Queensland (164 million ha) has been mapped at a 1:100 000 scale or finer. Completion is expected at the end of 2015. To date there are 1 358 RE recognised across the state. Twenty thousand sampling sites exist in a state-wide database and are publicly available. The rate of change in extent of RE is documented and updated every two years (Accad et al. 2013). Detailed vegetation type descriptions, a standardised vegetation collection and mapping methodology and a broad scale vegetation map for Queensland are among many products from the mapping program. Regional ecosystems have become the primary dataset used in land management decisions in a wide range of spheres across the state. Standardising a numerical classification process for delineating the vegetation types of RE is currently underway.



Extent of the regional ecosystem mapping across Queensland, Australia.

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Are dams regulating diversity of riparian forests? Functional trade-offs and synergies in Mediterranean Europe

Francisca C. Aguiar (1), M. J. Martins (1), M. D. Bejarano (1), C. Nilsson (3), M. P. Portela (2), P. Segurado (1) & D. M. Merritt (4)

1) Centro de Estudos Florestais, Instituto Superior de Agronomia, Universidade de Lisboa, 1349-017 Lisboa, Portugal

2) Centro de Estudos de Hidrossistemas, Instituto Superior Técnico, Universidade de Lisboa, 1049-001 Lisboa, Portugal

3) Department of Ecology and Environmental Science, Umeå University, SE-90187 Umeå, Sweden

4) USDA Forest Service, Natural Resource Research Center, Fort Collins, CO 80526, USA

Correspondence: Francisca C. Aguiar, fraguiar@isa.ulisboa.pt

Background & Aim: Alteration of flow regimes by dams causes shifts in the composition and diversity and the trait syndromes of streamside plant communities (Merritt et al. 2010). There is still limited knowledge of riparian strategies to stream-flow regulation and moreover to different dam operations. Such an understanding would enable us to more strategically manage dams to both accommodate human uses and provide for the functioning of riparian ecosystems. In this study, we explored the adaptive strategies of riparian plant communities under the influence of different flow components.

Materials & Methods: We used paired data from rivers downstream from dams and from free-flowing rivers in Portugal (31 sites; 9 case studies). Cover data of 66 riparian woody species and 26 traits were used to derive riparian guilds as expressions of responses to stream flows, a variable representing seasonal and inter-annual water availability in arid-land rivers. Trait values were primarily obtained from FLOWBASE (http://www.isa.ulisboa.pt/proj/flowbase/). UPGMA clustering using Gower similarity measure and a principal coordinate analysis (PCoA) were performed. We calculated the 33 Indicators of Hydrological Alteration (IHA), for each case study and reduced the dimensionality of the variable matrix using the leaps algorithm, resulting in a subset of variables as proxies of the whole set of variables. Guilds and species' assemblages in relation to hydrological gradients were analysed using redundancy analysis (RDA). Variables were selected for the final model using forward selection. Functional diversity indices were calculated.

Main Results & Interpretations: Six riparian guilds were identified at 65% similarity level (Global R_{ANOSIM}=0.66). The first two axes of PCoA (~ 48% of variation explained) were mostly related with *Leaf phenology*, *Tolerance to drought*, *CSR strategies*, *Maximum height* (Axis 1), *Diaspore and Fruit type*, *Seed bank longevity* (Axis 2). A clear segregation was obtained between obligate riparian competitors with hygromorphic leaves and high waterlogging tolerance (*guild a*), facultative riparian, with physical defences, tap roots and high tolerance to drought (*guild b*), and non-riparian short-lived perennials, with high light requirements and dry fruits (*guild f*). As expected, *guild a* was more abundant in natural hydrographs than in dam-regulated rivers, but we found similar cover of *guilds b* and *f*, reflecting the widespread terrestrialization of Mediterranean rivers. We also observed low functional richness and evenness in the overall study area, and high functional divergence in regulated rivers from runoff river dams, revealing a high degree of niche differentiation. October median flows and high pulse duration were the most influential hydrological variables in RDA and account for 16.6% of variation. The first variable (magnitude of flows) separated most sites with low alterations (run-off-river dams; dams with powerhouses at the dam-toe) from those with higher water storage capacity; and high pulse duration (duration of flows) segregates free-flowing rivers from downstream dam sites. Regulated flows especially in rivers with reservoir dams favour alien species cover, and a wide range of riparian guilds. Allowing occasional high flows from reservoir dams, more seasonal variability, and varying inter-annual flows would favour establishment of riparian pioneer species and a better functioning riparian ecosystem.

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Dancing with multiple partners: Plant investment in different root symbiotic associations under nitrogen or phosphorus limitation

Felipe E. Albornoz (1), Hans Lambers (1), Benjamin L. Turner (1,2), François P. Teste (1) & Etienne Laliberté (1)

1) School of Plant Biology, The University of Western Australia, 35 Stirling Hwy, Crawley WA 6009, Perth, Australia

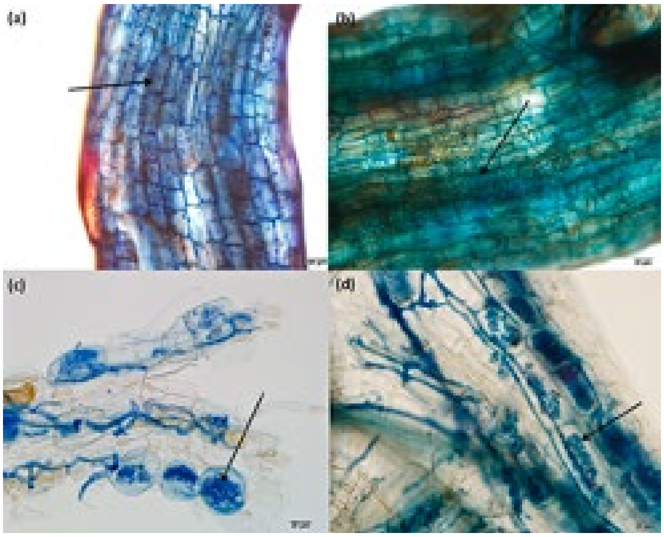
2) Smithsonian Tropical Research Institute, Apartado 0843-03092, Balboa, Ancon, Republic of Panama

Correspondence: Felipe E. Albornoz, 21181439@student.uwa.edu.au

Background & Aims: Plants allocate substantial amounts of carbon to sustain symbiotic associations with mycorrhizal fungi or N_2-fixing bacteria (Smith & Read 2008). Some plant species can form dual symbiotic associations with arbuscular mycorrhizal fungi (AMF) and ectomycorrhizal fungi (EMF; Lapeyrie & Chilvers 1985; Pagano & Scotti 2008), and sometimes a triple symbiosis involving nitrogen (N) fixing microorganisms occurs (Founoune et al. 2002). We hypothesised that plants preferentially allocate resources to different symbionts depending on the strength and type of nutrient limitation.

Materials & Methods: Using a long-term dune chronosequence along which there is a shift from N to strong phosphorus (P) limitation of plant growth with increasing soil age, we grew two species that form multiple symbiotic associations in soils of different ages (~100 years, ~1000 years, ~120,000 years). We measured AMF and EMF colonisation, nodule biomass, and foliar and soil nutrient concentrations.

Main Results & Interpretations: Arbuscular mycorrhizal root colonisation and investment in root nodules decreased with increasing soil age, while root colonisation by EMF increased. These changes were associated with marked increases in foliar N:P ratios. Additionally, we found a negative correlation between AMF and nodules with increasing EMF root colonisation, but only the main term "soil age" of the ANOVA was significant. Our results suggest that instead of a direct negative effect of one symbiont on another with soil age, the changes in soil nutrients are the main drivers of these shifts. Ectomycorrhizal fungi become increasingly important in severely P-impoverished soils where organic P is proportionally more abundant (Read 1989), while AMF enhance P acquisition in younger soils with more minerals (George et al. 1995). Investment in N_2-fixing symbioses declined with increasing P limitation, possibly because of high P requirements (Raven 2012).



Stained roots from *Acacia rostellifera* (a, c) and *Melaleuca systena* (b, d) showing ectomycorrhizas (a, b) and arbuscular mycorrhizas (c, d). Arrows in panels (a) and (b) show Hartig net; arrows in panels (c) and (d) show arbuscules.

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Do novel competitors shape species' response to climate change?

Jake M. Alexander (1), Jeffrey M. Diez (1,2) & Jonathan M. Levine (1)

1) Institute of Integrative Biology, Swiss Federal Institute of Technology (ETH Zürich), Universitaetstrasse 16, CH-8092 Zürich, Switzerland

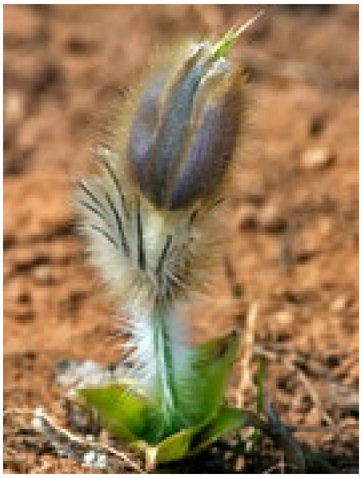
2) Department of Botany and Plant Sciences, University of California Riverside, 900 University Ave, Riverside, CA 92521, USA

Correspondence: Jake Alexander, jake.alexander@usys.ethz.c

Background & Aim: Climate change can have both direct ecophysiological effects on species, and indirect effects that are mediated through changes in interactions with other community members, such as competitors. Whilst effects of changing competition have been investigated among species that already co-occur today, much greater changes are expected due to changing identity of competitors through local extinction and immigration. These changes have, however, received very little empirical attention, and present a great uncertainty about species responses to climate change that is addressed by our study.

Materials & Methods: We transplanted four focal alpine plant species (*Anthyllis vulneraria* subsp. *alpestris, Plantago atrata, Pulsatilla vernalis, Scabiosa lucida*) and intact plant communities along an elevation gradient in Switzerland to simulate extreme scenarios for the competitive environments that they will encounter following climate warming. The scenarios differed depending on whether the focal species, or their surrounding community, either migrate, or fail to migrate, following climate warming. Specifically, to simulate focal species migration to track climate, we transplanted them into their original site at 2000 m a.s.l., where they either competed with their original community from 2000 m (as if it also migrated to track climate) or with a novel community from 2600 m (as if it failed to migrate). To simulate cases where focal species fail to migrate and so experience warming, we transplanted them to a lower elevation site at 1400 m a.s.l., where they either competed with their original community (as if it also failed to migrate) or with a novel low elevation community from 1400 m (as if it migrated to track changing climate). We assessed performance as growth and survival of the focal species after one year.

Main Results & Conclusions: Under scenarios in which the focal species track climate change (and so grew under their current climate), their performance (growth, survival) did not differ depending on whether they competed together with their current community or with a novel community of high elevation competitors. By contrast, when focal plants grew under warmer climate, their performance was greatly reduced by competition with a novel low elevation community compared to competition from their current community. These results indicate that the greatest impacts of climate warming on these species will be caused by the immigration of warm-adapted species from low elevation, and not by direct effects of climate or of changed interactions with their current competitors. Thus, we must find ways to explicitly account for effects of changing competitor identity in order to accurately forecast species responses to climate change.



Experimental garden in the Swiss Alps and one of the investigated species — *Pulsatilla vernalis* (above). Photos: J. Alexander.

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Global patterns and processes of plant invasions along elevation gradients: the Mountain Invasion Research Network (MIREN)

Jake M. Alexander (1) & MIREN Consortium (2)

1) Institute of Integrative Biology, Swiss Federal Institute of Technology (ETH Zürich), Universitaetstrasse 16, CH-8092 Zürich, Switzerland

2) http://www.miren.ethz.ch/people/

Correspondence Jake Alexander, jake.alexander@usys.ethz.ch

Background: Unlike most other ecosystems, high elevation environments in mountains currently experience relatively low levels of invasion by non-native plants. The Mountain Invasion Research Network (MIREN; www.miren.ethz.ch) was founded in 2005 to understand the reasons for this, document patterns and understand processes of plant invasions in mountains, and support preventive measures against potential future invasion. In particular, we ask which processes limit the spread of invasive species along elevation and land-use gradients, how this differs across regions with different climatic and introduction histories, and how mountain invasions will be impacted by climate change. MIREN has grown to represent 11 mountain regions including every continent. It is a boundary organization bridging local to global scales, as well as academia and conservation practitioners, with activities ranging from globally replicated experiments to networking and contributing to the development of locally-adapted solutions to plant invasions in mountains.

Results & Implications: Among other activities, we have conducted globally replicated, standardized surveys in the MIREN regions. These have shown that non-native plant richness consistently declines from low to high elevation, irrespective of the elevation extent and other environmental differences among regions. By applying such a standardised approach, we could explain these patterns by a process we call "directional ecological filtering" operating in all regions. This operates through the progressive loss of warm-adapted species with increasing elevation, so that the species found at the highest elevations are generalists that are also found at low elevation. This lack of specialist mountain species in non-native floras suggests that mountains are not inherently resistant to invasion, and explains the success of the few pre-adapted mountain species that are becoming invasive in some regions. Whilst helping to guide management strategies, our data also give insight into basic ecological questions such as the causes of species richness gradients. More generally, global but locally rooted networks such as MIREN bridging academia and management have the potential to address many important global change issues.

Outlook: We have found that until now, most non-native species in mountains are confined to disturbed (e.g. roadside) habitats and few invade semi-natural vegetation. However, this might change in the future, especially following climate change, which is expected to increase the susceptibility of plant communities to invasion. This general hypothesis is however difficult to test in most systems. Within the MIREN network, we are currently undertaking coordinated, replicated experiments in eight mountain regions (Chilean Andes, USA (Montana, Sierra Nevada), Swiss and German Alps, Kashmiri Himalaya and two sites on the Tibetan plateau) to ask: Does climate warming promote the invasion of native communities? The general approach involves transplanting intact communities to lower elevations to simulate warming, and then testing for differences in the performance of invaders sown into these communities. As well as providing a general answer to this important question, we hope to use our global replication to understand local contingencies and variability across broad bioclimatic gradients.

Sampling native and alien species along a roadside in the Swiss Alps, as part of a globally replicated survey conducted by the MIREN network. Photo: J. Alexander.

Alexander, J.M. & MIREN Consortium. 2014. Global patterns and processes of plant invasions along elevation gradients: the Mountain Invasion Research Network (MIREN). In: Mucina, L., Price, J.N. & Kalwij, J.M. (eds.), *Biodiversity and vegetation: patterns, processes, conservation*, p. 66. Kwongan Foundation, Perth, AU.

Environmental and land use drivers of patterns in steppe vegetation of the inner Anatolian landscapes

Didem Ambarlı & Can C. Bilgin

Biodiversity and Conservation Lab,
Department of Biological Sciences,
Middle East Technical University,
06800, Ankara, Turkey

Correspondence: Didem Ambarlı,
didem.ambarli@gmail.com

Background & Aim: Steppes of Turkey harbour high plant species diversity with a diverse land use history. However, the major factors driving patterns in the Turkish steppe vegetation have not been documented at a landscape level in a systematic way. Our aim was to reveal those factors, testing also for the influence of recent land use history dating back to a century ago, on the steppe vegetation of Inner Anatolia.

Materials & Methods: Focusing on one million hectares of mountainous land in a transition spanning Central and Eastern Anatolia, survey sites were selected using a gradsect sampling approach. Our study area was stratified using intersecting maps of major environmental parameters suspected to affect patterns in the steppe vegetation (aridity, soil type and bedrock, etc.). As there was no information available on spatial pattern of land use, this parameter was not included in the stratification. The stratification was followed by choice of two major gradients of environmental change and one site was surveyed in each eco-section (environmentally different unit) along these gradients, representing different environmental conditions. In each of resultant 31 sites, two replicates were set and in each replicate 10 plots (2 m X 2 m) were sampled. In each plot, plants with more than 10% cover were identified and their % cover was recorded. In addition, data on climate and soil parameters were compiled. The data on land use (forest destruction, arable land history, and grazing regime) were collected by means of a questionnaire involving local expert opinion. The data sets were merged at site level and analysed with Spearman's rank correlation, partial canonical correspondence analysis (pCCA) and interpreted with two-way indicator species analysis.

Main Results & Interpretations: The questionnaires revealed that all of the sites (n=31) originated from destruction of woodlands dominated by trees of *Quercus*, *Juniperus* or *Pinus sylvestris*. pCCA revealed three parameters, altitude, volcanic bedrock and rock cover with significant explanatory power on the variance of plant community composition at 0.05 significance level, explaining 24% of the variation altogether. Of the 31 sites, 16 of them were abandoned croplands of varying age (5–110 years). Age since last ploughing had the highest explanatory power (24%) as the single parameter yet it was tested as non-significant. The final CCA analysis with three parameters of significance explained 24% of the variation in species data.

Altitude was the factor with the highest correlation (0.98) with Axis 1 of the ordination. On the positive side of Axis 1 there was subalpine vegetation dominated by perennial forbs and perennial grasses, marked by high constancy of species of semi-natural steppes. Those were high-altitude sites (above 1900 m of alt.) that were not ploughed at least for 300 years and experienced transhumance grazing. At the opposite pole of Axis 1 there were sites located at altitudes spanning 1200–1400 m – mostly abandoned croplands. Those sites were dominated by annual grasses and forbs some of which are known as invasive weeds (e.g., *Taeniatherum caput-medusae* and *Aegilops* spp.). In the centre of the ordination space (projection of Axes 1 and 2) there were mid-altitude sites (alt. of 1400–1900 m) supporting semi-natural mountain steppes (n=10) and dominated by various other perennial forbs and grasses.

Acknowledgements: This study was supported by Rufford's Small Grant Foundation, Nature Conservation Centre (Turkey) and TEMA Foundation (Turkey).

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Ecosystem services related to plant diversity and vegetation in a forested watershed near Mexico City

Víctor Ávila-Akerberg (1), Xarhini García-Cepeda (2), Eileen Gómez-Álvarez (2) & Raquel Ortíz-Fernández (2)

1) Institute for Agricultural and Rural Sciences, Autonomous University of the State of Mexico, Toluca, Mexico
2) Mountain Ecosystems Laboratory, National Autonomous University of Mexico, Mexico City, Mexico

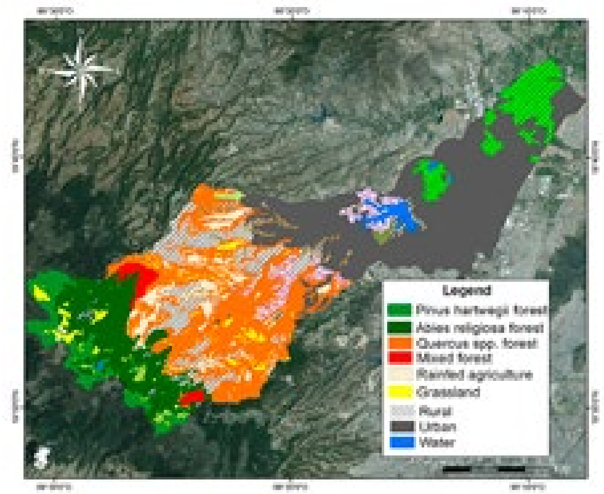
Correspondence: Víctor Ávila-Akerberg, vicaviak@gmail.com

Background & Aim: Mexico City has forested lands in the surrounding mountains that suffer from severe anthropogenic pressure. An understanding of the values and benefits provided by the plant and vegetation diversity of these areas is of fundamental importance to their conservation.

Materials & Methods: The main ecosystem services and goods related to phytodiversity of a forested watershed with a high altitudinal gradient (2200–3800 m) in the northwest of Mexico City were assessed. The main vegetation types dominating the region are oak forest (*Quercus rugosa* and *Q. laurina*), fir forest (*Abies religiosa*) and pine forest (*Pinus hartwegii*) at the highest altitudes, while a mosaic of grasslands and agricultural lands is typical of lower altitudes. Stakeholders were interviewed to gauge people's perceptions of the benefits and the relative importance of the plants and vegetation. Carbon storage in trees, presence of useful plants, habitat conservation and the perception of the recreational value rendered by plant diversity were assessed.

Main Results & Interpretations: Stakeholders recognised the existence of ecosystem goods and services provided by plant diversity of the area and considered those related to firewood, carbon storage, and medicinal use to be the most important. The study region is an important biodiversity source hosting about 635 plant species, of which 209 are considered useful (economically and otherwise); 10 plant species are listed as threatened. The forests of the region store on average about 101 tons of carbon per ha. The oak forests, followed by *Abies religiosa* forests, have the highest carbon storage values. Recreation was also recognised as an important ecosystem service. Mexico City's inhabitants visit this watershed mainly on weekends in order to experience less crowded, green spaces where they can pursue activities such as hiking, motorcycling, fishing, biking. Recreational activities mainly occur near the access roads; there were no recognized preferences in relation to forest type or plant diversity. We are developing a floristic field guide including the most representative plant species featuring different benefits to people. This guide will serve to promote public awareness on the value of nature and plant diversity in this important natural region located close to the Mexico City.

Guadalupe catchment near Mexico City.



Map of major vegetation and land use units in the Guadalupe catchment.

Ávila-Akerberg, V., García-Cepeda, X., Gómez-Álvarez, E. & Ortíz-Fernández, R. 2014. Ecosystem services related to plant diversity and vegetation in a forested watershed near Mexico City. In: Mucina, L., Price, J.N. & Kalwij, J.M. (eds.), *Biodiversity and vegetation: patterns, processes, conservation*, p. 68. Kwongan Foundation, Perth, AU.

Responses of persistent high nitrogen deposition, decreased sulphur acidification and climate change on a vegetation community over time

Vegar Bakkestuen (1,2) & Per Arild Aarrestad (3)

1) Norwegian Institute of Nature Research, Gaustadalléen 21, N-0349 Oslo, Norway
2) Geo-ecological Research Group, Department of Research and Collections, Natural History Museum, University of Oslo, P.O. Box 1172, N-0318 Blindern, Norway
3) Norwegian Institute of Nature Research, P.O. Box 5685, Sluppen, N-7034 Trondheim, Norway

Correspondence: Vegar Bakkestuen, vb@nina.no

Background & Aim: We investigated how forest understory vegetation changed over time according to the impact of long-range transported nitrogen (N) deposition, decreased sulphur (S) acidification and climate change. We present results from a 15-year study in Lund municipality in southwestern Norway. This area has for decades been affected by N deposition of >1500 mg N/m^2 per year, well above the critical load of N for this habitat type at 500 mg N/m^2 (Bakkestuen et al. 2010; Bobbink & Hettelingh 2011; Aas et al. 2012). In addition, long-range transported S deposition has decreased in the last decades due to international conventions on sulphur reductions.

Materials & Methods: Permanently marked 1 m^2 vegetation plots from a forest reference area, dominated by *Betula pubescens* in southwestern Norway, have been monitored for plant species composition four times in 5-year intervals: 1996, 2001, 2006 and 2011. Species abundances of the plots were measured by recording occurrences of species within 16 subplots (subplot frequency) and by percentage cover. Changes in species abundance, plot species richness and composition were analysed using univariate and multivariate methods. Soil characteristics such as pH, extractable macronutrients, S and N were included in the analyses as covariables following Økland et al. (2004).

Main Results & Interpretations: Over a 15-year period, the overall subplot species numbers have increased, while the tree canopy has become denser. Grasses such as *Molinia caerulea* and *Poa* spp. increased in abundance, as did the bryophytes and algae. In contrast, most other herbaceous and dwarf-shrub species, especially blueberry (*Vaccinium myrtillus*), had significantly decreased in cover. The environment showed an increased accessibility of soil macronutrients, warmer climate with a longer growing season and higher N-deposition, but less acidification of the soil due to reduced deposition of long-range airborne transported S. We relate the increased plant diversity to a more nutrient-rich soil. We also suggest that the increased cover of *Molinia, Poa* spp. and algae is a direct consequence of the currently high N-deposition in the area. The increased bryophyte cover was probably a response to increased moss growth caused by a longer growing season in spring and autumn. The decreased herbaceous species cover was probably caused by a denser tree canopy allowing less light to reach the forest floor. The increased soil macronutrients availability can be explained by increased soil mineralization due to warmer microclimate and less S acidification. This study shows fast responses in vegetation caused by broad scale environmental impacts. It also shows the importance of long term monitoring projects.

Acknowledgements: This work is supported by the Norwegian Environment Agency and the monitoring project 'TOV' terrestrial monitoring (http://tinyurl.com/nboa743).

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A network of springs as an indicator system across landscapes to predict long-term changes in ecosystems

Carl Beierkuhnlein & Andreas Schweiger

Department of Biogeography,
University of Bayreuth, D-95440
Bayreuth, Germany

Correspondence: Carl Beierkuhnlein,
carl.beierkuhnlein@uni-bayreuth.de

Background & Aim: Springs and their vegetation can serve as natural ecological laboratories. They provide a sound tool to assess ecosystem processes at landscape-scales by monitoring plant community changes. Species that prefer these habitats are very sensitive to any kind of environmental shifts in the catchment processes. Especially on siliceous bedrock, where the drainage to deep aquifer waters is marginal, the discharge of springs is closely connected with the state of their catchments. This, in turn, creates a close link between biogeochemical catchment processes, spring water chemistry, and the spring plant community response. Here we present results from 25-year long-term research on permanent plots in Central European forest springs.

Materials & Methods: We studied the water-spring habitats in forested regions of the Central European mountains. We focus on siliceous bedrock and complete forest cover in the catchment surface. In the 20th century these catchments have been exposed to acid rain that became reflected in the chemistry of spring waters and impacted on plant community composition. In recent years, increasingly climatic trends and extreme seasonal conditions are reflected in the physical and chemical conditions of spring waters. The spring vegetation is clearly separated from the forest floor plant community because the helocrenic springs exhibit a sharp boundary due to the frost impact in winter. As the vegetation of these specific habitats is adapted to long-term constancy of the environment, climatic changes are likely to cause shifts in dominance patterns and assembly rules (Audorff et al. 2011). We analyse hydrochemical, physical and plant community data from 102 springs that have been serving as permanent plots since 1989. We have sampled monthly both vegetation patterns as well as a series of hydrochemical properties. Since 1996 precisely localised transects were used to document fine-scale dynamic changes in plant species populations.

Main Results & Interpretations: The expected recovery from acidification (since the substantial decrease of anthropogenic air-borne sulphuric deposits) cannot be generalized, but seems to strongly depend on biogeochemical catchment characteristics. We found a clear separation in the behaviour between naturally acidified springs at high altitude, recently acidified springs at low altitude and non-acidified springs still supporting the pristine *Montio-Cardaminetea* communities. We also found that climatic extremes, such as the drought and heat period in 2003, modified the response patterns at both single plant species as well as community levels. However, recovery from this adverse period was rapid that illustrates an unexpectedly high flexibility of single species and the whole community response. We discuss the role of interacting drivers, such as pollution and climate change, on the community composition. Forest springs can serve as a model ecosystem since the other impacts are less important or constant. Direct human impact and disturbances are low or less diverse in these sites. This is why natural processes in the adaptation of plant communities to a modified environment can be studied in this system effectively.

Acknowledgements: This project is co-financed by the European fund for regional development of the European Union and the Bavarian State Ministry of the Environment and Consumer Protection.

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Do soil microbes drive *Acacia* species invasion in non-native ranges in Australia?

Christina Birnbaum (1, 2) & Michelle R. Leishman (1)

1) Macquarie University, Department of Biological Sciences, North Ryde NSW 2109, Australia

2) Murdoch University, School of Veterinary and Life Sciences, 90 South Street, Murdoch WA 6150, Australia

Correspondence: Christina Birnbaum, C.Birnbaum@murdoch.edu.au

Background & Aim: Australian acacias are one of the most notable invaders worldwide. Across Australian states, acacias became invasive or even naturalized after being introduced to ecosystems outside their natural distribution range. The relative importance of soil biota in their invasion success remains unknown, particularly that of rhizobial and fungal communities. We tested the Enemy Release Hypothesis and the Acquired Mutualism Hypothesis to disentangle the belowground invasion mechanisms that may have assisted in the invasion success of these acacias across Australia.

Materials & Methods: We examined the role of soil biota on the invasion success of four *Acacia* spp. (*A. cyclops, A. longifolia, A. melanoxylon* and *A. saligna*) and closely-related *Paraserianthes lophantha* in Australia. Soil and seed samples were collected from five native and five non-native populations of each species in four states (i.e. New South Wales, Victoria, South Australia and Western Australia). To assess the role of soil biota on plant performance we used a plant-soil feedback experiment to measure the net effect of beneficial and detrimental soil microbiota on plant performance. In addition, we used 454 sequencing to identify the nitrogen-fixing bacterial and fungal communities in nodules and soil.

Main Results: The plant-soil feedback experiment showed that soil origin had no effect on the performance of these five host species in their non-native range soils (Birnbaum & Leishman 2013). However, seed origin influenced the performance of two species, i.e. *A. cyclops* and *A. saligna*. Overall, 454 sequencing results revealed that geographic location had an effect on fungal, but not on rhizobial composition. Rhizobial and mainly fungal composition of *A. cyclops* were significantly different from the other four host species suggesting that this species encounters and plausibly associates with different soil microbiota compared to other acacias (Birnbaum et al. 2014). In conclusion, our results suggest that soil biota are unlikely to have impacted on the invasion success of these five species in Australia.

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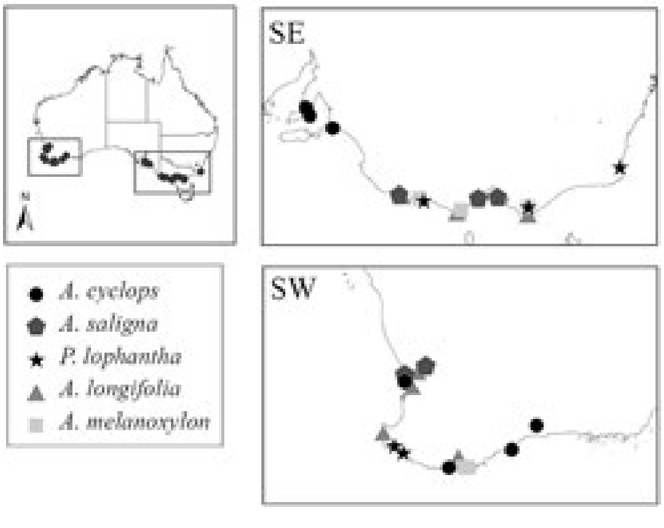

(Left) Locations of the native and non-native populations where seed and soil samples were collected for *Acacia cyclops*, *A. saligna*, *A. longifolia*, *A. melanoxylon* and *Paraserianthes lophantha* in Australia. Source: Birnbaum & Leishman (2013).

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Setting comprehensive and effective monitoring targets for banksia woodland restoration and management

Mark Brundrett (1,2), Karen Clarke (1) & Vanda Longman (1)

(1) Department of Parks and Wildlife,
Swan Region, Locked Bag 104,
Bentley Delivery Centre WA 6983,
Perth, Australia

(2) School of Plant Biology, The
University of Western Australia,
35 Stirling Hwy, Crawley WA 6009,
Perth, Australia

Correspondence: Mark Brundrett,
mark.brundrett@dpaw.wa.gov.au

Background & Aim: One of the greatest challenges in restoration practice is to develop completion targets based on flora and vegetation data that represents local plant community types while acknowledging limitations to plant recovery in disturbed habitats. This presentation describes how data from flora surveys were used to set targets for and monitor outcomes from restoration of vegetation and large-scale weed management. This work is part of an offset-funded restoration project targeting banksia (*Banksia* spp.; *Proteaceae*) woodlands on Bassendean Dunes on the Swan Coastal Plain, Perth, Western Australia.

Materials & Methods: Flora surveys in the topsoil source site and local reference areas were used to determine species richness and the relative abundance, dominance and frequency of occurrence of native and weed species. Vegetation maps were used to match completion targets to soil and hydrology variations within sites. Species area relationships were investigated using plots varying from 1 to 2500 m^2 to validate sampling protocols for monitoring restored areas. Monitoring surveys measured changes in the diversity and abundance of species over time using a network of plots in restored areas. Vegetation condition in existing banksia woodlands was assessed using 32 permanent monitoring sites along with aerial photographs from the past 60 years and satellite imagery from extending back 25 years.

Main Results & Interpretations: Species lists and plant cover and density targets were determined for specific plant community types using 100 m^2 plots in reference sites with similar banksia woodland floras. However, selecting species for restoration was complex because plant diversity varied considerably both within sites and between sites only a few km apart. Species were assigned to ecological categories based on propagation strategies to guide seed collection and to prepare plant lists for direct seeding and nursery orders. Data on the relative abundance, cover and frequency of native species was used to set monitoring targets for restoration. Aerial photographs of 1 ha areas in reference sites helped to set tree density targets, but also showed major historic disturbance impacts over the past 60 years.

There were more native species present in restored areas than in reference sites due to a combination of species that grew from the topsoil and those that recruited from within the site. Over 140 native species were present in these areas, including over 100 that emerged from the topsoil seed bank. However, the topsoil did not provide seed for trees or most large shrubs, so these were restored by planting seedlings and direct seeding. There also were 80 species of weeds. Plant diversity and density were dependent on the size of plants and area surveyed, so 130 small (1 m^2) plots were used to count seedlings, 76 medium sized (25 m^2) plots were used for herbs and shrubs and 12 large (625 m^2) plots were used for trees.

A network of 32 permanent monitoring sites (100 m^2) was established to monitor changes in vegetation condition in existing banksia woodlands due to weed management and other factors. The relative dominance of weeds and native plants changed substantially after weed control commenced. An unexpected severe fire in 7 of these plots provided the opportunity to measure vegetation recovery after fire and demonstrated diverse responses by different species. Long-term changes in tree health due to drought and fire were also measured using aerial photographs and satellite imagery. Past disturbance and recent fires in banksia woodland were linked to areas within nature reserves that now have a high degree of weed dominance.

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Flowering responses to twenty years of climate manipulation in an old, species-rich limestone grassland in North Derbyshire, England

Sarah M. Buckland (1) & Karl L. Evans (2)

1) Buxton Climate Change Impacts Laboratory, Harpur Hill, Buxton, Derbyshire, SK17 9JN, United Kingdom

2) Department of Animal and Plant Sciences, University of Sheffield, Sheffield S10 2TN, United Kingdom

Correspondence: Sarah Buckland, sarah.grime@btinternet.com

Background & Aim: It is well established that in temperate regions warmer spring temperatures associated with climate change has resulted in many plant species flowering earlier (Thackeray et al. 2010). Numerous aspects of climatic impacts on flowering responses, including their phenology, have, however, received insufficient attention. Our experimental study addresses three such issues. First, almost all studies of flowering phenology in temperate regions have focused solely on temperature as a driver of flowering time whilst precipitation regimes have received little attention. We quantify the relative contributions of temperature, precipitation regimes, and their interactions in driving flowering phenology. Second, we provide a rare test of whether winter warming reduces the magnitude of phenological advance, or results in delayed flowering, due to insufficient vernalisation (Cook et al. 2012). Finally, we assess how variation in temperature and precipitation regimes affects the duration and intensity of flowering which may have implications for other members of the community that consume resources generated by flowers, such as insect pollinators or seed predators.

Material & Methods: We explore these issues using phenological data from one of the world's longest running climate change manipulation experiments, i.e. the Buxton Climate Change Impacts Laboratory (BCCIL). This experiment established control and treatment plots on species-rich limestone grassland in 1993 across five treatments: winter and early spring warming, summer drought, summer watering, heating and drought, heating and watering. BCCIL provides an ideal case study for addressing our questions as despite the climate manipulations the floral composition in control and treatment plots is very similar (Grime et al. 2008), in part due to the buffering capacity of fine scale heterogeneity in soil depth (Fridley et al. 2011). The long-term nature of the experiment also enables us to take into account the effects of selection for divergent genotypes across treatment plots (Ravenscroft et al. 2014). Finally, the species rich nature of the site enables us to simultaneously assess responses across a large number of abundant species that comprise three major taxonomic and functional groups, i.e. grasses, sedges and forbs.

Results: We find that precipitation regime can be an important driver of phenological responses, no evidence that the experimental level of winter warming (3° C) caused delays in flowering, and that climatic variation can have marked impacts on the duration and intensity of flowering with potential impacts on other parts of the community at higher trophic levels.

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The Arctic Vegetation Map, Biodiversity Assessment and Vegetation Archive and the evaluation of changes in arctic flora and vegetation

Helga Bültmann (1), Frederikus J.A. Daniëls (1), Donald A. Walker (2), Amy L. Breen (2), Lisa Druckenmiller (2), Martha K. Raynolds (2) & Hans Meltofte (3)

1) Faculty of Biology, University of Münster, Schlossplatz 8, D-48143 Münster, Germany

2) University of Alaska Fairbanks, PO Box 757000, Fairbanks, AK 99775, USA

3) Department of Bioscience, Aarhus University, Ny Munkegade 116, DK-8000 Aarhus C, Denmark

Correspondence: Helga Bültmann, bultman@uni-muenster.de

Background: Global change poses a threat to the unique Arctic diversity. Hence, it is urgent to assemble the status quo of circumpolar knowledge of biodiversity. The Arctic biome spans the northern parts of N-America and Eurasia and has a comparatively uniform flora and vegetation. However, often different concepts and methods were applied in these areas in the description and classification of biodiversity. Thus a circumpolar approach is needed for future research and management. The Conservation of Arctic Flora and Fauna group (CAFF), the biodiversity working group of the Arctic Council, is the promoter of Arctic biodiversity studies and of developing conservation strategies and is also mandatory in communicating with governments and residents of the Arctic.

Current Research: The first important step is the Circumpolar Arctic Vegetation Map (CAVM Team 2003; Walker et al. 2005), which displays large scale vegetation units on a 1: 7 500 000 scale. The maps display five bioclimatic subzones A-E, topography, substrate chemistry, biomass and the floristic provinces.

The Arctic Biodiversity Assessment (ABA; Meltofte 2013) assesses status and trends of arctic biodiversity and recommends protection measures. In all, more than 21000 species of animals and plants are dealt with including 2218 vascular plants, 900 bryophytes and 1750 lichens. The patterns of plant and fungal diversity (Daniëls et al. 2013; Dahlberg & Bültmann 2013) will be discussed here in a global context.

Presently vegetation relevé data are assembled as a base for a circumpolar vegetation classification and development of spatial vegetation models. Several workshops showed the existence of an extensive number of relevés from all parts of the Arctic distributed in several databases. These will be combined in the Arctic Vegetation Archive (AVA; Walker et al. 2013). The archive is started with two prototypes for Alaska (A-AVA: Walker et al. 2014) and Greenland (G-AVA), which are developed in Fairbanks and Münster using the TURBOVEG program.

Future perspectives: These activities will collect and bundle data on Arctic flora and vegetation, which are not directly harvested and thus less monitored in comparison to fauna and avifauna. While some changes as shrub encroachment or greening can be observed from aerial photographs, finer changes in community composition (including small plant and animal species) would go unnoticed. Therefore red-listing and small-scale monitoring of arctic plant species and vegetation are urgently recommended.

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Is species turnover in the herb layer of old-growth beech forests driven by specific plant traits?

Giandiego Campetella (1), Sándor Bartha (2), Stefano Chelli (1), Camilla Wellstein (3), Marco Cervellini (1) & Roberto Canullo (1)

1) School of Biosciences and Veterinary Medicine, Population Ecology Laboratory, University of Camerino, Via Pontoni 5, I-62032 Camerino (MC), Italy

2) Institute of Ecology and Botany, MTA Centre for Ecological Research, H-2163 Vácrátót, Hungary

3) Faculty of Science and Technology, Free University of Bozen-Bolzano, Piazza Università 5, I-39100 Bozen, Italy

Correspondence:
Giandiego Campetella,
diego.campetella@unicam.it

Background and Aims: Studies of fine-scale dynamics, such as local species turnover and species mobility have great importance for understanding of both patterns of species coexistence and relative ecological mechanisms, but few of them are supported by long term observations. We address the question if species turnover in the herb layer in old-growth forests is driven by stochastic processes or if some specific plant traits can explain mechanisms of species extinction and species persistence.

Materials & Methods: We have selected four Permanent Monitoring Plots (PMPs; 50 m x 50 m) of the Italian Forest Ecosystem Monitoring Network (CONECOFOR) located in old growth (>100 years) beech forests distributed along a latitudinal span of 38° 25′ – 46° 03′ N and a climatic gradient (mean annual precipitation span: 1250–1900 mm). Within each PMP, we established a systematic grid of 100 quadrats (0.5 m X 0.5 m each) to monitor the cover of all plant species in the herb layer with eight surveys during a period of twelve years (1999–2011). We selected 19 plant traits (some named in italics below) responsible for key processes of resource acquisition, regeneration, reproduction, and stress tolerance, and compiled a complete species X trait matrix for all 93 species found in the monitoring sites. Distributions of traits (weighted by species presences) within the entire community were compared to the trait distributions in subsets of species that became extinct or remained persistent during the surveys. We used chi-square statistics to test if there were significant differences between the expected versus observed trait probability distributions.

Main Results & Interpretations: Considerable temporal species turnover was found but no successional trends. Within stands spatial heterogeneity was also significant. In all PMPs, *therophyte* species, plants with *non-clonal stem* and plants with low *seed mass* became extinct more often than expected. In the three southern PMPs, extinction was also more probable for species not equipped with a *below ground bud bank* and having *hygromorphic* leaves, while these patterns did not appear as prominent in the northernmost PMP characterized with the highest annual rainfall (1900 mm). Intermediate *SLA* values and *long dispersion* distances were characteristic for species with high persistence. We conclude that a rich pool of plant traits plays an important role in determining the fine-scale temporal dynamics of species in understories of old-growth beech forest. The slight variability found along the climatic gradient may point upon a context-dependent role of the functional traits.

Figure 2. (Above) Old growth beech forest in one of the investigated PMPs (VEN1) located in the Veneto Region, Venetian Prealps. Note the sticks marking the permanent sampling units. Photo: R. Canullo.

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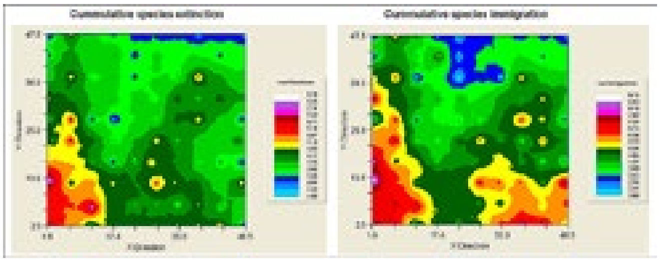

Figure 1. (Right) Cummulative (1999–2011) species extinction and species immigration (see the relative abundance in the colours sequence) maps in one of the investigated PMPs (CAM1) located in the Campania Region, Southern Apennines, Italy.

Campetella, G., Bartha, S., Chelli, S., Wellstein, C., Cervellini, M. & Canullo, R. 2014. Is species turnover in the herb layer of old-growth beech forests driven by specific plant traits? In: Mucina, L., Price, J.N. & Kalwij, J.M. (eds.), *Biodiversity and vegetation: patterns, processes, conservatio*n, p. 75. Kwongan Foundation, Perth, AU.

Solving the conflict between intensive and extensive approaches: transect based sampling design for comparative studies on fine scale plant community organization

Giandiego Campetella (1), Roberto Canullo (1), Ladislav Mucina (2), Miklós Kertész (3), Eszter Ruprecht (4), Károly Penksza (5), Stefano Chelli (1), András István Csathó (3), Zita Zimmermann (3), Cecília Komoly (3), Gábor Szabó (3), Judit Házi (3), Vera Besnyői (5), Péter Koncz (5), Andraž Čarni (6), Andrej Paušić (6), Nina Juvan (6), Camilla Wellstein (7), Mátyás Szépligeti (8), Sándor Csete (8), Róbert Kun (9) & Sándor Bartha (3)

1) Plant Diversity and Ecosystems Management Unit, School of Biosciences & Veterinary Medicine, University of Camerino, Via Pontoni 5, I-63032 Camerino, Italy

2) Iluka Chair, School of Plant Biology, The University of Western Australia, 35 Stirling Hwy, WA 6009 Crawley, Australia

3) Institute of Ecology and Botany, MTA Centre for Ecological Research, H-2163 Vácrátót, Hungary

4) Hungarian Department of Biology and Ecology, Babeş-Bolyai University, Republicii St 42, RO-400015 Cluj Napoca, Romania

5) Institute of Botany and Ecophysiology, Szent István University, Páter Károly u. 1, H-2103 Gödöllő, Hungary

6) Scientific Research Centre of the Slovenian Academy of Sciences and Arts, Jovan Hadži Institute of Biology, Novi trg 2, SI-1000 Ljubljana, Slovenia

7) Faculty of Science and Technology, Free University of Bozen-Bolzano, Piazza Università 5, I-39100 Bozen, Italy

8) Institute of Botany and Nature Conservation, Faculty of Forestry, University of West Hungary, Ady E u. 5, H-9400 Sopron, Hungary

9) Institute of Environmental and Landscape Management, Department of Nature Conservation and Landscape Ecology, Szent István University, Páter Károly u. 1, H-2103 Gödöllő, Hungary

Correspondence: Giandiego Campetella, diego.campetella@unicam.it

Background & Aims: Non-equilibrium ecological paradigm considers plant communities as a complex dissipative system, which calls for a methodology with explicit representation of spatiotemporal patterns. However, recording vegetation patterns at this fine scale is time consuming and labour intensive. In contrast, understanding general rules of community organization and vegetation structure would require a large number of comparative case studies. There is a clear trade-off between these intensive and extensive aspects in ecological applications. Here, we explore how field sampling techniques can be optimized compromizing between high resolution and large extent data collections. The coordinated distributed experiments and surveys based on these optimized sampling techniques might open new perspectives in comparative community ecology and macroecology.

Materiai & Methods: We used simulated data and field patterns recorded in the form of spatial coordinates of plant individuals or presence of species in high resolution grids. Applying computerized resampling techniques we tested how coenostate (Bartha et al. 2008) variables will change by changing the sampling parameters (resolution, extent and the shape of sampled area). We used information theory models for analyses which represent complex community patterns (beta diversity of species combinations and species associations) as a function of spatial resolution (Campetella et al. 2004).

Main Results & Interpretations: Results did not differ between high resolution grid data and spatial coordinate data. The absolute values of diversity and spatial dependence were similar between grids and transects, while the related characteristic scales slightly changed. Although scales were slightly biased when measured by transects, all ordering relations (i.e. differences between the compared vegetation types) remained invariant. Decreasing the spatial extent of samples resulted in a strong increase of stochastic variance and produced artefacts. These problems were less pronounced when transects were used or the shape of grids become elongated. Comparing the effects of different sampling parameters, sample extent was the most critical. Using the same extent, transects give more representative data. Transect sampling was also much faster than other sampling methods. We concluded that resolution and extent could be optimized if long (50 m) transects of contagious 5 cm X 5 cm sampling units were used. This protocol was tested and proved to be applicable in a wide range of vegetation types including forest herb layer communities, grasslands in old fields, tall- and shortgrass steppes, mountain grasslands and semi-desert communities. We propose using this sampling design in future coordinated distributed experiments and surveys for studying non-equilibrium dynamics and assembly rules of vegetation in a more operative way and improving the predictability of vegetation processes.

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Low carbon stocks and inputs of woody debris in two tropical, wind influenced lowland forests in Taiwan

Kuo-Jung Chao (1), Yi-Sheng Chen (2), Guo-Zhang Michael Song (3), Chien-Hui Liao (1), Yuan-Mou Chang (4) & Chiou-Rong Sheue (2)

1) International Master Program of Agriculture, National Chung Hsing University, 250 Kuo Kuang Road, Taichung 40227, Taiwan
2) Department of Life Sciences, National Chung Hsing University, 250 Kuo Kuang Road, Taichung 40227, Taiwan
3) Department of Biological Resources, National Chiayi University, 300 Syuefu Road, Chiayi City 60004, Taiwan
4) Department of Ecoscience and Ecotechnology, National University of Tainan, 33, Sec. 2, Shu-Lin St., Tainan 70005, Taiwan

Correspondence: Kuo-Jung Chao, kjungchao@dragon.nchu.edu.tw

Background & Aim: Taiwan, a small Pacific island, is one of the most typhoon-disturbed areas in the world. Typhoons may change carbon balance of forest ecosystems from positive to negative through causing death and damages of trees. Here, we present a test of a hypothesis that forests with a higher exposure to typhoons have higher stocks and inputs of woody debris.

Materials & Methods: Two lowland evergreen broad-leaved forests with similar biomass, but with different exposure to typhoons, were investigated in the Kenting National Park, Taiwan. Nanjenshan Forest Dynamics Plot are located in a valley, while the other forest (Lanjenchi Forest Dynamics Plot) is located on a nearby hilltop where it is exposed to strong winds including typhoons and winter monsoon. We used the line-intercept method to measure the amount of woody debris (diameter ≥ 1 cm) lying on the forest ground, and the plot method for the standing woody debris. Stocks of woody debris were censused in January of 2013 and 2014, and the inputs were sampled once every three months from April 2013 to April 2014. Two typhoons, Tembin (Aug. 2012) and Usagi (Sep. 2013), passed through the studied forests during the period of our investigations.

Main Results & Interpretations: Stocks and inputs of woody debris were lower in these two Taiwan forests when compared with other forests worldwide. We propose that frequent disturbance by typhoons reduces forest biomass (the source of woody debris) in Taiwan and, as a consequence, reduce stocks and inputs of woody debris. Interestingly, the studied two forests with different exposure to typhoons did not differ significantly in stocks and inputs of woody debris. This was attributed to the adaptation of structures (low tree height and high stem density) of the hilltop forest to frequent wind disturbance allowing trees to show more resistance to typhoons and in turn reducing stocks and inputs of woody debris.

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Figure 1. Vegetation profile in the Nanjenshan valley, Kenting National Park, Taiwan. It is a lowland evergreen broad-leaved forest and dominated by *Bischofia javanica*, *Ficus benjamina*, and *Dysoxylum hongkongense*. The height of the canopy is about 20 m.

Figure 2. Vegetation profile in the Lanjenchi hilltop, Kenting National Park, Taiwan. It is a lowland windswept evergreen dwarf forest and dominated by *Cyclobalanopsis championii*, *Castanopsis cuspidate* var. *carlesii*, and *Illicium arborescens*. The height of the canopy is about 3 to 5 m.

Chao, K.-J., Chen, Y.-S., Song, G.-Z.M., Liao, C.-H., Chang, Y.-M. & Sheue, C.-R. 2014. Low carbon stocks and inputs of woody debris in two tropical, wind influenced lowland forests in Taiwan. In: Mucina, L., Price, J.N. & Kalwij, J.M. (eds.), *Biodiversity and vegetation: patterns, processes, conservation*, p. 77. Kwongan Foundation, Perth, AU.

Global patterns of vascular plant species richness, endemic richness and endemicity: a new approach to identify hotspots and cold spots

Alessandro Chiarucci (1), Carl Beierkuhnlein (2), Franz Essl (3), Jose Maria Fernández-Palacios (4), Anke Jentsch (5), Carsten Hobohm (6), Holger Kreft (7), Pavel V. Krestov (8), Swantje Löbel (9), Manuel J. Steinbauer (2), David Storch (10), Kostas Triantis (11), Patrick Weigelt (7) & Jürgen Dengler (5,12)

1) Department of Life Sciences, University of Siena, I-53100 Siena, Italy
2) Biogeography, BayCEER, University of Bayreuth, D-95447 Bayreuth, Germany
3) Department of Botany and Biodiversity Research, University of Vienna, A-1030 Wien, Austria
4) Island Ecology and Biogeography, University of La Laguna, E-38206 La Laguna, Tenerife, Spain
5) Disturbance Ecology, BayCEER, University of Bayreuth, D-95447 Bayreuth, Germany
6) Interdisciplinary Institute of Environmental, Social and Human Sciences, University of Flensburg, D-24943 Flensburg, Germany
7) Biodiversity, Macroecology & Conservation Biogeography Group, Faculty of Forest Sciences and Forest Ecology, University of Göttingen, D-37077 Göttingen, Germany
8) Botanic Garden Institute of the Far-Eastern Branch of the Russian Academy of Sciences, 690024 Vladivostok, Russia
9) Department of Ecology and Genetics, Uppsala University, S-75236 Uppsala, Sweden
10) Center for Theoretical Study, Charles University in Prague and Academy of Sciences, CZ-110 00 Praha, Czech Republic
11) Department of Biology, National and Kapodistrian University of Athens, GR-15701 Athens, Greece
12) Synthesis Centre (sDiv), German Centre for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig, D-04103 Leipzig, Germany

Correspondence: Alessandro Chiarucci, chiarucci@unisi.it

Background: Endemic species, and their spatial distribution, have fascinated botanists for centuries, and regions with high levels of endemism have been the focus of much botanical and ecological research (Hobohm 2014). In this paper we refer to endemicity as the percentage of endemic species within an assemblage of species (flora), and to endemism as the corresponding absolute number and phenomenon in general. Endemicity is an ecological concept that is hard to tackle, as the level of endemism inevitably increases with area, both absolute and relative terms. This raises the question when a certain geographic entity can be considered as exceptionally rich in endemics. This study aims to propose a general framework to explain the variation of endemicity and the positive and negative deviation from its expectations.

Methods: We addressed this question by calculating a global mean level of endemicity of vascular plants in relation to grain size, for different regions spread in all the biomes of the planet. We did this by using a comprehensive data set of value triplets of area, native species richness and endemic species richness for several hundreds of geographic entities covering all continents and biomes and a very wide range of different sizes in a balanced manner. These triplets were collected by published and unpublished sources, as well as databases but also by the kind contribution of several colleagues from different continents. We then analysed the area dependence of total species richness (species-area relationships), endemic species richness (endemics-area relationships) and fraction of endemics (endemicity-area relationships). We carried out these analyses separately for islands and continents, and on the continents separately for the major zonobiomes. Several function types including some with breakpoints (Dengler 2010) were fitted for each of the datasets with non-linear regression.

Main Results & Interpretations: Generally, power functions provided a valid model to describe all three relationships. Like in the global analysis for species-area relationships of vascular plants by Gerstner et al. (2014), we found pronounced differences between zonobiomes (mostly in the c-value, partly also in the z-value) for all three types of diversity-area relationships. Islands had steeper species-area and shallower endemics-area curves than mainland areas. Finally, consistently across all subsets, the species-area relationships became steeper (i.e. had a higher z-value) above a certain grain size, typically at a grain size of about 100 000 km^2. Then, we combined the various diversity-area relationships of the various zonobiomes and islands into global mean functions, weighted by fractional area, of global vascular plant species richness, endemic richness and endemicity. Based on these global mean relationships we proposed a normal endemicity index to assess how much a geographic entity (of any size) is below or above the expected value.

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Physiography and spectral index based mixed models improve the explanation of variation in plant diversity: a study from the Himalaya

Vishwas S. Chitale (1), Mukunda D. Behera (1) & Partha S. Roy (2)

1) Spatial Analysis and Modelling Laboratory, Centre for Oceans, Rivers, Atmosphere and Land Sciences (CORAL), Indian Institute of Technology Kharagpur, West Bengal, Kharagpur, India

2) Center for Earth & Space Sciences, University of Hyderabad, Andhra Pradesh, Hyderabad, India

Correspondence: M. Behera, mdbehera@coral.iitkgp.ernet.in

Background & Aim: The Himalaya owing to its wider topographic and climatic gradient exhibits an exceptional concentration of biodiversity. Nonetheless understanding patterns of plant diversity in such a rugged terrain remains a challenge for ecologists. Remote sensing based vegetation indices have been observed to explain a moderate range of variance in plant diversity. However the mechanisms driving the spectral variation hypothesis, which assumes that spectral heterogeneity of a remotely sensed image is correlated with landscape structure and complexity, remain poorly explained. We demonstrate that integration of physiography along with vegetation indices, improves the prediction accuracy of generalized linear models (GLMs) in understanding the patterns of life-form based plant diversity.

Materials & Methods: We utilized field gathered life-form plant diversity data from the Indian Biodiversity Characterization project database. Four widely used spectral vegetation indices, such as NDVI, EVI, NDWI, and MSAVI2 as well as altitude, slope, and aspect were derived based on multi-temporal datasets of Landsat thematic mapper of the year 2010 and Shuttle Radar Topographic Mission (SRTM), respectively, for corresponding plots from seven dominant vegetation types from the Himalaya. These vegetation types include: grassland, scrubland, dry deciduous, moist deciduous, pine forest, pine mixed forest, and temperate coniferous forest. They vary in six structural characteristics: a) canopy structure, b) diversity, c) moisture content, d) structural complexity, e) leaf structure (broadleaf to needle leaf), and f) species diversity (monospecific or plurispecific).

Main Results & Conclusions: The variation in plant diversity explained by vegetation index (VI) models was observed to be highest (54%) in the grasslands (GL) owing to relatively open canopy structure and low diversity, while the moist deciduous (MD) and temperate coniferous (TC) forests (41%); this could be attributed to the multilayered canopy and high plant diversity of the forests. The explanation of variation plant diversity in GL, MD, and TC increased to 85%, 48%, and 52%, respectively upon addition of physiographic variables that indicates a strong influence of physiography in driving the patterns of plant diversity in high-altitude ecosystems.

We conclude that the integration of physiographic variables along with vegetation indices improves the degree to which remotely sensed spectral indices serve as proxies of plant diversity.

Two glacier snouts separated by an elephant-head shaped mountain in the Zanskar Valley, Western Himalaya (India). Photo: M. Behera.

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Species richness and composition of soil seed banks in three abandoned paddy fields in South Korea

Cho Yong-Chan (1), Oh Seung-Hwan (1), Lee Seon-Mi (2), Seol Ye-Joo (1), Cho Hyun-Je (3), Lee Chang-Seok (4) & Kim Sung-Sik (1)

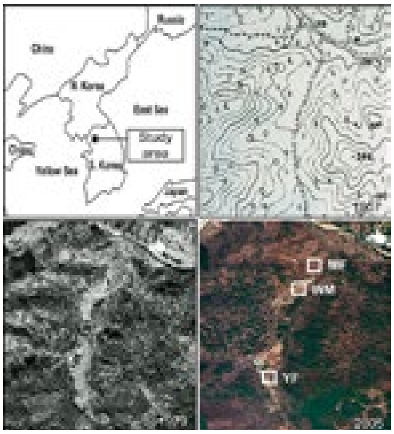
1) Plant Conservation Division, Korea National Arboretum, Pocheon 487-821, Republic of Korea
2) Park Survey Division, National Park Research Institute, Namwon 590-811, Republic of Korea
3) School of Bioresource Sciences, Andong National University, Andong 760-749, Republic of Korea
4) Faculty of Environment and Life Sciences, Seoul Women's University, Seoul 139-774, Republic of Korea

Correspondence: Cho Yong-Chan, bz0288@forest.go.kr

Background & Aim: Most floodplains of rivers and streams were transformed to rice fields in the past in Asian countries including Korea. Many rice paddy fields are now being abandoned because of socio-economic movements such as low economic value, low fertility, exodus of famers, and national policy. As a consequence, natural resource managers and professionals are beginning to pay attention to this new, emerging wetland habitat. Several management options are available, including retarding, 'wait and see', and facilitation of succession in fallow rice field. This leads to questions about the role of the soil seed bank for restoration of forest. We studied species composition of the soil seed bank and aboveground vegetation in abandoned paddy fields along a successional gradient from wet meadow to mature forest. We asked whether species richness and soil seed bank composition changed along three successional stages after paddocks have been abandoned. We evaluated the suitability of using seed banks to restore the vegetation of the abandoned paddies.

Materials & Methods: We selected three abandoned rice paddy fields in the Gwangneung Forest Biosphere Reserve, South Korea. We collected 147 seed bank samples representing a chronosequence from an open wet meadow to young and mature forests. The soil samples were spread thinly on a mixture of vermiculate, peat moss, and pearlite placed on plastic trays. The trays were randomly placed where they were prevented from invasion of other seeds from outside. We examined floristic characteristics, changes in species composition, abundance and richness of species. Furthermore, we compared similarity (Sørensen's index) between belowground and aboveground vegetation.

Main Results & Interpretations: Total of 59 species of 23 families and 44 genera were identified in the seed bank samples. *Cyperaceae* (14 species, 23.9%), *Poaceae* (10 species, 16.9%) and *Polygonaceae* (six species, 8.5%) were represented by the highest number of species. The richness and seedling density (59 taxa and 19 121 germinants from all samples) were high. Native annuals (40%) and wetland (55.4%) species dominated the seed banks. *Carex* spp. (11 921 germinant and 52.3% of all germinants) were the representative taxa in the seed bank of fallow paddy field. Based on the non-metric multidimensional scaling ordination, species composition changed gradually from wet meadow to mature forest. Sørensen's index of similarity (%) between above and below ground vegetation was higher in the order of wet meadow (29.3%), young forest (10.8%) and mature forest (2.1%) stages. Species richness in seed banks decreased along the following sequence: wet meadow had 10 256 germinants (205 120 individuals per m^2), young forest had 6 445 germinants (128 900 individuals per m^2), and mature forest had 2 420 germinants (48 400 individuals per m^2). The changes in the seed bank of abandoned paddy fields were consistent with the tolerance model of succession in the aboveground vegetation. Our results suggest that there is limited potential for recovery of riparian forest via the seed bank because of very low numbers seedlings of shrub and tree species. Due to the limited source of woody species, introduction of tree and shrub plantings was recommended to facilitate the forest reestablishment.



Topographic map constructed in 1907 (upper right), aerial photography taken in October 1979 (lower left) and a Quickbird satellite imagery taken in April 2005 (lower right) of the study area. Three sampling sites (MF: mature forest stage, WM: wet meadow stage, and YF: young forest stage) were established along a successional gradient.

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European Vegetation Archive (EVA): a new integrated source of European vegetation-plot data

Milan Chytrý (1), Stephan M. Hennekens (2), Borja Jiménez-Alfaro (1), Ilona Knollová (1), Jürgen Dengler (3), Joop H.J. Schaminée (2), Svetlana Aćić (4), Emiliano Agrillo (5), Didem Ambarlı (6), Pierangela Angelini (7), Iva Apostolova (8), Thomas Becker (9), Christian Berg (10), Erwin Bergmeier (11), Claudia Biţă-Nicolae (12), Idoia Biurrun (13), Zoltán Botta-Dukát (14), Luis Carlón (15), Laura Casella (7), János Csiky (16), Jiří Danihelka (1), Els De Bie (17), Panayotis Dimopoulos (18), Jörg Ewald (19), Federico Fernández-González (20), Úna Fitzpatrick (21), Xavier Font (22), Itziar García-Mijangos (13), Valentin Golub (23), Riccardo Guarino (24), Adrian Indreica (25), Deniz Işık (26), Ute Jandt (27), Florian Jansen (28), John A.M. Janssen (2), Zygmunt Kącki (29), Martin Kleikamp (30), Daniel Krstonošić (31), Anna Kuzemko (32), Flavia Landucci (1), Jonathan Lenoir (33), Tatiana Lysenko (23), Corrado Marcenò (1), Vassiliy Martynenko (34), Dana Michalcová (1), Marcela Řezníčková (1), John S. Rodwell (35), Eszter Ruprecht (36), Solvita Rūsiņa (37), Gunnar Seidler (27), Jozef Šibík (38), Urban Šilc (39), Željko Škvorc (31), Desislava Sopotlieva (8), Aleksei Sorokin (23), Francesco Spada (5), Zvjezdana Stančić (40), Jens-Christian Svenning (41), Grzegorz Swacha (29), Ioannis Tsiripidis (42), Pavel Dan Turtureanu (43), Emin Uğurlu (26), Milan Valachovič (38), Kiril Vassilev (8), Roberto Venanzoni (44), Lynda Weekes (21), Wolfgang Willner (45) & Thomas Wohlgemuth (46)

Correspondence: Milan Chytrý,
chytry@sci.muni.cz

Background: European Vegetation Archive (EVA) has been developed by the IAVS Working Group European Vegetation Survey as a centralized database of European vegetation plots.

Current status: EVA stores copies of national or regional vegetation-plot databases on a single software platform and links them via a reference database of plant taxa. Data storing in EVA does not affect the ongoing independent development of the source databases. EVA Data Property and Governance Rules (www.euroveg.org/eva-database) approved in 2012 guarantee that data property rights of the original contributors are respected. A prototype of the database management software Turboveg 3 was developed for joint management of multiple databases which use different species lists. This software also includes procedures for handling data requests, selections and provisions according to the approved Rules. A specific challenge for EVA is combining multiple species lists based on different taxonomies used in national and regional databases. This is managed using the SynBioSys Taxon Database, which was initially established for the purposes of the SynBioSys Europe project and is now further developed and extended within the framework of EVA. It is a system of taxon names and concepts used in the individual databases and their matches to a unified list of European flora.

By May 2014, 38 databases from all European regions, including the largest ones, agreed to join EVA, and 31 of them already contributed vegetation-plot data, in total 553 228 vegetation plots from 37 countries, 87% of them with geographical coordinates.

Outlook: EVA provides a basis for large-scale analyses of European vegetation diversity for both fundamental research in vegetation science, biodiversity science and macroecology, and applications for nature conservation including revisions of habitat classification systems, vegetation monitoring and providing indicators for ecosystem assessment.

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Affiliations of the authors

1) Department of Botany and Zoology, Masaryk University, Kotlářská 2, CZ-611 37 Brno, Czech Republic

2) Alterra WUR, P.O. Box 47, NL-6700 AA Wageningen, The Netherlands

3) Disturbance Ecology, University of Bayreuth, Universitätsstr. 30, D-95447 Bayreuth, Germany

4) Department of Agrobotany, University of Belgrade, Nemanjina 6, RS-11080 Belgrade-Zemun, Serbia

5) Botanical Garden, Department of Environmental Biology, Sapienza University of Roma, Largo Cristina di Svezia 24, I-00165 Roma, Italy

6) Department of Biology, Middle East Technical University, TR-06800 Ankara, Turkey

7) ISPRA - Italian National Institute for Environmental Protection and Research, Via Vitaliano Brancati, 60, I-00144 Roma, Italy

8) Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences, Acad. Georgi Bonshev St. 23, 1113 Sofia, Bulgaria

9) Department of Geobotany, University of Trier, Behringstraße 21, D-54296 Trier, Germany

10) Institute of Plant Science, Karl-Franzens-University Graz, Holteigasse 6, A-8010 Graz, Austria

11) Albrecht von Haller Institute of Plant Sciences, University of Göttingen, Untere Karspüle 2, D-37073 Göttingen, Germany

12) Institute of Biology, Romanian Academy of Sciences, 296 Spl. Independentei, RO-060031 Bucharest, Romania

13) Department of Plant Biology and Ecology, University of the Basque Country UPV/EHU, P.O. Box 644, E-48080 Bilbao, Spain

14) Institute of Ecology and Botany, MTA Centre for Ecological Research, H-2163 Vácrátót, Hungary

15) Jardín Botánico Atlántico, Avenida del Jardín Botánico s/n, E-33394 Gijón, Spain

16) Department of Ecology, University of Pécs, Ifjúság útja 6, H-7624 Pécs, Hungary

17) Research Institute for Nature and Forest (INBO), Kliniekstraat 25, B-1070 Brussels, Belgium

18) Faculty of Environmental and Natural Resources Management, University of Western Greece, GR-30100 Agrinio, Greece

19) University of Applied Sciences Weihenstephan-Triesdorf, Am Hofgarten 4, D-85354 Freising, Germany

20) Institute of Environmental Sciences, University of Castilla-La Mancha, Av. Carlos III s/n, E-45071 Toledo, Spain

21) National Biodiversity Data Centre, Carriganore WIT West Campus, Carriganore, County Waterford, Ireland

22) Department of Plant Biology, University of Barcelona, Avda. Diagonal 643, E-08028 Barcelona, Spain

23) Institute of Ecology of the Volga River Basin, Russian Academy of Sciences, Komzina 10, Togliatti 445003, Russian Federation

24) Department STEBICEF, University of Palermo, Via Archirafi 38, I-90123 Palermo, Italy

25) Department of Silviculture, Transilvania University of Braşov, 1 Şirul Beethoven, RO-500123 Braşov, Romania

26) Department of Biology, Celal Bayar University, Muradiye Campus, TR-45100 Manisa, Turkey

27) Institute of Biology, Martin Luther University Halle Wittenberg, Am Kirchtor 1, D-06108 Halle (Saale), Germany

28) Institute of Botany and Landscape Ecology, University of Greifswald, Soldmannstr. 15, D-17489 Greifswald, Germany

29) Department of Biodiversity and Plant Cover Protection, University of Wroclaw, Kanonia 6/8, 50-328 Wroclaw, Poland

30) Sieglindenweg 14, D-51469 Bergisch Gladbach, Germany

31) Faculty of Forestry, University of Zagreb, Svetošimunska 25, HR-10000 Zagreb, Croatia

32) National Dendrological Park 'Sofievka' NAS of Ukraine, 12a Kyivska str., 20300 Uman, Ukraine

33) UR "Ecologie et Dynamique des Systèmes Anthropisés" (FRE3498), Plant Biodiversity Lab, Jules Verne University of Picardie, 1 Rue des Louvels, F-80037 Amiens, France

34) Institute of Biology, Ufa Scientific Center, Russian Academy of Sciences, prosp. Oktyabrya 69, RU-450054 Ufa, Bashkortostan, Russian Federation

35) 7 Derwent Road, Lancaster LA1 3ES, United Kingdom

36) Hungarian Department of Biology and Ecology, Babes-Bolyai University, Republicii St. 42, RO-400015 Cluj-Napoca, Romania

37) Faculty of Geography and Earth Sciences, University of Latvia, 10 Alberta St., Rīga, LV-1010, Latvia

38) Institute of Botany, Slovak Academy of Sciences, Dúbravská cesta 9, SK-845 23 Bratislava, Slovakia

39) Institute of Biology, Research Centre of the Slovenian Academy of Sciences and Arts, Novi trg 2, SI-1000 Ljubljana, Slovenia

40) Faculty of Geotechnical Engineering, University of Zagreb, Hallerova aleja 7, HR-42000 Varaždin, Croatia

41) Department of Bioscience, Aarhus University, Ny Munkegade 116, DK-8000 Aarhus C, Denmark

42) School of Biology, Aristotle University of Thessaloniki, GR-54124 Thessaloniki, Greece

43) Faculty of Biology and Geology, Babeş-Bolyai University Cluj-Napoca, Republicii Street 42, RO-400015 Cluj-Napoca, Romania

44) Department of Applied Biology, University of Perugia, Borgo XX Giugno 74, I-06121, Italy

45) Vienna Institute for Nature Conservation and Analyses (VINCA), Giessergasse 6/7, A-1090 Wien, Austria

46) WSL Swiss Federal Research Institute, Zürcherstr. 111, CH-8903 Birmensdorf, Switzerland

Plant communities and hydro-geological drivers of species occurrence in ephemeral monsoon tropical rock pools

Adam T. Cross (1,2), Ladislav Mucina (1), Gregory R. Cawthray (1), David J. Merritt (1,2), Shane R. Turner (1,2), Michael Renton (1) & Kingsley W. Dixon (1,2)

1) School of Plant Biology, The University of Western Australia, 35 Stirling Hwy, Crawley WA 6009, Perth, Australia

2) Kings Park and Botanic Garden, Fraser Avenue, West Perth WA 6005, Perth, Australia

Correspondence: Adam Cross, Adam.Cross@bgpa.wa.gov.au

Background & Aim: Rock pools are unique ecosystems, forming small, isolated patches of freshwater habitat with defined boundaries in a dry landscape matrix of variable scale. Rock pools globally harbour high levels of endemism and contribute significantly to regional biodiversity, however these habitats remain unstudied in northern Australia and are generally not represented in regional conservation initiatives. This study aimed to (i) characterise the physical attributes and hydroregime of sandstone rock pools through field surveys and statistical modelling; (ii) describe the phytosociological patterns of rock pool communities in terms of their species composition and biodiversity value; and (iii) infer the role of hydro-geological factors as evolutionary drivers of community patterns in rock pools at local and metacommunity scales.

Materials & Methods: The study site was located in the North Kimberley, Western Australia. Over 180 vegetated rock pools were surveyed in the field using transects and quadrats, and incubator experiments assessing seedling emergence in response to temperature, light, and wetting/drying cycles were conducted on collected rock pool sediments. Statistical modelling of hydro-geological drivers was conducted using R.

Main Results & Interpretations: Eight vegetation types were identified from rock pool communities, harbouring 11 species from seven families. Four associations comprised species known only from sandstone rock pools, with all four dominant taxa representing short-range North Kimberley endemics. Vegetated rock pools experience a mean hydroperiod of only 25.0 ± 1.0 days, with an average of 5.0 ± 1.0 inundation events each year. Hydroperiod was determined as the strongest mechanistic driver of species distribution and community assemblage in rock pool habitats, in combination with pool depth and a degree of spatial autocorrelation. Laboratory studies suggest that a persistent sediment seed bank appears to be the primary mechanism facilitating community resilience and species persistence in rock pool habitats, with different species displaying markedly different patterns of seedling emergence in response to the duration and periodicity of inundation. Results suggest that rock pool flora display a high degree of adaptation to local hydro-geological conditions, potentially resulting from a long and relatively geologically and climatically stable evolutionary history.

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Freshwater rock pools harbouring the local endemic *Eriocaulon* sp. Morgan River (*Eriocaulaceae*) on typical Proterozoic (Pentecost) sandstone pavement formation in the central North Kimberley, Western Australia. Photo: A. Cross.

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A vegetation-structure map of the Northern Kimberley Region (Western Australia) to inform fire management planning

Glen Daniel (1,2) & Ladislav Mucina (2,3,4)

1) Fire Management Services Branch, Department of Parks and Wildlife, Locked Bag 104, Bentley Delivery Centre WA 6983, Perth, Australia

2) Department of Environment & Agriculture, Curtin University, GPO Box U1987, Bentley WA 6845, Perth, Australia

3) Iluka Chair of Vegetation Science and Biogeography, School of Plant Biology, The University of Western Australia, 35 Stirling Hwy, Crawley WA 6009, Perth, Australia

4) Department of Geography & Environmental Studies, Stellenbosch University, Private Bag X1, Matieland 7602, Stellenbosch, South Africa

Correspondence: Glen Daniel, glen.daniel@dpaw.wa.gov.au

Background: Effective fire management requires reliable information about the spatial distribution of vegetation structure and composition. These variables are informative of the nature and quantity of fuels in the landscape, and hence, of the potential occurrence and behaviour of fires. They also provide information about the likely characteristics of an ecologically appropriate fire regime. The northern Kimberley has a tropical seasonal (monsoonal) climate, with both rainfall and temperatures highest between November and March. The coincidence of high temperature and unimpeded water availability makes the wet season highly productive and particularly conducive to rapid grass growth. These grasses are ideal fuel for the propagation of large, intense and damaging fires in the subsequent dry season. Prior to the current project, vegetation mapping of the northern Kimberley was of variable quality and of limited use to fire managers. We sought to overcome this restriction by developing a vegetation-structure map of the northern Kimberley to improve fire management planning. This map also provides data for assessment of carbon distribution in the Kimberley landscapes.

Study area & Methods: The study area was the high rainfall zone of the Kimberley region, Western Australia. This is a colloquial descriptor of an area receiving >1000 mm rainfall per annum. The area extends about 360 km (13.70–17.03° S) by 600 km (123.25–129.00° E), a total area of about 164 000 km^2. Mapping was undertaken as a desktop modelling exercise that tested the relationships between vegetation structure and environmental parameters by assessing the capacity of various derived environmental data to predict the distribution of vegetation structural units. The most effective combination of data sets was then used to develop a map of the vegetation structure. Vegetation structure units were classified using a maximum likelihood classification in the Spatial Analyst extension of ArcMap. Training sites were located from aerial photographs and used to segment and classify Landsat 7/8 imagery. The output map was then validated against an independent set of sites classified from aerial photography.

Results & Application: The satellite image classification resulted in the most accurate vegetation structure map for the Northern Kimberley region of Western Australia to date, and the first fire management map in the region based on remote sensing imagery and spatial analyses. The final data set contained 353 000 polygons classified into 69 mapping units. These units were combinations of five vegetation structure categories and fifteen geological groups, plus the additional categories of water bodies, mangrove and mud/sand. The geological/vegetation structure units were then allocated to one of four categories: Open Forest, Eucalyptus Woodland, Sandstone Woodland, and Sandstone Heath. These categories are defined by the Carbon Farming Initiative methodology for Reduction of Greenhouse Gas Emissions through Early Dry Season Savanna Burning.

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Flooding regime and disturbance history shape soil seed-bank composition in restoring wetland

Samantha K. Dawson (1), Richard T. Kingsford (1), Jane A. Catford (2,3,4) & Peter Berney (5)

1) Centre for Ecosystem Sciences, School of Biology, Earth and Environmental Sciences, University of New South Wales, Sydney NSW 2032, Australia
2) School of Botany, The University of Melbourne, Melbourne VIC 3010, Australia
3) Fenner School of Environment and Society, The Australian National University, Canberra ACT 0200, Australia
4) Department of Ecology, Evolution and Behavior, University of Minnesota, Minneapolis, MN 55455-0213, USA
5) National Parks and Wildlife Services, Office of Environment and Heritage, Sydney NSW 1232, Australia

Correspondence: Samantha Dawson, s.dawson@student.unsw.edu.au

Background & Aim: Assisted natural regeneration is achieved by enabling key environmental factors to return toward historical conditions. This approach is contingent on seed availability via dispersal from neighbouring source populations or soil seed-banks. We examined the soil seed-bank in a wetland previously subject to cropping, grazing and artificially reduced flooding. Since restoration commenced in 2009, a succession of floods has driven an increase in native vegetation abundance, except in less frequently inundated areas which are dominated by exotics. We tested if seed-bank diversity is sufficient to facilitate further regeneration; whether there is higher potential for restoration in more frequently flooded areas and if land management history is still affecting seed-bank composition.

Methods: The study area experienced twelve different land use disturbances within which we sampled the soil seed-bank from nine random sites: three in shallow distributary channels, three immediately adjacent to channels and three 50–100 m from channels on the floodplain (n=108). The soil samples were germinated under damp, saturated and flooded conditions in greenhouses for nine weeks and then all samples were brought down to damp conditions for three more weeks, with continual seedling identification and removal. We tested for flooding, land-use and disturbance effects using mixed effect modelling.

Main Results & Implications: Areas with higher flooding frequency and lower land-use disturbance had greater diversity in the seed-bank. High disturbance and low flooding frequency areas also had seed-banks with greater capacity for regeneration than is currently in the above ground vegetation. These results indicate that, with appropriate flooding frequency, natural regeneration can be effective in semi-arid floodplain wetlands, but the rate may be dependent on land-use disturbance history.

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An uncleared soil seed bank collection site. Photo: S. Dawson.

Flooded and saturated pots in the greenhouse. Photo: S. Dawson.

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Fine-scale vertical position as an indicator of vegetation in alkali grasslands – a case study based on remotely sensed data

Balázs Deák (1,2), Orsolya Valkó (1), Cicimol Alexander (2), Werner Mücke (3), Adam Kania (2,4), János Tamás (5) & Hermann Heilmeier (2)

1) MTA-DE Biodiversity and Ecosystem Services Research Group, Egyetem tér 1, H-4032 Debrecen, Hungary
2) Technische Universität Bergakademie Freiberg, Interdisciplinary Ecological Centre, Leipziger Str. 29, D-09596 Freiberg, Germany
3) Department of Geodesy and Geoinformation, Vienna University of Technology, Gußhausstraße 27-29, A-1040 Wien, Austria
4) ATMOTERM S.A., ul. Łangowskiego 4, P-45-031 Opole, Poland
5) Faculty of Agricultural and Food Sciences and Environmental Management, University of Debrecen, Böszörményi út 138, H-4032 Debrecen, Hungary

Correspondence: Hermann Heilmeier, Hermann.Heilmeier@ioez.tu-freiberg.de

Background & Aim: Elevation is an important driver of vegetation zonation at multiple scales, acting through abiotic environmental factors such as climate, soil properties and water balance. While small-scale elevation differences have been found to significantly influence soil salt content and water balance, relationships between elevation and vegetation types have been rarely studied in inland alkali landscapes. Alkali landscapes of the Pannonian biogeographical region comprise an important salt-affected landscape in continental Europe providing a unique opportunity for studying elevation-vegetation relationships. Remote-sensing techniques offer an interesting solution to tackle this question. Application of airborne laser scanning (ALS) is a feasible tool for providing a high-resolution elevation model of extensive areas. In this study our goal was to test the correlation between fine-scale differences in small-scale elevation and vegetation patterns in inland alkali landscapes by using field vegetation data and elevation data generated using airborne laser scanning.

Materials & Methods: We studied whether vertical position influences vegetation patterns at the level of the main vegetation categories as detailed as the level of associations. Our study sites were situated in the lowland alkali landscape of the Hortobágy National Park (Eastern Hungary). ALS data were acquired using a RIEGL LMS-Q680i full-waveform laser scanner in March 2012. Field data were collected in June 2013 by means of 15 transects along an elevation gradient from the highest elevated plateau to the lowest-elevated terrain depressions. We recorded the dominant species in each plot and then assigned the relevés into association types using the syntaxa as defined by Borhidi et al. (2012). All typical associations recognised in the transects were mapped with a Trimble Geoexplorer 6000 differential GPS.

Main Results & Conclusions: The vegetation recognised in the study area can be classified into four main vegetation categories, such as (i) loess grasslands, (ii) alkali steppes, (iii) open alkali swards, and (iv) alkali meadows. Even though we detected a very limited range in the local elevation (121 cm), these main vegetation categories, very well separated along the elevation. The detected elevation gradient is likely to correspond to environmental gradients controlled by soil type, salt accumulation and water balance. At the level of the association, a more detailed elevation-based distinction was also detected. Based on the digital terrain model, we revealed a fine-scale vertical vegetation gradient. Our results show that high-resolution mapping based on remote sensing (RS) techniques is an ideal solution to disentangle the spatial patterns of vegetation in the alkali landscapes. This tool appears particularly useful since conventional habitat mapping in such complex landscapes is often very difficult and time-consuming.

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Local and landscape-level habitat patterns in southeastern Hungary

Áron József Deák

Department of Physical Geography
and Geoinformatics, Egyetem u. 2,
H-6722 Szeged, Hungary

Correspondence: Áron József Deák,
aron@geo.u-szeged.hu

Background & Aim: The Landscape Ecological Vegetation Database & Map of Hungary (MÉTA) and Natura 2000 surveys yielded detailed knowledge on the vegetation of Hungary making it possible to present vegetation patterns at different spatial scales. This research is building upon this knowledge and aims at recognition of landscape-specific habitat-complexes in southeastern Hungary in order to assist in more accurate delimitation of biogeographical units.

Materials & Methods: Local 1:4000 scale polygonal maps were created to reveal the detailed habitat patterns of the Natura 2000 sites. The landscape-level vegetation patterns were evaluated using the map of MÉTA (Molnár et al. 2007) based on 35-ha sized hexagon sampling units. This mapping exercise used General National Habitat Classification System of Hungary (Bölöni et al. 2011). The polygonal maps at landscape- and country-levels require comprehensive, descriptive categories with the identification of habitat-complexes and vegetation landscape-types.

Main Results & Interpretations: A landscape-level polygonal potential habitat map, featuring 10 potential vegetation categories, was produced for 1/3 of southeast Hungary. The landscapes of the Danube-Tisza Interfluve contains mosaics of sand steppe grassland and sand steppe oak forests with moor-type and/or saline habitats in deflation hollows, whereas mosaics of open sand grasslands and forests are linked to the dune systems. In the southeast part of the Danube-Tisza Interfluve, moor-type *Molinia* fens and tussock-sedge communities appears in the northwest parts of depressions while the southeastern parts are covered with saline habitats due to the interference between a regional groundwater-flow upwelling on the northwest side of depressions and the evapotranspiration. A landscape-level gradient was found, indicating that more saline habitats in larger areas appear further from the groundwater upwelling zones, while the moor-type habitats have larger diversity and extension in the upwelling zone. On elevated parts of the loess-covered alluvial cones, mosaics of loess steppe grasslands and oak loess-steppe-forests would represent the potential vegetation (today these have been converted into arable lands). Ancient salt-berm steppes with mosaics of loess steppe-grasslands and oak loess steppe-forests are found in loess-dominated landscapes and on loess-lag surfaces in the floodplains with abandoned riverbeds. They have diverse (9 types) and extended saline habitats, and the coverage of loess-vegetation is lower in the preserved grasslands. Meadows and wetland vegetation (comprising 13 natural habitats) are typical for alluvial mosaics of floodplain forests and swamps. Small moors with swamp forests and lakes (with 6 habitats) are associated with groundwater up-welling zones. Secondary saline grasslands (*Achillea* sub-type with salt meadows and *Achillea* alkali steppes, and meadow-steppic sub-type – the *Peucedano-Asteretum*) occur on alluvia that emerged the river-regulations; these habitats could be considered to have supported open salt-steppe oak forests.

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Don’t miss the forest for the trees! Diversity response of an African tropical rain forest to disturbance

Guillaume Decocq (1), Denis Beina (1), Aurélien Jamoneau (1), Sylvie Gourlet-Fleury (2) & Déborah Closset-Kopp (1)

1) Unité “Ecologie et Dynamique des Systèmes Anthropisés” (EDYSAN, FRE 3498 CNRS-UPJV), Université de Picardie Jules Verne, 1 rue des Louvels, F-80037 Amiens Cedex 1, France

2) UPR BSEF, CIRAD, Campus International de Baillarguet, F-34398 Montpellier, France

Correspondence: Guillaume Decocq, guillaume.decocq@u-picardie.fr

Background & Aims: It is traditionally assumed that trees reflect the floristic composition and richness of tropical rain forests. Ignoring plant species of the other structural compartments in vegetation surveys is thus believed to be an acceptable trade-off between exhaustiveness and representativeness. However, the consequences of missing species below a threshold diameter at breast height (dbh) value have been largely neglected so far. We evaluated whether the response of woody species diversity was a good surrogate for the response of other structural ensembles in a lowland tropical rain forest, namely treelets, saplings, and herbs to three disturbance regimes: natural gap dynamics (control), and selective logging with and without additional thinning.

Materials & Methods: We studied forest vegetation composition and diversity in a 20-yr replicated field experiment comprising nine 1-ha permanent plots established in a semi-deciduous rain forest of Central African Republic, equally distributed among the three treatments. Vascular plant species (except epiphytes) were scored for abundance (except herb species: occurrence) among four compartments: trees (dbh≥10 cm), juveniles and lianas (0.5≤dbh<10 cm), saplings (dbh<0.5cm, height ≥20 cm), and lianas with a dbh<0.5 cm, forbs, and grasses. We used additive partitioning of rarefaction curves and species abundance distribution curves followed by linear and non-linear models to investigate relationships between disturbance intensity and species diversity. Species composition was analysed using non-metric multidimensional scaling and non-parametric ANOVA followed by indicator species analysis.

Main Results & Interpretations: Once corrected by stem density, the species rarefaction index was similar between logged (20 years since logging) and untouched old-growth forest stands with respect to trees, but higher with respect to treelets. Within the sapling and herb layers, the rarefaction index and species turnover both linearly increased with disturbance intensity, with a scale-dependent response of species richness. Regarding the parameters of the partitioned rarefaction curves and relative abundance distribution curves, no relationship was found between trees and any of the other structural compartments. Whilst tree and treelet species composition was similar among treatments, the under-storeys still reflected past disturbance intensity, with a strong response of the sapling and herb layers. These results show that biodiversity surveys based solely on tree layers are misleading because their response to disturbance cannot be used as a surrogate for the response of other structural ensembles. Long-lasting effects of anthropogenic disturbance on the sapling bank and the herb layer may durably influence the long-term forest dynamics. Since over-storey but not under-story plant communities have recovered from human disturbances 20 years after silvicultural operations, African tropical rain forest ecosystems may not be as resilient to selective logging as previously thought.

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Sea-grass communities and phytosociology

Cornelis den Hartog (1,2)

1) Division Aquatic Ecology and Environmental Biology, Institute for Water and Wetland Research, Radboud University Nijmegen, Heyendaalseweg 135, NL-6525 AJ Nijmegen, The Netherlands

2) Oude Kleefsebaan 223d, NL-6572 AN Berg en Dal, The Netherlands

Correspondence: Kees den Hartog, C.denhartog@inter.NL.net

Nature of the sea-grass ecosystem: In the marine biological literature sea-grass beds are generally regarded as being more or less similarly structured, and usually indicated as the sea-grass ecosystem. This must be considered to be an unjustified simplification, as the world's sea-grass beds show, apart from differences in species composition, considerable variations in their structure, persistence and performance. Often terrestrial ecologists regard the sea-grass beds as lowly organised pioneer communities (Tüxen 1974). This probably goes back to their frequent monospecific character (most of the sea-grass beds contain only one angiosperm species) and their generally very uniform appearance as well as the idea that these beds, being aquatic communities, will in time develop into terrestrial communities (Chapman 1974; Burrows 1990). This is also fiction.

Classification of the sea-grass communities: As the sea-grass communities are well distinguished from all the other plant communities, and show only here and there some overlap with the communities of brackish and continental salt waters, their classification into vegetation types within the Braun-Blanquet system of syntaxa may be expected to be quite simple. However, as a consequence of the present procedure in phytosociology that demands that the classification is performed on the level of species or subspecies this leads to a useless, unworkable system (bottom-up). If the classification is carried out using genera and some structural vegetation characteristics as classification variables six well-defined classes of sea-grass communities can be recognised on a global scale (top-down). Another difficulty is caused by the current rules of the phytosociological nomenclature that demands typification of associations with relevés, a practice rarely applied by sea-grass researchers, and often impossible. So the proposed simple classification on a global scale may be not valid if the present rules of the Braun-Blanquet system are strictly handled. The importance of the proposed classification is in my opinion that comparisons of sea-grass communities can be made at the right level, and that generalisations may be considered in a more critical way. I suggest that also the syntaxonomy of the fresh-water plant communities to be revised, based on the shared set of floristic composition and vegetation-structure characteristics (based on growth-forms or life-forms) worldwide as in the classical floristic bottom-up approach these similarities are insufficiently considered and utilised in the classification process.

How to describe and identify the sea-grass plant communities: Descriptions of sea-grass communities are generally based on the dominant angiosperm component, and thus present in fact only taxocoenoses or merocoenoses. Consequently, they may show considerable variations from area to area, and even within the same area, if the algal flora, the fauna and environmental parameters, such as exposition to wave action, salinity, substrate, etc. are being considered. The concept 'faithful' or 'character-species' has not any additional significance for these vegetation units. The classification of the sea-grass communities will be presented in a summary way, in the form of an identification key, based on floristic composition, their physical structure (stratification), their relation to the substrate (soft substrate or rock), their degree of permanence (from annual presence to millennia), and geographical distribution.

Note on the *Ruppietea*: The formation of the aquatic plant communities of shallow poikilosaline coastal and continental waters consists presently of one phytosociological class — the *Ruppietea* with a worldwide distribution. This class contains one marine association. It cannot, however, be maintained in its present concept as a consequence of the currently progressing revisions of the taxonomy of the genus *Ruppia*.

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sPlot – the new global vegetation-plot database for addressing trait-environment relationships across the world's biomes

Jürgen Dengler (1,2,3), Helge Bruelheide (1,4), Oliver Purschke (1,4), Milan Chytrý (5), Florian Jansen (6), Stephan M. Hennekens (7), Ute Jandt (1,4), Borja Jiménez-Alfaro (5), Jens Kattge (1,8), Valério D. Pillar (10), Brody Sandel (9), Marten Winter (1) & the sPlot Consortium

1) German Centre for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig, Deutscher Platz 5e, D-04103 Leipzig, Germany

2) Disturbance Ecology, University of Bayreuth, Universitätsstr. 30, D-95447 Bayreuth, Germany

3) Bayreuth Center of Ecology and Environmental Research (BayCEER), University of Bayreuth, Universitätsstr. 30, D-95447 Bayreuth, Germany

4) Geobotany and Botanical Garden, Institute of Biology, Martin Luther Unversity Halle Wittenberg, Am Kirchtor 1, D-06108 Halle (Saale), Germany

5) Department of Botany and Zoology, Masaryk University, Kotlářská 2, CZ-611 37 Brno, Czech Republic

6) Institute of Botany and Landscape Ecology, University of Greifswald, Soldmannstr. 15, D-17487 Greifswald, Gemany

7) Alterra, Wageningen UR, Droevendaalsesteeg 3, NL-6708 PB Wageningen, Netherlands

8) Max Planck Institute for Biogeochemistry, Hans-Knöll-Str. 10, D-07745 Jena, Gemany

9) Department of Ecology, Universidade Federal do Rio Grande do Sul, 91540-000, Porto Alegre, RS, 91501-970, Brazil

10) Department of Bioscience, Aarhus University, Ny Munkegade 116, DK-8000 Aarhus C, Denmark

Correspondence: Jürgen Dengler, juergen.dengler@uni-bayreuth.de

Background: The trait composition of plant communities is determined by abiotic, biotic and historical factors. However, the importance of macro-climatic factors in explaining trait-environment relationships at the local scale remains unclear. In March 2013, the first sDiv workshop (sPlot) assembled a unique group of vegetation-plot data holders and data analysts to address these questions. Our main objective is to assess the following questions: (i) to which extent are relationships between traits preserved across environmental gradients worldwide, irrespective of macro climate? (ii) to which degree is the effect of local (abiotic and biotic) drivers mediated by climate? Such knowledge is crucial for ecological theory but also highly relevant to devise local management measures to mitigate the negative effects of climate change.

Available data and the database: While hundreds of millions of distribution records from individual species can be retrieved via data portals such as GBIF (http://www.gbif.org) and there is now also a global database of plant traits (TRY; Kattge et al. 2011), global accessibility of plant community data is more restricted. However, during the last decade many vegetation-plot databases have emerged all over the world, although still the bulk of data in databases comes from Europe, as can be seen in the meta-database GIVD (Dengler et al. 2012). While GIVD provides knowledge about more than 200 vegetation-plot databases on all continents, it does not contain the actual data in a single uniform database. The first huge supranational database joining data from different sources was the European Vegetation Archive (EVA; http://euroveg.org/eva-database) that has been launched in spring 2014. With the sPlot database, we go a step further and build the first vegetation-plot database aiming at being globally representative. Using the same database system (Turboveg 3), sPlot combines the majority of the EVA content with major databases from other continents. Presently sPlot contains more than 500 000 plots from the Eastern Hemisphere (Europe, Asia, Africa) and is constantly growing. We plan to extend sPlot via collaboration with the BIEN3 project also to the Americas. For the planned trait analyses, sPlot will have an agreement with TRY to get average trait values for a set of ecologically relevant traits. According to the sPlot 'Governance and Data Property Rules', only members of the sPlot Consortium have access to the sPlot data for analyses and publications, providing a strong incentive to join sPlot with your own data.

Status and prospects: In this talk we will give an overview on the structure and present content of sPlot in terms of spatial distribution, data properties as well as trait coverage in TRY. We will explain future steps and perspectives and encourage database owners to join the sPlot Consortium. We will present the first cross-biome analyses of community-weighted mean traits, trait variability and trait diversity. Finally, we will highlight the wealth of ecological questions that can be addressed with sPlot in a novel way.

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Re-surveys of wet grasslands in N Germany show a severe decline in plant diversity (and occasional restoration success)

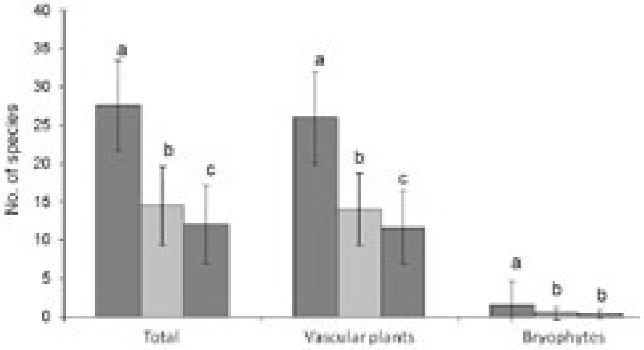
Martin R. Diekmann

Institute of Ecology, FB 2, University
of Bremen, Leobener Str., D-28359
Bremen, Germany

Correspondence: Martin Diekmann,
mdiekman@uni-bremen.de

Background & Aims: Wet grasslands are among the most species-rich vegetation types in the lowlands of northern Germany. Over the past decades, they have shown a strong decline in area as a result of drainage, fertilization and intensification of management. As a large number of sample plots of wet grasslands with known locations are available from the 1940s to the 1960s, re-sampling enables the examination of changes in species composition and richness. At the same time, some grassland areas that had previously been ameliorated for higher productivity were re-converted into extensively managed grasslands with subsequent restoration of the former water table.

Dactylorhiza incarnata (*Orchidaceae*) a species that succeeded to re-establish in the restored wet grassland area Ochsenmoor.
Photo: A. Pannek



Changes in species richness over the course of 42 years in 109 semi-permanent grassland plots in the Holtumer Moor area. The letters indicate significant differences between time periods.

Materials & Methods: I review the recent changes in wet grassland vegetation, focusing on two areas, the Holtumer Moor southeast of Bremen and the Ochsenmoor south of Lake Dümmer, both located in Niedersachsen. I also discuss the statistical problems associated with the comparative analysis of inventory and re-inventory data due to, for example, methodological differences (varying intensities in the recording and monitoring of plant species, taxonomic problems) and spatial inaccuracy (imperfect re-localization of sample plots).

Main Results: In the Holtumer Moor, the total number of plant species encountered declined from 146 in 1963 to 96 in 1988 and further to 71 in 2006. Average number of species per plot decreased by more than 50% for both vascular plants and bryophytes. Even in those sites that were continuously extensively managed, plant diversity declined. The change from species-rich vegetation characterized by various graminoids (*Bromus racemosus*, *Juncus filiformis*) and forbs (*Crepis paludosa*, *Lotus pedunculatus*, *Senecio aquaticus*, *Silene flos-cuculi*) to grassland swards dominated by *Alopecurus pratensis* is representative of large parts of the region. In the Ochsenmoor, 25 years of restoration efforts have reversed this trend: following re-wetting and extensification, plot species richness has increased again. Some red-listed species that had gone extinct from the area (without, to my knowledge, having remnant populations in the close surrounding) re-established in a number of sites, e.g., *B. racemosus* and *Dactylorhiza incarnata*. However, the large majority of species extinct from the Ochsenmoor did not succeed to re-enter the area even after 25 years of restoration.

Acknowledgements: I am grateful to the members of my working group Vegetation Ecology and Conservation Biology (especially to Volker Blüml and Burghard Wittig) who carried out most of the research on which this review is based. I also thank the NLWKN and local nature conservation authorities for working permits. Funds were provided from the University of Bremen.

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Conservation status assessment for habitat types in Greece

Panayotis Dimopoulos (1), Ioannis Tsiripidis (2), Fotios Xystrakis (1), Erwin Bergmeier (3), Maria Panitsa (1) & Athanasios Kallimanis (1)

1) Department of Environmental and Natural Resources Management, University of Patras, GR-30100, Agrinio, Greece

2) Department of Botany, Aristotle University of Thessaloniki, GR-54124, Thessaloniki, Greece

3) Albrecht von Haller Institute for Plant Sciences, Georg-August-University of Göttingen, D-37073 Göttingen Germany

Correspondence:
Panayotis Dimopoulos,
pdimopoulos@upatras.gr

Background: According to the Habitats Directive (Directive 92/43/EEC), the Natura 2000 network of protected areas was established throughout the EU so that natural habitat types will be sustained at a favourable conservation status. Monitoring of conservation status is a national obligation arising from Article 11 of the Habitats Directive for all habitats of Community interest (as listed in Annex I of the directive). This provision is not restricted to Natura 2000 protected areas. Thus, conservation status assessments need to be performed for each habitat type both inside and outside the Natura 2000 network. The main results of this monitoring have to be reported to the Commission every six years according to Article 17 of the Habitats Directive.

Assessment Methods: According to the EU guidelines (Evans & Arvella 2011) the conservation status assessment should take into account four factors: (1) area, (2) range, (3) structure and function, and (4) future prospects. However, there is no explicit methodology on how to quantify and measure these factors and assess the conservation status. Thus, for the Greek national report we designed and we are implementing an assessment methodology. (i) The first step was to determine the typical species of each habitat type on the basis of a dataset comprised of more than 19 000 relevés, representing most of the habitat types identified until today in Greece. Cluster analysis and estimation of species fidelity were applied for the determination of groups of typical species linked to particular habitats. In many cases we identified more than one set of typical species reflecting the geographic and ecological differentiation in the plant communities associated with each habitat type. (ii) The second step was to model the potential distribution of habitat types. Firstly, the potential distribution of the typical species with the higher fidelity value for each habitat type was modelled by means of MaxEnt using bioclimate, land use, geological substrate, soil depth and altitude layers as explanatory variables. Then, the potential distribution of habitat types was estimated overlaying the potential distribution of selected species-combinations with various vegetation and land-use/land-cover maps. In some habitat types, also the geological map or certain bibliographic data were used in order to restrict the estimated potential distribution of habitat types. The potential distribution of azonal habitat types was estimated only on the basis of environmental predictors. (iii) The third step was to prepare protocols for field data collection. These protocols included a checklist of typical species for each habitat, as well as a checklist of the structures and functions considered as indicative of a favourable conservation status of a habitat type. The protocols also include a selection list of pressures and threats. Finally (iv), the data collected in the field are analyzed in order to reach the national assessment for each habitat type. According to the performance of the criteria, each habitat types conservation status is to be designated as either *favourable*, *unfavourable inadequate*, and *unfavourable bad*.

Outlook: The methodology developed for the conservation status assessment is being applied in the field. The pilot applications highlighted the potential limitations and amendments were proposed in the protocols to overcome these limitations. This approach was used to assess the conservation status of the Habitat Type 9290 (*Cupressus sempervirens* forest).

Acknowledgements: This research is supported by the Hellenic Ministry of the Environment, Energy and Climate Change, Project: 'Surveillance and Conservation Status Assessment of Habitat Types in Greece'.

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Plant re-introductions in Germany – an overview

Cecilia Dupré, Josef Müller, Thilo Heinken & Martin R. Diekmann

Institute of Ecology, FB 2, University of Bremen, Leobener Str., D-28359 Bremen, Germany

Correspondence: Cecilia Dupré, dupre@uni-bremen.de

Background & Aims: Plant re-introductions and other forms of species translocations have become widespread practice in nature conservation and will gain growing importance in the future with climate change and increasing human pressure on nature. Especially in restored but fragmented habitats species re-introductions offer one of the most efficient tools for preserving or restoring plant diversity and communities. Here, we have compiled and reviewed plant re-introduction projects in Germany to answer the following questions: (1) Are the species considered in plant re-introduction trials representative of threatened species in Germany with respect to their taxonomy, habitat preferences and ecological strategy? (2) Do re-introduction efforts focus on species for which the country has a global responsibility for conservation? (3) Is the judgment of the success and failure of plant re-introductions biased by the choice of species used in the experiments?

Materials & Methods: We collated data on a total of 197 taxa of vascular plants used in conservation-oriented re-introductions. We then examined how these species were distributed across different plant families, habitat types (according to Ellenberg & Leuschner 2010) and strategy types (Grime 1979). The proportion of species groups considered in re-introduction trials were compared with the proportion of species included in national and regional Red Lists of vascular plants.

Main Results: Species of families with large and conspicuous flowers perceived as pretty (for example, *Gentianaceae* and *Orchidaceae*) were over-represented among the re-introduced species. Over-represented were also species typical of semi-natural open habitats such as heathlands and grasslands. Notably, many projects focused on calcareous grasslands, characterized by dry and infertile soils having high pH. In contrast, species from near-natural vegetation (alpine and rocky formations, forests) were under-represented. Taxa characterized by a stress-tolerance strategy had a higher share in re-introduction attempts than did competitors and ruderals. Of the 118 species critically endangered in Germany, 32 (27%) were considered in re-introduction trials. Concerning the species for which Germany has a particularly high responsibility for conservation (totally 154), the proportion (9%) was much lower, especially when disregarding the genus *Rubus* (20%). Many re-introduction attempts failed, most likely because of the high proportion of species typical of nutrient-poor environments that, often despite restoration efforts, no longer find suitable habitats in the country. Re-introductions with nutrient-demanding and competitive species showed a higher rate of success. We discuss these results with respect to future strategies for plant re-introduction.

Acknowledgements: The project was made possible through funding from the Deutsche Bundestiftung Umwelt (DBU).

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Euphorbia palustris, a species that has been successfully reintroduced in NW Germany. Photo: C. Dupré.

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Pitfalls of revisiting subjectively sampled vegetation relevés to assess change in large-scale conservation networks

Klaus Ecker, Ariel Bergamini & Meinrad Küchler

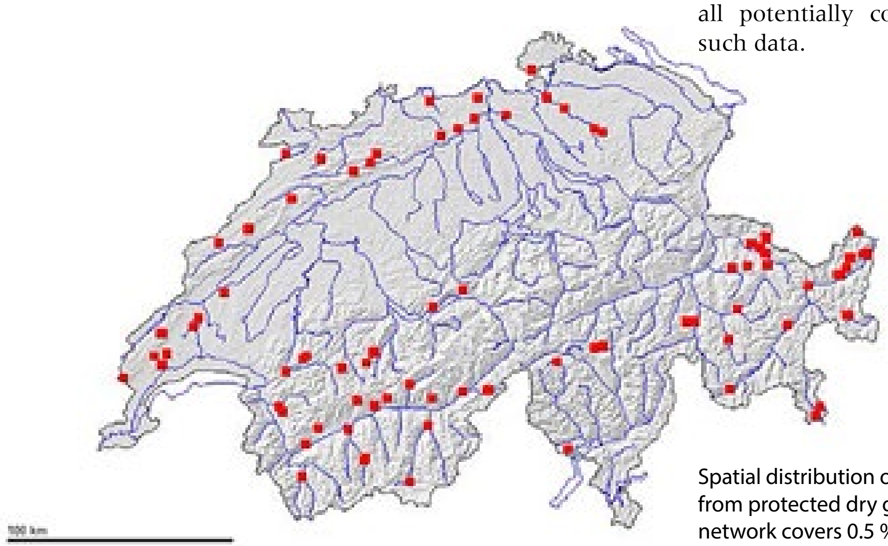
Swiss Federal Research Institute
WSL, RU Biodiversity & Conservation
Biology, CH-8903 Birmensdorf,
Switzerland

Correspondence: Klaus Ecker,
klaus.ecker@wsl.ch

Background & Aim: Assessing change in the species composition of large scale conservation networks requires past community data of the study area and protected vegetation types. However, existing vegetation relevés are rarely based on probability sampling designs. The data are typically subjectively sampled and located to optimally describe some typical vegetation type. Thus, the sample proportionality is unknown. Precise plot coordinates are often lacking and the data quality varies between regions and observers. In this study we investigated the potential of such data to infer vegetation change.

Materials & Methods: In Switzerland the dry grasslands of national importance are mapped and documented by subjectively sampled vegetation relevés. The coordinates of the sample plots were recorded by GPS. The measurements included accuracy estimates. 10 years after the first survey we revisited a subset of 122 plots all over Switzerland. We used the paired data to test for changes in species numbers, mean plant indicator values, plot homogeneity and conservation quality. All parameters were derived from the species lists. The trends were tested by the means of paired Wilcoxon tests. We used species lists with and without companion species to test the effect of the varying survey effort. We explored the effect of relocation problems by comparing plots with coordinates of low and high GPS accuracy. Finally, we tested opposing sampling strata of low and high conservation interest to account for the unknown sample proportions. All differences between classes were tested by the means of ANOVA.

Main Results & Interpretations: The simple tests suggest a significant increase in the species number and some mean plant indicator values such as soil moisture, humus and nutrients while mean values of temperature and light supply seem to be significantly reduced. The results are in line with the main conservation concerns for the dry grasslands. But are they reliable? More detailed analyses indicate that the previous results might be biased. Both the species number and the mean plant indicator values are seriously affected by relocation problems and varying survey effort. In addition, we found significant differences in the sampling strata stressing the effect of the unknown sampling proportions. As a consequence we recommend considering all potentially confounding factors in the evaluations of such data.



Spatial distribution of 122 revisited sample plots (circular, radius = 3 m) from protected dry grasslands in Switzerland. The total conservation network covers 0.5 % of the country area.

Ecker, K., Bergamini, A. & Küchler, M. 2014. Pitfalls of revisiting subjectively sampled vegetation relevés to assess change in large-scale conservation networks. In: Mucina, L., Price, J.N. & Kalwij, J.M. (eds.), *Biodiversity and vegetation: patterns, processes, conservatio*n, p. 94. Kwongan Foundation, Perth, AU.

Habitat requirements for mire specialist species in Switzerland

Elizabeth Feldmeyer-Christe & Meinrad Küchler

Swiss Federal Research Institute
WSL, Zürcherstrasse 111, CH-8903
Birmensdorf, Switzerland

Correspondence:
Elizabeth Feldmeyer-Christe,
elizabeth.feldmeyer@wsl.ch

Background & Aims: Like other wetlands in the temperate zone, the mires in Switzerland have been suffering from agriculture intensification, hydrological control and tourism. It is estimated that this densely populated country has lost up to 90% of its former mire surface during the last two centuries. The small-sized remnants are today reduced to isolated island-like habitats in a forested or agricultural landscape. In 1987 Switzerland adopted an initiative to enhance protection of mire ecosystems. According to the law, the Swiss mires of national importance defined as such in national inventories, have to be maintained in their present size and quality. Almost none of these mires are pristine, showing a high heterogeneity in plant communities mainly due to the level and type of disturbance they have suffered. These mires nevertheless harbour specialist species linked with specific water and nutrients needs. Our study aims at determination of factors best explaining the diversity of specialist species in the Swiss mires.

Material & Methods: Multiple regression analysis was used to model the relationships between mire specialist species and mire area, sampling area, elevation, distance to the edge of the mire and mire density. We tested these variables for 42 specialist species encountered in the hummock-hollow complex of the studied mires. For our study we analysed 4 054 vegetation records from 60 different mire sites using data from the Swiss mires monitoring program (Klaus 2007) as well as the ecological values of Landolt (1977) to interpret the patterns of diversity.

Main Result: Our results show that the distance to the edge of the mire is the variable best explaining the diversity of mire specialist species. We also identify the habitat preferences of specialist species along the ecological gradients of the margins of the mires and attempt to characterise them by using the indicator values of Landolt (1977).

Acknowledgements: The Swiss Mire Monitoring Program was funded by the Swiss Federal Office for the Environment FOEN.

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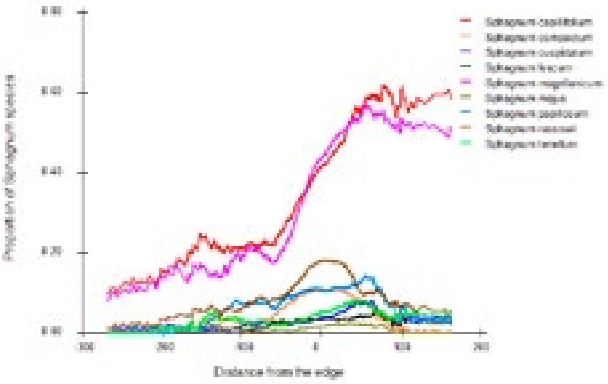
A mire of the Schwändital in the Swiss Northern Pre-Alps. Photo: M. Küchler.



Preferences of nine peat-mosses (*Sphagnum* spp.) in the margins of the bogs. Legend: Calculation of the relative frequency of species using moving average of presence = 1 and absence = 0.

Feldmeyer-Christe, E. & Küchler, M. 2014. Habitat requirements for mire specialist species in Switzerland. In: Mucina, L., Price, J.N. & Kalwij, J.M. (eds.), *Biodiversity and vegetation: patterns, processes, conservation*, p. 95. Kwongan Foundation, Perth, AU.

Probability of similarity and fuzzy sets: should we move to the Jaccard's diversity metrics?

Enrico Feoli (1), Paola Ganis (1), David W. Goodall (2) & Valério D. Pillar (3)

1) Department of Life Sciences, University of Trieste, I-34127 Trieste, Italy

2) School of Natural Sciences, Edith Cowan University, Joondalup WA 6027, Perth, Australia

3) Departamento de Ecologia, Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, Brazil

Correspondence: Enrico Feoli, feoli@units.it

Background & Aims: There are many resemblance functions used in vegetation ecology (Orlóci 1978), but only a few are based on probability, notwithstanding many can be interpreted in terms of probability. The Jaccard's index is one of those that express the probability in terms "something in common" between two objects; it is defined as a *diversity metric*. The aims of this paper are: 1) to evaluate the performance of some similarity functions based on probability in terms of predictivity of classifications obtained with them, with respect to chemical phyisical factors, 2) to discuss the contextual similarity versus the invariant similarity, the sample space versus the similarity space (fuzzy space) and, 3) to compare the Jaccard's diversity metric with the Euclidean metrics.

Goodall's and Pillar's indices: The similarity measures based on probability are of two types: 1) those where the similarity is given directly by the probability that two objects which are more similar than they should be if the attribute values would be randomly arranged among the set, the indices of Goodall (1966) and Pillar (1996), and 2) those in which the similarity is given by an index weighted by the probability of association between the attributes (the indices of Burnaby and COCHIS; Carranza et al. 1998). The similarity indices of Goodall, Burnaby and COCHIS are contextual because the similarity of two objects may change if they are considered in different sets of objects, while the index of Pillar is invariant if not applied after data transformations.

Examples: Both Goodall's and Pillar's resemblance functions have been applied to eigenvectors of the similarity matrix between the relevés obtained by the Jaccard and/or similarity ratio index. The fuzzy sets corresponding to the clusters are therefore 'probabilistic fuzzy sets'. We have applied the probabilistic similarity functions to two sets of relevés of grasslands of NE Italy in order to evaluate their performances in term of predictivity with respect to some chemical physical factors, by using the index proposed by Feoli et al. (2009) based on the evenness of the eigenvalues of the similarity matrix between the relevés calculated with chemical physical factors.

Main Results & Interpretations: With the grasslands of NE Italy, the Goodall's and Pillar's indices applied to the eigenvectors of the Jaccard's matrix produced more predictive classifications than the classifications based on ED or chord distance. This means that the diversity metrics should be preferred over the Euclidean metrics because the diversity metrics take into consideration also the richness and the diversity of plant communities. The use of probabilistic similarity functions (e.g., Goodall's and Pillar's) applied to the space generated by the Jaccard's function allow to introduce the possibility of hypothesis testing. We consider the difference between classification process and the identification process (supervised classification), and show how probabilistic similarity functions can be used in identification and how they can be used to create training sets for the application of neural networks to classify large data sets where it would be impracticable to use similarity-dissimilarity matrices between all the objects in a data set.

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Fire-related cues in seed dormancy and germination in Brazilian cerrado

Alessandra Fidelis (1), Fernando A.O. Silveira (2), Luís Felipe Daibes (1), Elizabeth Gorgone-Barbosa (1), Heloíza Lourenço Zirondi (1), Letícia Aurora Coelho da Silva (1), Henrique de Pinho José (1), Rafael de Barros Novaes (1) & Talita Zupo (1)

1) Departamento de Botânica, Universidade Estadual Paulista, Av 24A, 1515 Rio Claro, Brazil

2) Departamento de Botânica, Universidade Federal de Minas Gerais, Av Antônio Carlos, 6627 Belo Horizonte, Brazil

Correspondence: Alessandra Fidelis, afidelis@rc.unesp.br

Background & Aims: Plants in flammable ecosystems usually possess fire-related traits, such as thick bark, resprouting ability, germination triggered by heat-shock (physical dormancy) and smoke (Keeley et al. 2011). Brazilian tropical savannas (known as 'cerrado') are composed of a mosaic of vegetation types, showing different physiognomies (from grasslands to forest). They are species-rich and exposed to frequent fires. We believe that if fire is selecting for certain plant traits, we should find fire-related cues in seed dormancy and germination in cerrado species. In order to test our assumption, we studied germination responses to heat shock and smoke in dormant and non-dormant seeds in common plant families found in cerrado.

Materials & Methods: We collected seeds in cerrado grasslands and in open savannas where fire is recurrent (2–5 years fire return). We tested impermeable and permeable seeds (25 species) for the effects of heat shock (breaking dormancy) by exposing the seeds to different temperatures (60º, 100º and 200º C) for 1 minute. We also tested the effects of smoke in stimulating germination by imbibing seeds in smoke solutions for 24 hours.

Main Results: We found that permeable seeds were stimulated to germinate by smoke (e.g. *Melastomataceae*), whilst impermeable seeds had their dormancy broken and germinated the most after being exposed to 100º C (e.g. *Fabaceae*). Some species did not show any responses to heat shock and smoke (*Velloziaceae*). Some species (*Syngonanthus nitens*, *Eriocaulaceae* and some *Bromeliaceae* and *Velloziaceae)* germinated even after being exposed to high temperatures (>150º C). We also found that seeds of *Mimosa pteridifolia* (leguminose shrub) sampled in areas with different fire histories showed different germination outcomes: seeds from habitats recently burned germinated less than seeds from habitats that were excluded from fire for seven years. Thus, fire is affecting germination in different ways by breaking dormancy and stimulating germination of some species, whilst others are resistant, germinating after exposure to high temperatures. Our preliminary results show that in cerrado, there are some species with fire-resistant seeds while other species show fire-related germination cues. Further studies on fire-related cues pertinent to germination are being carried out in order to gain more insight into the role of fire in cerrado vegetation.

Cerrado of northern Brazil – wet grasslands and vereda surrounded by campo sujo. Photo: A. Fidelis.

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How specific is site specific? Using molecular markers to define seed zones for ecological restoration in Norway

Siri Fjellheim & Marte Holten Jørgensen

Department of Plant Sciences,
Norwegian University of Life
Sciences, N-1432 Ås, Norway

Correspondence: Siri Fjellheim,
siri.fjellheim@nmbu.no

Background & Aim: In Norway, the use of seed for ecological restoration and landscape management in compliance with the new Nature Diversity Act of 2009 is hampered by uncertainties about the question of what are site-specific seeds, and hence the lack of useable seed mixtures. A way of revealing site-specific areas of populations is to study geographic patterns in genetic diversity which reflects population genetic processes such as migration/gene flow and drift. Based on genetic relationships between populations seed transfer zones can be constructed where seed mixtures produced in the zone freely can be used in the zone, but not outside. We suggest a protocol for analysis of genetic diversity in a collection of species suitable for restoration with the aim of providing a scientific base for defining seed transfer zones to be used in development of sites-specific seed mixtures. This will meet the demand for site-specific material as well as give manageable guidelines for users of seeds in restoration.

Materials & Methods: We collected eight species commonly used in commercial seed production from 20 localities across Norway: 15 specimens per species per site. To assess the genetic diversity we used amplified fragment length polymorphisms (AFLPs); a protocol ideal for studies of non model organisms as it generates large datasets without prior knowledge of an organism's genome. The resulting matrices were subjected to standard statistical tools such as ordination and clustering analysis.

Results & Conclusions: Most species show geographical structuring of genetic diversity, however no strong division between genetic groups was found. For example, *Agrostis mertensii* populations from northern Norway were genetically distinct from the other populations. *Carex bigelowii* populations were split into a northern and a southern group, but with a more southern border than for *A. mertensii*. In *Festuca ovina*, we detected a group in southern Norway, whereas in *Scorzoneroides autumnalis* and *Avenella flexuosa*, there was a clear north-south gradient, but the populations were overlapping. These results show that the species do not necessarily have congruent genetic structuring of variation and seed transfer zones needs to be defined for each species, increasing the number of different seed mixtures that have to be developed. Although neutral markers may not neccessarily reflect the distribution of adaptive traits, they do reflect historic gene flow among populations, the conservation of which may be important in its own right, and can be used to inform further studies of adaptation within regions. We propose four seed zones for alpine plants in Norway, corresponding to the patterns observed in the included taxa.

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One of the studied localities of *Avenella flexuosa* (*Poaceae*) in Norway.
Photo: S. Fjellheim.

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The unimodal relationship between species richness and biomass in herbaceous plant communities

Lauchlan H. Fraser (1) & HerbDivNet(2)

1) Department of Natural Resource Sciences, Thompson Rivers University, Kamloops, British Columbia, V2C 0C8, Canada

2) HerbDivNet is the Herbaceous Diversity Network, an international group of ~60 scientists from 19 countries around the world

http://faculty.tru.ca/lfraser/HerbDivNet.htm

Correspondence: Lauchlan Fraser, lfraser@tru.ca

HerbDivNet Steering Committee:

Lauchlan Fraser, Thompson Rivers University, Canada

Anke Jentsch, University of Bayreuth, Germany

Marcelo Sternberg, Tel Aviv University, Israel

Martin Zobel, University of Tartu, Estonia

Background & Aim: A relationship that has received significant attention is that between species diversity and productivity. In plant ecology, the so-called humped-back model (HBM), a unimodal relationship between plant species richness and aboveground plant biomass, has provided foundation for theory and ecosystem management. However, a recent large-scale study cast doubt on the HBM and whether it can be generalized; which was followed by criticisms of the study, and rebuttals (Fraser et al. 2014). We present the results of a coordinated distributed experiment to test the HBM.

Materials & Methods: The design was an 8 X 8 metre grid containing 64 1 m^2 plots. Our study focused on grassland herbaceous community types (tropical and temperate). For each 1 m^2 plot, the number of species were identified and counted. Total aboveground biomass (including plant litter) at peak biomass was harvested dried and weighed by plot. We ran linear and quadratic regressions to determine the best relationship between biomass and species richness.

Main Results & Interpretations: Using globally coordinated sampling of diversity and productivity data spanning 19 countries and 6 continents, we present evidence for the unimodal relationship between grassland herbaceous total above-ground biomass and plant species richness by site, by grassland type and across a range of sampling grains from 1 m^2 to 64 m^2. As in the original HBM, the overall association (across all sites, and using each square-metre quadrat as an observational unit; N = 9016) takes the form of a unimodal relationship, which is statistically characterized by a significant concave-down quadratic relationship and a significant concave-down quantile regression (95% quantile). Changing the extent of the analyses to the scale of sites (i.e. regions within which individual investigators conducted sampling), 17 of the 28 models were characterized by concave-down relationships, 7 exhibited negative linear associations, 3 were positive linear, and 1 was concave-up. All of the within-site relationships fell within the bounds of the overall quantile regression. Thus, standing plant biomass plus litter, as a surrogate of primary production, can be a predictor for species richness in grassland plant communities.

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Re-visiting historical relevés to assess changes in species composition and diversity: A case study from Central Italy

Eleonora Giarrizzo, Sabina Burrascano, Laura Zavattero & Carlo Blasi

Department of Environmental Biology, University of Rome 'La Sapienza', Piazzale Aldo Moro 5, I-00185 Rome, Italy

Correspondence: Eleonora Giarrizzo, eleonora.giarrizzo@gmail.com

Background & Aim: Semi-natural dry grasslands are among the most species-rich plant communities in Europe. Their high nature conservation value has been recognized at an international level by the Habitat Directive (92/43/EEC). Since the maintenance of semi-natural dry grasslands depends on extensive management, the cessation of traditional practices activates processes of vegetation dynamics, with such modifications of species composition that often lead to significant reductions of the habitat's extent at the local and regional scale. Here, we present a new methodology based on re-visiting of historical vegetation plots for the assessment of compositional changes in the semi-natural dry grasslands listed in the Annex I of the Habitat Directive. Our method enables to: i) quantify the change in vascular plant species composition; ii) to assess the shifts in species diversity levels; and iii) to define the main drivers of the observed changes.

Materials & Methods: We tested this approach on three grassland communities on Mount Catria (Central Italy). We selected 24 historical relevés associated with a detailed vegetation map performed between 1976 and 1978. The spatial information derived from the map jointly with the geographic and topographic data reported in the relevé tables allowed us to substantially limit the spatial inaccuracy during the identification of the sites to be revisited. In 2013, we performed 24 new relevés following a stratified random sampling based on map polygon, locality, altitude, slope, and aspect of the historical relevés. For each phytosociological plot, we also performed a fixed-area floristic sampling (16 m^2) to analyze diversity levels. Environmental (climatic and topographic), management data (number and type of grazing animals), and soil variables (roots, percentage of gravel, stones, and $CaCO_3$) were recorded in order to identify the drivers of changes in vascular plant species composition.

We synthesized the compositional information of the historical relevés in a centroid within the ordination space and then used the distances between each individual new relevé and the centroid of the corresponding group of historical relevés as a measure of the amount of compositional change. These distances were used as response variables in multiple regression analysis with environmental, management, and soil data used as explanatory variables. We also calculated the indicator value of each species for the old and new groups of relevés.

Main Results & Conclusion: All the three grassland communities investigated showed changes in species composition. Surprisingly the influence of grazing was not significant in the regression analysis, while the percentage of CaCO3 and of litter, and exposition were significantly related to the observed changes in species composition. We did not find a significant correlation between distances from centroids of historical data and the species richness, therefore no changes in species density were associated with shifts in species composition. The indicator species analysis showed significantly higher frequency and abundance of both therophytes and woody species in the new relevés, whereas decrease in the occurrence of orchids was detected.

Based on our preliminary results we deem our approach particularly effective in studies involving re-sampling to overcome the issues related to: 1) the pseudo-turnover due to the shift in plot location, and 2) the lack of ecological data associated to the historical relevés. Indeed our approach allowed us to identify relevant shifts in species composition and those environmental conditions in which these took place more evidently.

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Plant functional types and traits as biodiversity indicators

Andrew N. Gillison

Center for Biodiversity Management,
Yungaburra QLD 4884, Australia;
www.cbmglobe.org

Correspondence: Andy Gillison,
andygillison@gmail.com;
andyg@cbmglobe.org

Background: Covariant patterns of plant and animal fitness and diversity along similar environmental gradients suggest species related traits in one set of biota (e.g. plants) might be used to predict biodiversity in another (e.g. fauna). Yet for many practitioners the identification of cost-effective predictors remains elusive.

Review of Progress: Comprehensive surveys in complex, lowland tropical landscapes indicate that, while measures of predictive success depend on purpose and scale, the sole use of species or abiotic variables (e.g. climate, substrate) as biodiversity indicators is inefficient. It is argued that the complementary use of plant functional types (PFTs) and traits (FTs) may offer significant improvements in indicator selection. At biome scale, current theory supports the use of FTs such as Specific Leaf Area (SLA), Leaf Mass per unit Area (LMA or 1/SLA), seed mass, root traits and leaf venation as parsimonious (independent) indicators of resource acquisition strategies. However, these traits are largely impractical as biodiversity indicators. At increasingly finer spatio-temporal scales, less-parsimonious traits assume relatively greater significance in resource acquisition trade-offs through specific functional cascades and networks. This is exemplified by whole-plant adaptations to exogenous impacts such as seasonality, fire and grazing, and by variation in progressively finer scale endogenous traits such as cortical photosynthesis, leaf inclination, stomatal dynamics and genetic infraspecific pleiotropy (Vasseur et al. 2012). It is argued that when coupled with species, traits of this kind may provide an improved logical and functional basis for the selection of biodiversity indicators – biodiversity being characterised by the sum of both taxa and functional types in any area of study.

Case Studies at Multiple Scales: Whole-plant (PFT) constructs of FTs using a pre-defined assembly rule set provided a logical framework for coupling readily observable (non-laboratory) FTs for each individual plant according to a scaled set of morpho-anatomical, ecophysiologically significant traits linking modified Raunkiærean life forms with leaf photosynthetic apparatus (size, inclination, venation pattern, stomatal distribution, succulence, phyllotaxis and longevity) and corticular photosynthesis. The occurrence of all vascular plant species, vegetation structure, cover-abundance of bryophytes and lichens and site physical attributes and history were included (Gillison 2013) and data for 1866 (40 x 5 m) plots worldwide were analysed including detailed multi-taxa comparative surveys in Sumatra and Brazil (Gillison et al. 2013). Outcomes show that plant species diversity (richness) can be reliably predicted by PFT diversity across multiple scales – a particularly useful feature where taxa cannot be readily identified. When combined, the vascular plant and PFT richness are often more successful as indicators of diversity among certain faunal groups (e.g. mammals, birds, termites) than if used individually.

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Functional responses of woody plant communities in grassland–forest transitions in southern Brazil

Mariana Gliesch-Silva (1), Rodrigo S. Bergamin (1), Valério D. Pillar (2) & Sandra C. Müller (1)

1) Laboratório de Ecologia Vegetal, Graduate Program in Ecology, Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, Brasil

2) Laboratório de Ecologia Quantitativa, Graduate Program in Ecology, Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, Brasil

Correspondence:
Mariana Gliesch-Silva,
marianagliesch@gmail.com

Background & Aims: Forest expansion into grassland has been observed worldwide in a process that is likely driven by a low level of grazing or by fire. In southern Brazil, present climatic conditions enable woody forest species to encroach into native grassland, generating forest-grassland transition zones. Here we aimed to identify assembly patterns of plant communities at forest and forest-grassland transitions, considering functional leaf traits of woody species. We asked (a) whether forest and transitional communities differ in species composition and (b) whether species in these communities differ in functional strategies, particularly in terms of leaf traits. Further, in view of harsher environmental conditions (higher light intensity and potential evapotranspiration), we asked whether trait-convergence would be found in forest-grassland transitions.

Materials & Methods: We selected seven 2 km X 2 km sites across the grassland biome in Rio Grande do Sul, Brazil. In each site we surveyed two 70 m X 140 m plots: one plot in a forest and the other in an adjacent transitional forest-grassland. In each plot 15 10 m X 10 m subplots were selected, in which all trees with a stem diameter ≥ 5 cm were identified and leaf traits sampled. Leaf trait measurements consisted of Specific Leaf Area (SLA), Leaf Area (LA), and Leaf Dry Matter Content (LDMC). The data were arranged in a matrix **W** of local species populations by plots, i.e. average species density standardized for the plot unit total, a matrix **B** of local species populations by traits, and a matrix **E** to represent the habitat type of each plot. We then computed the community weighted mean (CWM) for traits as **T=WB′**, and the fuzzy-weighted community composition after species similarities based on their traits, which allowed identification of trait-convergence and trait-divergence assembly patterns (Pillar et al. 2009).

Main Results & Conclusions: A permutational multivariate analysis of variance indicated significant differences between communities in species composition (P = 0.001), and functional strategy. Trait-convergence related to habitat type was not significant (Procrustes correlation between **T** and **E** = 0.37; P = 0.091). Furthermore, the values of CWM traits in forest-grasslands were lower for SLA (forest = 10.20 mm^2/mg; transition = 6.60 mm^2/mg, P=0.001) and LA (forest = 28.75 mm^2; transition = 20.53 mm^2, P=0.001), but not for LDMC (forest = 407 mg/g; transition = 412.11 mg/g; P=0.67). Thus, our results support environmental filtering shaping woody plant communities in forest-grassland transitions, i.e., only woody species with certain values of leaf traits were able to establish in the grassland and in this way developing a transition zone between forest and grassland.

A forest-grassland transition at Santo Antônio das Missões, southern Brazil. Photo: E. Vélez.

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Does an invasive species affect the recovery of native vegetation after fire in the Brazilian cerrado?

Elizabeth Gorgone-Barbosa (1), Vânia R. Pivello (2) & Alessandra Fidelis (1)

1) Departamento de Botânica, Universidade Estadual Paulista, Av 24A, 1515, Rio Claro, Brazil

2) Departamento de Ecologia, Universidade de São Paulo, Rua do Matão, 321, trav 14, São Paulo, Brazil

Correspondence:
Elizabeth Gorgone-Barbosa,
elizabethgorgone@yahoo.com.br

Background & Aim: Invasive species are considered threats to biodiversity in many ecosystems of the world. Some of the most aggressive and common invasive species in cerrados are the African *Urochloa* (*Poaceae*). African grasses can dominate the herbaceous community, having a negative effect on the abundance of native grasses and forbs (Pivello et al. 1999). Fire is a natural disturbance in cerrado, and the native vegetation is fire-adapted. Prescribed fires in specific seasons can be used as a restoration tool in cerrado (Pivello 2006). The aim of this study was to evaluate the effect of prescribed fires in two seasons on native vegetation recovery in areas invaded by *Urochloa brizantha.* We also evaluated the dynamics of the African grass and native species after fires. We hypothesized that fires in the middle of the dry season (July) will favor the native grasses, while fires at the beginning of the rainy season (October) will favor the invasive species.

Materials & Methods: The study was carried out in the Serra do Tombador Natural Reserve (Central Brazil), in an open savanna where *U. brizantha* was introduced to improve cattle raising. Since 2006 cattle were excluded from the Reserve and *U. brizantha* became invasive. Experimental fires were applied in four replicates (20 m X 15 m) in each treatment: July fires (middle of the dry season), October fires (end of the dry season) and Control (unburned plots), 4 replicates/fire season (12 plots in total). In all plots we have established 5 non-invaded subplots and 5 subplots (1 m X 1 m) invaded by *U. brizantha*. In all subplots we measured the ground cover of *U. brizantha*, graminoids, forbs, shrubs, palms, dead biomass, and bare soil, before the fire experiment (T_0) and one year after the fire treatments (T_{360}). Statistical analyses were conducted for each time of observation separately, using two-way ANOVA (factors: presence of *U. brizantha* and fire treatment).

Main Results: Data collected before the fire showed that the cover of forbs and graminoids was lower in the invaded plots in comparison to the non-invaded plots ($p=0.05$ and $p=0.004$, respectively). One year after fire, independently of the treatment, we found the same patterns: cover of the different groups was relatively the same before the fire ($p>0.05$) in non-invaded plots and the cover of forbs and graminoids was lower in plots with *U. brizantha* ($p=0.004$ and $p<0.001$, respectively); the cover of *U. brizantha* was statistically the same, independently of the treatment (>40%, $p>0.05$), showing its high capacity to recover after fire. Thus, in the short-term fire treatments did not affect the invasive species, and did not stimulate the native species recovery.

Native cerrado vegetation and the invasive *Urochloa brizantha*, fourty days after fire experiments at Reserva Natural Serra do Tombador, Brazil. Photo: E. Gorgone-Barbosa.

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Empirical modelling and a revised community assembly framework for predicting climate change impacts on plant communities

Greg R. Guerin

Australian Centre for Evolutionary Biology and Biodiversity, the Environment Institute, University of Adelaide, Adelaide SA 5005, Australia

Correspondence: Greg Guerin, greg.guerin@adelaide.edu.au

Background & Aim: An emerging impact of climate change is altered species composition in ecological communities. Accurate forecasting of species composition is important for prioritising the conservation of vulnerable communities, and for devising de novo species composition in revegetated landscapes to promote resilience. Spatial climate gradients can be used as analogues to model temporal climate change and predict future composition. The simplest types of such models are based on species sorting: the concept that species occurrences are determined to some degree by the environment and can be predicted from redistributed climatic variables. This approach is powerful because species inventory data are readily obtainable. Here, I present recent empirical examples that measured climatic influences on spatial and temporal variation in plant community composition and function, and develop a predictive framework for plant communities under climate change that relaxes some of the unrealistic assumptions of species sorting.

Materials & Methods: Plot-based datasets from the Mount Lofty Ranges and Flinders Ranges regions of southern Australia were used to evaluate the influence of climatic gradients on species composition, while controlling for confounding geographic factors. Compositional, spatial and environmental data were analysed using ordinations and regressions where ordination axes (representing composition with reduced dimensionality), pairwise dissimilarities or multivariate species occurrences were the response variables. Purely spatial influences on composition were accounted for by the inclusion of geographic distances or their principle coordinates as spatial covariates. Phylogenetic correlations to environmental variables were also assessed. In parallel, leaf traits in *Dodonaea viscosa* (*Sapindaceae*) were investigated across the same gradients. These studies and the wider literature informed the development of a quantitative model of plant community composition under climate change that has more realistic assumptions than species re-sorting.

Main Results & Interpretation: The community level analysis quantified the influence of climate on composition, which suggested that climate change will drive significant species and phylogenetic turnover. Observed turnover along spatial climate gradients involved ecotones between mesic and arid habitats suggesting that there are climate tipping-points. However, when these spatial climate models are applied to temporal change, they assume that a static set of species, with fixed traits and responses, are available to be re-sorted. These assumptions are flawed – or at least imperfect – due to species introductions and extinctions, and phenotypic variation. For example, leaf traits within *D. viscosa* varied significantly and were correlated with spatial and temporal climate gradients. Recognising the limitations of spatial models for predicting future composition, I propose a framework in which shifting environmental constraints on mean community traits can be broken down into intraspecific components (i.e. phenotypic variance/clines) and interspecific components, including changes to relative species abundance, and species replacement from a shifting species pool (Guerin et al. 2014). Basing predictions of composition on community metrics, rather than the sum of predictions for individual species, reduces complexity, is more realistic in its assumptions, and allows ecosystem function to be predicted independent of future species pools.

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Establishment of woody savanna species on various mined substrates: toward restoring self-sustaining plant communities at Navachab Gold Mine, Namibia

Emilia N. Haimbili (1), Peter J. Carrick (2) & Ndafuda Shiponeni (3)

1) Biological Science Department, University of Namibia, Private Bag 13301, Windhoek, Namibia
2) Nurture Restore Innovate & Plant Conservation Unit, Department of Botany, University of Cape Town, Private Bag X3, Rondebosch, 7701, South Africa
3) University of Namibia, Multidisciplinary Research Centre, Private Bag 13301, Windhoek, Namibia

Correspondence: Emilia Haimbili, haimbiliemilia@gmail.com

Background & Aim: Vegetation re-establishment is a necessary and critical step in achieving the goal of ecosystem restoration on mined soils (Yan et al. 2013). Much research has been done on native species rehabilitation on mined land but few studies have correlated native species establishment with mined substrate's properties. This study tested the suitability of various mined substrates for the establishment of indigenous savanna species, and explored which properties make a particular substrate suitable for plant growth.

Materials & Methods: The study was conducted at Navachab Gold Mine (21°56′ S, 15° 51′ E), located 170 km NW of Windhoek on the south-western coast of Africa in Erongo Region, Namibia. Vegetation surveys carried out in the greater Navachab area generated a list of species from which seven (*Acacia senegal, A. tortilis, A. erioloba, A. reficiens, A. erubescens, Catophractes alexandri* and *Adenolobus garipensis*) were selected for this study based on how common they were in the area. The seven species, grown from seeds in the nursery, were transplanted into nine mixtures of substrates at an experimental field site. Seedling growth and survival were monitored for 13 months. Soil samples of each substrate were analysed for chemical and physical properties.

Main Results & Interpretations: Survival percentage was highest in *Acacia senegal* followed by *A. tortilis, A. erioloba, A. reficiens, A. erubescens, Catophractes alexandri and Adenolobus garipensis*. We suggest that the species survival is determined by its range of tolerance. For instance, *A. senegal* is adapted to soil water stress through morphological and physiological mechanisms (Mohamed 2005) and has deep tap roots and far reaching lateral roots that could potentially redistribute soil water from deep layers (Hocking 1993). This may be a possible explanation for its high survival. Generally, trees that produce a deeper taproot can access soil moisture at greater depths, allowing them to survive longer during the dry season. This perhaps also explains the high survival recorded in *A. tortilis* and *A. erioloba* as they tend to have deeper taproots (Barnes et al. 1997). High growth and survival of seedlings was recorded in mixed substrates such as a marble and calcrete mixed, a sand, calcrete and marble mix compared to pure substrates such as marble, sand and calcrete. It is important to note that all species were able to grow and survive on all substrates, although growth and survival differed among species. We found that for most species survival and growth was strongest on calcium and clay substrate. This experiment showed that species were able to grow outside their natural range of soil conditions, and all the substrates were able to support growth and survival of different species. However, optimum soils or soil mixtures should be used to optimize early ecosystem restoration, especially where these are readily available.

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Local adaptation at range edges: comparing elevational and latitudinal gradients

Aud H. Halbritter (1,2), Regula Billeter (1,3), Peter J. Edwards (1) & Jake M. Alexander (1)

1) Institute of Integrative Biology, ETH Zürich, Universitätsstrasse 16, CH-8092 Zürich, Switzerland

2) Department of Biology, University of Bergen, Postbox 7803, N-5020 Bergen, Norway

3) Institute of Natural Resource Sciences, ZHAW, Grüental, CH-8820 Wädenswil, Switzerland

Correspondence: Aud H. Halbritter, aud.halbritter@env.ethz.ch

Background & Aim: Understanding local adaptation at range edges is becoming increasingly important against a backdrop of rapid climate change, since the capacity to evolve may determine whether a local population can persist. Local adaptation depends among other things on the amount and direction of gene flow and the availability of genetic diversity on which selection can act. Therefore, patterns of local adaptation might differ between a steep environmental gradient with high gene flow among populations (elevation) and a climatically similar but more gradual gradient (latitude).

Materials & Methods: To test this hypothesis, we performed a reciprocal transplant experiments with nine central and edge populations of *Plantago lanceolata* and *P. major* from two climatically comparable gradients that differ in their steepness. Three transplant sites were established along an elevational gradient in Switzerland (46° N; 500–2200 m) and two sites along a latitudinal gradient in Norway (64° N and 69° N). Additionally, we analysed neutral genetic variability (microsatellite markers) from 30–31 populations along these gradients, to characterize patterns of genetic diversity and differentiation.

Main Results & Conclusion: Both species showed stronger decrease in genetic diversity and a 1.5–2 times higher genetic differentiation (F_{ST} among populations) along the latitudinal than elevational gradient. The latter is consistent with the predicted higher gene flow along the steeper, elevational gradient. In general, fitness differed among origins within species. While *P. lanceolata* showed no evidence for local adaptation, central and elevational edge populations of *P. major* were locally adapted. We conclude that the degree to which populations are adapted to the conditions at the range edge is not explained by the magnitude of gene flow from central populations. Furthermore, our data suggest that local adaptation to similar changes in temperature within a species range for example to high elevation and latitude, might differ and can complicate predictions of how populations will react to a changing climate.

Field site of the transplant experiment at high latitude (69° N) in Tromsø, Norway. Photo: A. Halbritter.

Central, elevational and latudinal edge populations of *Plantago major* transplanted to a high elevation site in the Swiss Alps (Nesselboden, 1400 m). Photo: A. Halbritter.

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Contribution to the flora and vegetation of Sinai, Egypt

Mohamed Z. Hatim (1), Kamal H. Shaltout (1), Joop H.J. Schaminée (2), Hassan F. El-Kady (1), John A.M. Janssen (2) & Mohamed A. El-Sheikh (3,4)

1) Botany Department, Faculty of Science, Tanta University, Tanta, PO 31527, Egypt

2) Center for Ecosystems Studies, Wageningen University, PO Box 47 NL-6700AA Wageningen, The Netherlands

3) Botany Department, Faculty of Science, Damanhour University, Damanhour, Egypt

4) Botany & Microbiology Department, College of Science, King Saud University, P.O. Box 2455, Riyadh 11451, Saudi Arabia

Correspondence: Mohamed Z. Hatim, mohamed.zakaria@science.tanta.edu.eg

Background & Aims: This study aimed at (1) digitizing all available phytosociological data on the vegetation of Sinai, and (2) carrying out new field surveys in areas where no or little research has been done before. This data set will be used in constructing a new overview of the plant communities of Sinai, covering all variation in the region, and building up a digital database for Sinai vegetation as a core for the National Vegetation Databank of Egypt.

Materials & Methods: The study area is the Sinai Peninsula which is in the northeast of Egypt and covers an area of approximately 61 000 km^2. After digitising vegetation relevés from available literature, several parts of the Sinai were identified that were not represented well by relevés in the database. The first author carried out four field excursions to these places, resulting in a new set of 182 phytosociological relevés made according to the field methods Braun-Blanquet approach. The entire Sinai database (816 relevés) was stored in Turboveg and analysed in JUICE (using TWINSPAN) and DECORANA. In the resulting vegetation types, species richness, species turnover, and number of endemics were determined.

Results & Interpretations: In total 496 plant species were recorded (in 816 relevés), belonging to 281 genera and 69 families. *Asteraceae, Poaceae* and *Fabaceae* were the most represented families. 52 threatened species were recorded, as well as 16 endemic and 20 near-endemic species. 21 vegetation types were identified based on the classification performed. The vegetation types typical of sandy habitats have the lowest species richness and species turnover because of water scarcity. On the other hand, vegetation types characteristic of rocky habitats have the highest species richness and species turnover because of the relative water abundance in the habitats known to harvest rare precipitation by surface run-off.

Figure 1. Stand of the *Tanacetum sinaicum* community (with *Tanacetum sinaicum*, *Phlomis aurea* and *Teucrium polium*) in a wadi bed (South Sinai). Photo : M.Z. Hatim.

Figure 2. The *Tamarix nilotica* community on sand dunes of Central Sinai. Photo: M.Z. Hatim.

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Foliar nutrient concentrations and resorption in plants of contrasting nutrient-acquisition strategies along a chronosequence

Patrick E. Hayes (1), Benjamin L. Turner (1,2), Hans Lambers (1) & Etienne Laliberté (1)

1) School of Plant Biology, The University of Western Australia, 35 Stirling Hwy, Crawley WA 6009, Australia

2) Smithsonian Tropical Research Institute, Apartado 0843-03092, Balboa, Ancon, Republic of Panama

Correspondence: Etienne Laliberté, etienne.laliberte@uwa.edu.au

Background & Aims: Long-term pedogenesis leads to important changes in the availability of soil nutrients, especially nitrogen (N) and phosphorus (P). Changes in the availability of micronutrients can also occur, but are less well understood.

Materials & Methods: We explored whether changes in leaf nutrient concentrations and resorption were consistent with a shift from N to P limitation of plant productivity with soil age along a > 2-million-year dune chronosequence in southwestern Australia. We also compared these traits among plants of contrasting nutrient-acquisition strategies, focusing on N, P and micronutrients.

Main Results: The range in leaf [P] for individual species along the chronosequence was exceptionally large for both green (103–3000 µg P g^{-1}) and senesced (19–5600 µg P g^{-1}) leaves, almost equalling that found globally (Lambers et al. 2011; Vergutz et al. 2012). From the youngest to the oldest soil, cover-weighted mean leaf [P] declined from 1840 to 228 µg P g^{-1}, while P-resorption efficiency increased from 0% to 79%. All species converged towards a highly conservative P-use strategy on the oldest soils. Declines in cover-weighted mean leaf [N] with soil age were less strong than for leaf [P], ranging from 13.4 mg N g^{-1} on the youngest soil, to 9.5 mg N g^{-1} on the oldest soil. However, mean leaf N-resorption efficiency was greatest (45%) on the youngest, N-poor soils. The leaf N:P ratio increased from 8 on the youngest soil to 42 on the oldest soil. Leaf zinc (Zn) concentrations were low across all chronosequence stages, but mean Zn-resorption efficiency was greatest (55–74%) on the youngest calcareous dunes, reflecting a low Zn availability at high pH. Nitrogen-fixing species had high leaf [N] compared with other species. Non-mycorrhizal species had very low leaf [P] and accumulated Mn across all soils. We surmise that this accumulation of Mn in non-mycorrhizal species reflects Mn solubilisation by organic acids released for P acquisition. Our results show community-wide variation in leaf nutrient concentrations and resorption that is consistent with a shift from N to P limitation during long-term ecosystem development. High Zn resorption on young calcareous dunes supports the possibility of micronutrient co-limitation. High leaf [Mn] on older dunes suggests the importance of carboxylate release for P acquisition. Our results show a strong effect of soil nutrient availability on nutrient-use efficiency and reveal considerable differences among plants of contrasting nutrient-acquisition strategies.

The Jurien Bay dune chronosequence in south-western Australia. Along the coast, a series of dune systems have been deposited throughout the Pleistocene. Because some of these dune systems have not been buried by younger sediments, the Jurien Bay chronosequence creates opportunities to study how soils and ecosystems develop over millions of years. Photo: E. Laliberté.

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Resampling of vegetation data: call for a systematic approach

Radim Hédl

Department of Vegetation Ecology,
Institute of Botany, Academy of
Sciences of the Czech Republic,
CZ-60200 Brno, Czech Republic

Correspondence: Radim Hédl,
radim.hedl@ibot.cas.cz

Background & Aim: In light of recent environmental changes and the global biodiversity crisis, the need to understand vegetation changes has become increasingly important. To learn how ecosystems change and to predict future developments, we must be able to accurately reconstruct the past. In order to achieve this goal, the resampling of old vegetation records has become an increasingly frequented approach. Indeed, historical records of vegetation composition have a not yet fully utilized potential. Today, we can retrieve an almost unlimited set of samples from extensive vegetation databases and other resources. This calls for a structured approach to the correct resampling of historical vegetation data. Here, I critically evaluate the advantages and drawbacks which are inevitably present in historical data resampling.

Materials & Methods: I retrieved a comprehensive set of online-available peer-reviewed research papers that used plot resampling to quantify vegetation and environmental change. I extracted basic properties such as time span and record density, and compared more complex patterns such as vegetation type and geographical distribution. Furthermore, I assessed the approaches the authors used to deal with potentially distorting sources of variability: accuracy of plot re-location, authorship bias and detection of long-term trends rather than natural fluctuations.

The analysed resampling studies comprised temperate regions of north, northwest and Central Europe and North America. Mostly temperate forests, but also grasslands, heathlands, and alpine habitats were covered. Other regions and habitats were poorly represented, or not at all. Most resurveys span a time period of up to 40 years.

Main Results & Conclusions: The three main sources of excessive variation in resampling data, namely imprecise plot relocation, natural temporal variation due to inter- and intra-annual fluctuations and observer bias, were seldom taken into account. Some papers quantified the role of accuracy of old plot relocation, using sampling on transects or at random positions in the potential area of the resampled plot. The authorship bias applies not only to vegetation composition and assessment of biodiversity parameters change, but also to parameters associated with vegetation records, typically estimations of vegetation cover. The present era of 'big data' provides an unprecedented opportunity to resample vegetation plots of earlier studies. However, to assess vegetation dynamics over longer periods only high-quality data of known origin should be used.

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Arum cylindraceum still growing in one of the forest plots resampled after 50 years in Děvín, Czech Republic. Resampling can provide valuable information about changes in plant communities as well as environmental changes at a scale of decades. The 1953 photo was taken by J. Horák, the 2003 photo was made by R. Hédl.

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Increasing soil nutrient loads of European semi-natural grasslands strongly alter plant functional diversity independently of species loss

Kenny Helsen (1), Tobias Ceulemans (1), Carly J. Stevens (2) & Olivier Honnay (1)

1) Laboratory of Plant Conservation and Population Biology, Biology Department, University of Leuven, Arenbergpark 31, B-3001 Leuven, Belgium

2) Lancaster Environment Centre, Lancaster University, Lancaster, LA1 4YQ, United Kingdom

Correspondence: Kenny Helsen, kenny.helsen@bio.kuleuven.be

Background & Aim: Anthropogenically increased input of nitrogen (N) and phosphorous (P) have led to a severe reduction of plant species richness in European semi-natural grasslands. Although it is well established that this species loss is not trait-neutral, a thorough analysis of the effects of nutrient addition on plant trait based functional diversity and functional composition, independently of species loss, is lacking so far.

Materials & Methods: We combined two methodologically consistent datasets, which together consist of 279 *Nardus* grassland relevés from nine European countries, across a gradient of soil N and soil P content (Ceulemans et al. 2011; Stevens et al. 2011). Three measures of functional diversity (Petchy & Gaston's community based functional diversity (FDc), weighted FDc and quadratic entropy (RAO)) and mean trait composition (community-weighted trait means) were calculated for each relevé, based on 21 functional plant traits. Differences in functional diversity and functional composition of the grasslands were related to differences in soil N, atmospheric N deposition, soil P and soil pH, while controlling for geographic location and species richness using general linear models (GLM) and redundancy analysis (RDA).

Main Results & Conclusions: All three measures of functional diversity were found to decrease with increasing soil N levels, independent of species loss. An increase in soil P levels was furthermore observed to decrease weighted functional diversity (wFDc). This was accompanied by clear shifts in mean grassland functional trait composition, suggesting the loss of functional adaptation to nutrient limitation (nitrogen fixation, parasitism, ericoid and orchid mycorrhizal dependency) and a replacement of forbs by graminoid species. Furthermore, we observed a decrease in insect-pollinated therophytes and chamaephytes and an increase in long-lived, clonal graminoids and hemicryptophytes under increasing soil N and P. These functional community changes can be expected to alter both ecosystem functioning and ecosystem service provisioning of the studied grasslands. Our research emphasises the importance of a reduction of both N and P emission throughout Europe for sustainable conservation of these communities.

Overview of the *Nardus* grasslands sampled for this study. Source: Helsen, K., Ceulemans, T., Stevens, C.J. & Honnay, O. 2014. Increasing soil nutrients loads of European semi-natural grasslands strongly alter plant functional diversity independently of species loss. *Ecosystems* 17: 169–181.

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Global patterns of vascular plant endemism in relation to habitat and environment

Carsten Hobohm (1) & Alessandro Chiarucci (2)

1) Interdisciplinary Institute of Environmental, Human and Social Studies, University of Flensburg, D-24943 Flensburg, Germany

2) Dipartimento di Biologia Ambientale, Università, di Siena, Via P.A. Mattioli 4, I-53100 Siena, Italy

Correspondence: Carsten Hobohm, hobohm@uni-flensburg.de

Background & Aim: Several international conservation schemes have been developed that focus on endemism and vulnerability (e.g., Convention on Biological Diversity, Bern Convention). Different processes and conditions facilitate and promote endemism whereas others reduce endemism. The aim of this presentation is to identify and discuss the biotic and abiotic factors that cause distribution patterns of endemic vascular plants. The fundamental questions emerge: What are the most endemic-rich major vegetation types (group of habitats) in the world? What are the drivers of endemism? Why are there so many endemic vascular plants in regions dominated by nutrient-poor soils? Why are tropical forests, mediterranean-type ecosystems, and rocky habitats rich in endemics? The relationships between distribution patterns of vascular plant endemism and habitat should be discussed against the background of current concepts and theories on plant diversity and endemism.

Materials & Methods: Several methodologies and indicator values can be used to calculate patterns of vascular plant endemism and centres of endemism. Popular measures include the absolute number of endemics (E), proportion (level, percentage value), Range Size Rarity, and others. The results and trends are often similar but not the same in every case (Hobohm 2014). EUNIS habitat types (Level I) and other systems can be used to categorize habitat types worldwide (Davies et al. 2004). The richness of endemism related to habitat is calculated via endemics-area curves (for methodological details and collected data see Hobohm 2014).

Main Results & Interpretations: Most centres of endemism are concentrated in tropical, subtropical and warm-temperate regions. However, it is not possible to detect a clear latitudinal gradient for every group of habitats. Tropical rainforests, heathland and scrub (including fynbos, kwongan, matorral, chaparral), and rocky habitats, including coastal cliffs, are often rich in endemics. On the other hand boreal forests, seagrass habitats, inland water bodies (standing and running waters), mires, bogs and fens, and anthropogenic habitats are generally much poorer in endemic plants. Climate (water-energy, evolutionary speed), area (size of the habitat, ecoregion or biome), constancy (environmental conditions), and environmental heterogeneity have so far been found to be important factors determining the number of endemic vascular plants. Factors that might also be important include: biological constraints, species interactions (including plant-animal relationships), and catastrophic events. The significance of factors for the number of endemic taxa varies from region to region. In arid regions, the variability of rainfall might be more important than in humid regions. At high latitudes, the temporal variability of the length of the growing season might be more important than in the humid tropics.

Open-end question: Is there any comprehensive principle that is controlling the hierarchy of different processes and the meaning of environmental conditions which together determine the composition and number of endemic and non-endemic species in a region? Optimization principles might hold the answer (Dewar 2010).

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Niche displacement reinforces ecological differentiation in heteroploid *Jacobaea carniolica* (*Asteraceae*)

Karl A. Hülber (1,2), Michaela Sonnleitner (1), Ruth Flatscher (3), Pedro Escobar García (1), Gerald M. Schneeweiss (1), Jan Suda (4) & Peter Schönswetter (3)

1) Department of Botany and Biodiversity Research, University of Vienna, Rennweg 14, A-1030 Wien, Austria

2) Vienna Institute for Nature Conservation and Analyses, Giessergasse 6/7, A-1090 Wien, Austria

3) Department of Systematics, Palynology and Geobotany, University of Innsbruck, Sternwartestrasse 15, A-6020 Innsbruck, Austria

4) Department of Botany, Charles University, Benátská 2, CZ-128 01 Praha, Czech Republic

Correspondence: Karl Hülber, karl.huelber@univie.ac.at

Background & Aims: The ability of species to coexist in a particular habitat is a major driver of biodiversity. Niche differentiation allows species with similar ecological demands to co-occur (in sympatry). Ecological character displacement, i.e. the more pronounced differentiation of habitat requirements of ecologically similar taxa amongst co-occurring individuals than when populations are spatially separated (in allopatry), might initiate niche differentiation. Thereby, particularly the spatial distribution of lineages within heteroploid species can provide valuable insights into evolutionary processes.

Materials & Methods: *Jacobaea carniolica* is a common herbaceous perennial plant inhabiting a variety of habitats on siliceous bedrock, like grasslands, dwarf shrub communities, stable screes, moraines, rock crevices and fellfjelds, ranging from timberline up to an altitude of 3300 m a.s.l. Based on 2826 individuals sampled on 99 mountains across the entire Eastern Alpine distribution we tested for differences in the ecological niche optima (Treier et al. 2009) of its three main cytotypes (di-, tetra- and hexaploids) using mean Landolt (2010) indicator values of accompanying plant species as microhabitat descriptors in a canonical correspondence analysis.

Main Results: We found niches of cytotypes to be differentiated along a complex ecological gradient. As a key result we observed niche optima in pure populations inhabited by only one ploidy level to be closer to each other than in populations of cytotype mixture. Thus, the niche displacements among sympatric and allopatric populations within cytotypes reinforce ecological differences among ploidy levels and might contribute to the frequent co-occurrence of cytotypes. These results support ecological character displacement as one key driver of adaptive diversification in *J. carniolica* eventually leading to speciation and enhancing local diversity.

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Hexaploid *Jacobea carniolica* on Mt. Schoberriegel, Austria.
Photo: M. Sonnleitner.

The alpine habitat of *Jacobea carniolica* on Piz Lad, Italy.
Photo: M. Sonnleitner.

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Diversity in mesic meadows: differences between the core and satellite species indicated by their functional traits

Monika Janišová (1) & Mária Májeková (2)

1) Institute of Botany, Slovak Academy of Sciences, Dúbravská cesta 9, SK–84523 Bratislava, Slovak Republic

2) Department of Soil Science, Faculty of Natural Science, Comenius University, SK-842 15 Bratislava, Slovak Republic

Correspondence: Monika Janišová, monika.janisova@gmail.com

Background & Aims: Mesic semi-natural meadows of the *Arrhenatherion elatioris* alliance belong to common and widespread grassland types of the temperate Europe supported by many types of geological bedrock. Due to their intermediate position along two important environmental gradients of soil moisture and nutrients their habitat conditions are suitable for a large variety of species and therefore increased occurrence of species from neighbouring habitats can be observed. These satellite species are not regular components of mesic meadows as their ecological optima lie in another vegetation types. In order to elucidate their coexistence with the core mesic grassland species, we compared functional traits of core and satellite species asking the following questions: i) Do core and satellite species in mesic grasslands have similar traits? ii) Do different kinds of satellite species share similar traits? iii) What functional traits are typical for the core species of the four studied habitat types? iv) Are the core grassland species that can achieve dominance different from the species that are frequently present but never dominate, and from the rare species?

Materials & Methods: Species data were extracted from the Slovak Vegetation Database. Based on the fidelity to a plant community, we defined core species of four habitats: the target mesic grasslands, and the neighbouring urban, agricultural and forest habitats. Within each of the neighbouring habitats we then distinguished between species that do or do not colonize the mesic grasslands. A set of key plant functional traits (canopy height, LDMC, SLA, seed weight, seed bank longevity index and clonal index) was used to explore species' life history.

Main Results: We found that the important traits for the species from the three neighbouring habitats reflect the C-S-R triangle with the mesic grasslands placed in its middle. In the triangle, urban species are the competitors (tall-grown species with strong clonal growth), agricultural species are the ruderals (annuals with low LDMC and long persistence in the seed bank), and forest species are the stress-tolerants (perennial species with high SLA). We later discuss the potential causes and consequences of the functional differences between the core and satellite species as well as the rare and dominant species with special emphasis on their functional originality in these habitats.

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Carpathian mesic meadows occur usually in close vicinity of forests, agricultural fields and villages. These meadows are supplied by numerous satellite species from the neighbouring habitats (Štefanová, Malá Fatra Mts., Slovakia). Photo: M. Janišová.

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Joining biodiversity experiments, climate change research and invasion biology to assess European gradients of grassland resilience in the face of climate extremes

Anke Jentsch (1), Jürgen Kreyling (2), Iva Apostolova (3), Michael Bahn (4), Sándor Bartha (5), Carl Beierkuhnlein (2), Juliette Bloor (6), Hans de Boeck (7), Jürgen Dengler (1,8), Catherine Picon-Cochard (6), Giandiego Campetella (9), Roberto Canullo (9), Ivan Nijs (7), Andreas Stampfli (10), Marcelo Sternberg (11), Emin Uğurlu (12), Julia Walter (1), Camilla Wellstein (13), Michaela Zeitler (10) and the SIGNAL PhD students

1) Disturbance Ecology, Bayreuth Center of Ecology and Environmental Research (BayCEER), University of Bayreuth, Universitätsstraße 30, D-95447 Bayreuth, Germany

2) Biogeography, University of Bayreuth, Universitätsstraße 30, D-95447 Bayreuth, Germany

3) Insitute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences, G. Bonchev St., Block 23, 1113 Sofia, Bulgaria

4) Institute of Ecology, University of Innsbruck, Sternwartestraße 15, A-6020 Innsbruck, Austria

5) Centre for Ecological Research, Hungarian Academy of Sciences, Alkotmány ú. 2-4, H-2163 Vácrátót, Hungary

6) INRA, UR0874 Grassland Ecosystem Research Unit, 5 Chemin de Beaulieu, F-63100 Clermont-Ferrand, France

7) Research Group Plant and Vegetation Ecology, Department of Biology, University of Antwerp, Universiteitsplein 1, B-2610 Wilrijk, Belgium

8) Synthesis Centre (sDiv), German Centre for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig, Deutscher Platz 5e, D-04103 Leipzig, Germany

9) Plant Diversity and Ecosystems Management Unit, School of School of Biosciences and Veterinary Medicine, University of Camerino, Via Pontoni 5, I-63032 Camerino (MC), Italy

Background & Aim: Grasslands are spatially and economically highly important for European agriculture and biodiversity. However, their species diversity and ecosystem functioning might increasingly be threatened by climate extremes and invasion dynamics. SIGNAL is a coordinated, distributed field and mesocosm experiment across a pan-European precipitation and continentality gradient connecting 10 experimental sites between Belgium and Israel. We address vulnerability and resilience of grasslands towards extreme drought and invasive pressure.

Materials & Methods: By newly implementing a coordinated distributed experiment, we test the following 4 hypotheses: Extreme weather events (Hypothesis H1) and the presence of invasive species (H2) can act as pressures threatening biodiversity, resilience and ecosystem services of semi-natural grasslands and can suddenly drive them beyond thresholds of system integrity (tipping points and regime shift). On the other hand, biodiversity itself may buffer against change. Potential stabilising mechanisms include species richness, presence of key species such as legumes (H3) and within species diversity (H4).

Main Results & Conclusions: Data from the SIGNAL field-experiment clearly suggest, that mesic grasslands throughout Europe are surprisingly stable under drought and invasive pressure. In contrast, drier sites are more endangered**.** In mesic grasslands, biomass production was not reduced by a severe drought event, invaders were not able to spread and showed high mortality. However, drier (more southern and more continental) sites along the gradient suffered more from drought, showing losses in biomass production directly after drought (which did not persist until the end of the growing season, though). Our multisite-experiment highlights a surprising degree of stability against extreme drought and invasive species in mesic grasslands.

Acknowledgements: The coordinated, distributed SIGNAL experiment is mainly funded by the ERA-Net BiodivERsA (http://www.biodiversa.org), with the national funding bodies Belgian Science Policy Office (belspo), German Federal Ministry of Education and Research (BMBF), Bulgarian Science Found and Ministère de l´Écologie, du Développement durable et de l´Énergie (France) as part of the 2011-2012 BiodivERsA call for research proposals.

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10) Institute of Plant Sciences, University of Bern, Altenbergrain 21,CH-3013 Bern, Switzerland

11) Department of Molecular Biology and Ecology of Plants, Tel Aviv University, Tel Aviv, Israel

12) Department of Biology, Faculty of Science and Letters, Celal Bayar University, Muradiye, Yagcilar Campus, 45140 Manisa, Turkey

13) Faculty of Science and Technology, Free University of Bozen, Universitätsplatz 5, I-39100 Bozen, Italy

Correspondence: Anke Jentsch, anke.jentsch@uni-bayreuth.de

Jentsch, A., Kreyling, J., Apostolova, I., Bahn, M., Bartha, S., Beierkuhnlein, C., Bloor, J., de Boeck, H., Dengler, J., Picon-Cochard, C., Campetella, G., Canullo, R., Nijs, I., Stampfli, A., Sternberg, M., Uğurlu, E., Walter, J., Wellstein, C., Zeitler, M. & the SIGNAL PhD students 2014. Joining biodiversity experiments, climate change research and invasion biology to assess European gradients of grassland resilience in the face of climate extremes. In: Mucina, L., Price, J.N. & Kalwij, J.M. (eds.), *Biodiversity and vegetation: patterns, processes, conservatio*n, p. 114. Kwongan Foundation, Perth, AU.

Broad-scale distribution modelling of community types: an example using European vegetation-plot databases and MaxEnt

Borja Jiménez-Alfaro (1), Susana Suárez-Seoane (2), Milan Chytrý (1), Stephan M. Hennekens (3), Joop H.J. Schaminée (3), John Rodwell (4) & the database partners (5)

1) Department of Botany and Zoology, Masaryk University, Kotlářská 2, CZ-61137 Brno, Czech Republic

2) Department of Biodiversity and Environmental Management, University of León, Campus de Vegazana, ES-24071 León, Spain

3) Alterra, Wageningen UR, PO Box 47, NL-6700 AA Wageningen, The Netherlands

4) 7 Derwent Road, LA1 3ES Lancaster, United Kingdom

5) Michal Hájek, Wolfgang Willner, Daniel Dítě, Petra Hájková, Ariel Bergamini, Lucia Sekulová, François Gillet, Emiliano Agrillo, Henry Brisse, Jörg Brunet, Jonathan Lenoir, Ute Jandt, Florian Jansen, Zygmunt Kącki, Jozef Šibík, Željko Škvorc, Ioannis Tsiripidis and Xavier Font

Correspondence: Borja Jiménez-Alfaro, borja@sci.muni.cz

Background & Aim: Ecological niche modelling includes a wide range of methods commonly used to predict the distribution of taxa. From the very beginning, these methods have been used for vegetation mapping at the landscape scale using survey data and fine-scale predictors. At broad-scales, vegetation modelling is mainly focused on land-cover mapping and dynamic vegetation models, which offer relevant information about dominant functional types but few details about the diversity and distribution of plant communities. Although several methods have been proposed for spatial modelling of ecological communities (Ferrier & Guisán 2006) very few of them have been applied to vegetation data at large scales. In this work we test the performance of correlative models for predicting the spatial distribution of community types using vegetation plot databases at continental scale.

Data & Modelling Methods: We collected data from two vegetation types widely represented in Europe and previously subjected to numerical classification, representing acidophilous beech forests (*Luzulo-Fagion;* Willner et al. unpublished) and base-rich fens (*Caricion davallianae;* Jiménez-Alfaro et al. 2014). Occurrence data were used to compute niche models over the distribution extent of the two vegetation types using MaxEnt (Elith et al. 2011) with climatic and soil predictors. Model performance was evaluated with the area under the ROC curve by testing (i) random 10-fold cross validation and the transferability to different (ii) geographic sectors and (iii) bioclimatic regions.

Main Results & Interpretations: Model outputs provided a realistic picture of the distribution of the two vegetation types in Europe, and model performance was generally high for random cross-validation. However, we detected limitations in the transferability to geographic regions that are marginal to the distribution centres of the community types. These limitations were reduced when training data were representative of different climatic regions. Our results suggest that ecological niche models are powerful tools for detecting the occurrence of vegetation types in unexplored regions. We also provide a rough guide of the main assumptions and limitations that, in comparison with the common procedures based on species distributions, should be considered for these exercises.

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The affiliations of the database partners

Michal Hájek, **Petra Hájková** and **Lucia Sekulová,** Department of Botany and Zoology, Masaryk University, Kotlářská 2, CZ-61137 Brno, Czech Republic

Wolfgang Willner, Vienna Institute for Nature Conservation and Analyses, Giessergasse 6/7, A-1090 Wien, Austria

Daniel Dítě, Institute of Botany, Slovak Academy of Sciences, Dúbravská cesta 9, SK-845 23 Bratislava, Slovakia

Ariel Bergamini, Biodiversity & Conservation Biology, Swiss Federal Research Institute WSL, Zürcherstrasse 111, CH-8903 Birmensdorf, Switzerland

Francois Gillet, Chrono-environnement, CNRS, Université de Franche-Comté, UFR Sciences et Techniques,16 Route de Gray, F-25030 Besançon Cedex, France

Emiliano Agrillo, Botanical Garden, Department of Environmental Biology, University of Rome 'La Sapienza', Largo Cristina di Svezia, 24 I-00165 Roma, Italy

Henry Brisse, Université de Marseille, Faculté des Sciences, MEP av. Escadrille Normandie-Niemen - Boite 441, F-13397 Marseille Cedex 20, France

Jörg Brunet, Southern Swddish Forest Research Centre, Swedish University of Agricultural Sciences, Rörsjöv 1, SE-230 53 Alnarp, Sweden

Jonathan Lenoir, Plant Biodiversity Lab, Jules Verne University of Picardie, 1 rue des Louvels, FR-80037 Amiens Cedex 1, France

Ute Jandt, Institute of Biology, Geobotany and Botanical Garden, Martin Luther Halle-Wittenberg, University Am Kirchtor 1, D-06120 Halle (Saale), Germany

Florian Jansen, Institute of Botany and Landscape Ecology, University of Greifswald, Soldmannstr. 15, D-17489 Greifswald, Germany

Zygmunt Kącki, Department of Botany, University of Wrocław, Kanonia 6/8, 50-328 Wrocław, Poland

Josef Šibík, Department of Geobotany Institute of Botany, Dúbravská cesta 9 SK-845 23 Bratislava, Slovak Republic

Željko Škvorc, Faculty of Forestry, University of Zagreb, Svetošimunska 25, HR-10000 Zagreb, Croatia

Ioannis Tsiripidis, Department of Botany, School of Biology, Aristotle University of Thessaloniki, GR-54124 Thessaloniki, Greece

Xavier Font Castell, Department of Plant Biology, University of Barcelona Av. Diagonal 645, E-08028 Barcelona, Spain

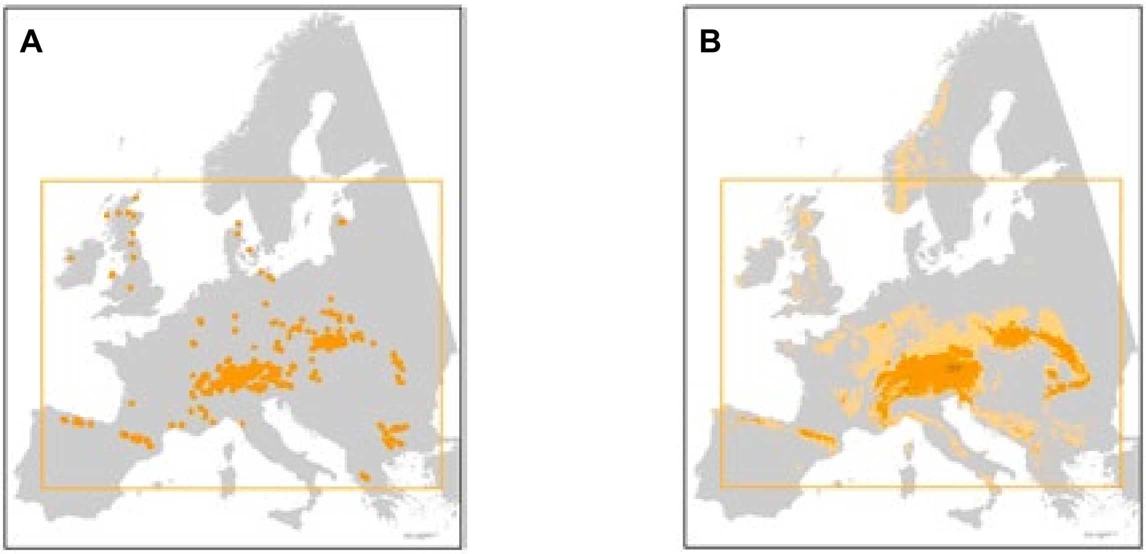

Figure 1. Occurrence data compiled for base-rich fens (*Caricion davallianae*) in Europe **(A)** and niche model reflecting areas of low, medium and high habitat suitability as performed by MaxEnt. **(B)**. Inner rectangle represents the geographic extent used to select background data.

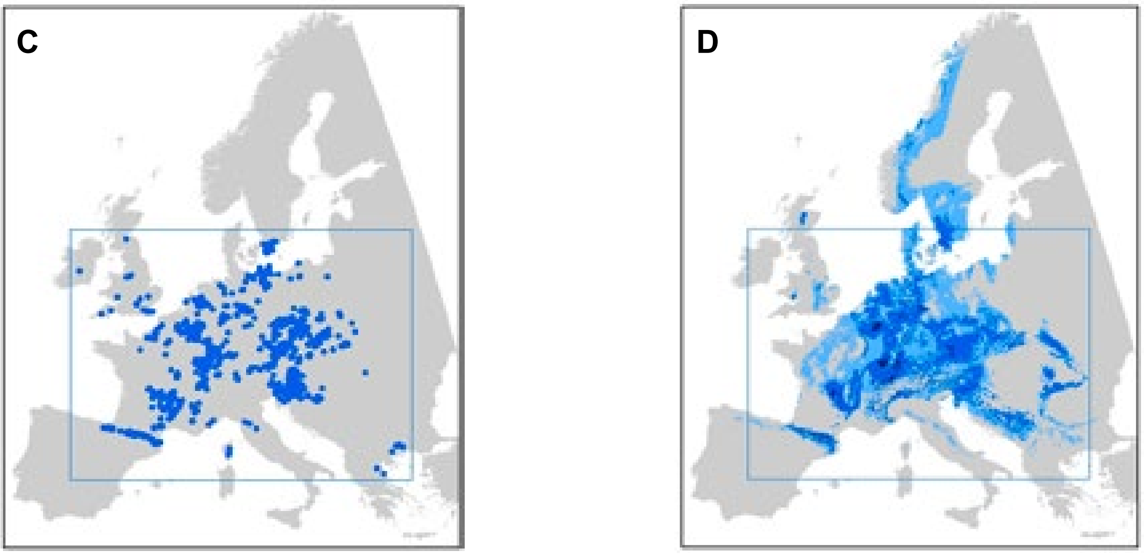

Figure 2. Occurrence data compiled for acid beech forests (*Luzulo-Fagion*) in Europe **(C)** and niche model reflecting areas of low, medium and high habitat suitability as performed by MaxEnt. **(D)**. Inner rectangle represents the geographic extent used to select background data.

Can vegetation records done by undergraduates be reliable enough to provide data for research?

Gerald Jurasinski, Marian Koch, Anke B. Günther & Birgit Schröder

Landscape Ecology Group, Faculty of Agricultural and Environmental Sciences, University of Rostock, Justus-von-Liebig-Weg 6, D-18059 Rostock, Germany

Correspondence: Gerald Jurasinski, gerald.jurasinski@uni-rostock.de

Background & Aim: The resampling of historical vegetation plots can be a valuable approach to analyse vegetation change at medium (and multiple) time scales (Milberg et al. 2008). Over the past more than a hundred years vegetation scientists have accumulated a vast fundus of data that may be of great value today. In this study we analyse observer bias by comparing vegetation records done by experienced botanists with those done by undergraduates in a Bachelor programme.

Materials & Methods: The data were gathered during a field course in summer term 2014 as part of a resurvey study that addressed the effect of a change from low intensity grazing by sheep drive to sheep grazing in temporary folds in dry and wet grassland communities in a nature reserve in northeastern Germany. Since the individual plots of the first survey could not be located exactly, we used a stratified random resampling within the respective vegetation types while using the same sampling unit size as in the first survey: 160 plots of 5 m X 5 m divided amongst five grassland communities. Each plot was surveyed by a group of 4–5 students as well as by an experienced botanist within one week. For each plot, all vascular plant species were recorded and percent cover values were estimated.

The student groups received instructions during a one-day field trip to the study area. Majority of the species were introduced and special attention was paid to plant family identification traits. Each group was equipped with a full iconography of the species known to be growing in the respective associations in the area. On the second day each student group surveyed 10 plots. The experienced botanists also recorded data on 10 plots per field day. The surveys done by the students were compared to those of the experienced botanists as to species diversity, found/not found species, and species composition. The variation between the two surveys was analysed by comparing the variation across surveys using non-metric multidimensional scaling and associated statistics. Locally rare species (< 3 occurrences) were omitted from all analyses.

Main Results & Conclusion: Across all plots, experienced botanists found about 18 species per plot that the students overlooked (up to 35) while the students identified only about 8 species that were not recorded by the experienced botanists (up to 19). On average, 10 species per plot were recorded by both groups. Several of the species recorded by the students were likely to be wrongly identified. This fact is also reflected in the species richness: 27.43 vs. 17.35 in the expert vs student data, respectively. Contrastingly, the gamma diversity was 145 and 169 in the expert and the student data, resp. When including also rarely found species, the values of gamma diversity increased (178 and 248, resp.), while the species richness values remain almost unchanged. This supports the hypothesis that the students misidentified a considerable number of species. The differences between the experts and students in the identified species per plot were less pronounced in wet grassland plots when compared to dry grassland plots. Despite the considerable differences in the identified species per plot, the results for both groups are consistent in an NMDS ordination of the data. Thus, vegetation surveys carried out by inexperienced undergraduates may provide interesting data for resurvey studies whilst allowing the students to experience education close to scientific research.

Acknowledgements: We thank the numerous students that recorded vegetation data in the field.

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Propagule pressure, not climate change, instigates rapidly ascending upper altitudinal limits of exotic plants

Jesse M. Kalwij (1,2), Mark P. Robertson (3) & Berndt J. van Rensburg (3,4)

1) Department of Vegetation Ecology, Institute of Botany, Academy of Sciences of the Czech Republic, CZ-602 00 Brno, Czech Republic
2) Department of Zoology, University of Johannesburg, Auckland Park 2006, South Africa
3) DST-NRF Centre for Invasion Biology, Department of Zoology and Entomology, University of Pretoria, Hatfield 0028, South Africa
4) School of Biological Sciences, The University of Queensland, Brisbane QLD 4072, Australia

Correspondence: Jesse Kalwij, jessek@uj.ac.za

Background & Aim: Investigating the upper altitudinal limits of exotic species is a cost- and time-efficient means to detect trends in invasive alien species, assuming that altitudinal distribution is a reasonable proxy of geographical distribution (Kalwij et al. 2008). We present the results of a six-year study on exotic plants in the Sani Pass road.

Materials & Methods: The study area was Sani Pass road (an altitudinal gradient of 1500–2874 m a.s.l.) in the Drakensberg Alpine Centre, South Africa. Each January 2008–2014, a team of observers walked down this road, to record the three highest observations of annual and perennial exotic plant species. Repeated-measures ANOVAs were fitted to species that were observed in each year.

Main Results & Interpretations: Over time, the upper altitudinal limits of exotics increased: 27.6 m year^{-1} for annuals (N = 17 species), and 14.0 m year^{-1} for perennials (N = 28). Annuals were randomly located along the road while perennials were spatially clustered around potential points of introduction such as houses and border posts. In addition, the first naturalised *Solidago gigantea* Aiton (*Asteraceae*) population for southern Africa was documented on an unmanaged grassland adjoining a tourist accommodation. The upward trend in upper limits of exotics was too rapid to be explained by climatic change or time since introduction. A more plausible explanation is that road verges were regularly disturbed by erosion and maintenance, creating unoccupied habitats, while traffic (vehicles and hikers) brought new species into the area. A strong and continuous propagule pressure as a major cause of exotic range expansion is therefore likely. The increasing number and altitudinal range of exotics suggest that more invasive species will invade the Drakensberg area in the near future. For example, the establishment of *S. gigantea* is of great concern since it is a perennial species, reproducing through a combination of seeds and below ground rootstock development, making a perfect suit for a fire-prone ecosystem such as the grassland biome. Moreover, *S. gigantea* is a notorious invader of unmanaged grasslands in the northern hemisphere. An early-stage eradication is therefore highly recommended, ideally before it becomes yet another unmanageable and costly invasive species (Kalwij et al. In Press). Long-term research projects, such as the one exemplified here, can be a time-effective means to measure such trends and to help detecting new invaders at an early stage.

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View on Sani Pass in the Drakensberg, South Africa. The 20-km road winds up-hill from 1500–2874 m a.s.l., making it one of the steepest and highest altitudinal gradients in southern Africa. Photo: J.M. Kalwij.

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Driving forces of species diversity in unmanaged semi-natural grasslands

Jutta Kapfer (1), Einar Heegaard (2), Svein O. Krøgli (3), Christian Pedersen (3), Gregory N. Taff (1) & Wenche Dramstad (3)

1) Norwegian Forest and Landscape Institute, N-9269 Tromsø, Norway

2) Norwegian Forest and Landscape Institute, N-5244 Fana, Norway

3) Norwegian Forest and Landscape Institute, N-1431 Ås, Norway

Correspondence: Jutta Kapfer, jka@skogoglandskap.no

Background & Aim: Land-use regimes and their changes, as well as landscape heterogeneity are key determinants of the distribution and composition of species in cultural landscapes. In European agricultural landscapes, habitat loss due to both abandonment and intensification of agriculture fields are major causes for the decline of species diversity. Those landscapes that are diverse in habitats and species are important to maintain basic ecosystem functions and services as, for instance, pollination or habitat preservation. In Norway, semi-natural species-rich habitats, such as agricultural grasslands, often occur in mosaics with forests and crop fields. This research studies key information for design of conservation plans focused on these habitats, addressing how landscape structure and land-use history affect the distribution, richness and composition of species in species-rich grasslands across geographical regions.

Material & Methods: We recorded vegetation (species occurrence and cover) of agricultural grasslands of varying intensity and type of using 569 plots of 8 m X 8 m, systematically distributed throughout Norway (from 64 to 78° N latitude). To identify the most important driving factors of species diversity and composition, we explored the combined effects of historic and current land-use and the spatial landscape configuration of nearby land cover types (e.g. minimum distance to or area of neighbouring wetland, forest, cultivated land) taking into account the effects of grazing, elevation, and moisture conditions. Non-metrical multidimensional scaling (NMDS) was applied to identify the most important drivers of species composition. We used Generalized Additive Mixed Models to test the relationship of these drivers with patterns in species richness.

Main Results & Interpretations: NMDS revealed species composition to be explained most by the distance to surface cultivated land and transportation corridors (r=0.905, p<0.001 and r=-0.982, p<0.001; NMDS axis 1) as well as shape of the patch in which the vegetation plot is embedded (patch shape) and grazing intensity (r=0.988, p<0.001 and r=-0.952, p<0.001; NMDS axis 2). The observed patterns in species richness were statistically significantly linked to the combined effects of elevation, grazing intensity, historical land-use, patch shape, distance to transportation corridors and forest, and area of nearest wetland.

Our results demonstrate the importance of a variety of factors influencing the species composition and richness in Norwegian grasslands. We found that both the landscape element harbouring the observed plot and also the surrounding landscape structure and intensity of land-use are important determinants of species diversity. The fact that distance to more intensively managed agricultural land is one of the strongest explanatory factors signals how agricultural management practices reach outside the field itself and into adjacent landscape elements. This suggests that the entire landscape needs to be taken into consideration when management of a particular habitat patch is planned.

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Gunnar Engan sampling grassland vegetation in Norway.
Photo: C. Pedersen.

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Does seedling establishment change after 10 years of different management of meadows

Gerhard Karrer

Institute of Botany, Universität für Bodenkultur Wien, Gregor-Mendel-Strasse 33, A-1180 Wien, Austria

Correspondence: Gerhard Karrer, gerhard.karrer@boku.ac.at

Background & Aims: An important issue for nature conservation is to understand the dynamics and regeneration of target vegetation types. One of most relevant questions is: what requirements must be met for species to succeed in regeneration and therefore to persist in an ecosystem? Seedling emergence, seedling mortality, and seedling establishment in meadows depend very much on the type of management.

Materials & Methods: We compared seedling performance in 1999 and 2010 in a naturally nutrient rich meadow (*Festuco-Trisetetum, Ranunculo bulbosi-Arrhenatheretum elatioris*) represented by five sites (replicates). At all sites an area of 144 m^2 was fenced to exclude the influence of a large population of wild boars. Plot were subdivided into four subplots belonging to three different management types: two subplots were mown once a year, one subplot mown every second year and one was not mown since 2000. All plots are situated in the Lainzer Tiergarten (Vienna, Austria). Each subplot consisted of five randomly placed micro-plots 25 m X 25 cm in size. We followed the individual seedling performance from April to April of the following year in 1999 and 2010 via six measurement campaigns. We compared the specific seasonality of germination and establishment (development to juveniles or adults) per species, with respect to different management types, sites, and years. A stepwise regression was used to select for cover of vegetation and litter, aboveground biomass or established dominant species as covariables.

Main Results: Mean seedling emergence (sum of germination events) was 1176 seedlings per m^2 and year, but varied greatly between plots, time of the year, and years. The higher the vegetation cover and biomass, the lower seedling emergence (germination) was. Seedling mortality was 75.5% throughout one vegetation period and increased up to 95.6% in the following spring. Mortality of seedlings that emerged in summer was significantly lower than those emerging in spring and autumn. Vegetation cover and biomass were correlated significantly with mortality. 32 seedlings/m^2 established to juveniles from spring until summer, 192 from summer to autumn and only 16 from autumn to the following spring. Hence the establishment of summer seedlings was obviously most successful in this type of vegetation. Strength of correlation between seedling establishment and the environmental factors (cover of vegetation, open soil, litter, and aboveground biomass) varied with the season of emergence. The lower the biomass the better was seedling establishment between spring and summer. The establishment of the autumn seedlings was slightly more successful in plots with higher biomass. Although mortality of spring-emerged seedlings was the highest, many species (*Achillea millefolium, Centaurea jacea, Cruciata laevipes, Trifolium pratense*) concentrated their regeneration efforts on spring producing many seedlings in order to secure survival at the population level. Most seedlings of *Ranunculus* sp. and *Rumex acetosa* emerged in summer and autumn and could therefore benefit from lower mortality rates.

The mowing regime of these annually mown meadows was too extensive with respect to the potential of nutrient supply and may account for the high mortality of seedlings. The meadows should rather be mown two times a year. Biomass accumulation until the date of mowing (first half of July) led to very high humidity in the stands, fostering infection by fungi. Besides, the seedlings suffered from competition from fast growing grassy dominants. The recurrence of safe sites appears to be essential especially for those species usually emerging in spring as demonstrated by the very low mean number of seeds in the full abandoned subplots as compared to the mown plots.

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Increase in species richness and functional diversity after habitat degradation and fragmentation

Liis Kasari, Liina Saar, Krista Takkis & Aveliina Helm

Institute of Ecology and Earth
Sciences, University of Tartu,
EE-51005 Tartu, Estonia

Correspondence: Liis Kasari,
liis.kasari@ut.ee

Background & Aim: During the last century, anthropogenic impact has led to extensive fragmentation and loss of area of natural and semi-natural habitats, rendering many species vulnerable to local extinctions due to changed environmental conditions. In Estonia, alvar grasslands (rare calcareous species-rich semi-natural grasslands on limestone pavements) used to be quite widespread, covering c. 34 000 hectares. During the past century, the area and habitat quality of these grasslands has decreased drastically due to the cessation of traditional management, enlargement of human settlements, and expansion of intensive agriculture and limestone quarries. Nowadays, only 6000 hectares of these grasslands remain, most of them without proper management and in poor habitat quality. However, while decreased area and changed environmental conditions have become unsuitable for a number of habitat specialist vascular plants, there are also many species that can benefit from the altered conditions. By comparing historical (1923) and present-day plant species inventories from currently highly fragmented and degraded alvar grasslands, we investigated the changes in plant species composition, richness, and functional diversity during the past ninety years. In addition, we aimed to find out which life-history traits characterise the species that have benefited from the changed environmental conditions and have colonized the sites since the historical survey ('winning species').

Materials & Methods: Eight study sites were located in northern Estonia, where the most extensive habitat loss of alvar grasslands has occurred during the past century. Current plant species data were collected between 2009 and 2012, historical data (maps, exact locations, grassland descriptions and exhaustive vegetation surveys) originated from 1923. Thirteen life-history traits describing species persistence, dispersal and competitive abilities, as well as habitat requirements, were extracted from databases. Mean pairwise distance was calculated to compare functional diversity of current and historical communities. Community mean trait values were obtained to characterise 'winning species'.

Main Results & Conclusions: The studied grasslands had lost 87% of their original area and declined considerably in habitat quality. However, both total species number in all grasslands (current 281, historically 214), as well as species richness per site was higher now than historically. Grasslands had lost 38 species, and altogether 105 new native species had colonized the sites during the past 90 years. Most of the colonizers were common species widespread in other open habitats, but also several ruderal species. Functional diversity had increased for a number of traits (seed weight, specific leaf area, dispersal type, terminal velocity), and only the diversity of plant height had decreased, which can be explained by ceased grazing. Compared to historically present species, 'winning species' had heavier seeds (but also more seeds per shoot), lower light requirement, higher soil fertility requirement and higher growth, indicating better abilities for local competition in degraded habitats. In conclusion, although we detected an increase in species richness and functional diversity at a local scale, this was caused mostly by common species that were already widespread in the surroundings. Thus, at a regional scale, we can expect a decrease in diversity as some habitat characteristic grassland specialist species had already gone extinct and several showed decreases in their population size. Thus, at larger scales the spread of 'winning' native plants may lead to biotic homogenization, and a previously distinct habitat type will become progressively more similar to other open habitats in the region.

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Seed dispersal by a herbivore maintains meta-populations of short-lived plant species on ant-hills

Timothy J. King

Wolfson College, Oxford University,
Linton Road, OX2 6RL, United
Kingdom

Correspondence: Tim King,
timothy.king@virgin.net

Background and aim: Ant-hills built by *Lasius flavus* are characteristic of grazed grasslands throughout northern Europe. They may persist for hundreds of years and grow at up to 3L/year. Their vegetation often differs strikingly in species composition and relative abundances from the surrounding pasture (King 1977). North and south aspects harbour different floras, particularly bryophytes. Many short-lived plant species occur only on the ant-hills. I describe the dynamics of two short-lived plant species on 645 mapped ant-hills over four years. The aim was to explain how their dispersal from one mound to another counteracts local extinction.

Materials and Methods: Study area (40 m X 40 m) was a species-rich calcareous grassland grazed by rabbits and occasionally by sheep on Aston Rowant NNR, UK. Volumes of the mapped mounds were estimated. On each mound I estimated the covers of bare soil and major species. I counted the rabbit droppings and flowers of *Arenaria serpyllifolia* (winter annual) and *Cerastium fontanum (*annual/short-lived perennial), confined to ant-hills. Significant positive and negative associations emerged.

Main results and interpretations: Numbers of flowers of the two short-lived species were strongly correlated with the area of bare soil ($P<0.001$). Bare soil area increased with ant-hill surface area ($P<0.001$). The areas of thyme (*Thymus polytrichus*), rock-rose (*Helianthemum nummularium*) and grasses were all negatively correlated with one another ($P<0.01$/$P<0.001$). Rabbits (*Oryctolagus cuniculus*) dung preferentially on the larger ant-hills ($P<<0.001$). As per cent cover of rock-rose increased, the density of rabbit droppings decreased ($P<0.001$), and so did the flowers of *A.serpyllifolia* ($P<0.05$). Rock-rose repels rabbits. Conversely, as grass or thyme cover increased, so did the density of rabbit droppings ($P<0.001$) and both the short-lived plant species ($P<0.001$). It is unlikely that the seeds of the two short-lived species, though light (0.07, 0.18 mg), are blown from the tops of one ant-hill to another. Hence rabbits probably disperse seeds in droppings or on feet or fur, maintaining the meta-populations of short-lived species. This confirms the importance of herbivores in local seed dispersal. It also provides evidence that avoidance of a perennial by a seed-dispersing herbivore determines that two short-lived species occur mainly where this perennial is less abundant. What are the implications for seed dispersal and the resulting plant species patterns in diverse grazed grassland in which plant species differ markedly in palatability to herbivores? Has enough attention been devoted to the micro-patterns of seed dispersal?

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Research site with scattered ant hills at Aston Rowant NNR, United Kingdom. Photo: T. King.

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The relative importance of biotic and abiotic drivers of local plant community composition along climate gradients

Kari Klanderud (1,2), Vigdis Vandvik (2) & Deborah E. Goldberg (3)

1) Department of Ecology and Natural Resource Management, Norwegian University of Life Sciences, P.O. Box 5003, N-1432 Ås, Norway

2) Biology Department, University of Bergen, P.O. Box 7803, Bergen N-5020, Norway

3) Department of Ecology and Evolutionary Biology, University of Michigan, Ann Arbor, MI 48109, USA

Correspondence: Kari Klanderud, kari.klanderud@nmbu.no

Background & Aims: Disentangling the relative impact of biotic and abiotic factors on species assemblages, and how these vary with environmental conditions, are urgently needed to understand how climate change affects ecological processes and diversity across landscapes (Lavergne et al. 2010). We aim to assess if the relative importance of biotic and abiotic factors for species composition differ between local communities along regional environmental stress gradients, and if biotic interactions affect functional groups differently. If so, we ask what implications this may have for plant community composition in a warmer and wetter future.

Material & Methods: The study was performed in boreal and alpine grasslands in southern Norway. We used a grid of twelve sites spanning regional-scale temperature and precipitation gradients, where these two main climate variables varied independently. Within each site, we sampled vegetation and associated biotic and abiotic factors on a fine-scale. We combined broad- and fine-scale ordination analyses by using a hierarchical variance partitioning approach supplemented by replicated local-scale ordination analyses, to assess the relative explanatory power of the biotic and abiotic factors for local plant community composition.

Main results & Conclusions: The local scale vegetation responded predictively to biotic and abiotic factors across the regional climate grid. However, local-scale variables, whether biotic (vegetation height, bryophyte and litter cover) or abiotic (soil moisture, pH, organic content) explained relatively little of the variation in species composition across sites. On the other hand, these same variables had high explanatory power in site-wise analyses, with their relative importance depending on climate. Abiotic variables explained a larger proportion of the local variation in species composition towards colder sites, whereas biotic variables explained more towards warmer sites, supporting the stress gradient hypothesis (Bertness & Callaway 1994). The patterns along the precipitation gradient were more variable, as biotic variables explained more towards wetter sites in the warm lowland, but more towards drier sites in the cold alpine. This suggests that in the alpine, positive effects of increased precipitation on productivity may be overruled by negative effects through shorter growing seasons due to later snowmelt. Graminoid abundance increased with both precipitation and soil moisture, whereas forbs were negatively correlated with graminoids, suggesting that graminoid abundance may increase at the expense of forbs in a warmer and wetter climate. Competitive biotic interactions may become more important in alpine and boreal grasslands in the future, although more winter precipitation may counteract this trend in oceanic alpine climates. These results suggest that the role of local-scale environmental variables can be obscured when they are analysed over regional scales. Instead, hierarchical variance partitioning can disentangle the local vegetation-environment relationships and their regional-scale drivers. Such a partitioning in our system revealed that a focus on temperature as the key driver of vegetation change with global climate change misses both complex effects of precipitation and effects of biotic interactions.

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Assessing grassland sensitivity to extreme drought – the EDGE experiment

Alan K. Knapp

Department of Biology and Graduate Degree Program in Ecology, Colorado State University, Fort Collins, CO 80526, USA

Correspondence: Alan K. Knapp, aknapp@colostate.edu

Background & Aims: The distribution of most temperate grasslands is determined primarily by precipitation gradients and on, a continental scale, variability in precipitation affects productivity more in grasslands than in most other biomes. Both the mean and extremes of precipitation (especially droughts) strongly affect ecosystem processes in most grasslands, with increases in the frequency and intensity of climate extremes projected to occur globally. Of particular concern are forecasts of severe periods of drought that span multiple years. In 2012, the Extreme Drought in Grasslands Experiment (EDGE) was established. The experiment was designed to impose a severe multi-year drought in six grasslands arrayed along a rainfall gradient – from desert grassland to mesic tallgrass prairie in the central US, and along a similar gradient in China - using identical rainfall manipulation shelters and sampling methods. The experiment will address two questions of fundamental importance for advancing our knowledge of how ecosystems will respond to climate change at regional scales: 1) How do grassland ecosystems differ in their sensitivity to a multi-year extreme drought and what determines their differential sensitivity?, and 2) How important are the attributes of ecosystems *per se* vs. the environmental context in which climate is changing in determining ecological responses to drought at regional scales?

Materials & Methods: In the pretreatment year of 2012, the central United States experienced the 4th largest drought in a century, with a regional-scale 40% reduction in growing season precipitation affecting all six EDGE grasslands. This provided an opportunity to assess grassland sensitivity to a drought of a common magnitude in all of these native grasslands. We tested the prediction that drought sensitivity is inversely related to mean annual precipitation (MAP) by quantifying reductions in aboveground net primary production (ANPP). Long-term ANPP data available for each site (mean length = 16 yrs) were used as a baseline for calculating reductions in ANPP, and drought sensitivity was estimated as the reduction in ANPP per mm reduction in precipitation.

Main Results & Interpretation: Arid grasslands were the most sensitive to drought, but drought responses and sensitivity varied by more than 2-fold among the six grasslands, despite all sites experiencing similar 40% reductions in growing season precipitation. Although drought sensitivity generally decreased with increasing MAP as predicted, there was evidence that the identity and traits of the dominant species, as well as plant functional diversity, influenced sensitivity. The results from this natural drought study and EDGE will be used to strengthen an existing process-based terrestrial ecosystem (TECO) model. With the TECO model, the relative importance of ecosystem attributes versus the environment for determining responses to climate change will be evaluated, and then scaling rules for extending site-based knowledge to regional scales will be developed.

Extreme Drought in Grasslands (EDGE) rainfall reduction shelters in the semi-arid shortgrass steppe grasslands of Colorado (USA). Photo: A. Knapp.

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Effects of a shift from traditional sheep herding to fenced grazing on species rich semi-natural grassland vegetation

Marian Koch, Birgit Schröder, Anke B. Günther & Gerald Jurasinski

Landscape Ecology and Site
Evaluation, University of Rostock,
Justus-von-Liebig-Weg 6, D-18059
Rostock, Germany

Correspondence: Marian Koch,
marian.koch@uni-rostock.de

Background & Aim: Nutrient-poor grasslands are biodiversity hotspots (Wilson et al. 2012). In Europe, they have typically formed under historic land use regimes with low-intensity cattle or sheep grazing. Major threats are either land use intensification (amelioration) or abandonment in connection with atmospheric eutrophication. The latter typically leads to scrub encroachment and succession to forest and subsequent loss of biodiversity. Conservation management and agro-environment schemes aim at counteracting this development (Kleijn et al. 2001). A way to prevent negative impacts on biodiversity in European grasslands is to keep up the original land use practices. However, economic developments have rendered traditional herding systems unremunerative due to increasing labour costs. This often leads to alternative management regimes that are still in compliance with agro-environment schemes, but considered to be inappropriate to conserve the original species composition of such species-rich grasslands (Römermann et al. 2009). For instance, formerly grazed grasslands are now mown or the grazing system has changed. Here, we address the effect of a change from low intensity sheep grazing by traditional herding to free-ranging grazing in temporarily fenced areas in dry and wet semi-natural grassland communities.

Materials & Methods: In the Kösterbeck Nature Reserve, NE Germany, we analysed, using Ellenberg's ecological indicator values, the change in floristic and functional composition, diversity at various scales, based on repeating a 20-year old phytosociological survey. 10 years after the original survey, the grazing regime changed from traditional sheep herding to free-ranging grazing in fenced areas. Since the exact locations of plots of the original survey could not be reconstructed, we used a stratified random resampling within the respective communities repeating the sample size of the first survey.

Main Results & Interpretations: The change in grazing regime did not cause a pronounced change in plant species alpha, beta, and gamma-diversity. An analysis of the species indicator values showed a slight but not significant trend towards more eutrophic conditions. Despite low species turnover, we observed marked changes in frequency and abundance of some species. However, these species did not show unambiguous common ecological preferences or life history traits, thus neutral effects might have dominated. There was no evident sign for the effect of preferential feeding. For instance, among the species that increased in abundance, there are both grasses and sedges. There was also no evidence for scrub encroachment. We conclude that the shift to the less labour intensive fenced grazing did not have negative effect on the vascular plant species composition and diversity of the nature reserve after one decade.

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Vegetation refugia and shifting vegetation zones under climate change: biodiversity loss or enrichment?

Pavel V. Krestov (1,2) & Yukito Nakamura (3)

1) Botanical Garden-Institute, Far Eastern Branch of the Russian Academy of Sciences, Vladivostok 690024, Russian Federation

2) Institute of Biology and Soil Science, Far Eastern Branch of the Russian Academy of Sciences, Vladivostok 690024, Russian Federation

3) Tokyo University and Agriculture, 156-8502 Sakuragaoka 1-1-1, Setagaya, Tokyo, Japan

Correspondence: Pavel Krestov, pavel.krestov@icloud.com

Background & Aim: The current vegetation of Northern Asia has been uninterrupted by glaciers history since the Tertiary boreo-nemoral vegetation complex. The most dramatic transformation of vegetation took place in the Late Glacial Maximum (LGM) when low temperatures along with aridisation caused a profound change in the vegetation in the broad inland areas and provided an opportunity for migrations of drought- and cold-tolerant species. One of the important kinds of habitat, from where species could have spread, were the refugia. Here, we examine the contribution of the major Asian floristic centres and the refugia to the formation of the currently dominating major vegetation types of Northeast Asia.

Material & Methods: Our approach is based on: 1) examination of the relationships between current bioclimate, vegetation and floristic composition composing each vegetation type at a regional level and 2) analysis of the correspondence between vegetation and the regional climate at the landscape level and calculation of a 'refugium index' (integral compensation for regional climate limitations in insolation, heat and moisture provided by particular habitat, based on digital elevation model; DEM). The study involves DEM- and climate-based predictive spatial modelling (GAM, GRASP) of extensive vegetation (5 500 phytosociological relevés), floristic (distribution for 26 000 taxa), and climatic (records from 2 200 climate stations) data from northern Asia coupled with contemporary knowledge on phytogeography of major taxa, dominating in Northeast Asia, and climate scenarios based on BCC-CSM, CCSM, MIROC and others.

Results & Conclusions: Following the Pliocene, North Asia was never fully covered by an ice shield, thus allowing its vegetation to undergo uninterrupted formation. Despite this, severe climatic conditions in LGM considerably altered the vegetation compared to its previous condition. Heat- and moisture-dependent taxa disappeared from the Asian mainland but remained in isolated refugia along the Pacific coast and on the islands. The modern zonal vegetation of North Asia includes species complexes formed during trans-North-Asian migrations during the Pleistocene and the Holocene. Aridisation and low temperatures across most of Northern Asia during the LGM most likely supported vegetation represented by a combination of steppe and tundra communities, enriched by Central Asian species, that spread over extensive ice-free continental areas in Asia. Pleistocene megafauna appeared to be one of the important factors for vegetation fragmentation supporting high plant species diversity. With warming and humidisation in the Holocene, the humid coastal areas became the center for expansion of *Picea*, *Larix*, *Betula* forests and *Pinus pumila* thickets westward and northward to the continental areas. Temperate forests dominated by *Pinus koraiensis* and deciduous broadleaved species expanded from refugia in mountainous areas of northern China and Korea, causing regional biodiversity enrichment. The decreasing grazing animal population and increasing temperature and humidity caused the expansion of larch on permafrost area; fragments of steppe and xeric tundra remained in refugia. Increasing oceanic influence favored moisture-dependent tundra species that spread westward along the Arctic coast. As a consequence, the extensive and seemingly homogenous appearance of modern Siberian and Far Eastern forests represents at least four floristic nuclei with different formation histories. During the LGM the diversity of moisture-dependent thermophiles decreased considerably, but at the same time the North Asian flora has been enriched with drought-tolerant species of Central Asian origin, the contemporary distribution of which is limited to modern refugia.

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Persistence of common plants: comparative trait-based analysis of distribution changes in the UK and Estonia during the 20th century

Lauri Laanisto (1), Tiiu Kull (1) & Michael J. Hutchings (2)

1) University of Life Sciences, Kreutzwaldi 5, Tartu EE-51014, Estonia

2) School of Life Sciences, University of Sussex, Falmer, Brighton, Sussex, BN1 9QG, United Kingdom

Correspondence: Lauri Laanisto, laanisto@ut.ee

Background & Aims: The abundance and distribution ranges of many plant species have declined dramatically in recent decades and various human activities are considered to be the main inducers behind these changes. Although much information has been assembled about species' ranges, detailed analyses of their changes over time have only recently become possible as a result of the publication of second and even third generation national distribution maps. It is now possible to compare decline for different types of plants, and in some cases to determine whether decline has been similar in different parts of species' ranges.

Materials & Methods: Based on data extracted from distribution atlases we compared the persistence of plant species in the United Kingdom and Estonia; in both countries the presence of species was recorded on maps in 10 X 10 km grid squares. We studied the distribution changes of 736 species occurring in both the UK and Estonia, which were determined during two major survey periods: 1st 1930–1969, 2nd 1987–1999 in the UK; and between 1921–1970, and 1971–2004 in Estonia.

Main Results: Species declined less in Estonia – average persistence rate was 75.7%. In the UK plants survived in 69.7% of their initial number of grid cells. Regardless of comprehensive differences in anthropogenic conditions between the two countries, the general persistence patterns were mainly driven by biogeographic (affiliation to floristic element) and eco-evolutionary (plant strategy) factors, while tolerance to human activities influenced only local (within country) persistence rates. All the studied plant species both in Estonia and in the UK had lost more local populations than gained new ones. Nearly one third of the species in Estonia (239 out of 736) retained at least 90% of their local populations, while less than one fifth of species (141) had such high persistence rates the UK. In Estonia, 99 species had lost more than half of their local populations compared with 127 species in the UK. Species persistence was strongly and positively related to their distribution density in both countries. Rather expectedly in some families, like *Orchidaceae* and *Potamogetonaceae* local extinction rates were much higher in the UK than in Estonia, yet in the case of *Juncaceae* mean persistence rate was higher in the UK. Despite a rather long history of nature conservation in both the UK and Estonia, protected species were still more vulnerable than non-protected, and lost the most of their local populations. Although human influence in Europe is rather strong everywhere in nature, distribution patterns of plant species are still more influenced by evolutionary and ecological background of plants, rather than anthropogenic factors.

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Lady's-slipper orchid (*Cypripedium calceolus* L.) has widespread distribution throughout Eurasia, but due to habitat loss and overcollecting it has been losing populations. In Estonia the persistence of lady's-slipper orchid is 72%; the populations have persisted in 154 grid squares out of 251 squares registered during the first survey period. In the UK only one population in Yorkshire has survived (1 grid square out of 22 has persisted between survey periods; persistence 5%). Photo: L. Laanisto.

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WetVegEurope – a formalized classification of aquatic and marsh vegetation at the continental scale: approach and first results

Flavia Landucci (1), Kateřina Šumberová (2), Lubomír Tichý (1), Milan Chytrý (1) & WetVegEurope partners (3)

1) Department of Botany and Zoology, Masaryk University, Kotlářská 2, CZ-61137 Brno, Czech Republic

2) Institute of Botany, Academy of Sciences of the Czech Republic, Lidická 25/27, CZ-60200 Brno, Czech Republic

3) Liene Aunina, Aleksandr Bobrov, Liubov Borsukevych, Andraž Čarni, János Csiky, Els De Bie, Dmytro Dubyna, Panayotis Dimopoulos, Tetiana Dziuba, Úna Fitzpatrick, Xavier Font, Daniela Gigante, Valentin Golub, Stephan M. Hennekens, Richard Hrivnák, Lorenzo Lastrucci, Svitlana Iemelianova, Ute Jandt, Florian Jansen, Zygmunt Kącki, Konrád Lájer, Dalytė Matulevičiutė, Attila Mesterházy, José Antonio Molina, Jaanus Paal, Eva Papastergiadou, Alessandro Properzi, Vladimir Ranđelović, Marcela Řezníčková, John S. Rodwell, Joop H.J. Schaminée, Urban Šilc, Zofija Sinkevicienė, Aleksei Sorokin, Zvjezdana Stančić, Jazep Stepanovich, Boris Teteryuk, Rossen Tzonev, Roberto Venanzoni, Lynda Weekes, Wolfgang Willner, Igor Zelnik

Correspondence: Flavia Landucci, flavia.landucci@gmail.com

Background & Aims: The project WetVegEurope started more than a year ago with the scientific support of the European Vegetation Survey (EVS). It was born from the necessity to increase the consistency of vegetation classification in Europe, unify classification concepts and propose a sharable classification system. Aims of this project are (1) to provide a synthesis and formalized classification of freshwater aquatic vegetation (*Lemnetea* and *Potametea* classes) and marsh vegetation (*Phragmito-Magno-Caricetea* class) to the level of phytosociological associations, and (2) to characterize these associations in terms of ecology, distribution and nature conservation status.

Current Status: Now the project involves more than 150 000 vegetation plots from 26 European countries and more than 40 people including data contributors and experts. A lot of experience in the management of such a large amount of data and related issues has been acquired. Protocols for data collection, management and analysis, and formalised classification using an improved version of the Cocktail method (Bruelheide 1997; Kočí et al. 2003) were tested with the support of the European Vegetation Archive (EVA) and thanks to the technical tools provided by the programs TURBOVEG (Hennekens & Schaminée 2001) and JUICE (Tichý 2002). In this talk we present our general approach to the classification of vegetation at a continental scale and feature the first results of our formalized classification.

Perspective: The work is still in progress. Logical formulas for automatic classification of aquatic and marsh vegetation are under development. The results will offer not only a synthesis and an integration of the knowledge at the continental scale but also a formalized classification system for aquatic and marsh vegetation usable as a tool for nature conservation.

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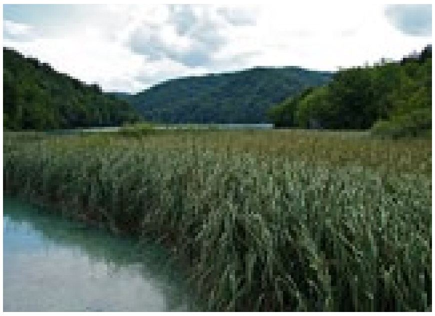

Figure 1. A stand of the *Cladietum marisci* Allorge 1921.

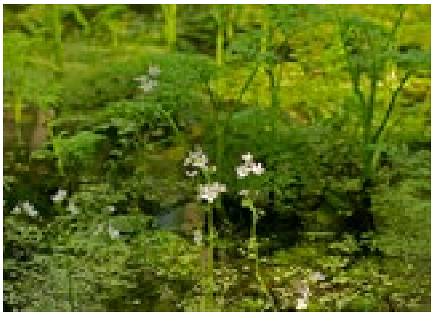

Figure 2. *Hottonia palustris* is an aquatic plant growing in mesotrophic to eutrophic still waters.

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Affilitations of the WetVegEurope partners

Liene Aunina, Laboratory of Geobotany, Institute of Biology, University of Latvia, 3 Miera Street, LV-2169 Salaspils, Latvia

Aleksandr Bobrov, Institute for Biology of Inland Waters, Russian Academy of Sciences, Borok 152742, Yaroslavl Region, Russian Federation

Liubov Borsukevych, Botanical Garden, Ivan Franco National University of Lviv, Cheremshyny, 44, 79014 Lviv, Ukraine.

Andraž Čarni, Institute of Biology, Scientific Research Center of the Slovenian Academy of Sciences and Arts, Novi trg 2, SI-1000 Ljubljana, Slovenia

János Csiky, Department of Ecology, University of Pécs, Ifjúság u. 6., Pécs, H-7624 Pécs, Hungary

Els De Bie, Unit Environment and Climate, Research Institute for Nature and Forest, Kliniekstraat 25, B-1070 Brussels, Belgium

Dmytro Dubyna, Department of Geobotany and Ecology, M.G. Kholodny Institute of Botany NAS of Ukraine, Tereshchenkivska St. 2, 01601, Kyiv, Ukraine

Panayotis Dimopoulos, Laboratory of Ecology and Biodiversity Conservation, University of Patras, G. Seferi 2, GR-30100 Agrinio, Greece

Tetiana Dziuba, Department of Geobotany and Ecology, M.G. Kholodny Institute of Botany NAS of Ukraine, Tereshchenkivska St. 2, UA-01601, Kyiv, Ukraine

Úna Fitzpatrick, National Biodiversity Data Centre, Carriganore WIT West Campus, Carriganore, County Waterford, Ireland

Xavier Font Castell, Department of Plant Biology, University of Barcelona Av. Diagonal 645, E-08028 Barcelona, Spain

Daniela Gigante, Department of Chemistry, Biology and Biotechnology, University of Perugia, Borgo XX giugno 74, I-06121 Perugia, Italy

Valentin Golub, Institute of Ecology of the Volga River Basin, Russian Academy of Sciences, Komzina 10, 445003 Togliatti, Russian Federation

Stephan M. Hennekens, Alterra, Wageningen UR, PO Box 47, NL-6700 AA, Wageningen, The Netherlands

Richard Hrivnák, Institute of Botany, Slovak Academy of Sciences, Dúbravská cesta 9, SK-84523 Bratislava, Slovakia

Lorenzo Lastrucci, Department of Biology, Laboratory of Plant Systematics and Phytogeography, University of Florence, Via La Pira 4, I-50121 Firenze, Italy

Svitlana Iemelianova, Department of Geobotany and Ecology, M.G. Kholodny Institute of Botany NAS of Ukraine, Tereshchenkivska St. 2, UA-01601, Kyiv, Ukraine

Ute Jandt, Institute of Biology, Geobotany and Botanical Garden, Am Kirchtor 1, D-06120 Halle (Saale), Germany

Florian Jansen, Institute of Botany and Landscape Ecology, University of Greifswald, Soldmannstr. 15, D-17489 Greifswald, Germany

Zygmunt Kącki, Department of Botany, University of Wrocław, ul. Kanonia 6/8, PL-50-328 Wrocław, Poland

Konrád Lájer, Department of Environmental Engineering, Óbuda University, RKK, Doberdó u. 6, H-1034 Budapest, Hungary

Dalytė Matulevičiutė, Institute of Botany, Nature Research Centre, Žaliųjų Ežerų 49, LT-08406 Vilnius, Lithuania

Attila Mesterházy, Institute of Botany and Nature Conservation, University of West Hungary, Bajcsy-Zs. u. 4, H-9400 Sopron, Hungary

José Antonio Molina, Department of Plant Biology II, Complutense University, Plaza Ramón y Cajal s/n, E-28040-Madrid, Spain

Jaanus Paal, Institute of Ecology and Earth Sciences, University of Tartu, EE-51005 Tartu, Estonia

Eva Papastergiadou, Department of Biology, School of Natural Sciences, University of Patras, University Campus Rio, GR-26500 Patras, Greece

Alessandro Properzi, Department of Chemistry, Biology and Biotechnology, University of Perugia, Borgo XX giugno 74, I-06121 Perugia, Italy

Vladimir Ranđelović, Department of Biology and Ecology, University of Niš, Višegradska 33, RS-18000 Niš, Serbia

Marcela Řezníčková, Department of Botany and Zoology, Masaryk University, Kotlářská 2, CZ-61137 Brno, Czech Republic

John S. Rodwell, 7 Derwent Road, LA1 3ES Lancaster, United Kingdom

Joop H.J. Schaminée, Alterra, Wageningen UR, PO Box 47, NL-6700 AA, Wageningen, The Netherlands

Urban Šilc, Institute of Biology, Scientific Research Center of the Slovenian Academy of Sciences and Arts, Novi trg 2, SI-1000 Ljubljana, Slovenia

Zofija Sinkevicienė, Institute of Botany, Nature Research Centre, Žaliųjų Ežerų Str. 49, LT-08406 Vilnius, Lithuania

Aleksei Sorokin, Institute of Ecology of the Volga River Basin, Russian Academy of Sciences, Komzina 10, 445003 Togliatti, Russian Federation

Zvjezdana Stančić, Faculty of Geotechnical Engineering, University of Zagreb, Hallerova aleja 7, HR-42000 Varaždin, Croatia

Jazep Stepanovich, V.F. Kuprevič Institute of Experimental Botany, National Academy of Sciences of Belarus, Akademičnaja 27, 22072 Minsk, Belarus

Boris Teteryuk, Department of Flora and Vegetation of North, Institute of Biology, Academy of Sciences of Russia, Kommunisticheskaya St. 28,167982 Syktyvkar, Russian Federation

Rossen Tzonev, Department of Ecology and Environmental Protection, Faculty of Biology, Sofia University "St. Kliment Ohridsky", Dragan Tzankov Blvd. 8, Sofia 1164, Bulgaria

Roberto Venanzoni, Department of Chemistry, Biology and Biotechnology, University of Perugia, Borgo XX giugno 74, I-06121 Perugia, Italy

Lynda Weekes, National Biodiversity Data Centre, Carriganore WIT West Campus, Carriganore, County Waterford, Ireland

Wolfgang Willner, Vienna Institute for Nature Conservation and Analyses, Giessergasse 6/7, A-1090 Wien, Austria

Igor Zelnik, Department of Biology, Biotechnical Faculty, University of Ljubljana, Večna pot 111, SI-1000 Ljubljana, Slovenia

Figure 3. *Carex buxbaumii* Wahlenb.

Figure 4. *Potamogeton coloratus* Hornem.

Figure 5. *Sagittaria sagittiflia* L.

Classification of the distribution patterns of plant taxa occurring in the unglaciated southeastern United States

Michael T. Lee & Alan S. Weakley

Department of Biology, University of North Carolina, CB #3280, Chapel Hill, NC 27599, USA

Correspondence: Michael T. Lee, Michael.lee@unc.edu

Background & Aim: Numerical classification has been used to identify and delineate groups of plants occurring together in the same physical location (plots), a basis for vegetation ecology community types. The approach uses repeated co-occurrence patterns of plants within plots to define vegetation types (Peet & Roberts 2013). These analytical tools can also be used on a regional scale to group plant taxa into distinct 'chorotypes' or repeated distribution and abundance patterns of taxa. Chorotype analysis is more commonly employed outside North America (Bolognini & Nimis 1993), and for animal taxa. The goal of this investigation was to determine the number and extent of phytogeographic patterns (chorotypes) in the unglaciated southeastern United States.

Methods: Our analysis included 4 895 plant taxa present in the unglaciated southeastern United States, with their complete distribution and abundance patterns at the state – physiographic province scale. 34 regional units were used in the analysis across the Coastal Plain, Piedmont, Mountains, and Interior Low Plateau provinces of 15 states: Alabama, Delaware, the District of Columbia, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, New Jersey, North Carolina, South Carolina, Tennessee, Virginia, and West Virginia. We employed hierarchical clustering and non-hierarchical partitioning methods to determine the best-defined set of chorotypes. Each chorotype is summarized by the frequency of occurrence in each geographic unit (whether only one, several, up to all units) and the best fitting plant taxa occurring within the chorotype. We also summarize the environmental conditions of each chorotype with word clouds of the habitat description of each taxon. Word clouds display words with font sizes proportional to the frequency of their occurrence in a set of data, in this case, the habitat description of all taxa in a chorotype.

Main Results & Conclusions: The *optpart* non-hierarchical partitioning algorithm (Roberts 2013) outperformed the flexible-beta hierarchical clustering (Oksanen et al. 2013), resulting in groups that had more similar distributions of taxa within the group and less similar distribution patterns to taxa in other groups. *Optpart* showed that 22 chorotype groups were the highest quality partitioning of the data. The most clearly delineated chorotypes followed two patterns: plants with highly ubiquitous ranges, and plants with narrow distributions at the southern range of the area investigated, the north part of the Florida Coastal Plain.

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A burning issue: the effect of fire on persistence, regeneration and flammability of plants under elevated CO_2

Michelle R. Leishman (1), Anthony Manea (1) & Peter J. Clarke (2)

1) Department of Biological Sciences, Macquarie University, Sydney NSW 2109, Australia

2) School of Environmental & Rural Science, University of New England, Armidale NSW 2351, Australia

Correspondence: Michelle Leishman, michelle.leishman@mq.edu.au

Background and aim: Fire is an important process that shapes the structure and composition of many vegetation types globally. Changes in climate and atmospheric CO_2 concentration are likely to alter fire regimes in fire-prone environments via direct climatic effects on fire weather and by elevated CO_2 effects on fuel structure, fuel load and flammability. Increasing atmospheric CO_2 is also likely to affect plant persistence, regeneration and flammability. The aim of this study was to examine the effect of elevated CO_2 on plant growth, flammability and resprouting ability for a range of plant types from fire-prone vegetation and to assess if responsiveness to elevated CO_2 was affected by soil nutrient availability.

Materials & Methods: We conducted two glasshouse experiments using species from fire-prone woodlands of eastern Australia. In the first experiment, congeneric species pairs of contrasting resprouting ability (obligate seeder vs resprouter) were grown under ambient (380–420 ppm) and elevated (530–570 ppm) CO_2 and attributes of growth (biomass and allocation) and persistence (root biomass, total non-structural carbohydrates) were measured. In the second experiment a range of grass and woody species were grown in a factorial experiment with CO_2 and nutrient availability as the factors. Leaf traits (moisture, C, N, P), biomass and components of flammability (ignitibility, flame duration and smouldering duration) were measured.

Main Results & Interpretations: Resprouters had greater total biomass, greater allocation to roots and higher non-structural carbohydrate concentration compared to obligate seeders. Although elevated CO_2 resulted in significantly greater total biomass this did not vary between obligate seeders and resprouters. Leaf flammability (flame and smouldering duration) was positively correlated with foliar C and negatively correlated with leaf moisture, foliar N & P. Elevated CO_2 reduced leaf moisture (grasses and woody plants) and foliar N (C_4 grasses and non N_2-fixing woody plants) and increased root and shoot biomass (grasses), while nutrient addition had no effect on plant response to elevated CO_2. These results suggest that elevated CO_2 will not shift the balance between obligate seeding and resprouting woody species, but that flammability at both the plant- and community-level of fire-prone vegetation may increase in the future thus increasing the risk of fire. The enhanced resprouting ability of grasses due to increased root biomass may be beneficial to their persistence relative to woody plants which may result in a shift in vegetation structure.

Range of plant types growing under elevated CO_2. under controlled glasshouse conditions. Photo: A. Manea.

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Multi-taxa richness is related to land use and climate in species-rich grasslands of southern Brazil

Mark Leithead (1), Eduardo Vélez (1), Gerhard E. Overbeck (2), Carla S. Fontana (3), Samanta Iop (4), Luciana Podgaiski (1), Ronei Baldissera (1), Mauricio da Silveira Pereira (3), Sandra C. Müller (1), Sonia Z. Cechin (4), Ilsi I. Boldrini (2) & Valério D. Pillar (1)

1) Department of Ecology, Universidade Federal do Rio Grande do Sul (UFRGS), Porto Alegre, RS, Brazil
2) Department of Botany, Universidade Federal do Rio Grande do Sul (UFRGS), Porto Alegre, RS, Brazil
3) Laboratory of Ornithology, Museum of Science and Technology, Pontifical Catholic University of Rio Grande do Sul (PUCRS), Porto Alegre, RS, Brazil
4) Department of Biology, Universidade Federal do Santa Maria (UFSM), Santa Maria, RS, Brazil

Correspondence: Mark Leithead, markleithead@gmail.com

Background & Aim: Natural species-rich 'campos' grasslands of southern Brazil are under intense anthropogenic land use pressures. Conservation of species richness and persistence of these grasslands is maintained through rotational cattle grazing and preservation of natural soil conditions. Intense and extensive expansion of silviculture and agriculture (including rice and soy) over the last decade threatens species richness and persistence of stable grasslands in southern Brazil. This change in land use at the local scale reduces species richness, affects ecosystem services, and greatly reduces the potential for soil and grassland ecosystem recovery. An effect of adjacent agriculture reducing richness at the landscape scale, however, remains to be tested. Land use, along with climate, may define current richness and help predict future richness in grassland mosaic landscapes, either conserved with contiguous formations or degraded by fragmentation through agriculture. Our aim was to test how land use (% grassland, agriculture, silviculture, rice crop, natural forest), temperature and precipitation define richness of plants, arthropods, birds and vocal anurans both within and across taxa in conserved and degraded grasslands of southern Brazil.

Materials & Methods: Members of the SISBIOTA biodiversity project, a collaboration among seven universities and research institutions in Rio Grande do Sul State, southern Brazil, collected richness information for plants (grasses, forbs and other grassland vegetation (morphospecies)), arthropods (order), birds (species) and vocal anuran amphibians (species) in 27 landscape units of 2 km X 2 km (with subsampling designs for each taxon) from 2011 to 2014. Regressions were performed to test for a relationship between richness and land use (2009 data on grassland (%); silviculture, agriculture, rice crop, degraded land, natural forest (# of hectares)) and climate variables (temperature and precipitation: mean, seasonality, max (month), min (month), highest quarter, lowest quarter). We performed regressions for both taxa richness and total richness.

Main Results & Interpretations: Plant morphospecies richness was positively related with % grassland ($y = 0.12x + 18$; $df = 14$, $P = 0.005$) whereas the other three taxa groups showed no relationship. Plant morphospecies richness was also negatively related with the higher occurrence of rice crop ($y = -0.03x + 28$; $df = 14$, $P = 0.012$) whereas the other taxa again were not. Arthropod order richness showed a decreasing trend ($P = 0.072$) with higher occurrence of silviculture. The quantity of forest in each landscape unit also did not influence any taxa richness. Climate did not affect individual taxa richness; however total richness was negatively related with precipitation seasonality ($y = -5.4x + 180$; $df = 10$, $P = 0.036$) and positively related with precipitation of the coldest quarter ($y = 0.21x + 40$; $df = 10$, $P = 0.05$). The climate results highlight differences in natural grassland formations across the state: high altitude grasslands have greater precipitation during the coldest quarter, and richness, than shallow-soil, and *Acacia caven* (*Fabaceae*) grasslands. Precipitation seasonality however did not clearly divide the grasslands into their classified types, and we speculate the role of precipitation seasonality on defining richness in different grassland formations of the state. Our results indicate that achieving high grassland plant richness may require large contiguous conserved formations across a landscape, where large-scale rice cultivation can divide natural grasslands that may limit seed dispersal.

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Out of sight, out of mind: is fine-scale moisture variability an under-appreciated coexistence mechanism in fire-prone heathlands?

Andrew D. Letten (1), David A. Keith (1,2,3) & Mark G. Tozer (2)

1) Centre for Ecosystem Science, School of Biological, Earth and Environmental Sciences, UNSW, Sydney NSW 2052, Australia
2) NSW Office of Environment and Heritage, Hurstville NSW 2220, Australia
3) Long Term Ecological Research Network, Terrestrial Ecosystem Research Network, Fenner School of the Environment Australian National University, Canberra ACT 2601, Australia

Correspondence: Andrew Letten, a.letten@unsw.edu.au

Background & Aim: Despite decades of research, one simple question continues to vex plant ecologists: how do so many species coexist when competing for the same finite suite of limited resources? While numerous spatio-temporal processes likely contribute to plant coexistence, general empirical support for any one mechanism remains enigmatic. In recent years, however, evidence has begun to emerge that niche partitioning along fine-scale hydrological gradients may well reflect one of the most general mechanisms discovered to date (Silvertown et al. 1999; Araya et al. 2011). I will present findings from a high-resolution study of plant compositional turnover and co-occurrence along a fine-scale soil moisture gradient in a fire-prone heathland.

Materials & Methods: The study was conducted in coastal heathland in Royal National Park, NSW, Australia. Access tubes for use with a soil moisture profile probe were installed at each of 56 0.5 m X 0.5 m vegetation quadrats in July 2013 and sampled monthly until July 2014. The abundance of all herbaceous species in the quadrats was surveyed in February 2014. A model-based approach was then used to investigate patterns of co-occurrence and composition as a function of hydrological variability, light availability and soil chemistry.

Main Results & Interpretations: Contrary to expectations, preliminary results indicate relatively consistent species responses, with most species favouring microhabitats less susceptible to drying stress. While this shared response suggests fine-scale moisture variability may be unimportant for niche segregation in this community, it does still appear to have a strong influence on compositional turnover and local scale richness patterns. I will discuss these results in the context of other common fine-scale drivers of niche differentiation in plant communities.

Figure 1. Sampling soil moisture in Royal NP using a PR2 profile probe.

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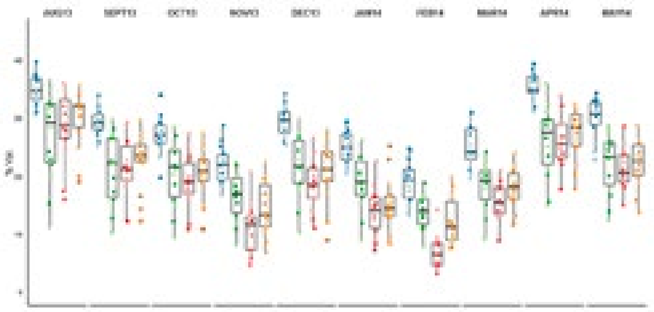

Figure 2. Soil moisture at 10 cm sampled monthly (colours represent plots within 'sites' spaced 100–300 m apart).

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Accurate dark diversity and species pool estimates: An empirical assessment of two existing methods

Robert J. Lewis, Robert Szava-Kovats & Meelis Pärtel

Institute of Ecology and Earth
Sciences, University of Tartu,
EE-51005 Tartu, Estonia

Correspondence: Rob J. Lewis,
robert.lewis@ut.ee

Background & Aims: Species present in a community can be viewed as a subset of all species theoretically able to persist (Pärtel 2014). This idea is analogous to the species-pool concept (Eriksson 1993; Zobel 1997), in that communities maintain a theoretical suite of species that could potentially co-occur, but are in-fact absent. The absent species that 'belong' to a habitat-specific species pool constitutes dark diversity, an ecologically meaningful biodiversity metric (Pärtel 2014). Estimating 'dark diversity' is however not straightforward, yet necessary if we are to accurately quantify species pools, and utilize dark diversity measures for biodiversity assessments (e.g. community completeness; Pärtel et al. 2013). Here, we assess two existing methods for estimating habitat-specific species pools: 1) species co-occurrence probability and, 2) ecological requirements of species expressed by Ellenberg indicator values (Ellenberg et al. 1991). Species co-occurrence defines the probability of a species occurrence based on the co-occurrence with all other species. A species is thus considered absent from the species pool if it typically co-occurs with observed species present in the focal community, yet remains unobserved. Ellenberg indicator values (i.e. indicators of Central European plant species preferences in respect to several environmental factors) provide a semi-quantitative measure of species environmental thresholds and distributions. Here a species is considered absent from the species pool if it shares similar ecological requirements as those species in the focal community, yet remains unobserved.

Materials & Methods: Species pools were estimated and assessed using a unique, national-scale, nested (i.e. 4 m^2 – 200 m^2) dataset of semi-natural coastal grassland vegetation of Scotland. Species compositions from c. 4000 small-scale vegetation plots (4 m^2) were modeled to estimate habitat-specific species pools. Data from the larger-scale plots (200 m^2) were used to validate our estimations. We first performed a series of sensitivity analyses to approximate any dissimilarity between species pool size estimates from the two methods being tested. We examined a range of thresholds values centered on the 5% quantile limits for co-occurrence, and a series of species ecological amplitudes computed following Pärtel (1996) for the Ellenberg method. Thresholds, that resulted in the most similar species pool size between the two methods, were selected. These were used to compute estimates of species pools and validate their relative success against species observed at the larger 200 m^2 plots.

Main Results: Although, both these methods considers a species affinity to the local and regional environmental conditions, accounting for a species site-specific establishment probability, the different nature of the methods results in fairly divergent threshold sensitivity and overall performance success. Species co-occurrence probabilities were shown to be far more robust to changing thresholds values relative to the Ellenberg approach that displayed a high degree of sensitivity. Furthermore, co-occurrences resulted in far fewer false negatives (i.e. species observed but not predicted) compared with the Ellenberg method that consistently failed to predict species observed at the larger scale. We conclude that for the tested study system, species co-occurrence probability outperforms species ecological requirements as a method to successfully detect absent species from large-scale species compositional datasets.

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No absolute compensation among plant species production contributes to temporal stability of a steppe community against fluctuating climate

Frank Yonghong Li & Taogeta Baoyin

Laboratory of Grassland Ecology,
College of Life Sciences, Inner
Mongolia University, Huhhot, Inner
Mongolia, 0210001, China

Correspondence: Frank Yonghong Li,
treetulip@clear.net.nz

Background & Aim: Relations between species diversity and community stability are a central topic in ecology. The asynchrony of species environmental response, that is, species responding to the same environmental change differently, is identified as a key mechanism for species diversity inducing community stability. The aim of this study is (i) to test if asynchronous changes in species production exist in response to precipitation fluctuation, and contribute to the community stability against climatic perturbation, and (ii) to examine how species diversity and community stability relationships change under animal grazing and mowing.

Materials & Methods: We analysed the temporal stability of grassland community production (quantified as $S = m/\sigma$, where m and σ were the long-term mean and standard deviation of annual production) and using three long-term (over 12 to 30 years) grassland production data sets (Li et al. 2008; Baoyin et al. 2014) in a semi-arid steppe environment in northern China. We also used linear regression to examine the relationships between the variation in plant species, functional groups and community production and the variation in precipitation across years.

Main Results & Conclusions: We found that (i) annual production of grassland community or dominant species (*Leymus chinensis*) co-varied significantly with precipitation in a natural community under protection. Most species showed a non-significant positive co-variation with precipitation, but no species showed a negative correlation (i.e., no species production changed in asynchrony with precipitation variation). However, the rates of plant production-to-precipitation response differed among species, thus contributed to the community stability under climatic perturbation. (ii) Plant community stability decreased under grazing or mowing mostly due to a decline in mean production (m) instead of an increase in variation amplitude (σ). Mowing or livestock grazing eliminated the controlling effects of dominant species, and allowed for more species to respond to precipitation sensitively. However, all these species (except dominant *L. chinensis* which showed no significant correlation with precipitation), when clustered into plant functional groups (PFG), showed a significant positive co-variation with precipitation. That is, no asynchronous species precipitation response was detected in these mowed or grazed communities that support the asynchrony of species environmental response as a mechanism for community stability.

Our results suggest a high resilience of the natural steppe community and its dominant species under a fluctuating climate. The low stability or high variability of plant production under a fluctuating climate reflects the capacity of the natural steppe community in using the unstable climatic resources in a semi-arid environment. To maintain or restore the response of plant production to favourable climatic conditions is fundamentally important for conservation and sustainable use of the steppe grasslands.

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The evaluation of community resilience to disturbances using compositional beta-diversity

Jaan Liira (1), Ave Suija (1), Kaupo Kohv (1,2) & Martin Zobel (1)

1) Institute of Ecology and Earth Sciences, University of Tartu, EE-51005 Tartu, Estonia

2) State Forest Management Centre, Rõõmu tee 1, EE-51013 Tartu, Estonia

Correspondence: Jaan Liira, jaan.liira@ut.ee

Background & Aims: Community resilience (disturbance-resistance) to disturbances can be seen as a important property of community assembly. Resilience is usually illustrated with the help of a model system of a ball in a bowl and how it returns to the centre of stability after a push toward outside. In real-life situations, however, ecosystem parameters depicting the shape, size and content of the imaginary bowl are difficult to quantify. We expect that a resilient (disturbance-resistant) community should experience a minor change of composition in response to weak disturbances, however they would respond to intensive disturbance, hence one can observe a J-shape relationship between driver and response. In contrast, a non-resilient community will show a response to small disturbances and small additional changes in respect to strong disturbances, i.e. showing a reversed J-shape relationship between driver intensity and response reaction. The ecosystem's response to disturbance is relatively easy to describe in conditions of a single strong-effect driver. The estimation of response patterns becomes more complicated in the case of multiple drivers of weak or modest effect strength and, particularly, when relationships between driving forces and responses are non-linear.

Responses are usually evaluated as a change in alpha-diversity (species richness or various other diversity indices) or in easily measurable quantitative ecosystem service (e.g. biomass, height, cover). However, richness and other analogues reflect only a fraction of changes in species composition. Ordination methods have been used to evaluate compositional change, but these results are not easy to interpret in quantitative units to estimate resilience. We suggest that beta-diversity is a useful, yet underemployed tool because of its complex interpretation potential.

Development & Testing of the New Tool: We propose a new method combining variogram analysis with multi-factorial general linear modelling (i.e. changes in the intensity of multiple drivers predicting the change of response variable alias compositional beta-diversity; shortly labelled lag-lag-relationship). We shall illustrate the application of this new tool using some case studies from two boreal communities. First we will examine, how important is the impact of the forest management induced disturbances on field layer vegetation besides natural variation. In the second case, we will explore the resilience of epiphytic lichen communities to change in pH of the substrate.

Main Results & Interpretations: By searching for the J-shape in lag-lag relationships and estimating descriptive power of each potential environmental driver, we found that the forest field layer is sensitive to the management disturbances in general, but specifically strong effect is caused indirectly and even that only in stressful environmental conditions. At intermediate levels of productivity the natural heterogeneity dominates. In the second case study, an epiphyte community of lichens on pine was shown to be resistant to pH changes up to certain limit, but after the community is pushed out of balance (as a ball in bowl), it would diverge because of other factors. The results imply that the J-shape of beta-diversity patterns along driver gradients can be used to evaluate the resilience of communities. We conclude that the assembly resilience depends on context conditions, and therefore, biodiversity-oriented sustainable forestry should diversify silvicultural practices and/or enhance the within-stand mosaic ensuring all potential conditions for various responses of community.

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Colonization of rural parks by forest species is affected by habitat quality and management

Kertu Lõhmus, Taavi Paal & Jaan Liira

Institute of Ecology and Earth Sciences, University of Tartu, EE-51005 Tartu, Estonia

Correspondence: Kertu Lõhmus, kertu.lohmus@ut.ee

Background & Aim: Rural parks as novel forest-like habitats on former agricultural landscapes may serve as a refugium habitat for forest-dwelling plant species (Liira et al. 2012). Whether such species successfully colonize rural parks depends on two processes: dispersal and establishment. Both processes are affected by the species functional traits, landscape properties and habitat quality. Traditionally, these processes are studied in forest habitats, but not in rural parks. These parks are structurally diverse and are located in a landscape with ancient forest land and connecting corridor habitats. In Estonia rural parks are common and widespread. Estonian rural parks therefore provide an ideal setting for landscape-level colonization studies. In this paper we first characterize the shade-tolerant species groups by analysing the trait patterns of forest and corridor specialists. We then evaluate the relative importance of dispersal and establishment in the colonization of forest-like habitats by specialist groups.

Materials & Methods: We first sampled species presences from forests (230 continually forested habitats), novel habitats (74 rural park habitats), corridors (151 linear wooded habitats), and open habitats (97 surrounding agricultural habitats) throughout southern Estonia. Habitat scores from a non-metric multidimensional scaling ordination were used to classify forest (107 species), corridor (53 species), and open habitat specialists (56 species). Plant trait values were obtained from databases and literature. We subsequently fitted generalized linear mixed models to predict colonization success using trait patterns of herb layer plants and habitat types.

Main Results & Interpretations: Forest specialists were confirmed as stress-tolerant species with limited competition abilities. In addition, these forest specialists were ephemeral species sensitive to disturbance and had shorter growth forms. In contrast, corridor specialists were shade-tolerant generalists with adaptations to competition and for dispersal between habitats. Some 40% of the forest specialist of local species pools had colonized old parks with 63% of park species being forest specialists. The colonization success of forest specialists was explained by the forest history of the surrounding area, local management regime to enhance habitat quality, and by plant traits (Lõhmus et al., in press). Corridor specialists profited from the openness of the surrounding landscape and from mowing as management. These results confirm that rural parks have a potentially high biodiversity value (Lõhmus & Liira 2013), but that this value primarily depends on local management. Our results showed that understory disturbance, such as mowing, facilitated the establishment of competitive generalist species of lesser conservation value. This further suggests that the colonization success of forest specialists in rural parks could be enhanced by nurturing a heterogeneous mid-story shrub and tree layer.

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Taxonomic distinctness measures of biodiversity: assessing biogeographical patterns in mountain ranges of the Iberian Peninsula

Javier Loidi, Gonzalo García-Baquero, Idoia Biurrun, Mercedes Herrera, Itziar García-Mijangos & Juan A. Campos

Department of Plant Biology and Ecology, University of the Basque Country (UPV/EHU). P.O. Box 644, E-48080 Bilbao, Spain

Correspondence: Javier Loidi, javier.loidi@ehu.es

Background & Aim: Taxonomic distinctness (TD) is a measure which attempts to capture phylogenetic diversity existing in a set of species as an assessment of its shared evolutionary and biogeographic history. This is done by measuring their taxonomic relatedness calculating the average 'distance' between all pairs of species, where distance is defined as the path length through a standard Linnean or phylogenetic tree connecting these species (Clarke & Warwick 1999). TD has the advantage of being independent of sample size and sampling effort. Here we (i) explore the TD of frigophilic (cold-loving) flora of the Iberian Peninsula mountains using Average TD (Δ^+) and Variation in TD (Λ^+), and (ii) assess the biogeographic relationship between these mountain systems using the Gamma$^+$ (Γ^+) similarity index, which takes into account the taxonomic relationship existing among the species sets.

Materials & Methods: We selected 999 frigophilic taxa living mainly above 1600 m in any of the six Iberian mountain ranges: Pyrenees, Cantabrian, Northern Iberian, Southern Iberian, Central and Baetic. Taxa were first classified into four floristic elements: Arctic-boreal (155 species), European orophilous (250), Iberian endemic (536) and Iberian-North African (58), and then to their preferred habitats: screes, rocks, psychro-xerophilous grasslands, chionophilous grasslands and scrubs. Relationships among the mountain ranges were explored by means of NMDS ordination and hierarchical agglomerative clustering. Similarity matrix was calculated with Jaccard and Γ^+ similarity indices. Randomization tests on TD of the mountain ranges, floristic elements and habitat types were performed comparing Δ^+ and Λ^+ values against expectations from the master taxonomic list of 999 species on a 95% confidence funnel diagram.

Main Results & Interpretation: The Iberian endemic element showed that most endemics occur in the Baetic Range (190) and in the Pyrenees (129). Species richness was positively correlated with extent above 1600 m. The endemic species richness was significantly correlated with the maximum altitude in each range. Jaccard and Γ^+ similarity indices resulted in similar dendrograms, showing that the Pyrenees-Cantabrian Range and Central Range-Northern Iberian Range were closely related. The results about TD analysis indicate that the northern ranges (Pyrenees and Cantabrian Range) have higher TD values than expected. The Arctic-boreal element showed a clear positive deviation from expected TD for all mountain ranges. Patterns of TD were less clear. Psychro-xerophilous grasslands had lower Δ^+ values than expected, while Λ^+ values of rocky and hygrophilous habitats were higher. In conclusion, the Arctic-boreal element contributed mainly to the taxonomic diversity of the cold adapted flora in the Iberian mountains. This floristic element showed strong association with hygrophilous habitats.

A view of the alpine belt of the Central Pyrenees. Photo: J. Loidi.

Acknowledgements: Funds from the project IT299-10 for research groups of the Basque Government have been used for this survey.

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Alien plants tend to invade phylogenetically clustered vegetation and cause even stronger clustering

Zdeňka Lososová (1), Francesco de Bello (2,3), Milan Chytrý (1), Petr Pyšek (4,5), Jiří Sádlo (4), Marten Winter (6) & David Zelený (1)

1) Department of Botany and Zoology, Masaryk University, Kotlářská 2, CZ-611 37 Brno, Czech Republic

2) Department of Functional Ecology, Institute of Botany, Academy of Sciences of the Czech Republic, CZ-379 82 Třeboň, Czech Republic

3) Department of Botany, Faculty of Science, University of South Bohemia, Branišovská 31, CZ-370 05 České Budějovice, Czech Republic

4) Department of Invasion Ecology, Institute of Botany, Academy of Sciences of the Czech Republic, CZ-252 43 Průhonice u Prahy, Czech Republic

5) Department of Ecology, Faculty of Science, Charles University in Prague, Viničná 7, CZ-128 44 Praha, Czech Republic

6) German Centre for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig, DE-04103, Leipzig, Germany

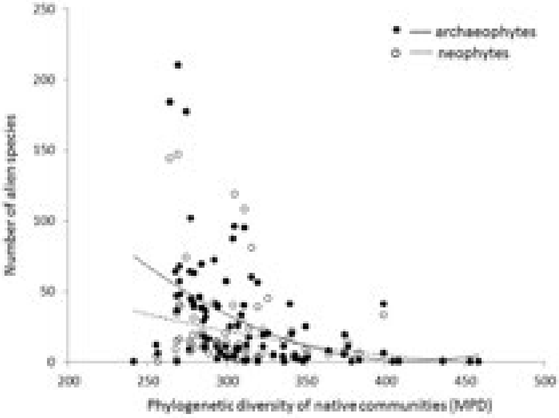
Correspondence: Zdeňka Lososová, lososova@sci.muni.cz

Background & Aim: One of the key questions of invasion biology is to identify which factors facilitate species invasion. A number of hypotheses postulate that invasion is controlled by the interplay between the phylogeny of the invasive species and phylogenetic structure of invaded communities. Some of them suggest that either phylogenetic relatedness of invaders to native communities is predicted to promote naturalization, which makes alien species closely related to native species more successful invaders, because of appropriate niche-adaptation. The other hypothesis predicts that phylogenetic relatedness hampers naturalization because of niche overlap with native species (known as 'Darwin's naturalization hypothesis'). We thus ask if differences in phylogenetic structure of native communities affect the number of invasive species (e.g. level of their invasion).

Materials & Methods: We used species pools of 88 vascular plant communities of central Europe, representing distinct habitat types, and comprising 2306 species. Of these species 1785 were native, 246 archaeophytes and 275 neophytes. For each community, we quantified phylogenetic diversity using the mean phylogenetic distance (MPD) and mean nearest taxon distance (MNTD) to test the relationship between these phylogenetic quantifiers and the level of invasion.

Main Results & Interpretation: The level of invasion was strongly community-dependent, and it depends on both the phylogenetic structure of the community and the phylogeny of the invasive species. The most-invaded community types were anthropogenic habitats and open riverine, wet or mesic meadows. These communities are phylogenetically more clustered possibly due to disturbance acting as environmental filter. Here, invasive species increased the degree of phylogenetic clustering as they tend to be from the same lineages as native species. Such trends were not detected for phylogenetically diverse communities like forests. Our findings do not support the Darwin's naturalization hypothesis per se; they rather suggest that the contrary hypothesis of environmental filtering is the mechanism in play.

Acknowledgements: This study was funded by the Czech Science Foundation (Centre of Excellence PLADIAS, 14-36079G).



The relationship between the alien species pool and phylogenetic diversity of native species in 88 plant communities of Central Europe.

Vegetation of river bank invaded by *Impatiens glandulifera* near Kyjov, Distr. of Hodonín, Czech Republic. Photo: Z. Lososová.

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Model-based approaches to vegetation community classification

Mitchell Lyons (1), David A. Keith (1,4), Richard T. Kingsford (1), David Warton (2), Scott Foster (3), Adam Roff (4) & Jillian Thonell (4)

1) Centre for Ecosystem Science University of New South Wales, Sydney NSW 2033, Australia
2) Mathematics and Statistics Evolution & Ecology Research Centre, University of New South Wales, Sydney NSW 2033, Australia
3) Computational Informatics, CSIRO, Hobart TAS 7001, Australia
4) NSW Office of Environment and Heritage, Hurstville NSW 2220, Australia

Correspondence: Mitchell Lyons, mitchell.lyons@unsw.edu.au

Background & Aim: Vegetation community classifications are artificial frameworks required for management and decision-making. Unfortunately, uncertainties in classification are inherent and unavoidable as discrete community classifications contain uncertainties arising from incomplete knowledge, sampling design and measurement issues. The challenge is often intensified by engrained methodologies that are driven by subjective "expert knowledge" or methodologies that make dubious statistical assumptions about underlying multivariate species data. Consequently, the exact pathway to a particular classification is subjective or difficult to understand, and provides no quantitative information on a classification's quality or accuracy. We reconcile some of these challenges with model-based approaches that 1) quantify uncertainty in existing *a priori* vegetation community classifications and 2) cluster vegetation survey plots into groups.

Data and Methods: We demonstrate these two applications using a database of floristic vegetation surveys from New South Wales (Australia), with over 10 000 observations and over 2500 species. First, we use an extension of generalised linear models (GLMs) to explicitly test how well separated existing community groupings are in light of their floristic abundance. Using pairwise multiple comparisons, each species is modelled as a function of community classification. Classification quality is tested using both hypotheses testing (p-value) with residual resampling and model selection (using an information criterion) with community resampling.

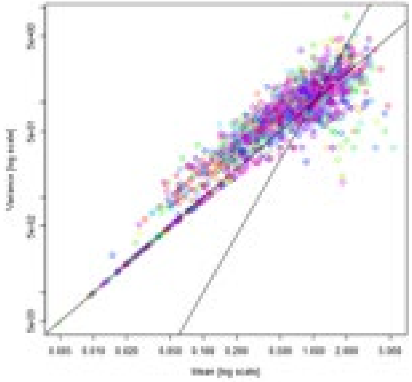

Figure 1. Mean-variance plot for a full floristic survey data set. Each point represents a species mean abundance vs. variance in abundance, where sites a grouped (coloured) by community allocation. Note the assumptions that distance-based (Bray-Curtis) approaches make (annotated), and how this is not observed in the vegetation data.

Main Results & Conclusions: We found that communities were over-classified, and were able to identify particular communities that were not discernable from each other, as well as communities that were not floristically distinct at all. We were also able to explicitly test alternative or competing classifications. Second, we use a special type of mixture model (a mixture-of-experts model) to simultaneously model environmental covariate data and floristic data. This is done by modelling region-type (unobserved-yet-inferred groups/clusters of locations), that are distinguished by having unique means of the component species. The model for the region types defines the probability of group occurrence as a function of the environmental gradients. Region type is similar to a traditional distance-based cluster. Importantly, the mixture-of-experts model provides an alternative approach to traditional distance-based clustering, enabling both soft and hard cluster allocations, which were then compared to the existing vegetation community classification. Additionally, the hypothesis of how many community types are supported by the floristic and environmental data was tested using model selection, by varying the number of region types.

Acknowledgements: Funding provided by the New South Wales Environmental Trust Fund.

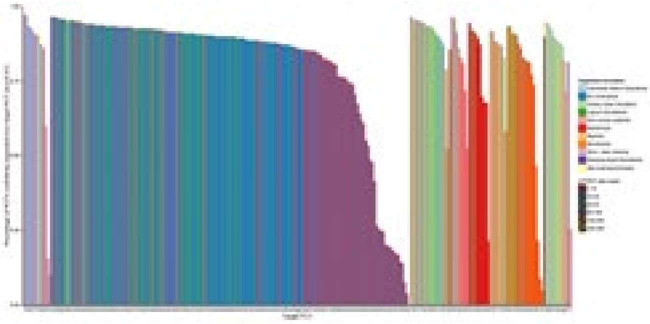

Figure 2. Graphical representation of overall community separability – x-axis denotes individual target communities; y-axis is the percentage of pair-wise test results (against all other communities) indicating strong floristic separability from target community. Communities to the left are highly separable from all other communities, vice versa to the right. Plot is grouped by vegetation formation.

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Fine-scale predictive mapping of the kwongan vegetation of the Eneabba sandplains, Western Australia

Paul D. Macintyre (1), Ladislav Mucina (1,3), Mark P. Dobrowolski (1,2), Adriaan van Niekerk (3), Garth Stephenson (3) & Theo Pauw (3)

1) School of Plant Biology, The University of Western Australia, 35 Stirling Hwy, Crawley WA 6009, Perth, Australia

2) Iluka Resources Limited, 140 St Georges Terrace, Perth WA 6000, Australia

3) Centre for Geographic Analysis, Department of Geography and Environmental Studies, Stellenbosch University, Matieland, 7600, Stellenbosch, South Africa

Correspondence: Paul Macintyre, 20163103@student.uwa.edu.au

Background & Aim: Prediction modelling has been widely used in ecological studies for a variety of purposes. At coarse scales (1:250 000 to 1:1 000,000+) vegetation prediction maps have been successfully created, yet there is currently little data on how these models perform at fine scales (1:10 000 to 1:50 000). Using the protocols developed by Mucina et al. (2013) which have been successfully applied at coarse scales, this project set out to (1) determine whether the existing protocols can be successfully applied at fine scales, (2) examine the vegetation patterns of the sclerophyllous kwongan scrub vegetation of the Eneabba sandplains, and (3) determine whether knowledge of the vegetation-environment relationship can be used to improve the accuracy of the prediction model.

Materials & Methods: The study region was located in the Eneabba sandplains approximately 270 km north of Perth (29°49′ S, 115°16′ E), Western Australia. A total of 200 classified plots were used in the training of a decision tree through the Salford Systems' Classification and Regression Tree (CART) algorithm; for each plot a combination of 109 variables (remotely sensed climatic and topographic variables, and soil/geology variables) were used as predictors. Two decision trees were constructed: one at the level of three large-scale vegetation units ('class') and the other at the level of floristically defined plant community types ('associations') as defined by Tsakalos (2013) and Tsakalos et al. (2014). The mapping region was segmented into image objects using eCognition Developer and the decision trees were applied to the objects to produce a spatial representation of the models.

Main Results: The model used to predict vegetation at the class level resulted in a decision tree with 25 terminal nodes and a total cost of 0.60; the model predicting at the association level resulted in a final tree containing 18 terminal nodes and a total cost of 0.49. Within both models the characteristics of the soil were major factors predicting the classification patterns. The accuracy of the classifications was tested using an additional 343 plots from the region that were excluded from tree construction. The class and association models had an initial accuracy of 33% and 71%, respectively, but when a 30 m buffer was applied to each validation point the accuracy of the models improved to 42% and 76% for the class and association level. Overall it has been shown that the protocols developed by Mucina et al. (2013) can be used at fine scales, but that a much larger number of training points must be used.

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Multifaceted analysis of patch-level plant diversity in response to landscape spatial pattern and patch history on Mediterranean dunes

Marco Malavasi (1), Luisa Conti (1), Marta Carboni (2), Maurizio Cutini (1) & Alicia T. R. Acosta (1)

1) Dipartimento di Scienze,
Università degli Studi di Roma Tre,
V.le Marconi 446, I-00146 Roma,
Italy

2) Laboratoire d'Ecologie Alpine,
Université Joseph Fourier / CNRS
Grenoble BP 53, 2233 Rue de la
Piscine, F-38041 Grenoble
Cedex 9, France

Correspondence: Marco Malavasi,
marco.malavasi@uniroma3.it

Background & Aims: In recent years, coastal dune landscapes have undergone consistent transformations and currently they are pinpointed as one of the most threatened ecosystems worldwide, being prone to particularly high biodiversity loss. Understanding the probable drivers that shape the distribution of biological diversity along coastal dune ecosystems in response to landscape pattern and transformation processes is a priority. We analyzed how landscape spatial pattern and local history have affected taxonomic (TD), functional (FD) and phylogenetic (PD) plant diversity on natural dune patches along the Lazio Coast (Central Italy). While the effect of landscape spatial pattern on TD has been previously investigated, the effect on FD and PD remains unclear.

Materials & Methods: Floristic data was derived from a preexisting database of random vegetation plots (4 m^2), functional trait information was available for the surveyed species from field measurements and a dated phylogenetic tree was reconstructed using a super-tree approach. A set of landscape patch-based metrics, considered as adequate proxies of the main processes affecting plant diversity, was computed relying on multi-temporal land cover maps (1954–2008). In particular, patch local history was taken into account by quantifying temporal urbanization trends and coastal line change occurring in the last 50 years. Rao's quadratic entropy index was used to estimate the TD, FD and PD of each patch at the alpha, beta and gamma level. Diversity measures were then related to the landscape metrics using linear models.

Main Results: We observed that each diversity facet responded differently to landscape parameters. It seems that TD, FD and PD are all heavily affected by ongoing human pressure transforming the coastal landscape. While the TD of plant communities tends to decrease with greater shared border to contemporary human structures, FD seems to be highest in patches bordering such structures, probably in relation with the entrance of new functionally distinct species such as ruderals. However, when considering urbanization trends over time, FD also turns out to be negatively affected in the long run. PD decreases where the dune plant communities are more fragmented, indicating that the integrity of the full vegetation zonation is particularly important for preserving the accumulated evolutionary history. Moreover, within all facets, α and γ are affected by similar landscape parameters. On the contrary, we observed no clear trends for β diversity. In order to preserve the functionality and uniqueness of coastal dune ecosystems our results support the need to redefine conservation priorities and adapt management strategies to include different, but complementary components of biodiversity.

Figure 1. Coastal dune landscape of Central Italy. Montalto di Castro (Lazio Region, Italy). Photo: M. Malavasi.

Figure 2. Northern sector of the study area (Lazio Region, Italy). Series of historical orthophotos used to describe the urbanization process across the coastal dune landscape.

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Changing species co-occurrences over a post-fire succession

Inger E. Måren (1), Jutta Kapfer (2), John-Arvid Grytnes (3), Per Arild Aarrestad (4) & Vigdis Vandvik (3)

1) Department of Geography, University of Bergen, Fosswinckelsgate 6, NO-5007 Bergen, Norway

2) Norwegian Forest and Landscape Institute, Holtveien 66, NO-9269 Tromsø, Norway

3) Department of Biology, University of Bergen, Thormøhlensgate 53A, NO-5008 Bergen, Norway

4) Norwegian Institute for Nature Research (NINA), Høgskoleringen 9, NO-7034 Trondheim, Norway

Correspondence: Inger E. Måren, inger.maaren@geog.uib.no

Background & Aim: One of the central ideas in contemporary ecology is that disturbance plays an important role in natural communities, influencing population persistence, community composition, and maintenance of diversity. Human-induced disturbances have shaped the semi-natural habitats surrounding us today. The coastal heathlands of northern Europe are a good example of a low intensity farming system where marginal lands are burned and grazed by large herbivores. The keystone species *Calluna vulgaris* dominates this vegetation and the evergreen shoots serves as winter fodder, whereas herbs and grasses serve as summer fodder. Fire is important in these coastal heathlands, and most of the plant communities are in a state of post-fire succession. Models of succession differ; some models predict individual responses of species, whereas others assume that species will change more simultaneously, resulting in changing vegetation patterns over time. Here, we compare temporal changes in co-occurrence patterns to see if the same set of species occur together throughout the succession or not, and we compare grazed and non-grazed areas with different moisture regimes. We also investigate which species co-occur with *Calluna vulgaris* over the course of the succession.

Materials & Methods: We re-sampled vegetation, vascular plants and bryophytes, in 7 out of the 12 first years of the post-fire succession by means of a balanced design consisting of three different moisture regimes (wet, intermediate and dry), where half of the plots were subjected to feral sheep grazing, while the other half was non-grazed. A site-specific change in species co-occurrence (community stability) was quantified by comparing how many times species co-occurred before and after a specified time. We tested whether the changes observed were significantly greater than those expected by chance using a restricted randomisation test.

Main results & Discussion: Over the course of this post-fire succession we found 151 species; 77 vascular plants and 74 bryophytes. Changes in species co-occurrences of vascular plants and bryophytes were greater than those expected by chance. These differences in co-occurrence were, overall, found to be strongest at the very beginning of the post-fire succession, and more pronounced in the non-grazed wet plots, suggesting that site-specific factors, such as land-use and moisture regime, are important in controlling co-occurrences over this post-fire succession. We did not find the same trends in the bryophytes, whose co-occurrence changes were more stochastic. When investigating changes in the co-occurrence of other species with *Calluna* over the course of the succession we see that species like *Empetrum nigrum, Lycopodium clavatum* and *Anemone nemorosa* co-occur less frequently, while *Carex pilulifera, Polygala serpyllifolia, Lotus corniculatus* and *Hypericum pulchrum* co-occur more frequently right after fire in the grazed plots, but this changes over the course of the succession. From a management perspective it is important to be aware of the transient nature of plant-plant interactions over a post-disturbance succession, where environmental variation and land use may influence community composition and diversity.

Acknowledgements: This project was supported by the Norwegian Research Council, the Norwegian Institute for Nature Research, Bergen Myrdyrkningsfond and Grolle Olsens Legat.

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Observing relationships between habitat, host, and AMF communities utilizing massive parallel sequencing

Alexandra Martynova-Van Kley, James Van Kley & Armen Nalian

Stephen F. Austin State University,
Department of Biology, Box 13003,
Nacogdoches, Tx 75962, USA,

Correspondence:
Alexandra Martynova-Van Kley,
avankley@sfasu.edu

Background & Aim: Arbuscular mycorrhizal fungi (AMF) form symbiotic relationships with the roots of >80% of plant species thereby enhancing root absorption. While critical to terrestrial ecosystems, they were historically difficult to study. Recent advances in molecular techniques have made investigations of AMF communities possible. This study aimed to provide preliminary observations of relationships between AMF, habitat type, host plant, and seasonality in forests of eastern Texas, USA.

Materials & Methods: AMF from eastern Texas forests were sampled from roots of three widely-occurring native host plants: *Callicarpa americana*, *Chasmanthium sessiliflorum*, and *Toxicodendron radicans*. Sample sites were chosen to represent the range of east Texas habitats from dry-sandy longleaf pine forest and dry-mesic mixed upland forest to mesic lower slope and stream bottom forest and floodplain forest. The study extends previous work done in our group using Denaturing Gradient Gel Electrophoresis (DGGE) (Martynova-Van Kley et al. 2006; Nalian et al. 2010) with massive parallel sequencing of fragments of the 18s rDNA gene to identify all taxonomic units of fungi present in each sample.

Main Results: AMF showed some preference for certain host plants: samples from the three hosts occupied largely distinct regions in ordination space. AMF communities also differed across different habitat types. For example AMF taxa including *Glomus hoi*, *G. proliferum*, and *Gigaspora decipiens* tended to associate with upland habitats while *Glomus intraradices* and *G. mosseae* favored mesic sites and floodplains. AMF communities also changed seasonally with the chief difference being between wet and dry periods rather than temperature or season.

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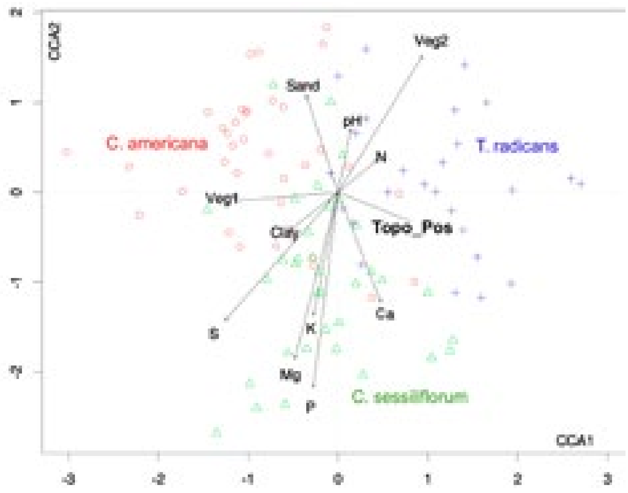
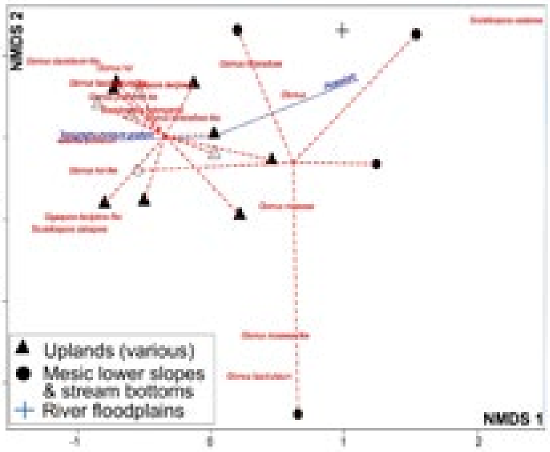


CCA of samples from roots of three host plants (colors) from a range of east Texas USA forest sites based on presence of DGGE bands representing AMF taxa. Bi-plot vectors represent the direction and magnitude of correlations. N,S, Ca, P, K, Mg: % of the respective nutrients in topsoil; Sand & Clay: % of sand & clay in topsoil; Topo_Pos: elevation of the site relative to the nearest local ridge top and stream bottom; Veg 1 & 2: DCA scores for the vascular plant community.



Two-dimensional NMDS ordination of 16 samples from 2 host plants from a range of east Texas, USA, forest habitats based on AMF taxa identified from sequences obtained from 454 pyrosequencing. Joint-plot vectors represent the direction and magnitude of correlations with external factors. Potassium: percentage of K in topsoil, Topo-moisture gradient: a ranking of sample sites based on topographic position, soil texture, and hydrology. Species loadings were subsequently calculated and overlain on the ordination diagram. Open symbols: *C. americana*; filled symbols: *T. radicans*.

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The utility of polygon and point intercept methods in quantifying vegetation change using aerial photography

Tanya J. Mason (1) & David A. Keith (1,2)

1) Centre for Ecosystem Science, University of New South Wales, Sydney NSW 2052, Australia

2) Office of Environment and Heritage, Hurstville NSW 1481, Australia

Correspondence: Tanya Mason, t.mason@unsw.edu.au

Background & Aim: Time series aerial photography has important applications in assessing vegetation change. Dynamics such as deforestation, reforestation, weed spread, and the effects of climatic, fire, grazing and groundwater processes on natural vegetation may be documented over time scales of up 80 years with aerial photographs. The ability of aerial photography to quantify vegetation change consistently is dependent in part on the photo-interpretation technique. Automated methods applicable to digital data are usually inappropriate for older imagery. It is important to use a repeatable, reliable method to assess the area of different vegetation communities for both static and change detection studies.

Materials & Methods: This study compared two methods: (i) complete manual digitisation and attribution of vegetation polygons, and (ii) attribution of random sample points overlain at varying densities. For the comparison we used recent imagery of coastal upland swamp vegetation communities with discernible structural forms interspersed in a woodland matrix in Eastern Australia. We then quantified agreement between polygon and point intercept methods, determined the interpretation time required for each method, and evaluated respective costs and benefits.

Results & Interpretations: We found that agreement between the methods was dependent on boundary attributes: communities with diffuse vegetation boundaries had poorer agreement between the methods than communities with sharp boundaries. The point intercept approach had significantly lower time allocation requirements than the polygon approach and a density of 1 point per 1000 m^2 was sufficient to distinguish woodland from swamp vegetation. The study indicates that a sample-based approach to vegetation classification is more efficient than complete polygon mapping. However a combination of methodological approaches may be required to accurately capture areal extent and spatial boundaries for a landscape mosaic of vegetation communities.

The findings contribute a robust methodology to landscape monitoring and change detection studies. Recommendations are made on the most cost effective approach for scenarios defined by available imagery, landscape configuration, resource availability and resolution requirements.

Acknowledgements: This work was supported by an UNSW Faculty of Science Early Career Researcher Grant.

Figure 1. An example of complete mapping of polygons on a 0.25 km^2 aerial photograph.

Figure 2. An example of a sample-based approach (attribution of random sample points) on a 0.25 km^2 aerial photograph.

Mason, T.J. & Keith, D.A. 2014. The utility of polygon and point intercept methods in quantifying vegetation change using aerial photography. In: Mucina, L., Price, J.N. & Kalwij, J.M. (eds.), *Biodiversity and vegetation: patterns, processes, conservation*, p. 145. Kwongan Foundation, Perth, AU.

Are long-established golf courses habitat for grassland species?

Toshikazu Matsumura (1), Yoshinobu Hashimoto (2) & Yoshihiro Sawada (3,4)

1) Department of Human Science, Konan Women's University, Higashinada Morikita 6-2-2, Kobe, Hyogo, Japan

2) Division of Ecological Restoration, Museum of Nature and Human Activities, Hyogo, Yayoigaoka 6, Sanda, Hyogo, Japan

3) Awaji Landscape Planning & Horticulture Academy, NojimaTokiwa 954-2, Awaji, Hyogo, Japan

4) Institute of Natural and Environmental Sciences, University of Hyogo, Japan

Correspondence: Toshikazu Matsumura, matutosi@gmail.com

Background & Aim: Semi-natural grasslands are one of the most important habitats for plants in Japan. However, species richness of semi-natural grasslands has decreased due to land uses changes. Most of these grasslands were abandoned for several decades and their area has also declined. Remnants of semi-natural grasslands are small. In landscapes dominated by agricultural land use, field margins of traditional paddy fields are the most important habitats for grasslands supporting species-rich plant assemblages (Matsumura & Takeda 2010). Some of the endangered species survive in commercial grasslands such as pastures and on ski slopes. Although the long-established pastures and the ski slopes have previously been investigated, the golf courses remained neglected. The objective of this study is to clarify the availability of the long-established golf courses (including the oldest course in Japan established in 1903) for conservation of grassland species.

Methods: We selected four golf courses in Hyogo Prefecture, Central Japan. All courses have been used for a long time (62, 88, 84, and 101 years, respectively). We studied plants of two habitats (fairway and rough) of the golf courses in 2012–2013. Fairway was intensively managed; the grass turf is being cut lower than 2–3 cm above ground more than 10 times in a year. Rough was extensively managed; it is cut at about 3 cm above ground and less than 5 times in a year. We recorded all vascular plant species in each habitat.

Results & Discussion: We found greater numbers of grassland species in the rough of the golf courses, but few in the fairway. In the rough, we recorded 57–79 grassland species, and 1–4 endangered taxa (*Atractylodes japonica*, *Chaenomeles japonica*, *Dianthus superbus* var. *longicalycinus*, *Cynanchum paniculatum*, *Scabiosa japonica*, *Vicia amoena*). In more than three courses, 29 grassland species were recorded including *Adenophora triphylla* var. *japonica*, *Cirsium japonicum*, *Lespedeza pilosa*, *Miscanthus sinensis*, *Spiranthes sinensis*, *Sanguisorba officinalis*, *Salvia japonica* and *Viola mandshurica*. Most of these species are perennials commonly occurring in semi-natural grasslands in Japan. One of the golf courses has grassland species that do not exist in the semi-natural grassland near the golf course. The species-rich grasslands were distributed more widely than before the establishment of the golf course (earlier than 1950). The grasslands were managed for fodder and material for thatch roofing. The rough have been continuously cut several times per year. The grassland species persist after the development of golf courses due to the grassland management. In recent times, the golf courses have been constructed using heavy machinery such as excavators and bulldozer, causing heavy disturbance resulting in the demise of the grassland species. The long-established golf course is considered to be one of the important habitats for grassland species and could serve as seed sources or refugia for conservation of grassland species in Japan. Managers and green keepers in some golf courses recognize the importance of some grassland species in their golf courses and therefore it is important to cooperate with them in order to conserve the plant species in these unusual grassland refugia.

Sanguisorba officinalis (*Rosaceae*) is surviving in the rough of a long-established golf course in Japan.

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Comparison between the montane forest vegetation of East Africa and Southeast Asia

Shin-ichi Meguro

Institute for Global Environmental Strategies, Japanese Center for International Studies in Ecology, 222-0033 Yokohama, Japan

Correspondence: Shin-ichi Meguro, smeg-716@jise.jp

Background & Aim: Both Africa and Southeast Asia regions are included in Palaeotropical Kingdom (Takhtajan 1986). There are not many reports that focused on comparison of forest vegetation types of both areas using phytosociological data. Here I aimed at finding commonalities and establish differences in patterns of occurrence of representative families in the montane forest vegetation of East Africa and Southeast Asia. Both areas support only small patches high-altitude forest vegetation in the equatorial regions.

Materials & Methods: The vegetation survey was done using traditional field phytosociological methods of the Braun-Blanquet (1964) approach in forested regions of Kenya and the Malaysian part of Kalimantan (Borneo). The data were collected at sea level of about 2210 m in Sawawak and Sabah States, Kalimantan, at altitudes from 2885 m in the Embu, Isiolo, Meru, Nyeri, Samburu, Marsabit and Martakwet regions of Kenya. 86 and 102 relevés were collected in Kenya and Kalimantan, respectively.

Main Results & Interpretations: Two natural, high-altitude (above 1300 m a.s.l.) forests types were distinguished in Kenya: One community was formed by *Diospyros abyssinica* (*Ebenaceae*), *Vepris simplicifolia* (*Rutaceae*) and *Olea capensis* subsp. *hochstetteri* (*Oleaceae*), while the other consisted of *Prunus africana* (*Rosaceae*), *Ocotea kenyensis* (*Lauraceae*), *Rapanea melanophloeos* (*Myrsinaceae*) and *Rhamnus prinoides* (*Rhamnaceae*). The latter community is found at higher altitudes (1840–2885 m), while the former community occurs at altitudes between 1420 and 2160 m.

In Kalimantan *Dipterocarpaceae* showed concentration at low altitudes, while *Lauraceae* such as *Beilschmiedia assamica*, *Cinnamomum parthenoxylon* and *Phoebe macrophylla* appear at mid-altitudes (625–1150 m). *Fagaceae*, *Theaceae* and *Rosaceae*, typically occurring in the cool-temperate and warm-temperate forests of the Northern Hemisphere, became more important with increasing altitude characterized by cooler climate. I found that communities that support *Prunus* species and *Lauraceae* tend to occur at higher elevations than the *Diospyros*-dominated communities found both in East Africa and Southeast Asia. *Myrtaceae* and *Podocarpaceae* (both considered Gondwanan elements) showed preference to high altitudes. While *Lauraceae* are considered to be air-moisture demanding, the Gondwanan elements prefer sunny, oligotrophic and yet well-watered habitats (Morley 2000) such as forest gaps at high altitudes.

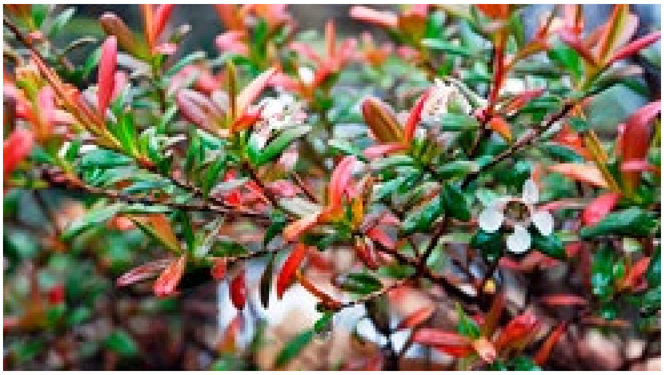

Figure 1. *Leptospermum javanicum* (*Myrtaceae*) in a montane forest in the Sabah State (Malaysia), Kalimantan. Photo: S. Meguro.

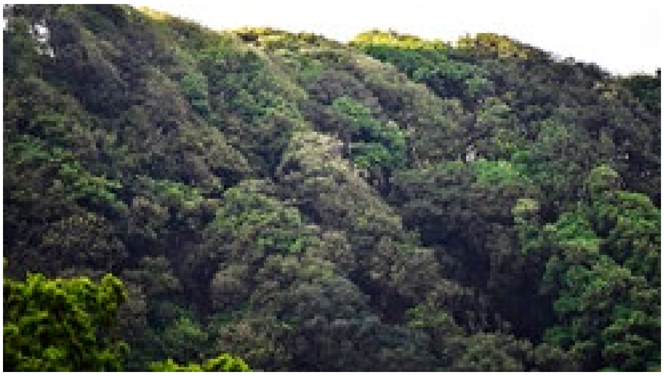

Figure 2. Montane forest in Marsabit National Park, Kenya. Photo: S. Meguro.

Acknowledgements: This work is supported by the Japan Federation of Economic Organizations and Mitsubishi Co. The author has been supported by Profs Akira Miyawaki and Kazue Fujiwara.

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Drivers of plant community assembly on sediment deposition sites at the River Emajõgi floodplain, Estonia

Jaak-Albert Metsoja, Ott Luuk & Martin Zobel

Department of Botany, Institute
of Ecology and Earth Sciences,
University of Tartu, EE-51005 Tartu,
Estonia

Correspondence: Jaak-Albert Metsoja,
albert@ut.ee

Background & Aim: In 2011, LIFE+ project HAPPYFISH re-connected ten river meanders (oxbows) to the River Emajõgi in Alam-Pedja Nature Reserve, Estonia. During re-opening of the oxbows, alluvial sediments were excavated and deposited on adjacent flooded meadows. On these deposition sites, vegetation recovery has been monitored for three years. Our research aim is to explain the processes underlying plant community functional assembly during vegetation succession. We hypothesize that the driving mechanisms of functional assembly would change from random colonization in the beginning to competition and environmental filtering later on.

Materials & Methods: On eight sites, the vegetation was analysed before (2011) and after (2012–2013) the project activities. We randomly located six 1 m X 1 m plots in each site and estimated cover values for all the detected plant species. To study community assembly patterns, we used plant functional traits taken from different databases and compared their community weighted means (CWM) in different successional stages.

Results & Conclusions: The average number of species per plot was 6 in 2011 and 23 in 2012. Many of the new species were not characteristic to flooded meadows and often had a ruderal life strategy. The proportion of ruderals started to decrease in 2013, probably because of competitive exclusion – the proportion of C-strategists started to increase in 2013. The newly arrived species also had a high proportion of unspecialised species in terms of dispersal agent, supporting the idea that first year community assembly is not strongly dispersal-filtered, and arrived species may originate either from the seed bank (which is still under study) or be carried to the sites by annual floods even without specialized means for water dispersal.

CWM specific leaf area was much higher in 2012 than in 2011, and then started to decrease. This unexpectedly high SLA in an early successional community with ample light is mostly attributed to a single species only (*Barbarea stricta*). In 2012, the CWM proportion of grasses decreased dramatically, and recovered later. The proportion of species adapted to wet, badly aerated soils (Ellenberg F-value 9) also decreased in 2012, and recovered thereafter.

We conclude that the plant community formation on the sediment deposition sites is governed by random colonization, biotic drivers (plant competition), and by environmental filtering. The study continues to assess the role of the latter within a longer timeframe.

Acknowledgements: This work was supported by the European Union LIFE+ project HAPPYFISH: “Saving life in meanders and oxbow lakes of Emajõgi River on Alam-Pedja NATURA 2000 area“, LIFE+07 NAT/EE/000120, and by grants from the Estonian Science Foundation (9050, 9157), targeted financing (IUT 20-28) and the European Regional Development Fund (Centre of Excellence FIBIR).

Overview of study area in the Alam-Pedja Nature Reserve, Central Estonia. The red mark indicates an example site of an oxbow opening. Photo: A. Ader.

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Ecological stability of the world's largest arid alpine ecosystem despite or a consequence of climate change and life-stock grazing?

Georg Miehe (1), Sabine Miehe (1), Jürgen Kluge (1), Yun Wang (2) & Karsten Wesche (2)

1) Faculty of Geography, Marburg University,Deutschhausstrasse 10, D-35032 Marburg, Germany

2) Senckenberg Museum Natural History Görlitz, Post Box 300 154, D-02806 Görlitz, Germany

Correspondence: Georg Miehe, miehe@staff.uni-marburg.de

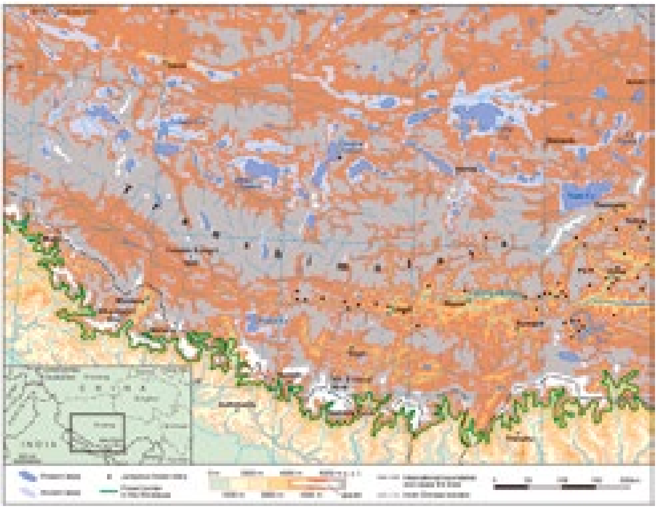
Background & Aim: Arid and alpine ecosystems are supposed to be highly sensitive to ongoing climate change, to be vulnerable to overgrazing and desertification, and to have undergone dramatic climate-driven changes during the Quaternary. With a total area of 800 000 km^2, the alpine steppe is the largest arid alpine ecosystem, being located in the NW Tibetan Highlands (China: Xizang, Qinghai) at altitudes between 4200 and 5400 m a.s.l. We challenge the assumed vulnerability of this system to changing climate and life-stock grazing impact, and hypothesize that the world's largest alpine arid ecosystem remained ecologically stable during the Last Glacial Maximum, over the mid-Holocene climatic optimum and under subsequent millennia characterised by mobile (nomadic) animal husbandry.

Material & Methods: We tested the hypothesis based on 1) extended field surveys, 2) vegetation records in transects with increasing distance from settlements, 3) quantitative analyses of plant life forms, 4) analyses of distributional ranges of plant species, and 5) the rates of endemism.

Main Results: The analyses of our vegetation records revealed that 1) the prevailing plant functional types are grazing resilient, and evidence for overgrazing is very limited. Only large-cushion plants and dwarf shrubs become increasingly rare around settlements, because they are uprooted for fuel. 2) The main set character species is present over the entire area spanning 350 mm of mean annual precipitation (MAP) in the East and 50 mm MAP in the West, of the vegetation records set cover a precipitation gradient between 50 and 350 mm/a, indicating the resilience of these species to precipitation changes. 3) About 83% of species have an altitudinal distribution range above 1000 m that is a proxy for resilience against temperature changes. 4) About 30% of the species are endemic, with 10 endemic genera, 5) including plate-shaped cushions as a unique plant life form.

Interpretations: These findings are in line with the palaeo-ecological proxies suggesting 3° C to 4° C lower temperatures during LGM summer leading to the conclusion that the alpine steppes remained ecologically stable and persistent during the Last Glacial Maximum. During the Mid-Holocene climatic optimum, forests could have locally replaced the alpine steppes, but not under the specific topographic conditions in the interior basins since these basins were then flooded and hence unsuitable for forest development.

Acknowledgements: German Research Council (DFG) and German Federal Ministry of Education and Research (BMBF) provided financial support to this project.



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Relative importance of temperature, nutrients and disturbance for the establishment of alien plants in sub-polar mountain regions

Ann Milbau (1), Jonas Lembrechts (2), Martin Nunez (3), Aníbal Pauchard (4) & Jonathan Lenoir (5)

1) Climate Impacts Research Centre, Department of Ecology and Environmental Science, Umeå University, Abisko Naturvetenskapliga Station, S-981 07 Abisko, Sweden
2) Research Group of Plant and Vegetation Ecology, Department of Biology, University of Antwerp, Universiteitsplein 1, B-2610 Wilrijk, Belgium
3) INIBIOMA Institute, Universidad Nacional del Comahue, Quintral 1250, 8400 S.C. de Bariloche, Argentina
4) Facultad de Ciencias Forestales, University of Concepción, Victoria 631, Barrio Universitario, Concepción, Chile
5) Jules Verne University of Picardie, UR 'Ecologie et Dynamique des Systèmes Anthropisés' (EDYSAN, FRE 3498 CNRS), 1 rue des Louvels, F-80037 Amiens Cedex 1, France

Correspondence: Ann Milbau, ann.milbau@emg.umu.se

Background: Arctic and alpine regions are currently amongst the least invaded in the world. However, the establishment of alien plants in these regions is increasing rapidly, which has been attributed to increasing human disturbances, climate warming, and increasing nutrient levels in these nutrient-poor environments.

Materials & Methods: In this study, we use a fully factorial design to test experimentally in two sub-polar mountain regions near Abisko, northern Sweden (68° N) and near Punta Arenas, southern Chile (53° S) how temperature, disturbance, nutrients, and their interactions influence the establishment and growth of six perennial alien plant species. Plots were established at 'Low', 'Mid' and 'High' elevations (reflecting a climatic gradient) at three mountains per region. At the lowest two elevations the species already sporadically occurred, whereas the species were absent from the highest elevation. Seeds of the study species were added to six replicate plots per altitude, each consisting of four subplots: control, fertilized (NPK), disturbed, fertilized + disturbed. We measured environmental variables (nutrient levels, soil temperature, soil moisture) and plant species composition, and we are following plant growth and survival in all plots over three years. Presented results are from the first growing season.

Main Results & Interpretations: Our results show that fertilization and disturbance significantly improved alien plant establishment, but that the strength of these effects depended on elevation. Fertilization improved establishment most at the 'Mid' and 'High' elevation sites, suggesting that especially at higher elevations low nutrient levels may be limiting the establishment of alien plants. Disturbance had a strong influence at 'Low' and 'Mid' altitudes, but almost no effect at 'High' altitudes, indicating that competition does not strongly limit invasion at high elevation sites. In general, establishment was highest in disturbed, fertilized plots on intermediate elevations. The observed patterns were similar across species, and between the different mountains.

Remarkably, all species could recruit at the 'High' sites in each region, thus above their current upper distributional limits. Although long-term survival still needs to be assessed, this suggests that cold temperatures may not be enough to prevent alien species from spreading to higher altitudes, or latitudes. We expect that an increased introduction of alien seeds, especially when combined with higher temperatures, more disturbance and increased nutrient levels, may rapidly result in high numbers of alien plants in precious arctic and alpine environments.

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Experimental plot in Abisko, northern Sweden, at alt. of 900 m. Upon installation, we disturbed half of the plot and, perpendicular to the disturbance, we fertilized another half of the plot. Each plot thus contains four subplots with the following treatments: (1) disturbed and unfertilized, (2) disturbed and fertilized, (3) undisturbed and fertilized, and (4) undisturbed and unfertilized (= control). In each subplot, seeds of six non-native species (*Achillea millefolium*, *Agrostis capillaris*, *Anthoxanthum odoratum*, *Medicago lupulina*, *Taraxacum officinale*, and *Trifolium repens*) were added at a low (5 seeds) or high (30 seeds) level of propagule pressure. White labels indicate where seeds have been added. We followed seed germination, seedling survival and seedling growth during two years. Photo: A. Milbau.

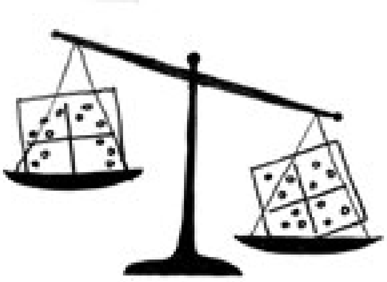
Milbau, A., Lembrechts, J., Nunez, M. & Pauchard, A. 2014. Relative importance of temperature, nutrients and disturbance for the establishment of alien plants in sub-polar mountain regions. In: Mucina, L., Price, J.N. & Kalwij, J.M. (eds.), *Biodiversity and vegetation: patterns, processes, conservation*, p. 150. Kwongan Foundation, Perth, AU.

Guidelines for the evaluation of ordination techniques

Peter R. Minchin

Biological Sciences, Southern Illinois University Edwardsville, Edwardsville, IL 62026, USA

Correspondence: Peter Minchin, pminchi@siue.edu



Background & Aim: In the early days of the development of ordination, it was considered sufficient to apply a method to a few data sets and assess performance by the "ecological interpretability" of the results. Such an approach is inadequate because a precise specification of what would constitute an effective or accurate result is lacking. In order to quantify performance, two things are needed: a clearly defined objective and explicit criteria for assessing the degree to which that objective has been met. A common objective for ordination is to reveal community trends that result from the effects of underlying ecological factors (e.g., environmental conditions, resource levels). Constrained ordination has a different objective: to summarize that fraction of the community variation which is related to a specified set of measured ecological factors. A useful approach, developed more than 40 years ago (Swan 1970; Austin & Noy-Meir 1971), is to use simulated community data, derived from explicit models of species response to ecological factors, to evaluate ordination performance. Ordination results can be quantitatively assessed relative to the known structure of the generating model using Procrustes analysis (Fasham 1977). The performance of constrained ordination can be evaluated by incorporating an explicit model of how the constraining variables are related to the generating factors. The simulation approach has several advantages, including the ability to test how ecologically plausible variations in properties of the generating model affect ordination performance, the assessment of consistency of performance over replicate models with the same underlying structure, and the ability to explore the effects of the statistical distribution of the data on performance. Unfortunately, the potential of the approach has not been fully realized. Some applications have used inadequate simulation designs that severely limit the generality of their conclusions, while some recent studies revert to the old practice of simply applying the proposed methods to several data sets and subjectively evaluating the results. It is always possible to engineer a simple community model or select a real data set on which one's favourite ordination method appears to perform well but a thorough evaluation should include a wide spectrum of model types that vary in properties known to affect performance (Minchin 1987).

Materials & Methods: As an example, I demonstrate a replicated factorial simulation experiment that evaluates the performance of a range of currently popular ordination methods (non-metric multidimensional scaling, detrended correspondence analysis, correspondence analysis, constrained correspondence analysis, principal components analysis and redundancy analysis on Hellinger-transformed data) and two so-called "model-based" methods, latent variable models and Gaussian ordination. The factors varied include beta diversity, relative beta diversity ("shape" of the simulated ecological space), mean alpha diversity, sampling density and pattern, shape of species' response surfaces, trends in community properties (e.g., alpha diversity, total abundance), and the frequency distribution of the data (error or noise distribution).

Results & Interpretation: The results show that non-metric multidimensional scaling, with an appropriate choice of data standardization and dissimilarity measure, outperforms the other methods, showing remarkable robustness to variations in the generating model. Those proposing new methods for community analysis should thoroughly assess their performance against existing methods using replicated simulation experiments that span the range of data properties likely to be encountered in applications.

Acknowledgements: Among people that have greatly influenced my thinking about community analysis and the evaluation of methods are David Goodall, Mike Austin, Dan Faith, Dave Roberts, and Jari Oksanen. I thank them all for their insightful contributions to the literature and many hours of useful and enjoyable discussions over the years.

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Do invasives grow better? Testing the Growth Rate Hypothesis of a native herb and its invasive congener

Vanessa Minden & Lisann de Jong

Landscape Ecology Group, Institute of Biology and Environmental Sciences, University of Oldenburg, D-26126 Oldenburg, Germany

Correspondence: Vanessa Minden, vanessa.minden@uni-oldenburg.de

Background & Aim: The Growth Rate Hypothesis (GRH; Sterner & Elser 2002) states that increasing growth rates requires more nitrogen (N) and phosphorus (P) relative to carbon (C) and more P relative to N, resulting in higher C:P and N:P ratios in slow-growing individuals and vice versa. Here, we test the applicability of the GRH with two congeneric species from the genus *Impatiens*, from which one is native to Central Europe (*I. noli-tangere*), while the other is considered invasive (*I. parviflora*). We ask if the growth rates of the two species differ along a gradient of nitrogen and phosphorus availability, and if a higher growth rate translates into decreased C:P and N:P ratios. Given that *I. parviflora* is considered a highly invasive species which outperforms *I. noli-tangere* at natural sites, we expect the invasive species to show a positive correlation between increasing nutrient availability and growth rate, whereas the response of the native species could be unimodal, with decreasing growth rates at both ends of the nutrient gradients.

Figure 1. *Impatiens noli-tangere* L. (Touch-me-not Balsam)
Source: http://babij.blox.pl/2008/01/Impatiens-parviflora-niecierpek-drobnokwiatowy.html

Figure 2. *Impatiens parviflora* DC. (Small Balsam)
Source: http://sophy.u-3mrs.fr/photohtm/SI1311.HTM

Materials & Methods: We conducted a greenhouse experiment with six N- and P- treatments, representing two gradients from low to high N-, and P-availability. Each of the treatments included ten replicates for each species (N1-N6, and P1-P6, respectively). We harvested aboveground and belowground biomass and determined C, N and P of each plant organ (leaves, stems and roots).

Main Results & Interpretations: Growth rates for both species were higher along the phosphorus gradient than along the nitrogen gradient, indicating that the growth rate of a species is indeed more dependent on phosphorus than on nitrogen. The response of *I. noli-tangere* was unimodal, with lowest values at both extremes of the gradients. Our expectation of faster growth of *I. parviflora* relative to its native congener was not confirmed. However, we established that *I. noli-tangere* achieved maximum growth earlier than *I. parviflora*. This indicates that the utilization of higher nutrient availability at a site is greater in the invasive *I. parviflora* that might contribute to its success over its native congener.

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Spatial models of biodiversity are improved by biotic interactions

Heidi K. Mod (1), Peter C. le Roux (1,2), Antoine Guisan (3,4) & Miska Luoto (1)

1) Department of Geosciences and Geography, University of Helsinki, Gustaf Hällstöminkatu 2a, FI-00014 University of Helsinki, Finland
2) Department of Plant Science, University of Pretoria, Private Bag X20, Pretoria 0002, South Africa
3) Department of Ecology and Evolution, University of Lausanne, Biophore, CH-1015 Lausanne, Switzerland
4) Institute of Earth Sciences, University of Lausanne, Geopolis, CH-1015 Lausanne, Switzerland

Correspondence: Heidi K. Mod, heidi.mod@helsinki.fi

Background: Biotic interactions have been demonstrated to shape the distribution of species both in observational and experimental studies. However, most species richness models, predicting current or future biodiversity, do not consider inter-specific interactions. Explicitly accounting for biotic interactions in these models is thus expected to release a limitation on predictions of spatial distribution of species richness, improving models of biodiversity.

Methods: We tested this hypothesis by incorporating key biotic variables (the cover of three dominant arctic-alpine plant species) into the two methodologically divergent species richness modelling frameworks: stacked species distribution models (SSDM) and direct richness modelling (DRM). Both modelling frameworks were repeated for vascular plants, bryophytes and lichens, using an ensemble of generalized linear models (GLM), generalized additive models (GAM) and generalized boosting method (GBM). Predictions from models including biotic interactions were then compared to the predictions from models based on climatic and abiotic data only.

Main Results & Interpretations: Including plant-plant interactions consistently and significantly lowered bias in species richness predictions and increased predictive power for independent evaluation data (measured by R^2, correlation, AUC and TSS), irrespective of the modelling framework used. Further, the same improvement was found for each of the three ecologically and evolutionary distinct taxonomic groups. Thus, biotic interactions consistently improved biodiversity predictions in both statistical frameworks and all three taxa examined. The current global biodiversity crisis necessitates accurate predictions of how changes in biotic and abiotic conditions will impact species richness patterns. We demonstrate that predictions of the spatial distribution of species richness can be improved by explicitly accounting for biotic interactions. Future biodiversity forecasts under climate change should therefore benefit from the incorporation of inter-specific interactions into species richness models.

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Figure 1. *Empetrum nigrum* subsp. *hermaphroditum* (*Ericaceae*), Kilpisjärvi, Finland. Photo: P.O. Niittynen.

Figure 2. The summit of Saana fjell covered in fog, Kilpisjärvi, Finland. Photo: A.K.J. Niskanen.

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Woody plant functional group richness drives herbaceous plant and herbivorous invertebrate trait variability

Melinda L. Moir (1), Jodi N. Price (1), Mei Chen Leng (1), Norman Mason (2), Rachel J. Standish (1), Michael Perring (1) & Richard Hobbs (1)

1) School of Plant Biology, The University of Western Australia, 35 Stirling Hwy, Crawley WA 6009, Perth, Australia

2) Landcare Research, Hamilton, 3240, New Zealand

Correspondence: Melinda Moir, melinda.moir@uwa.edu.au

Background & Aim: Plant functional traits can respond to environmental gradients through species turnover and by within-species plasticity (intraspecific variation). In woody communities, herbaceous trait variability is likely to respond to the environmental conditions beneath the canopy, either due to mean changes when compared to reduced canopy cover (e.g. reduced light availability), or through changes in heterogeneity of these variables. In turn, herbivorous insect traits can respond to plant trait changes (e.g., Moretti et al. 2013). We explored the influence of woody plant functional group richness on understory plant and invertebrate communities by investigating how traits vary within-species, and at the community level, by examining changes in functional composition and diversity of understorey plants and invertebrates.

Materials & Methods: At a large-scale restoration and ecosystem services experiment in southwestern Australia, we examined herbaceous trait variability in unplanted controls, in monocultures, and in mixtures of woody plants (0, 1, 4 and 8 species of woody plants, respectively) that differed in functional group richness. We collected plant community data, plant trait data, and environmental data. We also sampled plant-dwelling invertebrates and recorded traits of herbivorous insects that encompassed feeding strategy and dispersal. These traits were expected to be influenced by the plant traits (see Moretti et al. 2013), and important indicators of whether the insects could disperse to the restored plot and, if they persisted (as indicated by feeding and egg-laying strategies).

Results & Conclusions: Both the mean and variability in soil moisture and light availability differed among the experimental treatments, and this impacted on herbaceous plant community functional composition. For example, increased shading in monocultures and in the four-species mixtures was associated with an increase in community-weighted mean specific leaf area (SLA). Leaf dry matter content (LDMC) was reduced in monocultures that had greater soil moisture than mixtures. Plant trait variation was partly attributable to intraspecific plasticity in relation to the changed environmental conditions, and partly due to species turnover. As expected, environmental factors had little direct influence on herbivorous insect traits, but herbivore traits responded to vegetation structure and trait range, as has been shown previously for grasshoppers in grasslands (Van der Plas et al. 2012). In treatments with higher mean SLA, herbivorous invertebrates tended to respond by decreasing dispersal potential (as measured by wing and tibia length). Hence, insects in the woody plant treatments were less mobile than in unplanted treatments. Further, insects associated with plots with greater mean SLA and lower LDMC tended to be larger, suggesting that these herbivorous insects may have an associated trade-off between dispersal capability and growth depending on the experimental treatment. Overstorey functional characteristics affect herbaceous functional trait variability, with flow-on indirect effects on the herbivorous invertebrate fauna.

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The puna vegetation of Moquegua, South Peru: Chasmophytic communities and grasslands

Daniel B. Montesinos Tubée (1), Antoine M. Cleef (2) & Karlè V. Sýkora (1)

1) Environmental Sciences, Nature Conservation and Plant Ecology Group, Wageningen University, Droevendaalsesteeg 3a, NL-6700 AA Wageningen, The Netherlands

2) University of Amsterdam, Institute for Biodiversity and Ecosystem Dynamics (IBED), P.O. Box 94248, NL-1090 GE Amsterdam, The Netherlands

Correspondence:
Daniel B. Montesinos Tubée,
daniel.montesinos@wur.nl

Background & Aims: The phytosociology and ecology of puna vegetation in the Moquegua region (South Peru) is still poorly known, despite high endemism and diverse vegetation that deserves conservation through establishment of nature reserves. This contribution is aimed at filling the gap in our knowledge of the vegetation patterns in this region.

Materials & Methods: 166 phytosociological relevés at altitudes spanning 3750–4500 m in northern Moquegua (south Peru) were made. The study area is characterized by pluviseasonal bioclimate with prevalent summer rainfall. In each relevé soil samples were taken and analysed for different basic soil physico-chemical characteristics. Other environmental parameters were: altitude, soil depth, inclination, rock percentage, vegetation cover (including % bare soil), and cover of leaf litter. TWINSPAN (Hill 1979) was used for classification of vegetation and PC-ORD (McCune & Mefford 1999) was used to construct a dendrogram based on the Bray–Curtis resemblance. Detrended correspondence analysis, principal components analysis, and canonical correlation analysis as implemented in CANOCO 4.5 (ter Braak & Šmilauer 2002) were adopted to explore the relationship between the species composition and environmental variables.

Main Results & Interpretations: 218 vascular species belonging to 131 genera and 52 families were found in the area. The most diverse families were *Asteraceae, Caryophyllaceae* and *Poaceae,* followed by *Fabaceae* and *Brassicaceae*. The puna vegetation of Moquegua hosts some rare, endangered and/or protected plant species in Peru. Three main vegetation types were distinguished in the study area, such as (1) chasmophyte-rich vegetation composed of a great diversity of shrubs, subshrubs and annuals, (2) *Puya raimondii* patches characterized by considerable shrub species richness, grasses and herbs, and (3) extensive puna grasslands, influenced by grazing.

Several new plant communities were described; their value for the protection of endemic species analysed and the importance of the need for conservation of the plant communities hosting *Puya raimondii* – the largest bromeliad in the world, was highlighted. This endemic species occurs in a handful of localities in Moquegua, between 3800 and 4400 m (Montesinos 2011) and has been classified as endangered by the IUCN (Lambe 2009). Apart from its scientific importance, the study is of importance to nature conservation as the area is very rich in both native and endemic species.

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EuroVegChecklist: a *post mortem*

Ladislav Mucina (1,2), Helga Bültmann (3), Klaus Dierßen (4), Jean-Paul Theurillat (5,6), Thomas Raus (7), Andraž Čarni (8), Kateřina Šumberová (9), Wolfgang Willner (10), Jürgen Dengler (11,12), Rosario Gavilán García (13), Milan Chytrý (14), Michal Hájek (9), Romeo Di Pietro (15), Dmytro Iakushenko (16,17), Jens Pallas (18), Frederikus J.A. Daniëls (3), Erwin Bergmeier (19), Arnoldo Santos Guerra (20), Nikolai Ermakov (21), Milan Valachovič (22), Joop H.J. Schaminée (23,24), Tatiana Lysenko (25), Yakiv P. Didukh (26), Sandro Pignatti (27), John S. Rodwell (28), Jorge Capelo (29), Heinrich E. Weber (30), Ayzik Solomeshch (31), Panayotis Dimopoulos (32), Carlos Aguiar (33), Helmut Freitag (34), Stephan M. Hennekens (35) & Lubomír Tichý (14)

Correspondence: Laco Mucina,
Laco.Mucina@uwa.edu.au

Background & Aims: The EuroVegChecklist is a long-term voluntary project shared by 33 vegetation scientists from Europe, USA, Asia and Australia. The aim of the project is to review the status of the syntaxonomic system of Europe+ (incl. Atlantic and Arctic islands groups, Cyprus, Caucasus and Greenland) at the level of alliances, orders and classes. Syntaxonomic classification is widely used for vegetation survey in Europe (and beyond). The long history of its use has produced many concepts and names of vegetation units that need to be revised and integrated into a single classification system. The time has come to collate this information, clarify the concepts, and create the first, comprehensive syntaxonomic vegetation system for biotic communities, dominated by vascular plants, bryophytes, lichens and algae. The aims of this project were to (1) present a new, hierarchical syntaxonomic system of alliances, orders, classes of the Braun-Blanquet syntaxonomy for vascular plant, bryophyte, lichen and algal communities of European vegetation, (2) to characterize all accepted syntaxonomic concepts in ecological and geographical terms, (3) to link all available synonyms to these concepts, and (4) to provide a list of diagnostic species for all classes of European vegetation.

Methods of Data Compilation: We reviewed about 10 000 bibliographic sources to compile the syntaxonomic systems of classes, orders and alliances, and species lists characterizing all classes. All known syntaxonomic concepts were critically evaluated by experts and their names revised according to the International Code of Phytosociological Nomenclature.

Results: The newly compiled EuroVegChecklist is a syntaxonomic conspectus that consists of systems of classes, orders, and alliances for the communities dominated by vascular plants (EVC1), bryophytes and lichens (EVC2), and algae (EVC3). EVC1 comprises 110 classes, 300 orders and 1088 alliances (with 4067 synonyms for all ranks); EVC2 27 classes, 53 orders and 137 alliances (with 410 synonyms for all ranks); EVC3 13 classes, 24 orders and 53 alliances (with 188 synonyms for all ranks). 13 289 diagnostic taxa were assigned to classes of EVC1, 2099 to classes of EVC2 and 346 to classes of EVC3. Information on each accepted syntaxonomic concept was made accessible through the software tool EuroVegBrowser. An expert system for an automatic identification of class membership based on the proportion of character species was also developed.

Conclusions: The Conspectus is the first comprehensive and critical account of syntaxa synthesizing more than 100 years of classification effort of European phytosociologists. It aims to stabilize the nomenclature of the syntaxa and of classification concepts for practical uses such as calibration of habitat classification used by the European Union, standardization of terminology for environmental assessment studies, management and conservation of nature areas, landscape planning and education.

Outlook: The new syntaxonomic is poised to serve as a core of several major tools of European Union legislature in the field management and conservation of natural resources. EuroVegChecklist, although static in terms of definite imminent printed publication, will remain a living, developing body of knowledge open to improvement. Several web-based applications featuring the products from the EuroVegChecklist are in the pipeline.

Mucina L. et al. 2014. EuroVegChecklist: a *post mortem*. In: Mucina, L., Price, J.N. & Kalwij, J.M. (eds.), *Biodiversity and vegetation: patterns, processes, conservation*, pp. 156-158. Kwongan Foundation, Perth, AU.

Affiliations of the authors:

1) Iluka Chair in Vegetation Science and Biogeography, School of Plant Biology M084, The University of Western Australia, 35 Stirling Highway, Crawley, WA 6009, Perth, Australia

2) Department of Geography and Environmental Studies, Stellenbosch University, Private Bag X1, Matieland 7602, Stellenbosch, South Africa

3) Institut für Biologie und Biotechnologie der Pflanzen, Universität Münster, Schlossplatz 8, D-48143 Münster, Germany

4) Institut für Ökosystemforschung, Christian-Albrechts-Universität Kiel, Olshausenstraße 75, D-24118 Kiel, Germany

5) Centre Alpien de Phytogéographie, Fondation J.-M. Aubert, Case postale 71, CH-1938 Champex-Lac, Switzerland

6) Section of Biology, University of Geneva, Case postale 60, CH-1292 Chambésy, Switzerland

7) Botanischer Garten und Botanisches Museum Berlin-Dahlem, Freie Universität Berlin, Königin-Luise-Str. 6-8, D-14195 Berlin, Germany

8) Institute of Biology, Scientific Research Center of the Slovenian Academy of Sciences and Arts, Novi trg 2, SI-1001 Ljubljana, Slovenia

9) Department of Vegetation Ecology, Institute of Botany, Academy of Science of the Czech Republic, Lidická 25/27, CZ-602 00 Brno, Czech Republic

10) VINCA – Vienna Institute for Nature Conservation and Analyses, Giessergasse 6/7, A-1090 Wien, Austria

11) Biodiversity, Evolution and Ecology of Plants (BEE), Biocentre Klein Flottbek and Botanical Garden, University of Hamburg, Ohnhorststr. 18, D-22609 Hamburg, Germany

12) Disturbance Ecology, Bayreuth Centre of Ecology and Environmental Research (BayCEER), University of Bayreuth, Universitätsstr. 30, D-95447 Bayreuth, Germany

13) Departamento de Biología Vegetal II, Facultad de Farmacia, Universidad Complutense, E-28040 Madrid, Spain

14) Department of Botany and Zoology, Masaryk University, Kotlářská 2, CZ-61137 Brno, Czech Republic

15) Dipartimento DATA, Sez. Paesaggio e Ambiente, Università di Roma La Sapienza, Via Flaminia 72, I-00196, Roma, Italy

16) Wydział Nauk Biologicznych, Uniwersytet Zielonogórski, ul. Z. Szafrana 1, 65-516 Zielona Góra, Poland

17) Rivne Nature Reserve, Dubky-Rozvylka, 34503 Sarny, Ukraine

18) Kanalstraße 81, D-48147 Münster, Germany

19) Albrecht-von-Haller- Institut für Pflanzenwissenschaften, Georg-August-Universität Göttingen, Untere Karspüle 2, D-37073 Göttingen, Germany

20) Unidad de Botánica, Jardín de Aclimatación de La Orotava-ICIA, C. Retama 2, E-38400 Puerto de La Cruz, Tenerife, Islas Canarias, Spain

21) Central Siberian Botanical Garden, Russian Academy of Sciences, Zolotodolinskaya 101, Novosibirsk 630090, Russian Federation

22) Institute of Botany, Slovak Academy of Sciences, Dúbravská cesta 9, SK-845 23 Bratislava, Slovakia

23) Alterra and Wageningen University, P.O. Box 14, 6700 AA Wageningen, The Netherlands

24) Institute for Water and Wetland Research, Radboud University Nijmegen, P.O. Box 8010, NL-6500 GL Nijmegen, The Netherlands

25) Department of Problems of Phytodiversity, Institute of Ecology of the Volga River Basin of the Russian Academy of Sciences, RU-445003 Togliatti, Russian Federation

26) M.G. Kholodny Institute of Botany, National Academy of Sciences of Ukraine, 2, Tereschenkivska str, 01601 Kyiv, Ukraine

27) Dipartimento di Biologia Ambientale, Università di Roma La Sapienza, Città Universitaria, I-00165 Roma, Italy

28) 7 Derwent Road, Lancaster LA1 3ES, United Kingdom

29) Instituto Nacional de Investigação Agrária e Veterinária, Av. da República, Quinta do Marquês, 2780-159 Oeiras, Portugal

30) Am Buehner Bach 12, D-49565 Bramsche, Germany

31) Department of Plant Sciences, University of California Davis, One Shields Ave, Davis, CA 95616, USA

32) Faculty of Environmental and Natural Resources Management, University of Patras, G. Seferi 2, GR-30100 Agrinio, Greece

33) CIMO-Centro de Investigação de Montanha, Instituto Politécnico de Bragança, Apartado 1112, 5301-855 Bragança, Portugal

34) Institute of Biology, University of Kassel, Heinrich-Plett-Str. 40, D-34132, Kassel, Germany

35) Alterra, Wageningen UR, Droevendaalsesteeg 3, NL-6708 PB Wageningen, The Netherlands

Climatic and spatial controls of woody plant species community composition in the tropical rainforests across Uganda

Edward N. Mwavu & Gerald Eilu

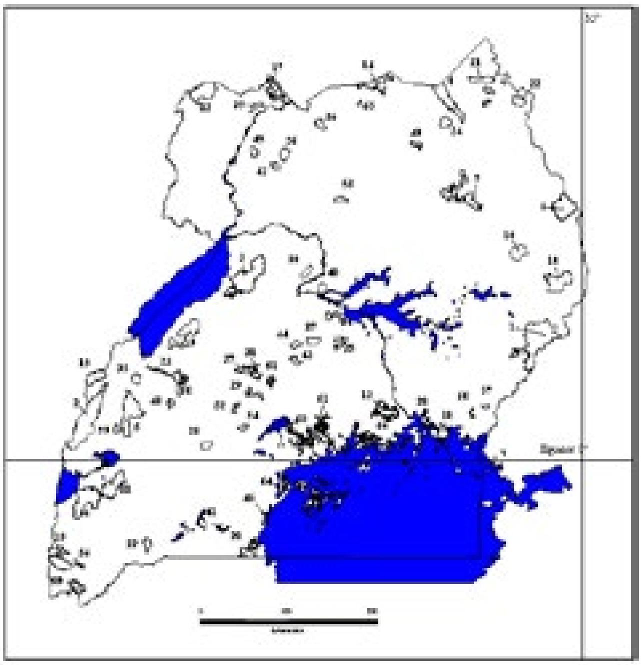
Department of Forestry Biodiversity & Tourism, Makerere University, P.O. Box 7062, Kampala, Uganda

Correspondence: Edward Nector Mwavu; Edward.Mwavu@gmail.com

Background & Aim: Understanding how biodiversity is distributed across landscapes is one of the central focuses of ecology and biodiversity conservation; and is fundamental to regional conservation planning (Whittaker et al. 2001; Ohmann et al. 2007). In this study we identify and quantify the relative contribution of climatic and spatial factors to the variation in woody species composition among 60 tropical forests of Uganda with a view to distinguishing between climatically driven and spatially structured patterns.

Methods: We used woody species (i.e. trees, shrubs and lianas) community composition data comprising 961 species from biodiversity surveys for 60 tropical forests across Uganda, coupled with corresponding information on 12 climate and 7 spatial variables. Patterns of woody species composition for the forests were analysed using detrended correspondence analysis and canonical correspondence analysis ordinations. We identified and quantified the relative contribution of climatic and spatial factors to the variation in species composition; and explored their patterns between the forests using variation partitioning.

Main Results & Conclusions: Climate and spatial variables contributed significantly to the variation in species composition between the forests; with pure climate contributing the highest portion in all cases. The amount of variation explained based on statistically significant variables varied among the woody species groups, being higher for trees only (27.0%), followed by total woody (21.8%), and lianas only (18.8%). In total climate and spatial variables together accounted for 48.5%, 51.7%, and 47.1% of the variation in total woody, trees only, and lianas only community composition respectively among the forests. The dominant and statistically significant explanatory variables for variation in species composition were different for trees and lianas, except for latitude that was common for both. Plant species community composition was mainly explained by climatic factors associated with water-energy, and spatial factors (i.e. latitude and longitude). However, their relative contribution varies with the plant growth form considered being higher for trees than for lianas. Our results also to a great extent offer credence to the hypothesis that the distribution of plant species and species composition of different tropical forests is patchy and environmentally determined. The relatively large unexplained variation in community species composition indicate that several factors such as availability of soil nutrients and landscape fragmentation as a result of anthropogenic factors could also explain assembly patterns in the forests.



Map of Uganda showing the studied forests marked with numbers 1-64. Four of the forests were not included in the analysis

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Vegetation degradation and eco-physiological traits in two *Allium* species in Mongolian desert steppe

Dai Nagamatsu (1), Takuyoshi Udagawa (1), Takehiko Ito (2) & Yunxiang Cheng (3)

1) Faculty of Regional Sciences, Tottori University, 680 8551 Tottori, Japan

2) Arid land Research Institute, Tottori University, 680 0001 Tottori, Japan

3) College of Pastoral Agriculture Science and Technology, Lanzhou University, Gansu, P.R. China

Correspondence: Dai Nagamatsu, daina@rs.tottori-u.ac.jp

Background & Aim: The occurrence of dust storms in inland arid regions of East Asia is a serious environmental problem. Vegetation structure of the Mongolian desert steppe may have a direct influence on mitigating this problem. We studied the present vegetation structure and eco-physiological traits of the dominating species in the Mongolian desert steppe in order to get insight on adaptive strategies of these species and their distribution pattern in the dust-rich desertic environments.

Materials & Methods: We surveyed vegetation structure in August 2012 in a region spanning Uraanbataar to Zamyn-Uud in the southeast part of Mongolia. Each survey plot was located at a large distance from the city, at every 60 km interval along a transect. In Mongolian grasslands, the effects of livestock on vegetation cover is large, so we selected survey plots very little impacted by grazing. In total, 18 survey plots were established. In every survey plot, species composition and coverage were recorded. Size parameters of two *Allium* species that were dominating these steppes were also measured. We collected the *Allium* samples for quantitative analyses of nitrogen and water use efficiency.

Main Results & Discussions: Seventy-five plant species were found in 18 survey plots containing five *Allium* species. Based on Hilbig (1995), the survey plots were classified into five vegetation types, such as the mountain steppe, grass steppe, desert steppe, shrub desert, and semi-desert. In the plots located in the north of the studied area, *Stipa* species were dominating. The importance of *Allium* species increased in a southward direction (along a gradient of decreasing rainfall). *Allium polyrhizum* and *A. mongolicum* occurred in 13 and 10 survey plots, respectively. *A. polyrhizum* was the larger species, however, the number of flowers in each individual was much higher in *A. mongolicum*. Number of flowers in *A. polyrhizum* increased as rainfall increased. The importance of vegetative/seed reproduction in life histories may differ in these two species. In both species, allocation to the root system became large as rainfall decreased. Specific leaf area significantly decreased in *A. polyrhizum* as rainfall decreased but not so in *A. mongolicum*. Only in *A. polyrhizum,* both root nitrogen content and water-use efficiency increased as the rainfall decreased. It seems that nitrogen partitioning in *A. polyrhizum* is more flexible than in *A. mongolicum* along rainfall gradients. *A. mongolicum* leaves had lower SLA than those of *A. polyrhizum*. *A. mongolicum* is more strongly tolerant to drought than *A. polyrhizum*. These characteristics may influence the distribution and dominance of the two *Allium* species in Mongolian desert steppe. Wide distribution of *A. polyrhizum* based on its flexibility of biomass partition may be important for dust control in Mongolian desert steppe.

Mongolian desert steppe dominated by *Allium polyrhizum* (white) and *A. mongolicum* (pink), near Sainshand, southeastern Mongolia. Photo: D. Nagamatsu.

Acknowledgements: This work is supported by the Project Asian Dust, assessment and control of dust emission in degraded drylands of East Asia, Tottori University, Japan.

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Altitudinal species richness patterns in three mountain regions of Iran

Alireza Naqinezhad (1), Hamid Gholizadeh (1), Rahman Dehghani (1), Aliakbar Daneshi (1), Jürgen Dengler (2,3) & Jens Oldeland (4)

1) Department of Biology, Faculty of Basic Sciences, University of Mazandaran, Babolsar, P.O. Box 47416-95447, Mazandaran, Iran

2) Disturbance Ecology, Bayreuth Center of Ecology and Environmental Research (BayCEER), University of Bayreuth, Universitätsstr. 30, D-95447 Bayreuth, Germany

3) Synthesis Centre (sDiv), German Centre for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig, Deutscher Platz 5e, D-04103 Leipzig, Germany

4) Biodiversity, Evolution and Ecology of Plants, Biocenter Klein Flottbek and Botanical Garden, University of Hamburg, Ohnhorststr. 18, D-22609 Hamburg, Germany

Correspondence:
Alireza Naqinezhad,
anaqinezhad@gmail.com

Background & Aims: Elevational gradients serve as baselines for comparison of population declines, range shifts and extinction risks. The majority of studies show a hump-back shaped model of altitudinal species richness patterns of plants. Climate, area, mid-domain effect and ecotone effects are considered as the main underlying predictors for these patterns. Iran is a mountainous country including different physiognomic formations ranging from the very wet Hyrcanian forests in the north to the hot deserts in Central Iran. This study is aimed at investigating species richness patterns along altitudinal gradients in several montane regions of Iran and searching for possible driving factors for these patterns.

Materials & Methods: Species richness patterns were investigated along altitudinal gradients in three mountain ecosystems, namely in a deciduous Hyrcanian forest in northern Iran (two transects), Zagros oak woodlands in western Iran (three transects), and steppic montane vegetation of the Central Plateau of Iran (three transects). The transects were sampled for vascular plant species richness using a uniform sampling method with 100 m altitudinal intervals from the valley bottom to a local mountain top. We sampled 96 plots of 400 m^2 (ranging from 300–2000 m of alt. for the Hyrcanian forests, 48 plots of 100 m^2 for the oak woodlands (ranging from 1100–2900 m of alt.), and 54 plots of 25 m^2 for the steppic vegetation in Shirkuh Mountains of Central Plateau of Iran (ranging from 2250 to 4075 m of altitude). All data were analysed using simple and polynomial regression analyses in order to reveal the main pattern of species distribution along the altitude.

Main Results & Interpretations: In the deciduous Hyrcanian forest, species richness did not show any significant relationship with altitude. The presence of a species-rich forest-to-steppe ecotone in the mountainous area of the Hyrcanian forest may be the main reason underpinning this pattern as this ecotone plays a role of a source of diversity at higher altitudes. There was a hump-back relationship detected of the species richness patterns in the Zagros oak woodland showing an altitudinal peak around 2100 m – a finding corroborated by many other literature sources publications (see McCain & Grytness 2010). A monotonic decrease of species richness along the altitudinal gradient was observed in the steppic vegetation. Species richness data for the altitudes lower than 2200 m is lacking in this mountain region. Nevertheless, previous studies in similar steppic ecosystems on the southern macroslopes of the Alborz range (altitudinal range of 1000–4000 m; Mahdavi et al. 2013) revealed the occurrence of a hump-back pattern with a peak at altitudes 1800–1900 m.

Figure 1. Hyrcanian deciduous forest of northern Iran.
Photo: A. Naqinezhad.

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Assessing vegetation rehabilitation using the BioCondition framework: lessons from an open-cut coal mine and a coral atoll recovering after guano mining

Victor John Neldner & M.R. Ngugi

Queensland Herbarium, Department of Science, Information Technology, Innovation and the Arts, Brisbane Botanic Gardens, Mt Coot-tha Road, Toowong, Brisbane QLD 4066, Australia

Correspondence: John Neldner, john.neldner@science.dsitia.qld.gov.au

Background & Aim: There is a need to provide defensible and objective methods of rating vegetation restoration performance. A quantitative 'scorecard' approach based on a number of key structural and floristic attributes (Hobbs & Norton 1996) is recommended. A scorecard provides both mine regulators and managers with a robust way of assessing rehabilitation for regulatory closure criteria requirements and community expectations for mine restoration. In Queensland, the BioCondition assessment framework (Eyre et al. 2011a) has been used for monitoring native vegetation condition and evaluating equivalency for biodiversity offsets. The framework requires the development of a benchmark (Eyre et al. 2011b) against which the target sites are compared and scored. For natural vegetation, this benchmark is usually derived from equivalent reference sites of the particular regional ecosystem that occupied the targeted site. In mining situations, the revegetation outcome is frequently not as specific as a particular regional ecosystem, but is defined in general terms in the mining approval and conditions. For Meandu mine, the requirement was to establish 'a self-sustaining native ecosystem'.

We applied the BioCondition framework to mining rehabilitation to assess its robustness and utility for this purpose. The aim was to provide simple tools to assist land managers and regulators to assess the condition of rehabilitated sites against suitable benchmarks.

Materials & Methods: The case studies were undertaken at Meandu mine, an open-cut coal mine in Southeast Queensland, approximately 170 km NW of Brisbane, and Lady Elliot Island the southernmost coral cay on the Great Barrier Reef, 80 km NE of Bundaberg. At Meandu mine, the BioCondition framework was applied to 25 permanent sites located in rehabilitated vegetation of 10 different ages, ranging from 3 to 20 years. Each site was based around a 50 m centre line plot, with basal area, stem density and cover attributes recorded for woody species two metres either side. Species richness for life forms was recorded from a 50 m x 14 m plot. A similar methodology was applied to Lady Elliot Island vegetation that carries a legacy of destructive guano mining activities in the 1860s, and subsequent revegetation efforts since 1969.

Main Results & Interpretations: Applying any assessment framework to the mining rehabilitation context faces two major challenges, such as: 1) what benchmark should be used, and 2) what is a satisfactory condition score for various ages of rehabilitation (Hobbs & Norton 1996). For novel ecosystems to be accepted as appropriate rehabilitation goals, all stakeholders would have to accept such an approach (Doley & Audet 2013). The approach taken here was to have one benchmark for rehabilitation that represents a conceptual aspirational model after an extended period of rehabilitation, i.e. equivalent to the pre-disturbance vegetation (Doley and Audet 2013). The maximum BioCondition score for rehabilitated sites at Meandu mine was capped at 65 because a) landscape attribute scores (up to 20) were not included, and b) no sites scored any values for large trees (maximum score of 15). The scores were plotted in a spider web diagram that demonstrated to all stakeholders the performance of the rehabilitation relative to the benchmark for each condition attribute.

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30 yrs of succession in an Estonian calcareous grassland: how does time and landuse history shape plant community functional composition?

Lena Neuenkamp, Robert J. Lewis & Martin Zobel

Department of Botany, Institute of Ecology and Earth Science, University of Tartu, EE-51005 Tartu, Estonia

Correspondence: Lena Neuenkamp, lena@ut.ee

Background & Aims: Plant traits that respond consistently to environmental changes are termed 'plant functional response traits'. They are useful for linking observed changes in the community to the environment. At local- and regional-scales, landuse change is nowadays the most important driver altering environmental conditions within grassland communities, particularly within Europe. Adapted to medium level disturbances present under traditional farming activities, European temperate semi-natural grasslands suffer from species loss when facing agricultural intensification as well as abandonment. In favourable conditions, these grasslands are among the Worlds most species rich habitats at small spatial scales, and therefore there is an urgent need to understand the patterns and processes underlying plant compositional changes during succession.

Materials & Methods: In our study, we investigated plant community functional composition of calcareous grasslands in western Estonia at a local scale with grasslands being foremost prone to abandonment. We examined temporal shifts in functional response traits and functional diversity metrics using a series of null models, multivariate and regression analyses. The goal of our study was to link detected temporal shifts in functional response traits and diversity metrics to changes in land use across time. In addition to commonly used plant fundtional traits (e.g. SLA, plant height) we included a direct measure of dispersal distance and an index of mycorrhizal status in our set of traits. Measuring dispersal distances we aim to investigate patterns of dispersal abilities, and identify species most threatened by landuse abandonment, while mycorrhizal status measures should shed light on the dynamics of plant-fungal interaction under changing landuse.

Main Results: Our preliminary results of functional diversity metrics show patterns of trait divergence under traditional landuse management (i.e. grazing) supporting the concept of limiting similarity. Cessation of landuse seems to promote trait convergence indicating habitat filtering. Abandonment also resulted in higher community weighted means of dispersal distances and lower mycorrhizal status presumably reflecting plant compositional change towards a higher proportion of grasses. We expect results to reveal successional patterns of functional plant community composition as well as their sensitivity to landuse. With these findings we finally aim to formulate implications for grassland restoration.

Acknowledgements: This work is supported by the European Union through the European Regional Development Fund (the Centre of Excellence FIBIR), the European Structural Assistance, the European Social Fund and by the University of Tartu through grant IUT 20-28 and the Doctoral School of Life Science and Ecology.

Early-, mid- and late-succession stages of an alvar grassland after abandonment from grazing. A. Early successional stage: traditionally grazed. B. Mid-successional stage (10–15 yrs after abandonment): partial overgrowth with juniper and pine. C. Late-successional stage (≥30 yrs of abandonment): complete overgrowth with pine.

Neuenkamp, L., Lewis, R.J. & Zobel, M. 2014. 30 yrs of succession in an Estonian calcareous grassland: how does time and landuse history shape plant community functional composition? In: Mucina, L., Price, J.N. & Kalwij, J.M. (eds.), *Biodiversity and vegetation: patterns, processes, conservation*, p. 162. Kwongan Foundation, Perth, AU.

Local topography and micro-climate shape refugia across arctic-alpine landscapes

Annina K. J. Niskanen & Miska Luoto

Department of Geosciences and Geography, University of Helsinki, Helsinki FI-00014, Finland

Correspondence: Annina Niskanen, annina.k.niskanen@helsinki.fi

Background & Aim: Climate change is predicted to affect plant species particularly at high latitudes through changes in abiotic conditions and fragmentation and spatial shifting of habitats. These events may cause extinctions or range shifts in plant communities, while some species may be able to persist in refugia. Determining the functions and main drivers of refugia is of particular importance in the preservation of arctic ecosystems and biodiversity. Therefore, we located and quantified contemporary refugia by inferring how climatic, topographic and geologic factors control the distributions and richness of refugia species outside their main distribution area.

Materials & Methods: The study is based on a comprehensive systematically collected plant distribution data set (n=2081). We combined this data set with an extensive environmental data set encompassing areas of northwestern Finland and Norway. Boosted Regression Tree (BRT) modelling was utilized to analyze the effects of climatic, topographic and geologic variables on refugia distribution and species richness of refugia. We built two sets of BRT models to locate and quantify refugia currently suitable for the refugial species. The predictive power of the refugia distribution models was assessed by comparing the predicted and observed occurrences of refugia by calculating the mean values of the area under the curve of a receiver operating characteristic plot (AUC) and the true skill statistics (TSS) based on 999 evaluation runs. Refugia species richness models were evaluated via mean Spearman's rank correlation values.

Main Results: Refugia within the study area were located and subsequently quantified. Overall, all refugia distribution models performed well with mean AUC values higher than 0.85 and TSS values higher than 0.57. The inclusion of extreme temperatures and topography significantly improved model performance. For refugia species richness, best model performance was achieved with the most complex model incorporating all variable groups. The most relevant variables for refugia were water balance, slope and maximal low temperatures.

Main Conclusions: Climate is a key factor controlling refugia at the considered spatial scale. However, the functioning of refugia is also based on the specific habitats they provide: model predictions of refugia location and species richness are significantly improved by the incorporation of locally relevant topographic variables and measures of extreme temperatures which aid in recognizing the locally heterogeneous environments that sustain refugia. Refugia are thus driven by climatic and topographic factors, such as shelter from extremes in temperature, high water balance and steep slopes, that determine local thermal and moisture conditions. In conclusion, our study demonstrates the need for spatially explicit species' data for refugia research, sampled at levels that reflect environmental gradients across large spatial extents at fine spatial resolutions.

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Climate change is predicted to affect species particularly in high-latitude environments. However, no attempts have been made to quantify contemporary refugia in regions such as Lapland, northern Fennoscandia. Photo: A. Niksanen.

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Different disturbance conditions favour diversity and dune specialists on land uplift coasts

Tua Nylén & Miska Luoto

Department of Geosciences and Geography, University of Helsinki, Helsinki FI-00014, Finland

Correspondence: Tua Nylén, tua.nylen@helsinki.fi

Background & Aim: The complex dynamics of beach and dune vegetation are of high interest in conservation planning. Conservation priorities include preserving both diversity and species that exclusively occur in these unique ecosystems. These specialists are pioneer species and are adapted to intensive littoral and aeolian processes. Productivity and disturbance are known to be the key factors controlling species richness. However, the boreal beach and dune coasts of the Baltic Sea are characterized by postglacial land uplift and experience rapid primary succession adding a temporal component to the system. The aim of our research was to analyse what are the interactive effects of substrate age, disturbance and vegetation abundance on total species richness and the richness of beach and dune specialist species.

Materials & Methods: The analyses were based on 39 transect surveys performed in the summer 2011 in natural sandy beach and dune systems of the Baltic Sea coast. The data consisted of 496 observations of vascular plant species, bryophytes, lichens, substrate age (time since land emergence), disturbance (percent cover of ground disturbed by aeolian and littoral processes and trampling) and vegetation abundance (sum cover of vegetation as a proxy of primary production). The data covered beach and dune systems of a large geographical area (60° N – 65° N) and a large range of relative land uplift rate (c. 1–8 mm/year). Total and beach specialist species richness were modelled as functions of environmental variables applying generalized linear mixed models, a modern modelling method taking the effects of the local environmental variability into account.

Main Results & Conclusions: The results indicate that the species richness pattern of uplifting beach and dune systems is determined by the strongly interactive effects of substrate age, disturbance and vegetation abundance. The individual effect of disturbance on richness is negative, but when both succession and vegetation abundance increase sufficiently, disturbance favours diversity, possibly by creating gaps in the vegetation. Maximum species richness results from a combination of long succession time, low disturbance and low vegetation abundance, although the individual effect of vegetation abundance on richness is positive. However, beach specialists are a group of opportunistic and disturbance-tolerant plants that exceptionally thrive at intermediate disturbance levels and are therefore able to take advantage of the more productive sediments. The two fundamental conservation goals, increasing diversity of the beach vegetation and preserving beach specialist species, may therefore require two different settings: on the one hand sheltered areas to create diversity hot spots and on the other hand intermediate sediment movement to provide niches for dune specialist species.

A typical beach and dune system on the northern Baltic Sea coast. The beach of Storsanden in Uusikaarlepyy in the Finnish Ostrobothnia is characterized by an unvegetated beachface, primary dune dominated by beach grasses and forbs and a forested secondary dune. Here a densely vegetated berm has developed. Photo: T. Nylén.

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Shift from facilitation to competition with increasing temperature: plant population dynamics along climate gradients

Siri L. Olsen (1), Joachim P. Töpper (2,3), Olav Skarpaas (4), Vigdis Vandvik (3) & Kari Klanderud (1)

1) Department of Ecology and Natural Resource Management, Norwegian University of Life Sciences, P.O. Box 5003, N-1432 Ås, Norway

2) Faculty of Engineering and Science, Sogn og Fjordane University College, P.O. Box 133, N-6851 Sogndal, Norway

3) Department of Biology, University of Bergen, P.O. Box 7803, N-5020 Bergen, Norway

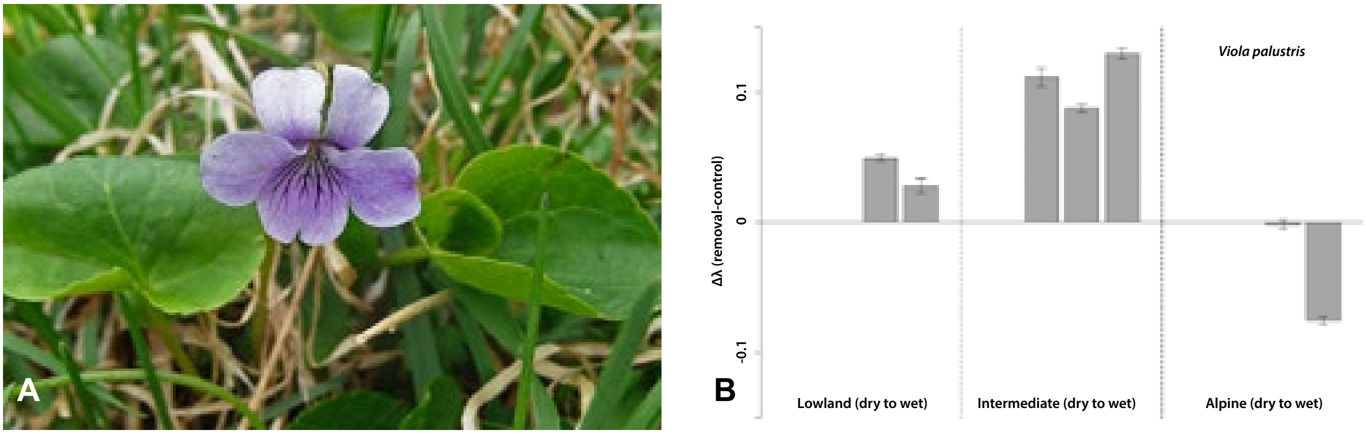
4) Norwegian Institute for Nature Research, Gaustadalléen 21, N-0349 Oslo, Norway

Correspondence: Siri L. Olsen,
siri.olsen@nmbu.no

Background & Aim: Biotic interactions are often ignored in assessments of climate change impacts. However, climate-related changes in species interactions, such as competition and facilitation, may have important effects on plant community composition, structure and function. Such community-level changes are driven by changes in the population dynamics of the component species. We examined how a dominant functional plant group affected population dynamics of sub-dominant species, and whether this effect varied with temperature and precipitation, by experimentally removing graminoids in semi-natural grasslands along natural climate gradients in southwest Norway.

Materials & Methods: We assessed the effect of graminoid removal on population growth rates of four co-occurring forb species at twelve study sites in the Norwegian fjord landscape. The sites were selected to fit within a "climate grid" composed of a natural temperature gradient (from lowland to alpine) replicated along a precipitation gradient (from continental to oceanic). Within each site we recorded survival, growth, production of clonal offspring and sexual reproduction of our study species in intact vegetation and with graminoids removed. We then used the demographic data to construct integral projection models, from which population growth rates were calculated.

Main Results & Interpretations: We found that temperature and precipitation influenced plant population dynamics by altering biotic interactions. The net outcome of species interactions varied along the climate gradients, with temperature as the main driver. For two of the four study species the net interaction with graminoids changed from facilitation of population growth rates at low temperatures to competition at intermediate and high temperatures. This increase in competition with temperature was mainly due to negative effects of graminoids on plant survival in warmer climates. Precipitation did not affect the net outcome of species interactions, but influenced the strength of interactions, regardless of whether they were positive or negative. Our findings suggest that a climate-driven increase in dominant species may negatively affect population growth rates of sub-dominant species. Moreover, the interacting effect of temperature, precipitation and biotic interactions on population dynamics could explain why it is difficult to detect a uniform response of plant communities to climate warming at large spatial scales.



Viola palustris L. (*Violaceae*) – one of our four study species **(A)**, and the difference in population growth rate (Δλ) between graminoid removal and control plots for this species at different levels of temperature (lowland to alpine) and precipitation (dry to wet) **(B)**. Values above the zero line indicate competition from graminoids, while values below the zero line indicate facilitation. Error bars represent 95 % SE confidence intervals.

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Field mycorrhiza studies in natural plant communities: lessons from the past, and future perspectives

Vladimir G. Onipchenko

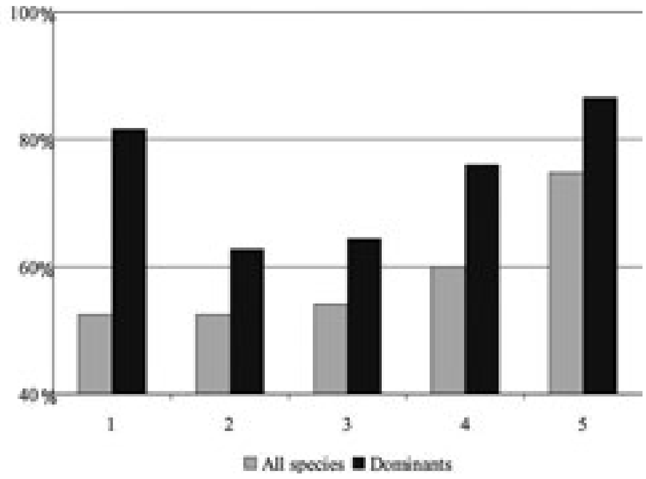
Moscow State Lomonosov University,
Moscow, 119991, Russian Federation

Correspondence: Vladimir
Onipchenko, vonipchenko@mail.ru

Background & Aim: Less than 10% of vascular plant species were studied on their mycorrhizal infection. More than 85% of the flowering plant species are expected to be mycorrhizal (Brundrett 2009). Our objective was to make a mini review of field mycorrhizal studies in the former Soviet Union (FSU) and Russia.

History: Russian scientist Ivan Selivanov (1919-1998) investigated the intensity of root colonization by mycorrhizal fungi for about 3000 species from all climatic zones across the FSU. Proportion of mycorrhizal species firstly increase and then decrease from the north to the south: Arctic (tundra zone) 48%, Forest zone 78%, Steppes 89%, Deserts 61% (Selivanov 1981). He first showed that the dominants of many plant communities (especially in forests and grasslands) have a more intensive mycorrhizal colonization than other species. Full Selivanov's database is available in open access (Akhmetzhanova et al. 2012).

Current status & Perspectives: Using Selivanov's approach it is possible to statistically compare the intensity of mycorrhizal infection between and within species, ontogenetic and seasonal stages, etc. For example, for several alpine communities we demonstrated higher levels of mycorrhizal infection for non-clonal species in comparison with clonal species; we also found a mid-summer depression in mycorrhizal infection for several plants, and a more intensive infection for seedlings and juvenile plants in comparison with adults. (Onipchenko & Zobel 2000). The results are in good correspondence with the modern concept of mycorrhizal networks and ideas about the role of mycorrhiza in carbon and nutrient transfer between plants. Large sets of field data revealed the main environmental factors determining the intensity of mycorrhizal infection, namely the mean temperature of the warmest month and the soil C/N ratio.



Mean mycorrhizal intensity (%, ordinate) for all and dominant species in 5 plant communities: **1**: birch forest, **2**: tall forb *Stipa* steppe, **3**: *Festuca valesiaca*-*Stipa* steppe, **4**: *Stipa* dominated steppe, **5**: *Artemisia*-*Stipa* steppe (based on Selivanov 1981).

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Refugia functional signature: An integrated trait-based conceptual framework

Gianluigi Ottaviani (1), Ladislav Mucina (1,2) & Gunnar Keppel (3)

1) School of Plant Biology, The University of Western Australia, 35 Stirling Hwy, Crawley WA 6009, Perth, Australia

2) Department of Geography and Environmental Studies, Stellenbosch University, Private Bag X1, Matieland 7602, Stellenbosch, South Africa

3) School of Natural and Built Environments and Barbara Hardy Institute, University of South Australia, GPO Box 2471, Adelaide SA 5001, Australia

Background & Aim: The concept of refugia (defined as places where species can retreat to, survive in, and eventually spread out from; Keppel et al. 2012) has been increasingly addressed due to their relevance in ecology and biodiversity conservation. Thus far, studies dealing with such habitats (or complex of habitats) involved phylogenetic, genetic, climate and species distribution modelling. However, apart from studies in eastern-Australian rainforests (Kooyman et al. 2011), plant community assembly and scale has been less considered. Therefore, in this work we aim to develop and provide an integrated trait-based conceptual framework to be applied in a refugial context.

Materials & Methods: In the proposed conceptual framework, we integrate four ecological approaches and methodologies: 1) the vegetation-environment axiom, 2) the mass ratio hypothesis (MRH), 3) the plant functional trait approach, and 4) the relationship between traits and ecosystem functions. Using the proposed framework, identifying the refugial status of the plant communities is achievable.

Main Results & Interpretations: The theoretical and conceptual construct lead to two testable hypotheses that in turn define the concept of refugial functional signature. Indeed, plant communities occurring in refugia should exhibit the following functional ecological features, when compared to similar but not refugial habitats: A) a peculiar composition of traits and traits' values, and B) higher functional diversity and/or functional redundancy (strongly context-dependent type of refugium). Therefore, this signature will be informative on the refugial status (past and anticipated) of the community. Further, we make some expectations on the functional signature in one case study: the granite outcrops (GOs) in south-western Australian floristic region, which are suggested to have acted as refugia for biota (Hopper & Gioia 2004). We predict plant communities occurring on, and nearby to, the GOs to differ in functional characteristics (hence determining the signature) compared to non-refugial comparable habitats. For instance, we expect the functional signature of refugial woodlands (well-watered and deep-soil habitat) to be defined by: 1) specific aboveground traits (e.g. plant structure, and leaf morphology and functionality, related to light capture and nutrient retention/allocation, such as bigger-stature, larger specific leaf area and ^{13}C foliar isotopic content, lower leaf dry matter content and ^{15}N foliar isotopic content); and 2) belowground characters (e.g. peculiar root types and mycorrhizal interactions, associated with specific nutrient-acquisition strategies). Also, functional diversity can either be larger (trait divergence associated with niche differentiation/limiting similarity, facilitation, and resource partitioning processes) or smaller (trait convergence related to abiotic and biotic filtering processes, structuring highly redundant functional guilds) in the refugium vs. non-refugial vegetation, although providing differential thus informative insights.

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Fire frequency and spatial scale mediate the strength of deterministic and stochastic processes in longleaf pine woodlands

Kyle A. Palmquist

Department of Botany, University of Wyoming, Laramie, WY 82071, USA

Correspondence: Kyle A. Palmquist, kpalmqu1@uwyo.edu

Background & Aim: There is ongoing debate on whether ecological communities are assembled by deterministic, niche-based processes or stochastic processes unrelated to species' differences. Recently, these two competing hypotheses have been merged into a single conceptual framework that seeks to identify how the relative importance of deterministic versus stochastic processes changes across a set of communities. One method for quantifying the relative importance of stochastic versus niche assembly is through use of species co-occurrence metrics that reveal whether community structure is more aggregated (species co-occur more frequently than expected by chance, evidence of environmental filtering), segregated (species co-occur less frequently than expected by chance, evidence of limiting similarity), or no different (evidence of stochastic assembly) than random expectation. Here, I use two complementary species co-occurrence metrics coupled with null model analysis to explore where longleaf pine plant communities fall along the continuum of deterministic to stochastic assembly. I examine how the relative importance of environmental filtering, competition, and stochastic processes change across a gradient of environmental stress, with time since disturbance, and with spatial grain.

Materials & Methods: This work was conducted in longleaf pine plant communities in North Carolina, US. In 2009, I sampled 59 nested vegetation plots (1000 m^2 each) and recorded presence-absence for all vascular plant species at a range of spatial scales. I assigned each plot to one of five broad community types to assess how species co-occurrence metrics change across the environmental gradient in the system. Fire history data for all plots were obtained from a GIS layer of prescribed fire events compiled from several land management agencies. To examine how the relative importance of competition and stochastic processes changed with time since fire, I classified each plot into one of three time-since-fire categories: <1 year since fire, 1 to 3 years since fire, and >3 years since fire. I then created a community type time-since-fire category for each plot, which reflected both environmental context and fire history. Two species co-occurrence metrics (mean C-scores and mean modified Raup-Crick dissimilarity metric) were calculated at multiple spatial scales for five broad community types, three disturbance categories, and 15 community-disturbance categories to examine how disturbance, environmental context, and spatial scale changed the relative importance of community assembly processes. I used null model analysis to examine whether species co-occurred more frequently, less frequently, or no different than random expectation.

Main Results & Conclusions: I found that sites became more dissimilar (e.g., segregated) in species co-occurrence as time since fire increased and spatial grain decreased, suggesting that competition became more important in structuring longleaf pine plant communities in those two cases. However, I did not detect large changes in the relative importance of community assembly processes along the environment gradient, except at the smallest spatial grain and in sites with less recent fire. These results suggest that the relative importance and identity of community assembly processes depends on the spatial scale of observation, and thus it is critical that studies using species co-occurrence data to identify ecological processes be conducted across a range of spatial scales. This work also indicates that both deterministic and stochastic processes shape longleaf pine plant communities, and that disturbance changes where communities fall along the deterministic-stochastic continuum.

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Comparing resource-based and co-occurrence-based methods for estimating species niche breadth

Angela Pannek (1), Michael Manthey (2) & Martin R. Diekmann (1)

1) Vegetation Ecology and Conservation Biology, Department of Ecology, FB 2, University of Bremen, Leobener Str., D-28359 Bremen, Germany

2) Institute of Botany and Landscape Ecology, University of Greifswald, Soldmannstr. 15, D-17487 Greifswald, Germany

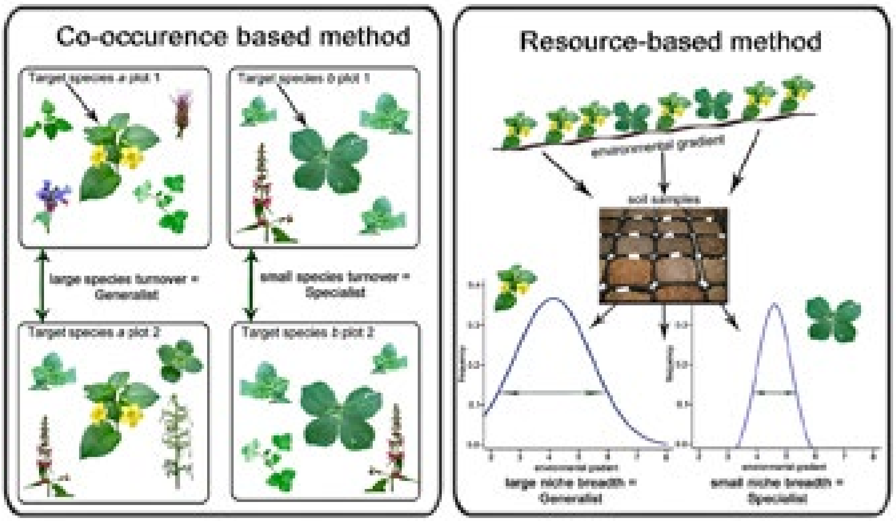
Correspondence: Angela Pannek, apannek@uni-bremen.de

Background & Aims: Being a generalist or a specialist species plays an important role for survival in environments affected by habitat destruction or climate change. One way of expressing the extent of specialisation of a species is to determine its niche as the range of resources it can utilize. A generalist then has a large niche breadth. Common species often show a large ‘available niche breadth’, combining the niche breadth of a species with the regional frequency of different resource states that species can exploit (Pannek et al. 2013).

Studying the responses and co-occurrence patterns of herbaceous forest plants in Germany, we asked: (1) Do the varying frequencies of rare and common species in the data set affect the niche breadth estimates? (2) Do the resource-based and co-occurrence methods give similar estimates of niche breadth?

Approach & Methods: This study deals with two different approaches to measuring niches: first, the classical method of determining niche breadth as the response of a species along environmental and resource gradients (here: soil pH and light availability) and, second, a recently introduced method (Fridley et al. 2007) calculating niche breadth based on the co-occurrence of species, assuming that generalists co-occur with many different species, while specialists would likely be associated with few species.

Main Results & Interpretations: When using the resource-based method, species with higher frequencies in the data set also had larger niches, while the co-occurrence method is not distorted by the different frequencies of species. Working with a constant number of plots revealed no significant relationship when comparing the estimates of soil pH niche breadth for the two approaches. The resource-based estimates of light niche breadth and available niche breadth for soil pH, however, were significantly positively related with the co-occurrence based estimates. So far, only a few studies have applied the co-occurrence method, and there is still need for further research. This study supports the usage of the co-occurrence method as a new and reliable alternative for extracting species niches from vegetation surveys even if no environmental data is available.



Graphical comparison between the co-occurrence-based and resource-based method for determining species niche breadth estimates.

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Exploring the spatial and temporal dynamics of the relationship between precipitation and aboveground vegetation biomass

Jessica P. Parker, Charles G. Curtin & Craig F. Conley

Department of Natural Resource
Management, New Mexico Highlands
University, Las Vegas, NM 87701, USA

Correspondence: Jessica P. Parker,
jparker2@live.nmhu.edu

Background & Aim: Climate has been long recognized as the key driving variable of the structure and function of grasslands. In arid regions where water availability is the primary constraint on the ecosystem, spatial and temporal variability in precipitation may be the most important influence on landscape vegetation patterns (Augustine 2010). At regional scales, annual precipitation is highly correlated with vegetation production in both space and time (Cleland et al. 2013), but is less influential over the long-term at finer scales (Sala et al. 2012). This may indicate that cross-scale, abiotic-biotic interactions are occurring that shape the landscape patterns of the system (Brown et al. 1997). A synthesis of aboveground granivorous rodent-vegetation interactions and belowground soil moisture dynamics may be the key factors in the precipitation-production relationship. We ask: (1) What is the cross-scale relationship (type, strength, and direction) between annual and seasonal rainfall variability at the landscape and local levels and above-ground vegetation biomass at the local level? (2) Does the interaction of above and belowground processes explain the spatial and temporal relationship between rainfall and vegetation biomass?

Materials & Methods: We used ten years of spatial and temporal precipitation data and field measurements of biomass at the m^2 and ha scale to detect a correlation between annual and seasonal precipitation and aboveground vegetation biomass of Chihuahuan Desert grasslands in New Mexico, USA. Granivorous rodent population abundance data was used from a mark-recapture study conducted from 2003–2009 at the same site as a measure of aboveground biotic interactions. Seasonal evapotranspiration rates, as a proxy for soil moisture, were estimated using the Blaney-Criddle method (Ward & Elliot 1995) with weather data from Antelope Wells, NM.

Main Results & Interpretations: Annual and seasonal precipitation and aboveground vegetation biomass showed significant interannual differences from 2000–2009 at both the m^2 and ha scale. No relationship was detected between either seasonal or annual average precipitation, from either the current or previous season or years, and aboveground vegetation biomass at either scale, except from 2007–2008. Above-average precipitation with low spatial variation was correlated with an increase in spatial variation of biomass with a two-year lag time. Below-average precipitation with low spatial variation was correlated with lower spatial variation in biomass the following year until above-average precipitation generated a two-year time lag in the spatial response of biomass. From 2007–2008, a two-fold increase in vegetation biomass was correlated with above-average precipitation in 2006. Granivorous rodent populations declined significant during this period whereas soil moisture was significantly higher than previous years. This suggests that the aboveground rodent–vegetation interactions and belowground soil moisture dynamics influence the non-linear vegetation response to precipitation variability.

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Big Data meets Darwin's "entangled bank": The macroecology of botanical diversity

Robert K. Peet (1), Brian Enquist (2), Brad Boyle (2), Jens-Christian Svenning (3), Brian J. McGill (4), Peter M. Jørgensen (5), Barbara Thiers (6), Susan K. Wiser (7), Cyrille Violle (8), Naia Morueta-Holme (3) & Mark Schildhauer (9)

1) Department of Biology, University of North Carolina, Chapel Hill, NC 27599-3280, USA
2) Department of Ecology and Evolutionary Biology, University of Arizona, Tucson, AZ 85721, USA
3) Ecoinformatics and Biodiversity Group, Department of Bioscience, Aarhus University, DK-8000 Aarhus C, Denmark
4) School of Biology and Ecology, Sustainability Solutions Initiative, University of Maine, Orono, ME 04469, USA
5) Missouri Botanical Garden, P.O. Box 299, St. Louis, MO 63166, USA
6) The New York Botanical Garden, 2900 Southern Boulevard, Bronx, NY 10458-5126, USA
7) Landcare Research, PO Box 69040, Lincoln 7640, New Zealand
8) CNRS, UMR5175, Centre d'Ecologie Fonctionnelle et Evolutive, F-34000 Montpellier, France
9) National Center for Ecological Analysis and Synthesis, University of California, 735 State Street, Suite 300, Santa Barbara, USA

Correspondence: Bob Peet, peet@unc.edu

Background & Aim: For many questions in comparative biology and biodiversity science, it is increasingly necessary to integrate heterogeneous sources of biological information across enormous geographic, temporal, and taxonomic scales. The informatics revolution, has transformed many parts of science. While many fields have embraced Big Data, ecology has lagged. The problem is that the nature of biodiversity data presents several unique hurdles that limit the advance of biodiversity science. To overcome these limitations we present a general workflow to standardize and integrate the world's ecological and collection databases, now implemented by the BIEN project.

Main Results & Interpretations: Focusing on plants in the Americas, we use our workflow to generate for the first time: (i) species range maps for ~100,000 species; (ii) a standardized species list and multi-gene phylogeny for all New World species; and (iii) continental-scale taxonomic, phylogenetic, diversity, and trait maps. These products allow us to show that broad-scale diversity patterns are characterized by an inverse relationship between phylogenetic diversity and taxonomic diversity and to visualize how continuous variation in key functional traits shifts across the continental scale. Together, our results provide a basis to assess long-standing hypotheses for the origin of diversity gradients and the drivers of functional traits, to improve our knowledge of the diversity and distribution of plant species, and to understand the drivers of plant species co-occurrence.

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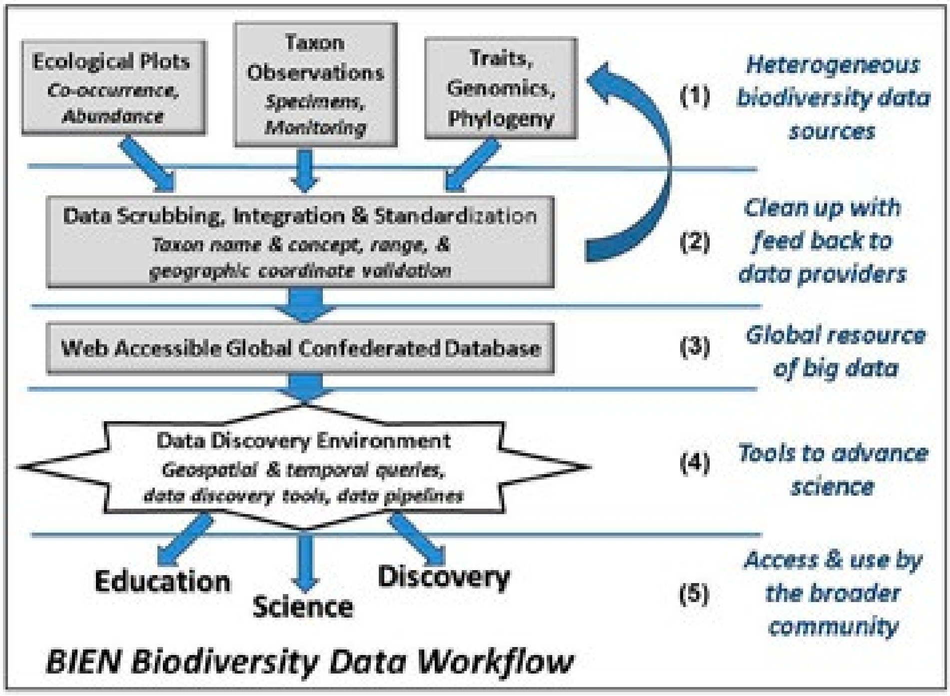

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Effect of an invasive grass on carbon stocks in the Brazilian cerrado

Vânia R. Pivello (1), Diana B. Garcia (1), Rodrigo Valeriote (1) & Plínio B. Camargo (2)

1) Instituto de Biociências, Dept. Ecologia, Universidade de São Paulo, São Paulo SP, 05508-090, Brazil

2) Centro de Energia Nuclear na Agricultura, Laboratório de Ecologia Isotópica, Universidade de São Paulo, Piracicaba SP, 13416903, Brazil

Correspondence: Vânia R. Pivello, vrpivel@usp.br

Background & Aim: Savannas and grasslands are globally important zones for carbon storage especially in the soil and belowground biomass, as the root:shoot ratio is >1. However, there is a big knowledge gap related to carbon dynamics in the the Brazilian tropical savannas called 'cerrado'. Changes in land use and the invasion of native communities by alien species can significantly alter the above- and belowground dynamics of nutrients – mainly carbon and nitrogen – due to distinctive ecophysiological characteristics of some exotic species. Such changes in the use of nutrients and resource allocation can bring significant and long-lasting effects to nutrient stocks. This study aimed to analyse the effect of *Urochloa decumbens,* an invasive African grass, on the carbon stocks of the Brazilian cerrado. Very few studies investigate the effects of biological invasion in cerrado carbon stocks.

Materials & Methods: Our study was conducted at the Itirapina Ecological Station (22°11′–15′ S; 47°51′–55′ W) in both invaded (U) and non-invaded (NI) areas submitted to a similar fire regime. We determined aboveground live and dead biomass (2 X 10 plots of 1 m X 1 m), belowground biomass of roots (2 X 8 blocks of 20 X 20 X 50 cm, in classes of 10 cm depth), and the total carbon in the soil (2 X 6 samples 1 m deep, at 0-5 cm and then in classes of 10 cm depth). Vegetation cover was estimated using a 10 X 10 cm grid; roots were separated according to diameter (<2 mm; 2–10 mm). Soil carbon stock was calculated based on the total amount of carbon in the soil, soil density and the thickness of the sampled layer. We compared aboveground live, dead and total biomass of U and NI plots through repeated ANOVA; carbon stocks in the soil and root biomass at different depths in the same plots were compared using Friedman and paired Wilcoxon tests; carbon stocks in the soil and root biomass of both U and NI plots were compared using Mann Whitney tests according to depth.

Main Results & Interpretation: About 24% of the U plot area was covered by the invasive grass. No significant differences were found in live and dead biomass or on aboveground carbon stocks of U and NI areas. Belowground biomass and its carbon stock were 45% higher in the U area, mainly due to fine roots (<2 mm) at 0–10 cm soil depth. Total soil carbon stocks at the 1-m profile were not significantly different between U and NI areas but they did differ according to soil layers. In conclusion, *U. decumbens* did not significantly change the aboveground (live, dead and total biomass) carbon stocks, but caused a greater input of carbon belowground due to much higher production of fine roots in the shallow soil. It is expected that the soil carbon stock follows the same pattern of the underground biomass, as it results mainly of root death and exudation. However, since total carbon stock did not differ in both U and NI areas up to 1-m depth we suppose decomposition rates in the U areas are greater. This study considered belowground soil stocks only up to 1.0 m soil depth. However, cerrado shrubs produce considerable biomass of thick roots at greater depths. Thus, despite increasing the stock of carbon in fine roots in the shallow soil we expect that invasion by *U. decumbens* decreases the overall belowground carbon stock.

Stand of the cerrado vegetation (*campo sujo* physiognomy) invaded by *Urochloa decumbens* at Itirapina Ecological Station, São Paulo State, Brazil. Photo: D.B. Garcia.

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Jaccard index revisited – a new method for evaluating structure in ecological data matrices

János Podani

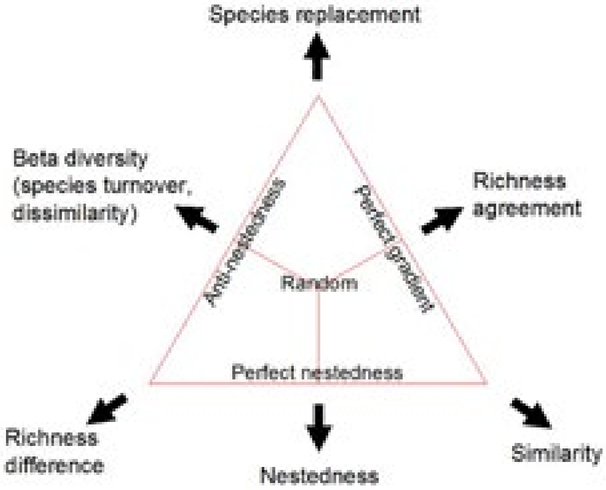
Department of Plant Ecology, Systematics and Theoretical Biology, Eötvös University, H-1066 Budapest, Hungary

Correspondence: János Podani, podani@ludens.elte.hu

Background & Aim: Structure in data matrices is most often demonstrated via ordination and cluster analysis, whereas beta diversity, nestedness, turnover and other, diversity-related properties of data remain unexplored by these techniques. As a resolution, I describe a conceptual and methodological framework, called the SDR simplex approach, which produces two-dimensional ternary plots for visual interpretation and percentage contributions for quantification of these properties.

Methods: The essence of the method is to decompose Jaccard dissimilarity between sites into richness difference (D) and species replacement (R) components and to use similarity (S) as a contrast, based on either presence-absence (Podani and Schmera 211) or abundance data (Podani et al. 2013). Since these three quantities always sum to 1, a simplex diagram may be used for graphical display. In this, each point represents a pair of sites, and the arrangement of points reflects the relative importance of similarity, species replacement and richness difference in shaping community structure. In addition, numerical expressions allow quantification of these basic phenomena. Composite measures may be used to express beta diversity, agreement in species richness and nestedness as well. The method is invariant to matrix ordering that means that results reflect truly inherent structural properties in the data. The SDR simplex approach can be extended to analyse bipartite ecological networks (Podani et al. 2014) or any other systems that may be described by rectangular data matrices. Further extensions include the comparison of matrix structures regardless of their actual dimensions and the visualisation of data structures obtained by various null models to enhance interpretation of statistical tests.

Results: The SDR simplex analysis is illustrated by small artificial examples and applications to actual data representing a wide range of ecological communities, biogeographic systems and interaction networks. Many studied examples follow similar trends in the arrangement of points, suggesting existence of some common assembly rules shaping community structure. Nevertheless, many extreme cases with low or high beta diversity and nestedness were also identified. Data without clear structure in terms of the S, D and R components are not exceptional either. Spatial and temporal effects on community structure are revealed on the example of grassland data and coral assemblages, respectively. Ordination analysis of the flora of Italian regions coincides well with gradients revealed by the simplex approach. Analysis of several taxonomic assemblages, such as bryophytes, fungi, spiders and birds, sampled in the same study site illustrate generalization of the method towards global analysis of multi-level community structure.



Conceptual scheme of the SDR simplex approach

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Contrasting water relations are associated with species distribution and crown decline in four common sympatric eucalypt species in southwestern Australia

Pieter Poot & Erik Veneklaas

School of Plant Biology, The University of Western Australia, 35 Stirling Hwy, Crawley WA 6009, Perth, Australia

Correspondence: Pieter Poot, pieter.poot@uwa.edu.au

Background & Aim: Drought-associated vegetation declines are increasingly observed around the world including Mediterranean southwest Australia which has experienced a 15% rainfall reduction over 40 years. We investigated whether differences in water relations can potentially explain species distribution and vulnerability to drought-induced decline in four co-occurring tree species.

Materials & Methods: We compared seasonal and daily water relations of four common southwest Australian eucalypt species (i.e. *Corymbia calophylla, Eucalyptus accedens, E. marginata, E. wandoo)* on a site where they all co-occurred as well as on nearby typical sites for each species. On site measurements included, pre-dawn and midday leaf water potentials, stomatal conductances and sapflow velocities. Leaf and stem samples were taken to the lab to generate pressure volume and xylem vulnerability curves.

Main Results & Interpretations: Species with their centre of distribution in drier regions (i.e. *E. accedens, E. wandoo*), were characterised by substantially lower leaf water potentials (predawn and midday), lower osmotic potentials, higher stomatal conductances, higher relative sapflow velocities and a much lower vulnerability to cavitation. On sites where they are dominant, *C. calophylla* and *E. marginata* showed greatly improved leaf water status indicating better soil water access. Our results suggest that the regional distribution of these species is consistent with their water relation characteristics and the implications that these have for growth and survival along a rainfall gradient. However, local distribution is also strongly dependent on soil profiles and root system architecture, with shallow-rooted *E. wandoo* only occurring on eroded soil profiles with clay layers close to the surface where it can make optimal use of its superior water extracting ability. In contrast, the wetter-zone species *C. calophylla* and *E. marginata* are deep-rooted and rely on accessing weakly held water in a large soil volume, explaining their dominance on deeper well-draining soils. Our work demonstrates that combining plant water relations with detailed local knowledge on soil profiles, species habitat preferences and root system architecture can greatly improve our understanding of local species distribution patterns. This is essential to improve our capacity to understand and predict drought-induced declines.

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Mixed eucalypt woodland, Julimar Conservation Park, Western Australia. This woodland contains the smooth-barked species *Eucalyptus accedens* (powderbark wandoo) and *E. wandoo* (wandoo), as well as the rough-barked species *E. marginata* (jarrah) and *Corymbia calophylla* (marri).

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How can we incorporate more successful science into restoration plantings? A case study of the Kahuterawa Stream Biodiversity Restoration Project

Gillian L. Rapson & Tessa L. Roberts

Ecology Group, Institute of Agriculture and Environment, Massey University, Palmerston North, New Zealand

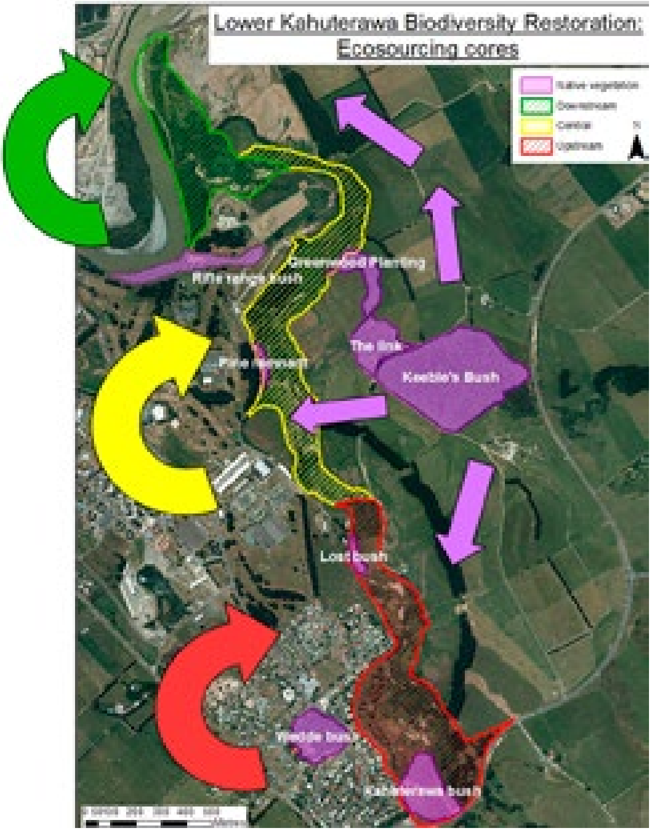
Correspondence: Jill Rapson, G.Rapson@massey.ac.nz

Background & Aim: The logic behind restoration plantings is to accelerate natural successional processes in their critical early stages, before leaving nature to complete the successional process. However current evidence suggests that restoration plantings do not appear to coalesce with natural secondary successional trajectories, diminishing their likelihood of reaching the desired local (climax?) vegetation. This suggests the interface between restoration and succession is not well understood. We present plans for a major restoration project into which we intend to build a number of experimental layers, to evaluate successional success.

Restoration plans: The Kahuterawa Stream Biodiversity Revegetation Project covers 70 ha along a 4.2 km tributary of the Manawatu River, surrounded by land tenured to Massey University and Linton Military Camp, New Zealand. Several small remnants (covering in total 9 ha) are included in the Project zone, which abuts the 17 ha high value remnant of Keeble's Bush, privately owned and reserved for scientific purposes. Plans are to protect and enrich existing remnants within the Kahuterawa Project zone, and to initiate planting on the large intervening areas. The initial planting (winter 2014) was of 3000 *Carex secta* (*Cyperaceae*) tussocks to partly restore a small wetland, and of 500 forest plants to begin infilling Kahuterawa Bush, the largest of the remnants within the Project.

Research opportunities: Experiments at various scales are under development for incorporation into these plantings. 1) The two early restoration plantings (New Zealand's oldest and best) by Keeble's Bush create an opportunity for a broad-scale temporal comparison with the Kahuterawa Project of lowland podocarp-hardwood forest restoration. 2) Division of the Kahuterawa Project into 3 core areas, each with internal eco-sourcing, where possible, will allow comparison of genetic composition in relation to ecological functioning, especially successional trajectory. 3) Four experimental areas are planned throughout the Kahuterawa, which can function as "replicates", but which also allow for extensive plantings on factorial designs of trials on the impact of taxonomic and structural complexity and restoration technique (e.g. addition of duff) on restoration success. 4) To begin infilling the large portion of the Project zone which will not be planted in the next decade, 40 small nuclei plantings (of 30-50 plants each) are planned, which will act as seed sources for natural expansion. Suggestions will be invited for their composition, particularly in terms of genetic diversity, and for their statistical analysis.

Conclusion: These experiments within the Kahuterawa Project will represent a significant future scientific resource for understanding restoration processes and successional dynamics.



Zones in need of restoration, downstream of Kahuterawa Bush, New Zealand. Left: willow and cleared zones; right: drainage from wetland associated with rock wall protecting housing, in front of pine plantation. Photo: G.Rapson.

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Dark diversity in dry calcareous grasslands is determined by dispersal ability and stress-tolerance

Kersti Riibak (1), Triin Reitalu (2), Riin Tamme (1), Aveliina Helm (1), Pille Gerhold (1), Sergey R. Znamenskiy (3), Karin Bengtsson (4), Ejvind Rosén (5), Honor C. Prentice (6) & Meelis Pärtel (1)

1) Department of Botany, Institute of Ecology and Earth Sciences, University of Tartu, EE-51005 Tartu, Estonia

2) Institute of Geology, Tallinn University of Technology, EE-19086 Tallinn, Estonia

3) Institute of Biology, Karelian Research Centre of the Russian Academy of Sciences, 185910 Petrozavodsk, Karelia, Russian Federation

4) School of Culture, Energy and Environment, Gotland University, SE-62167 Visby, Sweden

5) Department of Ecology and Genetics, EBC, Uppsala University, SE-75236 Uppsala, Sweden

6) Department of Biology, Lund University, Ecology Building, SE-22362 Lund, Sweden

Correspondence: Kersti Riibak, kersti.riibak@ut.ee

Background & Aim: Temperate calcareous grasslands are characterised by high levels of species richness at small spatial scales. Nevertheless, many species from a habitat-specific regional species pool may be absent from local communities and represent the 'dark diversity' of these sites. Here we investigate semi-natural dry calcareous grasslands in Northern Europe to determine what proportion of the habitat-specific species pool is realized at small scales (i.e. how the community completeness varies) and which mechanisms may be contributing to the relative sizes of the observed and dark diversity. We test whether the absence of particular species in suitable grassland sites is a consequence of dispersal limitation and/or a low ability to tolerate stress, such as drought and grazing.

Materials & Methods: We analysed a total of 1223 vegetation plots (1 m X 1 m) from dry calcareous grasslands in Sweden, Estonia and western Russia. The species co-occurrence approach was used to identify the dark diversity for each plot. We calculated the maximum dispersal distance for each of the 291 species in our dataset by using simple plant traits (dispersal syndrome, growth form and seed characteristics). Large seed size was used as proxy for small seed number; tall plant height and low S-strategy (*sensu* Grime) type scores were used to characterise low stress-tolerance.

Main Results & Conclusions: Levels of small-scale community completeness were relatively low (more species were absent than present) and varied between the grasslands in different geographic areas. Species of the dark diversity pool were generally characterised by shorter dispersal distances and greater seed weight (fewer seeds) than species in the observed diversity. Long-distance dispersal was only frequent among observed diversity species within sites surrounded by extensive areas of suitable habitat. A high potential for long-distance dispersal in the small fragments of calcareous grasslands might not be beneficial, because species with long dispersal distance have a high probability of dispersing into unsuitable parts of the habitat matrix. Species within the dark diversity were generally taller and had a lower tolerance of stressful conditions. Taller species may, at least temporarily, disappear from grassland communities because they suffer disproportionally more from intensive grazing and mowing than shorter species. In addition, taller, more competitive species are more likely than short stress-tolerators to be damaged by severe droughts. As an exception, species within the dark diversity were shorter than the species within the observed diversity in more mesic (and fertile) Russian calcareous grasslands. Our results suggest that in more productive calcareous grasslands, where levels of drought stress are likely to be lower, taller species may competitively exclude the shorter stress-tolerant species.

We conclude that, even if temperate grasslands have high levels of small-scale plant diversity, the majority of ecologically suitable species in the regional species pool are absent as a result of dispersal limitation and low stress-tolerance. Because community assembly in dry calcareous grasslands is largely dependent on dispersal-based processes, it is particularly important to promote seed dispersal between different grasslands patches, for instance, with the help of grazing animals to facilitate small-scale plant diversity.

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Hercules and the Hydra: Are mechanical, chemical, and/or grazing treatments of resprouting woody plants more effective when combined with fire?

William E. Rogers (1), Carissa L. Wonkka (1), Dirac Twidwell (2) & Michele D. Clark (1)

1) Department of Ecosystem Science and Management, Texas A&M University, College Station, TX 77843, USA

2) Department of Agronomy and Horticulture, University of Nebraska, Lincoln, NE 68583, USA

Correspondence: William E. Rogers, wer@tamu.edu

Background & Aim: According to the Greek myth, Hercules was successful in slaying the nine-headed Lernaean Hydra where others failed because he used fire to quickly cauterize the stump of each serpentine head he chopped off before it could regrow into multiple new heads. This may prove to be a fitting analogy for land managers who have had difficulty controlling woody encroachment in rangelands where persistent resprouting shrubs decrease biodiversity and degrade ecosystem services. Increasingly, attempts to utilize multiple management strategies (mechanical, chemical, biotic, pyric) in conjunction with one another are being employed to potentially maximize the efficacy of these woody control treatments and decrease the economic costs associated with methods requiring expensive machinery or synthetic herbicides. However, few systematic or quantitative assessments of the effectiveness of these various potential treatment combinations currently exist.

Materials & Methods: I will present data from five different experimental studies in woody encroached rangelands where we have on-going research assessing the factorial effectiveness of mechanical cutting, chemical herbicide applications, or ungulate grazing on resprouting woody plants coupled with and without prescribed fire treatments. The first of these studies assesses the interactive effects of fire and cattle grazing on bankrupt bush (*Stoebe plumosa*; *Asteraceae*), a sprawling problematic shrub found in degraded grasslands of the South African highveld. We established a companion study in a Texas Gulf Coast grassland examining the effects of fire and cattle grazing on woody encroachment (primarily *Prosopis glandulosa* and *Acacia farnesiana;* both *Fabaceae*) and the composition of native and introduced herbaceous species. In the same coastal grassland, another study experimentally tested the effectiveness of coupling intense prescribed fire with herbicide applications to control these resprouting woody species and examined the subsequent herbaceous community response to these treatments. This study was replicated in a significantly more arid region of southwest Texas that is also dominated by *Prosopis glandulosa*. Finally, I will present results from a study assessing the effectiveness of prescribed fire treatments combined with mechanical cutting of resprouting woody species in an area of South Texas dominated by various resprouting *Acacia* shrubs. We used woody plant survival and cover and herbaceous community composition and biomass to assess the various treatments effectiveness.

Main Results & Interpretations: Results from these studies suggest that dual-treatment combinations using traditional management applications to control undesirable resprouting plant species are not a panacea for issues of woody encroachment, but other novel methods of intervention (prescribed extreme fire during periods of drought) may prove ecologically useful and economically pragmatic in addressing problematic resprouting woody plants and restoring degraded rangeland ecosystems.

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Applying the dark diversity concept for plants at the European scale

Argo Ronk, Robert Szava-Kovats & Meelis Pärtel

Institute of Ecology and Earth
Sciences, University of Tartu,
EE-51005 Tartu, Estonia

Correspondence: Argo Ronk,
argo.ronk@ut.ee

Background & Aim Large-scale biodiversity maps are essential in macroecology. However, between-region comparisons of raw values of observed species richness have limited value because they fail to account for concurrent variations in dark diversity – the absent portion of the species pool (set of species which potentially could inhabit the study site) (Pärtel et al. 2011). Therefore, the local biodiversity can be more informative if it is expressed at a relative scale, exploring how much of the species pool is actually realized locally (Pärtel et al. 2013). We aim to quantify and map plant diversity across Europe by using a relative measure that accounts for both the observed and dark diversity. This aim requires examining two main issues: suitable delimitation of the species pool, and the evaluation of the potentials and limitations of a broad scale dataset.

Materials & Methods: We used *Atlas Florae Europaeae* (c. 20% of European plant species mapped within 50 X 50 km grid cells) and defined for each grid cell several species pools by applying various geographical and ecological filters: geographic species pool (number of species within 500 km radius), biogeographic species pool (additionally incorporating species distribution patterns: dispersion fields), site-specific species pool (additionally integrating habitat preferences of species obtained from co-occurrence index – estimated probability of species occurrence based on the co-occurrence of a given species with other species). We used dark diversity to quantify local diversity at the relative scale (Community Completeness: log-ratio of observed to dark diversity). We tested whether our results are robust against regional variation in data completeness. We performed a sensitivity analysis to test the dependence of Community Completeness (how much of the species pool is realized within a local community) on data inaccuracy. We also used independent datasets from national databases to test if *Atlas Florae Europaeae* (www.luomus.fi/en/atlas-florae-europaeae-afe-distribution-vascular-plants-europe) taxonomic coverage is a representative subset of the total species richness.

Main Results & Conclusions: Ecological filtering was the most influential determinant of species pools with more species filtered out in southern Europe. The site-specific species pool, derived from both geographical and ecological filtering of species, appeared to be a more suitable approach to determine the species pool than less sophisticated estimates. Both observed and dark diversity adhered to the well-known latitudinal gradient, but community completeness varied throughout Europe. This pattern was relatively insensitive to variations in regional sampling intensity. *Atlas Florae Europaeae* represented well the total variation in plant diversity. Dark diversity and community completeness add valuable information on broad-scale diversity patterns since local diversity is expressed at the relative scale. Such diversity values can be readily compared among regions.

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Introduced seed, native seed or natural succession for restoration on various soil types in an alpine environment

Line Rosef (1), Dagmar Hagen (2) & Trygve Aamlid (3)

1) Department of Plant Sciences (IPV), Norwegian University of Life Sciences (NMBU), P.O. Box 5003, NO-1432 Ås, Norway

2) Norwegian Institute for Nature Research (NINA), P.O. Box 5685 Sluppen, NO-7485 Trondheim, Norway

3) Norwegian Institute for Agricultural and Environmental Research (Bioforsk), Bioforsk Øst, Landvik, NO-4886 Grimstad, Norway

Correspondence: Line Rosef, line.rosef@nmbu.no

Background & Aim: The study area is situated in Bitdalen in Telemark County, South Norway (alt. of 950 m) located in the sub-alpine region. Bitdalen has a hydropower reservoir with a rock-fill dam in one end. From 2006 till 2008, the dam was rehabilitated by a rock-fill. The surrounding area consisted of mineral soil and peat soil. After the rehabilitation of the dam was finished, the surrounding area was restored and re-vegetated. This was done in order to minimize the environmental impact of the dam restauration, and to restore Bitdalen as a grazing and recreation area. In similar circumstances in Norway, imported seed has usually been seeded for restoration purposes. Our aim was to examine if seeding was needed for native vegetation establishment along local soil gradients, and whether native seeds were more efficient than imported seeds in restoration and re-vegetation.

Materials & Methods: A fully factorial experiment comparing three different native soil types (mineral soil vs. organic peat soil vs. 50/50 mineral/organic soil mixture) and 3 types of plant material (no seeding vs. conventional (imported) seed mixture vs. Norwegian native seed mixture) was established in 2008. Fifty-four permanent plots of 0.5 metres X 0.5 metres were placed in each combination of the experiment. During the following years (2009, 2010, 2011, and 2013) plant composition in percent as well as plant cover in percent was recorded in all 54 permanent plots.

Main Results & Conclusion: After five years, there was no significant difference between the different soil treatments in plant cover, species in total and number of not-seeded species. However, after five years, the organic soil had significantly more not-seeded alpine species from the surrounding than the mineral soil. On mixed soil, the number of not-seeded alpine species was not significantly different from the organic soil or the mineral soil. This indicates that at least some local organic soil should be used in restoration of this type of area to ensure that alpine species from the surroundings re-establish on the restored areas.

There were more species in the native seed treatment during all years registered, compared to the imported or not-seeded treatments. After five years, there was no difference in plant cover, not-seeded species in total or not-seeded alpine species among the different sowing treatments. These results indicate that sowing might not be essential for establishment of vegetation on an alpine restoration site, even though the native seeded treatment had most species in total. It seems like the soil at the site are more important for the establishment of local alpine species than the seeding within a five years perspective.

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The experiment at Bitdalen, southern Norway after five years, designed to study restoration using tree types of plant sources and three different native soil types. 1: peat soil, 2: mixed soil, 3: mineral soil.

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Plant extinctions and colonizations in European grasslands due to loss of habitat area and quality: a meta-analysis

Liina Saar, Krista Takkis & Aveliina Helm

Institute of Ecology and Earth Sciences, University of Tartu, EE-51005 Tartu, Estonia

Correspondence: Liina Saar, liina.saar@ut.ee

Background & Aims: During the last centuries, species rich grasslands in Europe have gone through extensive area loss due to cessation of traditional management, agricultural intensification, forestation and urbanization. Nitrogen deposition and eutrophication can additionally decrease habitat quality in remnant grasslands. Loss of habitat area and quality can lead to local extinctions of plant species, as conditions become unsuitable for many populations.

Over the last two decades, a number of studies have been published that focus on the response of plant species to habitat changes. Results have been ambiguous, depending on characteristics of the study system, observed time frame, species life-history traits etc. Thus, despite the intensive research, we are still lacking thorough knowledge of which species are most threatened by the changes in area and quality of European grasslands.

Materials & Methods: By compiling information from 17 studies that have used floristic resurveys, we have assembled a large dataset to describe changes in plant community composition in European grasslands. We extracted current and historical species lists as well as landscape and environmental factors that were used in the studies to explain the floristic changes. Detailed information about plant species extinction and colonization during the past 30 to 300 years allows us to reveal the changes in grassland community composition and in species abundances as well as identify the main driving factors behind the changes. Using the data from studies across Europe, we test which life-history traits and habitat preferences are related to species extinction and colonization patterns in grasslands with different land-use history.

Main Results: Our results allow us to explicitly characterize past anthropogenic changes in grassland ecosystems across Europe and can be applied to determine the species that are most susceptible to future extinctions in less degraded grasslands. Knowledge about species that have increased their abundance or have colonized the grasslands recently enables better predictions of future changes in European grasslands and may help in taking appropriate conservation actions.

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Figure 1. Calcareous grassland in Estonia in the 1920s: open and with low vegetation cover (Haavakannu alvar, 1924). Photo: G. Vilbaste. courtesy of Estonian National Museum Fk 1523:2500.

Figure 2. Degraded calcareous grassland in Estonia, affected by urbanization and eutrophication (Iru alvar, 2009). Photo: L. Saar.

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Dynamics of understory beech trees under canopy layers composed of different tree species in an old-growth beech forest

Keiji Sakamoto (1), Shu Kinoshita (1), Yasuaki Akaji (1), Uyanga Ariya (1), Taku Makimoto (2), Yuko Miyazaki (1) & Muneto Hirobe (1)

1) Graduate School of Environmental and Life Science, Okayama University, Okayama 7008530, Japan

2) Okayama Prefectural Office, Okayama 7008570, Japan

Correspondence: Keiji Sakamoto, skmtelm@okayama-u.ac.jp

Background & Aim: Beech (*Fagus crenata*) forests are deciduous broad-leaved forests in the cool temperate zone. The canopy layer is often dominated by different tree species, causing heterogeneity of light conditions in the understory. Seasonal canopy gap occurs when canopy trees of a species unfold leaves later and/or shed leaves earlier than canopy trees of other species. Therefore, differences in species composition of the canopy layer probably affect population dynamics of seedlings, saplings, and understory trees (Seiwa 1998; Tomita & Seiwa 2004). However, some studies have demonstrated the canopy seasonality affects comparatively larger-sized understory trees from long-term ecological research data. This study examines the effects of the heterogeneity in the canopy layer on the dynamics of understory beech tree populations by long-term ecological research in an old-growth beech forest.

Materials & Methods: We studied an old-growth beech forest (35º14′ N, 134º23′ E; 1050 m a.s.l.) in the Wakasugi Forest Reserve, Japan. The dominant species were *F. crenata* (*Fagaceae*) and *Magnolia obovata* (*Magnoliaceae*) while the understory was dominated by dense dwarf bamboo *Sasa kurilensis* (*Poaceae*). In 1992, we sampled trees with diameters at breast height (DBH) ≥ 4 cm, counted the trunks, identified the species, measured the DBH, and recorded the position in a study plot of 50 m X 240 m, and re-measured them in 2011. We calculated survival and DBH increments of *F. crenata* understory trees under canopy trees of *F. crenata and M. obovata,* respectively. We analysed spatial distribution correlations between canopy trees and *F. crenata* understory trees by pair correlation function with the position data. Additionally, in order to clarify seasonal changes of light conditions under canopy trees of both species, we recorded leaf phenology of both canopy trees species with automatic cameras, and measured light intensity at three points under each of three canopy trees of both species with colour acetate films.

Main Results & Interpretations: Survival and growth rate of *F. crenata* understory trees were higher under *M. obovata* canopy trees than under *F. crenata* canopy trees. Moreover, *F. crenata* understory trees had dissociated spatial distribution with *F. crenata* canopy trees, but had associate spatial distribution with *M. obovata* canopy trees. On the other hand, in spring *F. crenata* understory trees tended to unfold leaves later than *F. crenata* canopy trees and earlier than *M. obovata* canopy trees, and in autumn *F. crenata* understory trees tended to shed leaves later than *M. obovata* canopy trees and earlier than that of *F. crenata* canopy trees. Additionally, light intensity was higher under *M. obovata* canopy trees than under *F. crenata* canopy trees during the leafy season. Under *M. obovata* canopy trees, these benefits for light availability probably increased survival and growth rates of *F. crenata* understory trees. Therefore, we suggest that a *M. obovata*-dominated canopy layer contributes to the regeneration of *F. crenata*, and that canopy layer heterogeneity is an essential factor in the population dynamics of the beech forests.

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Riparian willow forest regeneration following a large flood

Hitoshi Sakio (1) & Kanako Nikkuni (2)

1) Field Center for Sustainable Agriculture and Forestry, Faculty of Agriculture, Niigata University, 94-2 Koda, Sado, Niigata 952-2206, Japan

2) Faculty of Environmental Science and Technology, Graduate School of Science and Technology, Niigata University, 8050 Ikarashi-2-no-cho, Nishi-ku, Niigata 950-2101, Japan

Correspondence: Hitoshi Sakio, sakio@agr.niigata-u.ac.jp

Background & Aim: Flooding is a key factor affecting regeneration in riparian forests. Disturbance in riparian areas vary in frequency, magnitude, and size. Some tree species depend on large disturbances for regeneration and have adapted their life-history characteristics to environmental unpredictability. However, recovery processes after a large disturbance event have not been fully explored in relation to early-stage regeneration. A large flood occurred in Niigata and Fukushima Prefectures, Japan, when 700 mm of precipitation fell in 72 h from 28 to 30 July, 2011. The maximum precipitation over a 24-h period was 527 mm. Mud resulting from the flood struck houses and paddy fields and the floods extensively damaged the riparian willow forests in the area. Here, we investigated the recovery process in these forests to understand the processes of regeneration after flooding.

Materials & Methods: Following the flood in 2011, we established a 1-ha research plot in the riparian forest, including the sub-flow path, of the Ina River, Fukushima Prefecture, eastern Japan. All trees were mapped using a compass survey. In addition, all living and dead trees > 5 cm in DBH were numbered and identified to species, and their DBH was recorded. This plot was divided into 100 subplots (10 m X 10 m), in which microtopography, substrate, and openness were recorded. In the spring of 2012 we set 25 seedling plots (1 m X 1 m) at regular intervals in the 1-ha plot. In these plots we studied the dispersal of willow seeds, the growth and survival of willow seedlings, and environmental factors (substrate, cover degree, soil water content, and light condition). We also investigated resprouting that originated from underground stems buried by flood mud.

Regenerating alluvial vegetation (Ina River, japan). Many willow seeds germinated on newly deposited sand and gravel. Photo: H. Sakio.

Destroyed riparian willow forest along the Ina River, Japan, following a large flood. Photo: H. Sakio.

Results & Interpretations: The dominant canopy species were *Salix jessoensis*, *Salix hukaoana* and *Pterocarya rhoifolia*, distributed randomly in the relatively high sandbar site. The shrub willows *Salix gracilistyla* and *S. sachalinensis* were densely distributed in the sub-flow path. Damaged trees, mainly willow species, were located on a lower site near the mainstream. After the flood, the surface microenvironment was a mosaic of sand, gravel, rock, and herbaceous patches; during the following spring many willow seeds were dispersed and germinated on newly deposited sand and gravel. However, the seedlings died rapidly, and those that survived were confined to only a few sites. In addition, since willow species also reproduce via resprouting as many sprouts emerged from the ground and willow stems. After 2 years, the sprouts grew taller than seedlings, suggesting that sprouts may play an important role in the regeneration of willow forests. In future, we plan continuing our monitoring of the regeneration processes in this riparian forest.

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A review on the halophytic vegetation of Dominican Republic

Carlos Salazar (1), Antonio García-Fuentes (1), M. Lucía Lendínez (1), Juan Quesada (2), J. Antonio Torres (1), Luis Ruiz-Valenzuela (1) & Yolanda León (3)

1) Departamento de Biología Animal, Biología Vegetal y Ecología, Universidad de Jaén, E-23071-Jaén, España
2) Laboratorio de SIG y Teledetección, Instituto de Ciencias Ambientales, Universidad de Castilla-La Mancha, Av. Carlos III, s/n, E-45071 Toledo, España
3) Laboratorio de Cartografía y Teledetección, Universidad INTEC, Santo Domingo, República Dominicana

Correspondence: Carlos Salazar, csalazar@ujaen.es

Background & Aim: Halophytic formations in tropical and subtropical regions, specifically mangrove swamps and salt marshes, are vegetation of major scientific interest. Nowadays this vegetation is seriously threatened by many human impacts. This vegetation has been studied in Central America by several authors, both on the Pacific coast (Peinado et al. 1995) as well as on the coast of the Caribbean (Borhidi 1991; Rangel Churio 2012). Little attention has so far been paid to the Caribbean salt marshes. The main objective of this work is to analyse the floristic composition, structure and biodiversity of the Dominican halophytic vegetation.

Materials & Methods: 151 phytosociological relevés were made during 2006-2007. Data were analyzed with *Ginkgo* program (De Cáceres & Font 2007). Two data matrices with 101 relevés X 75 species (mangrove swamps) and 50 relevés X 37 species (salt marshes) were subjected to a multivariate exploration by means of fuzzy C-means classification and principal coordinate analysis ordination.

Main Results: A total of 75 species have been found in the Dominican mangrove swamps. The best-represented life forms in this vegetation were phanerophytes (32%), followed by hemicryptophytes and chamaephytes. The salt marshes had lower species diversity (37 spp.) and the predominant life forms in this vegetation were hemicryptophytes (46%) and therophytes (35%). Seven vegetation types have been singled out. Three of them are mangrove swamp associations, all previously described from the Pacific coasts – a finding that contradicts the doubtful data recently reported by Cano et al. (2012) from the Caribbean. Four associations were described in the salt marshes. These include: the previously described *Salicornietum bigelovii* Peinado et al. 1994 (dominated by annual halophytic succulents) and three new associations, such as the grassland *Fimbristylo cymosae-Sporolobetum virginici,* the *Batidetum maritimae* (characterized by creeping succulent plants) and the shrubby succulent *Suaedo tampicensis-Heterostachydetum ritterianae*. The latter two units were reported by Ciferri (1936), but not described in detail.

Figure 1. Mangrove swamps with button mangrove (*Conocarpus erectus*) surrounded by stands of succulent creeping halophyte *Batis maritima* in Cabo Rojo, SW Dominican Republic (*Lagunculario racemosae-Conocarpetum erecti* and *Batidetum maritimae*). Photo: C. Salazar

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Assessing changes in broad-leaved deciduous forests in Western Norway by the use of total inventory lists of vascular plants

Fride H. Schei (1), Magne Sætersdal (1), Einar Heegaard (1) & John-Arvid Grytnes (2)

1) Norwegian Forest and Landscape Institute, Fanaflaten 4, N-5244 Fana, Norway

2) Department of Biology, University of Bergen, Allégaten 41, N-5007 Bergen, Norway

Correspondence: Fride H. Schei, hof@skogoglandskap.no

Background & Aim: Broad-leaved deciduous forests of Western Norway are supposed to be threatened by invasive tree species, increased browsing by wild ungulates, and lack of traditional anthropogenic disturbance. However, little tangible data have been gathered to support this claim as there are low numbers of old permanent vegetation plots suitable for resampling. Resampling of historical studies without the use of permanent plots, and to use these data to detect temporal changes in the vegetation, have always been assumed to be a major challenge. The aim of our paper is to analyse two sets of total inventories of broad-leaved deciduous forests, with a sampling interval of 20 years, and to use frequency data of vascular plants (on a frequency scale of 0 to 5) as a tool to quantify vegetation changes and to relate them to environmental changes.

Materials & Methods: Sætersdal and Birks (1993) made a total inventory list of vascular plants in 60 isolated patches of broad-leaved deciduous forests located along fjords in Western Norway. These forests are located on non-arable land in steep hills with favourable local climate, and have high biotic diversity, productivity and several Red-Listed species of vascular plants and lichens. The study by Sætersdal and Birks (1993) was carried out in 1988 and 1989. 20 years later, in 2009, 25 forests were re-surveyed by our two teams.

Main Results & Conclusion: As expected there were differences in the frequency registrations by the two teams engaged in the re-survey. Each team visited each forest only once and it has been shown previously that only 2/3 to 3/4 of all species were recorded at one visit (Kirby et al. 1986). Both resurveys show similar trends when we compared with the original study: we revealed an increase in species richness, decrease in several light demanding species often found in open forest with human activities, e.g. *Malus sylvestris* (European crab apple), and an increase of several boreal forest species, e.g. *Trientalis europea* and *Vaccinium vitis-idaea*. These data indicate that the broad-leaved deciduous forests of Western Norway are becoming denser, which could be ascribed to an effect of recent climate change, however most likely it is due to ceased traditional forest management, like pollarding, coppicing and grazing by domestic animals. We have not found a strong increase in the presence of invasive tree species, such as black-listed *Acer pseudoplatanoides* as we originally expected, since this species actually disappeared from several of the analysed forests in the last 20 years.

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Spatial pattern model of herbaceous plant mass as a tool for characterizing the community structure

Masae Shiyomi (1) & Jun Chen (2)

1) Ibaraki Study Center, The Open University of Japan, Bunkyo 2-1, Mito, Japan

2) College of Animal Science and Technology (Grassland), Northwest A&F University, Yangling, Shaanxi, China

Correspondence: Masae Shiyomi, shiyomi@mx.ibaraki.ac.jp

Background & Aims: Individual plant species are spatially distributed according to their own pattern in a community. We measure the pattern by measuring plant mass per quadrat and thereby clarify the abundance and spatial heterogeneity level of each species in a community.

Materials & Methods: We derived a frequency distribution model and an index for measuring the spatial pattern formed by individual plant species, based on dry weight mass. First, we show that the frequency distributions of mass for individual plant species per quadrat in a plant community are theoretically expressed using the gamma distribution with two parameters (Fig. 1), i.e., λ (mean) and *p*, as follows: $(p/\lambda)^p x^{p-1}\exp(-px/\lambda)/\Gamma(p)$, $x \geq 0$, where *x* denotes the plant mass of a species. The gamma distribution was derived under assumptions that (1) the mass of a single plant species per quadrat changes with time according to the logistic assumption; (2) the carrying capacity of the logistic equation determined by physical, chemical, and biological environments in a plant community varies stochastically according to a normal distribution; and (3) plant growth is balanced by defoliation. The parameter *p* is a measure indicating the level of spatial heterogeneity of plant mass as follows: (1) when $p = 1$, the plant mass per quadrat has a random pattern; (2) when $p > 1$, the plant mass has a spatial pattern with lower heterogeneity than would be expected in the random pattern; and (3) when $p < 1$, the plant mass has a spatial pattern with higher heterogeneity than would be expected in the random pattern. The value of *p* for a given species can be calculated as [mean plant mass per quadrats]^2/[variance in plant mass among quadrats]. The scatter diagram of (λ, *p*) for individual plant species exhibits the spatial characteristics of each species in the community.

Main Results: Fig. 2 is an example of the (λ, *p*) diagram for each species composing an actual weedy grassland community in central Japan. Frequency distributions for the plant mass of individual species per quadrat followed the gamma distribution. This means that the frequency distributions were approximated by the assumptions mentioned above, and individual species exhibited an inherent level of spatial heterogeneity.

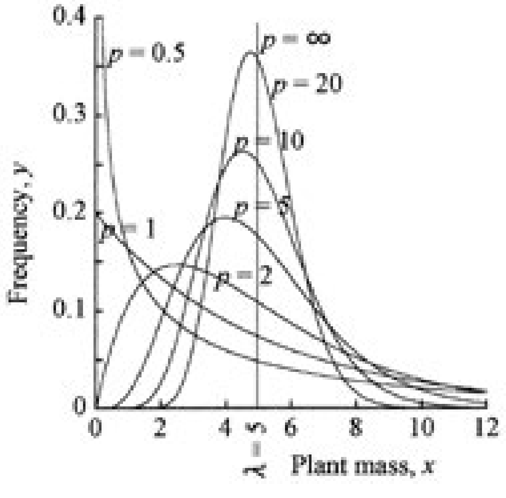

Figure 1. Gamma distributions for various p, expressing plant mass frequency distribution with mean λ = 5.

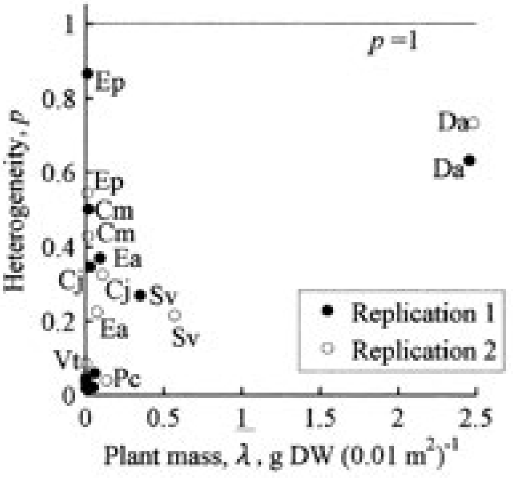

Figure 2. An example of the (λ, p) diagram for each species composing an actual weedy grassland community. Symbols denote species.

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Wetlands in a largely arid land: distribution, ecological drivers and conservation importance of wetland vegetation types in South Africa

Erwin J. J. Sieben (1), Hlengiwe Mtshali (1) & Matthew Janks (2)

1) Department of Plant Sciences, University of the Free State, Qwaqwa Campus, Private Bag X13, Phuthaditjhaba 9866, South Africa

2) Department of Botany, Rhodes University, P.O. Box 94, Grahamstown 6140, South Africa

Correspondence: Erwin J.J. Sieben, siebenej@qwa.ufs.ac.za

Background & Aims: Since the 1990s, the ecosystem services provided by wetlands are increasingly appreciated by South African policy-makers, as exemplified by the inclusion of wetland restoration in public work programmes. Planning around water management in South Africa has been built around the National Freshwater Ecosystem Priority Areas that provides a framework for the availability of water and biodiversity in various ecosystems; wetlands form an important part of this framework. Knowing the variability of wetland vegetation and understanding the major ecological drivers underpinning this variability is one of the major pre-requisites in successfully managing these vulnerable ecosystems.

Material & Methods: The wetland vegetation has been studied by means of representative vegetation plots in wetlands in all parts of South Africa and by collating a large database storing the vegetation data and associated environmental variables. We built a database that captures vegetation data from historical studies on wetlands as well as data collected during our field studies in those regions that had been neglected in the past. Vegetation plots recorded species abundance data as well as basic environmental descriptors. In some cases, soil samples were collected and analysed for physical and chemical attributes. Subsets of data extracted from the database were subjected to a cluster analysis and canonical ordination in order to reveal the main patterns in the vegetation data.

Main Results & Interpretations: The cluster analysis revealed 275 plant communities and these were grouped into eight main vegetation types: Sclerophyllous wetland vegetation, Subtropical wetland vegetation, Swamp forests, Saline and Brackish wetland vegetation, Montane grassy wetland vegetation, Temperate grassy wetland vegetation, Short-lawn grassy wetland vegetation, and Aquatic (submerged) vegetation. Some of these wetland vegetation types are widespread (e.g., the Temperate grassy wetland vegetation), while other types are restricted to specific regions; this holds particularly for Sclerophyllous wetland vegetation (embedded within Fynbos Biome) and Swamp forests (embedded within the subtropical Indian Ocean Coastal Belt). South Africa has a strong climatic gradient, with dry climates in the West, where Saline and Brackish wetland vegetation and Short-lawn grassy wetland vegetation are dominant, towards mesic climates in the East, where Temperate grassy wetland vegetation and Subtropical wetland vegetation are most prominent. Within a single wetland, communities from various main vegetation types can co-occur. Hydroperiod (the duration of soil waterlogging) was the primary explanatory environmental factor of species composition in the studied wetlands. Interaction between local hydrology and regional climatic and geological conditions determine the distribution of wetland plant communities in the country. This is reflected in plant species response to factors such as pH, concentrations of major cations, nitrogen, phosphate and electrical conductivity. Wetland communities were species poor when dominated by clonal plants. The most species-rich communities were found in the lowlands of the Western Cape and in the montane regions of KwaZulu-Natal and Eastern Cape. The areas with the highest diversity of wetland habitats were Maputaland in northern KwaZulu-Natal as well as the Western Cape.

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The role of seed germination ecology in community assembly in neotropical montane grasslands

Fernando A.O. Silveira (1), Daniel Negreiros (2), G. Wilson Fernandes (2) & José P. Lemos-Filho (1)

1) Department of Plant Biology, Federal University of Minas Gerais, Av. Antônio Carlos, 6627, 30161-970, Belo Horizonte, Minas Gerais, Brazil

2) Department of General Biology, Federal University of Minas Gerais, Av. Antônio Carlos, 6627, 30161-970, Belo Horizonte, Minas Gerais, Brazil

Correspondence: Fernando A.O. Silveira, faosilveira@icb.ufmg.br

Background & Aim: Despite the recognized role of dormancy and germination requirements in shaping plant distributions, seed germination ecology is still not commonly considered when explaining the distribution patterns of plant species and communities (Poschlod et al. 2013). Here, we provide the first examples of how seed germination ecology can contribute to the assembly of Neotropical species-rich plant communities using two functionally distinctive, ecologically diverse and species-rich clades of flowering plants.

Materials & Methods: Germination requirements for 12 *Bromeliaceae* and 50 *Melastomataceae* species from species-rich heterogeneous montane grasslands in SE Brazil were determined. We calculated germination percentage, mean germination time (MGT), synchrony, temperature range and light requirement for all species. For the *Bromeliaceae*, we ran a RLQ (R-mode linked to Q-mode) analysis based on our matrices of species occurrence, environmental parameters and germination traits. For *Melastomataceae*, we implemented ecophylogenetic analyses (incorporating phylogenetic data in ecological studies) to determine environmental filtering in specific microhabitats and to investigate niche differentiation in closely related species.

Main Results & Interpretations: For the *Bromeliaceae*, we found a significant association between germination traits, and the characteristics of sites where adult plants occur. The variation of germination responses to environmental factors was not random with habitat-generalist plants having broader germination niches and habitat-specialist plants having narrower germination niches. We found an association between the regeneration niche of a species and its ecological range, and this also provides support for the idea that the regeneration niche may help assemble plant species into heterogeneous, species-rich communities (Marques et al. 2014). For the *Melastomataceae*, germination traits were convergent (lower divergent width than expected by chance) in the endemic clades and divergent (higher divergent width than expected by chance) in the widespread clades, suggesting environmental filtering in the former and niche differentiation in the latter. We decomposed trait diversity in the phylogenetic tree and found a large contribution of MGT and germination synchrony in the tips of the tree, suggesting that phylogenetically close species germinate at different times, a mechanism that can decrease competition. Factorial analyses indicated the formation of groups separated by geographic distribution (endemic vs. widespread species), microhabitat specialization (mesic vs. xeric microhabitats) and dispersal mode (biotic vs. abiotic). Therefore, our data strongly support the idea that seed germination ecology plays a major role in structuring plant communities and contribute to our understanding on the importance of the regeneration niche in community assembly (Grubb 1977).

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Drought-Net: A global network to assess terrestrial ecosystem sensitivity to drought

Melinda D. Smith (1), Osvaldo Sala (2) & Richard P. Phillips (3)

1) Graduate Degree Program in Ecology, Department of Biology, Colorado State University, Fort Collins, CO 80523, USA

2) School of Life Sciences and School of Sustainability, Arizona State University, Tempe, AZ 85287, USA

3) Biology Department, Indiana University, Bloomington, IN 47405, USA

Correspondence: Melinda Smith, melinda.smith@colostate.edu

Background: All ecosystems will be impacted to some extent by climate change, with forecasts for more frequent and severe drought likely to have the greatest impact on terrestrial ecosystems. Terrestrial ecosystems are known to vary dramatically in their responses to drought. However, the factors that may make some ecosystems respond more or less than others remains unknown, but such understanding is critical for predicting drought impacts at regional and continental scales. To effectively forecast terrestrial ecosystem responses to drought, ecologists must assess responses of a range of different ecosystems to drought, and then improve existing models by incorporating the factors that cause such variation in response. Traditional site-based research cannot provide this knowledge because experiments conducted at individual sites are often not directly comparable due to differences in methodologies employed. Coordinated experimental networks, with identical protocols and comparable measurements, are ideally suited for comparative studies at regional to global scales. The US National Science Foundation-funded Drought-Net Research Coordination Network (www.drought-net.org) will advance understanding of the determinants of terrestrial ecosystem responses to drought by bringing together an international group of scientists to conduct two key activities conducted over the next five years: 1) planning and coordinating new research using standardized measurements to leverage the value of existing drought experiments across the globe (Enhancing Existing Experiments; EEE), and 2) finalizing the design and facilitating the establishment of a new international network of coordinated drought experiments (the International Drought Experiment, IDE). The primary goals of these activities are to assess: (1) patterns of differential terrestrial ecosystem sensitivity to drought and, (2) potential mechanisms underlying those patterns.

Current Status: As a central activity of Drought-Net, IDE will significantly expand the scope of past drought experiments by including a greater range of ecosystem types (particularly forests), insuring that these experiments are accessible to as many investigators as possible, and overcoming the limitations of past drought experiments (i.e., lack of coordination, differences in approaches and methodologies, etc.). IDE will follow in the pioneering footsteps of the Nutrient Network (NutNet; http://www.nutnet.umn.edu/), in that (1) network design will be hypothesis driven, (2) the experiment will be designed with simplicity in mind to minimize fiscal and logistical constraints, and (3) an important features of the network are a universal experimental design to be used at all sites, a clear set of guidelines for data sharing, intellectual participation in network-level data analyses, and authorship of manuscripts. Currently, IDE is still under development, but the plan is to finalize the experimental design in 2014. To date, over 100 investigators from more than a dozen countries have agreed to participate in IDE. The goal is to initiate IDE in 2015, with sites collecting one year of pre-treatment data and drought treatments starting in 2016.

Future Directions: The next steps with Drought-Net are to hold an organizational meeting in early 2015 to design the EEE activity. With EEE, we will take an additional step forward in advancing our understanding of how and why ecosystems differ in their sensitivity to drought by coordinating new standardized measurements across a range of existing drought experiments – essentially envisioning these as a network-scale platform that can be leveraged to advance our understanding of drought well beyond the individual site scale. Thus, a primary goal of EEE will be to recruit researchers to participate in new and innovative network-level studies based on this existing experimental platform.

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Potential distribution of cerradão, an endangered woodland formation of the cerrado biome, Brazil

Alexandro Solórzano (1,2), Sunil Kumar (2) & John D. Hay (3)

1) Departmento de Geografia e Meio Ambiente, Pontifícia Universidade Católica do Rio de Janeiro, Rio de Janeiro 22451, RJ, Brazil

2) Natural Resource Ecology Laboratory, Colorado State University, Fort Collins, CO 80523-1499, USA

3) Departamento de Biologia, Universidade de Brasília, Brasília DF, Brazil

Correspondence: Alexandro Solórzano, alexandrosol@gmail.com

Background & Aims: Although the challenges of the 'Linnean shortfall' (Lomolino et al. 2010) for the Brazilian cerrado biome (tropical savanna) has been greatly overcome, with the description of more than 12 thousand vascular plant species, there is still much to be understood regarding their distribution and ranges. The *cerradão*, a unique upland woodland formation, is among the rarest and most threatened habitats in the cerrado biome. Our aim was to understand which environmental variables are associated with the distribution of the cerradão vegetation at the cerrado biome level and to map its potential distribution comparing two different community models, one based on community composition and the other based on the distribution of characteristic cerradão species.

Materials & Methods: We used presence-only data from 42 points collected in cerradão, both from field plots (34 points) and data in the literature (8 points), spatially distributed throughout the entire cerrado biome. Set of 21 environmental variables, including the remote-sensing vegetation indices such as EVI, NDVI, climatic, and physiographic variables were used in the final model. We used Maxent to model the potential distribution of the cerradão due to its high performance with presence-only data sets. To evaluate overall model performance we used a threshold independence test, the area under the receiver operating characteristic (ROC) curve (AUC). The AUC is a valid measure of the models capability to correctly classify presence more accurately than a random prediction (Phillips et al. 2006). The AUC values range from 0.5 to 1.0 with random prediction corresponding to an AUC of 0.5.

Main Results & Interpretations: Overall the model for the cerradão vegetation presented a high AUC (0.893) and high test gain (1.558) and low omission rate (0.14), rendering a good performing model. The individual species models presented lower test AUC values compared to the whole cerradão model. One explanation for this is that the species used in the individual models tend to occur in other habitats (e.g. gallery forest, open savanna) rendering difficult the modelling of species requirements specifically for cerradão. Climatic and physiographic variables, namely precipitation seasonality and flow accumulation, were important descriptors for cerradão distribution at the regional level. The total area predicted as cerradão (10% of the cerrado biome, approximately 22.8 million hectares) is in accordance with past descriptions for the biome, prior to the expansion of agro-pastoral activity, and also in accordance with recent evidence of cerradão expansion in the southern portion of the biome vegetation (Durigan & Ratter 2006). The current cerradão potential distribution map can be used as a benchmark to understand its current state of habitat loss. Cerradão was targeted as providing ideal locations for crops since it occurs in upland areas with little to no slope and in more fertile soils. Currently its scarcity, coupled with the prediction of continued agricultural land expansion within the biome, makes the cerradão a rare and highly threatened woodland formation that needs urgent conservation initiatives that should target where its predicted cover is higher such as São Paulo, eastern Mato Grosso and western Maranhão and Tocantins States.

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A long-term nutrient addition experiment in a temperate sandy grassland: nutrient concentration, phytomass production, and community response

Christian Storm & Linda Freund

Vegetation Ecology, Department of Biology, Technische Universität Darmstadt, D-64287 Darmstadt, Germany

Correspondence: Christian Storm, storm@bio.tu-darmstadt.de

Background & Aim: Temperate, nutrient-poor calcareous sandy grasslands in Europe have low productivity yet are of high conservation value. These grasslands are threatened by enhanced nutrient availability, for instance by airborne deposition or fertilization. We continued the fertilization field experiment reported by Storm & Süss (2008) and by Faust et al. (2012) to reach a study period of 12 years and analysed the new data to answer the following questions: What are the long-term effects of nutrient addition on (1) nutrient concentration in plant tissue, (2) phytomass of plant functional types, and (3) vegetation composition and species diversity?

Materials & Methods: We studied the *Koelerion glaucae* xeric sand calcareous grasslands (Natura 2000 code 6120) in the Upper Rhine Valley, Germany. In 2000 a five-fold replicated randomised block design was established. Besides the control (0), the treatments involved addition of phosphorus (P), nitrogen in low (N: 25 kg ha^{-1} yr^{-1}) and high (N: 100 kg ha^{-1} yr^{-1}) doses and in combinations of N+P (NP), + potassium (NPK), + all other essential nutrients (NPKM). Carbon (C) addition was included in order to reduce plant-available soil nitrogen. The treatments can be grouped into two groups: N-: no or low nitrogen dosage (0, C, P, n), and N+: high nitrogen dosage (N, NP, NPK, NPKM). We sampled the experimental plots twice a year for above- and below-ground phytomass of plant functional types and analysed total N and P in plant tissues. Data were analysed using canonical correspondence analyses and linear mixed-effect models.

Main Results & Conclusions: Question 1: Already 3 months into the experiment, P concentration was significantly higher in sites that had P added. The N concentration in phanerogams and cryptogams following N+ treatments increased also significantly, but only around 1.2-fold. The N:P ratio in the above-ground phytomass of phanerogams was 10 on control plots. After N+ treatment this ratio increased to 15, while it decreased to 6 on plots treated with P only. C treatment had no significant effects on the element concentrations; n-treatment had only a small significant effect on the N concentration of cryptogams. Question 2: The above-ground phytomass of phanerogams had significantly increased 1.9-fold by N addition by the 4th year. In contrast, the cryptogam phytomass decreased continuously to 0.5-fold in the last year. Phytomass after the n-, C- and P-treatments did not differ significantly from the control. Question 3: In N+ sites, the species composition changed until the 4th year, after which not further changes occurred. Species diversity was significantly reduced 0.85-fold following the N+ treatments after the 5th year. The dominant role of N is indicated by the N:P ratio. After 7 years of nutrient addition the system stabilized and no further significant changes of the investigated variables could be found in the last 5 years. Low N, P or C inputs had only minor effects even after 12 years (besides the luxury accumulation of P).

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Relationships between environmental heterogeneity and plant species richness: the role of spatial scale and evolutionary history

Riin Tamme (1), Antonio Gazol (2), Jodi N. Price (3) & Meelis Pärtel (1)

1) Institute of Ecology and Earth Sciences, University of Tartu, EE-51005 Tartu, Estonia

2) Pyrenean Institute of Ecology, Spanish National Research Council, (IPE-CSIC), Avda. Montañana 1005, E-50059 Zaragoza, Spain

3) School of Plant Biology, The University of Western Australia, 35 Stirling Hwy, Crawley WA 6009, Australia

Correspondence: Riin Tamme, riin.tamme@ut.ee

Background & Aim: Environmental heterogeneity is often considered as a universal driver of species richness allowing niche differentiation and promoting co-existence. However, the heterogeneity-richness relationship varies with spatial scale, and negative relationships can emerge if heterogeneity is measured at small spatial scales (Tamme et al. 2010). Heterogeneity can reduce richness if some species in a community are better adapted to small-scale resource patchiness and outcompete others. Moreover, the heterogeneity-richness relationship may vary between regions if species of different origins are adapted to heterogeneity levels that have been more prevalent during evolutionary history (Pärtel et al. 2008). Here, we test the generality of the relationship between environmental heterogeneity and plant species richness at different spatial scales and in regions with varying evolutionary history.

Materials & Methods: In a coordinated survey, we sampled temperate grasslands from across the world - Estonia, Iceland, Spain, Mongolia, Canada, Argentina and Australia. We collected data on vascular plant species richness, soil moisture (% vol.), and light availability (ratio of PAR below and above vegetation) in 10 cm X 10 cm plots. The plots were arranged in transects (length 10 m), and between 4 and 13 transects were sampled in each country. This sampling design enabled us to vary the patch size and, thus, to distinguish heterogeneity at different spatial scales. Specifically, for each transect we calculated the coefficient of variation of soil and light conditions using values averaged over 0.001, 0.02, 0.04 or 0.05 m^2. We then used soil and light heterogeneity as well as mean transect conditions in linear mixed-effect models to determine the effect of environmental factors on species richness patterns.

Main Results & Conclusions: The relationship between environmental heterogeneity and species richness varied with spatial scale and amongst regions. Overall, heterogeneity in light conditions was negatively related to species richness at the smallest scales (patch size 0.001–0.02 m^2) but positively related to richness at the larger scales (0.04–0.05 m^2). Heterogeneity in soil conditions negatively impacted on species richness across all scales. However, there were differences between regions. Light heterogeneity had a negative effect on species richness in Estonia, Iceland, Australia and Canada, but showed a positive effect on richness in Mongolia, Spain and Argentina. Soil heterogeneity had a negative effect on species richness in Estonia, Spain and Australia, whereas in Argentina and Canada the effect was positive. In Iceland and Mongolia, however, the effect of soil heterogeneity depended on the spatial scale and was negative at the smallest scales, but positive at larger scales. These results suggest that resource patchiness at scales similar to the extent of plant individuals' shoot or root systems may alter competitive interactions between species, and reduce species richness. We found no evidence for a globally universal relationship between environmental heterogeneity and plant species richness. We therefore suggest that spatial scale and regional differences are important factors influencing this pattern.

Acknowledgements: We thank the numerous local experts and collaborators of the project.

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A simple tool for exact estimation of tree layer cover from hemispherical photographs

Lubomír Tichý

Department of Botany and Zoology, Masaryk University, Kotlářská 2, CZ-611 37 Brno, Czech Republic

Correspondence: Lubomír Tichý, tichy@sci.muni.cz

Background: Plant communities are usually described as assemblages of plant species and their presence quantified by projective cover. The cover is frequently defined subjectively by means of visual estimation as projection of the aboveground biomass onto the soil surface. The total ground cover data can be used in assessments of stand density, light reduction, biomass production and the like. The total ground cover can also assist in correction of individual species cover estimates. Sunlight penetration through forest canopy openings was first estimated from hemispherical photographs by Evans & Coombe (1959). Chazdon & Field (1987) analysed hemispherical photographs using a computerised technique. In order to mitigate the observer bias of visual estimates, many authors measured canopy cover (canopy closure) using hemispherical photographs taken from the forest understory and then computerised the images. This practice became rather popular and various software applications were developed for the analysis of hemispherical canopy photographs. Currently, cell phones as small computers with camera and operation system are capable for both taking canopy photographs and efficient analysis (Escribano-Rocafort et al. 2014). Even though the hemispherical photographs can be a source of useful data informing about leaf area index, direct or diffuse solar irradiation and other environmental parameters, these characteristics are poorly comparable with tree layer cover (crown closure) estimates traditionally used in vegetation surveys. While tree layer cover is a vertical projection of trees onto the ground surface, canopy closure represents the amount of sky covered by forest tree and shrub vegetation from a certain position on the ground.

New Approach & Evaluation: 'Tree Layer Cover Index' calculated from hemispherical photographs is a new parameter I introduce here. It is closely related to the tree layer cover estimated by observers in vegetation survey research. This new parameter will be compared with calculation of the Canopy Cover (Frazer et al. 1997) and evaluated using a data set of the South Ural (Russian Federation) forests with hemispherical canopy photographs and expert based estimations of tree layer cover. Automatic calculation of a new index is available using my own simple Android software named 'Gap Light Analysis Mobile Application' freely available on the internet (*https://play.google.com/store/apps/details?id=com.mobilesgla*). The program is designed as a field work application. In combination with a fisheye lens and tablet or cell phone with a camera and Android operation system it can help increase the accuracy of the tree-layer cover estimation in the field as well as it can be used as a standard for training of visual estimation. Obtained measurements can be combined with numerous visually observed estimates of tree layer cover stored in vegetation databases.

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Grassland vegetation recovery using seed mixtures: regional differences and application problems in Europe

Péter Török, Orsolya Valkó, Balázs Deák & Béla Tóthmérész

MTA-DE Biodiversity and Ecosystem Services Research Group, Egyetem tér 1, H-4032 Debrecen, Hungary

Correspondence: Péter Török, molinia@gmail.com

Background & Aims: Recovery of grasslands and their biodiversity is a vital element for conservation of biodiversity in agricultural landscapes in Europe. In the last few decades both the area and connectivity of grasslands have been decreased dramatically caused by the intensification in agriculture. To recover former grasslands the most frequently applied grassland restoration measure is the sowing of low to high diversity seed mixtures. Low-diversity seed mixtures contain seeds of a few competitive graminoid or forb species characteristic to target grasslands. High-diversity seed mixtures contain seeds of 15–30 species (up to 60 species).

Materials & Methods: Seed sowing is successfully used in grassland restorations in Europe but with marked differences in application circumstances influenced by aims and regions. Low-diversity seed mixtures are cost effective, thus, widely used to the fast recovery of perennial vegetation, which is beneficial for (i) the rapid healing of landscape scars, (ii) for the prevention of soil erosion or (iii) to suppress noxious plant species. High diversity seed mixtures are much more expensive and difficult to compose but higher species richness can be expected within a relatively short time, which is crucial where spontaneous immigration of species is limited. To obtain information for the evaluation of the cost-effectiveness and application circumstances of seed mixture sowing we made a literature review (Török et al. 2011) and contacted directly many restoration experts across Europe.

Main Results: There were several problems identified including (i) the species composition of the mixture; (ii) the species proportions and sowing density, (iii) and the post-restoration management required for sustaining favourable restoration state of sown grasslands. In Western European countries there is a well developed seed market and regionally focused seed propagation strategy invented for the production of seed mixtures of local provenance. In contrast, in some of the East European countries even the seeds of foundation species are unavailable. In East-Europe large and species rich grassland areas are missing from most Western European countries, which provide a great landscape-scale spontaneous regeneration potential, and act as good research objects studying ecosystem functions. It can be concluded that a knowledge transfer is necessary between the different regions in Europe to preserve and increase effectively grassland biodiversity.

Figure 1. Loess grassland restored using *Festuca rupicola* (*Poaceae*) seeds: Hortobágy National Park, Hungary, 2 years after sowing, 30 kg/ha.

Figure 2. Loess grassland restored with a high diversity seed mixture: Hortobágy National Park, Hungary, 2 years after sowing, 20 loess species, 30 kg/ha.

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Empirical evidence for a humped-back relationship between biomass and species richness

Béla Tóthmérész (1), Balázs Deák (1), Tamás Miglécz (2), András Kelemen (1), Orsolya Valkó (1), Viktória B-Béres (3), Gábor Borics (4), Enikő Török-Krasznai (2) & Péter Török (1)

1) MTA-DE Biodiversity and Ecosystem Services Research Group, Egyetem tér 1, H-4032 Debrecen, Hungary
2) University of Debrecen, Department of Ecology, Egyetem tér 1, H-4032 Debrecen, Hungary
3) University of Debrecen, Department of Hydrobiology, Egyetem tér 1, H-4032 Debrecen, Hungary
4) MTA Centre for Ecological Research, Bem tér 18/C, H-4026 Debrecen, Hungary

Correspondence: Péter Török, molinia@gmail.com

Background & Aims: The study of the relationship between biomass production and species richness is essential for understanding dynamic changes in ecosystems. To explain the relationship along a broad biomass production gradient, the humped-back model has been proposed. In the model species richness first increases and then decreases along with increasing biomass. At the initial part of the curve the low diversity and biomass production are both explained by the extremely unproductive environment where only a few species are able to establish. The decreasing part of the humped back curve is generally explained by increasing competition and other limiting biotic interactions (Grime 1973).

Materials & Methods: We studied the relationship between biomass production and species richness along a broad gradient in two contrasting species groups (vascular plants in alkali and loess grasslands, and phytoplankton assemblages in standing waters). Altogether 240 grassland biomass samples were collected in 8 grassland types, in 24 stands, and were sorted into species. For the phytoplankton assemblages altogether 772 samples were collected in 20 standing waters, and specific bio-volumes were measured. We classified the species into functional groups: for the grasslands we used mixed CSR strategy types (Hodgson et al. 1999), for the phytoplankton codons (Padisák et al. 2009).

Main Results: We found that for both species groups a humped-back curve explained the relationship between biomass production and species richness. The novelty of our study is that the same relationship was detected with standardised sampling for two contrasting species groups. Both the diversity of mixed CSR strategy types and the codons showed a humped-back relationship along with increasing productivity. The most likely explanation for the detected humped-back relationship between biomass and species richness is resource partitioning, which is supported by the findings that the diversity of functional groups showed also a humped-back curve along an increasing productivity gradient.

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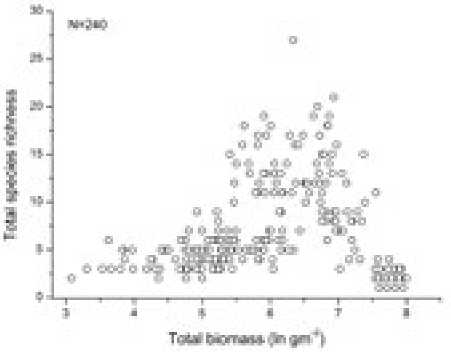

Figure 1. Relationship of biomass and species richness in alkali and loess grasslands sampled in an alkali landscape in NE Hungary.

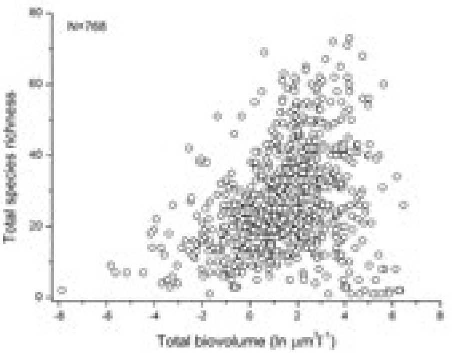

Figure 2. Relationship of biovolume and species richness of phytoplankton assemblages in standing waters of NE Hungary.

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Mapping the extent and spread of multiple plant invasions in Galapagos National Park

Mandy Trueman (1,2,3), Rachel J. Standish (1), Daniel Orellana (2,4) & Wilson Cabrera (5)

1) School of Plant Biology, The University of Western Australia, 35 Stirling Hwy, Crawley WA 6009, Perth, Australia
2) Charles Darwin Foundation, Puerto Ayora, Santa Cruz, Galápagos, Ecuador
3) Department of Land Resource Management, PO Box 496, Palmerston NT 0831, Australia
4) Universidad de Cuenca, Av. 12 de Abril y Agustín Cueva Ciudadela, Cuenca, Ecuador
5) Directorate of Galapagos National Park, Puerto Ayora, Santa Cruz, Galápagos, Ecuador

Correspondence: Mandy Trueman, truemandy@gmail.com

Background & Aim: Mapping is an important tool for the management of plant invasions. If landscapes are mapped in an appropriate way, results can help managers decide when and where to prioritize their efforts. We mapped vegetation with the aim of providing key information for managers on the distribution, abundance and rates of spread of multiple invasive species across the landscape. Our case study focused on an area of Galapagos National Park that is faced with the challenge of managing multiple plant invasions.

Methods & Results: We used satellite imagery to produce a spatially-explicit database of plant species abundances in the canopy of a 14 214 ha study area in Santa Cruz Island (data at http://dx.doi.org/10.1594/PANGAEA.833752). Our map of invasive species' abundance showed that the canopy is dominated by invasive plants in some areas and contains only scattered individuals in other areas. We found that 92% of the humid highlands within the National Park on this island had some degree of invasion, whilst 41% of the canopy was comprised of invasive plants. We also calculated the rate of spread of eight invasive species using known introduction dates. This illustrated that species with the most limited dispersal ability had the slowest spread rates while those able to disperse long distances had a range of spread rates.

Discussion & Application: Our results on spread rate fall at the lower end of the range of other published spread rates of invasive plants because most studies are based on the entire geographic extent, whereas our estimates took extent and density into account. A spatial database of plant species abundances, such as the one developed in our case study, can help curtail the spread of current plant invasions as it can inform managers in decisions on applications of appropriate management actions. For example, it can be used to identify sites containing several invasive plant species, to find the abundance of a particular species across the landscape, or to locate where native species make up the majority of the canopy. Similar databases could be developed elsewhere to help inform the management of multiple plant invasions over the landscape.

Acknowledgements: Planet Action provided the satellite imagery used for this work. Galapagos National Park Directorate and the Charles Darwin Foundation provided permission for fieldwork and logistical support. The University of Western Australia provided postgraduate funding and support for this work. Many people helped in the field and in discussions on the arrival and spread of plant species. This abstract is based on a paper that has been accepted for publication in Neobiota.

Vegetation in the highlands of Santa Cruz Island, Galapagos. The left foreground is dominated by native *Pteridium arachnoideum* while the central distinct patch is dominated by introduced grass *Pennisetum purpureum*. Behind this is dominated by endemic *Scalesia pedunculata*, also containing several introduced species, such as *Rubus niveus*, *Cestrum auriculatum* and emergent *Cedrela odorata* trees. There is also a small patch on the mid left that is dominated by introduced tree *Persea americana*. Dead trees in the foreground are the remains of introduced *Cinchona pubescens* that have been treated with herbicide. The hinterland close to the coastline contains arid-adapted native species. Photo: M. Trueman.

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Floristic patterns and drivers of kwongan vegetation patterns in Eneabba region of the Northern Sandplains, Western Australia

James L. Tsakalos (1), Monika Dršková (1), Jaroslav Hruban (1), Ladislav Mucina (1,2) & Mark P. Dobrowolski (1,3)

1) School of Plant Biology, The University of Western Australia, 35 Stirling Hwy, Crawley WA 6009, Perth, Australia

2) Centre for Geographic Analysis, Department of Geography and Environmental Studies, Stellenbosch University, Matieland, 7600, Stellenbosch, South Africa

3) Iluka Resources Limited, Perth WA 6000, Australia

Correspondence: James Tsakalos, James.Tsakalos@research.uwa.edu.au

Background & Aim: Plant community studies based on floristic composition are important for improvement of conservation and restoration strategies, especially in areas with high endemism and species richness. Vegetation classification and ordination are the main tools used in community studies that seek to describe vegetation patterns and searching for the origins of the patterns. The central goals of this paper are to (1) classify the kwongan (mediterranean-type scrub of SW Australia; see Mucina et al. 2014), and (2) establish how habitat (soil) heterogeneity and regional climate may drive the vegetation patterns in this enigmatic, species- and endemic-rich vegetation.

Materials & Methods: The study area is located in the Northern (Geraldton) Sandplains around the township of Eneabba (29°82′ S, 115°27′ E), approximately 250 km north of Perth, Western Australia. The vegetation plot data set, collected using standard field methodology of the Braun-Blanquet approach, comprises 542 relevés, sharing 801 taxa. Environmental data matrix consists of 105 variables, mainly extracted from 200 soil samples collected as a representative subset of the entire vegetation-plot data set as well as from topographic and BioClim data. Series of multivariate analyses were employed to classify and ordinate both vegetation and environmental data, using the programs JUICE, PC-ORD, and Syntax 2000. OptimClass was used as a tool to assist in the selection of the most robust combination of transformation, resemblance and clustering algorithm. Clustering embedded within JUICE was used to define plant community types. Canonical correspondence analysis (CCA), and a series of partial CCAs were performed to infer major ecological drivers of vegetation patterns.

Main Results & Interpretations: Presence-absence transformation, Bray-Curtis resemblance and flexible beta clustering were revealed as the most robust data-analytical combination that was used to produce a dendrogram yielding 24 well-defined plant communities. Three groups of communities (alliances?) were detected each was floristically unique and having only 8.3% of species shared across all alliances. Two of the groups represented typical kwongan vegetation (on deep sandy soils vs. on laterite pavements, respectively), while the third unit was composed of largely non-kwongan (woodlands and thickets) vegetation or very specialised kwongan scrub on limestone and very rare ferricrete kwongan on 'bog-iron' formation (Griffin et al. 1983). Although the role of soil factors has been suggested in the past as a major vegetation pattern driver (Hnatiuk & Hopkins 1981), our study brings unequivocal quantitative support to this assertion.

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Banksia hookeriana (*Proteaceae*) – a typical low scrub species on deep Bassendean sand dunes in the Eneabba sandplains. Photo: L. Mucina.

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Herbaceous community structure and function in northern Canada: the value of long-term experimental plots

Roy Turkington (1) & Jennie R. McLaren (1,2)

1) Botany Department & Biodiversity Research Centre, University of British Columbia, Vancouver, BC, V6T 1Z4, Canada
2) Department of Biological Sciences, University of Texas at El Paso, 500 W University Ave, El Paso, Texas 79968

Correspondence: Roy Turkington, royt@mail.ubc.ca

Background & Aims: Numerous examples of the central role that long-term studies play in ecology now exist. Almost every system is undergoing long-term change and these changes can only be studied by long-term experiments. Among the ongoing long-term studies in northern ecosystems are the LTER experiments at Toolik Lake, Alaska, the International Tundra Experiment (ITEX) at a number of circumpolar sites, and long-term experiments in both Abisko, Sweden and Barrow, Alaska. Research at such long-term sites can monitor and lead to understanding of slow events and also of the infrequent events that are often important shapers of ecosystems. Long-term ecological research is particularly valuable for understanding disturbance dynamics over long time periods.

Materials & Methods: We illustrate these concepts using two long-term projects on the herbaceous vegetation in the Kluane region, Yukon. The first study was done in boreal forest understory vegetation in southwestern Yukon over a 20-year period. It was a 2 X 2 factorial design with fertilizer (0/+) and mammalian herbivores (0/-) as the main effects and the response variable being percent cover. The second study investigated how removing plant functional groups (graminoids, legumes, forbs) from a northern grassland (SW Yukon) influences its functioning.

Main Results: The first study showed that nutrient availability, and not herbivory, controlled herbaceous biomass. While fertilization increased the amount and nutrient content of vegetation, 13 species were lost; natural levels of mammalian herbivory rarely affected this vegetation or its diversity. In the second study, over a seven-year period, we determined that functional group identity was important in determining ecosystem properties and that graminoids were more influential than expected from their proportional biomass. In both of these studies, and a common conclusion from many long-term studies, is that short-term responses are transient and not indicative of longer-term responses of the communities being studied. In the understory experiment, our conclusions might have been different had the data been collected after one year (beginning of the hare decline), five years (during a hare low), or 10 years (during a hare peak), but the general trends identified are important. It is likely that ecosystems such as these northern communities (the herbaceous community is characterized by slow-growing, long-lived plants) never attain equilibrium because the density of herbivores fluctuates, forests burn, and climate is slowly but constantly changing. This means that transient responses may be the only ones we have to work with, because permanent shifts in vegetation composition may not be evident until many years later, or a steady state may never be attained. These findings reinforce the need for long-term experiments, especially in northern ecosystems. The long-term plots from both projects will continue (now years 25 and 10 respectively) to be valuable, and they may detect shifts in the plant community due to climate change or unique events in the area.

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ÆKOS: A new paradigm enabling reuse of complex ecological data

David J. Turner (1,2), Paul Chinnick (1,2), Anita Smyth (1,2) & Craig Walker (1,2)

1) Eco-informatics Facility, Terrestrial Ecosystem Research Network Level-12 Schulz Building, The University of Adelaide, Adelaide SA 5005, Australia

2) School of Earth and Environmental Sciences, The University of Adelaide, Adelaide SA 5005, Australia

Correspondence: David Turner, d.turner@adelaide.edu.au

Background: ÆKOS – The Australian Ecological Knowledge and Observation Service reduces the time spent by researchers who use third party data to create new science. It does this by integrating source data nationally at a site level, which leads to faster discovery and provides well-described metadata to enable exploration of the suitability of data – a must for scholarly reuse of third party data. ÆKOS has adopted best practice and innovative approaches from a diverse range of disciplines to produce a 'first cut' system and position for future enhancement and collaboration.

Challenges facing ecology is a data-intensive science: Ecological data are inherently complex, not only because of the underlying complexity and context dependency of natural systems but also due to the way that ecology as a discipline operates. Most data collection activities are relatively small-scaled and focused on a particular objective, meaning there are a myriad of different collection protocols, measurement standards and classification systems in use. From the perspective of data reuse, this creates challenges around integration and interpretation, especially where there is a need to incorporate data from multiple sources.

For data reuse to be effective, information needs to be stored and presented in a manner that facilitates examination and manipulation. Current barriers that restrict re-use by third party researchers, include poor discoverability and access constraints. While there are many examples of systems that attempt to address these, we argue that this is only part of the solution.

Well-described data leads to robust science: ÆKOS places significant emphasis on the provision of detailed contextual information. In particular, information about sampling design, data collection, measurement protocols and classification systems employed, are required to enable researchers to make an informed assessment of the data. This minimizes the chance of inappropriate interpretation and helps guard against misuse.

Mission of the ÆKOS: ÆKOS has been designed to expose the richness of plot data rather than a narrow subset, and presents this in a fully integrated way to the user. This means that it is mapped to common ontological concepts where possible without distorting the underlying knowledge. Data are stored at the individual plot level meaning the user can directly search against, view results at, and freely download at this level. For more information consult http://www.aekos.org.au.

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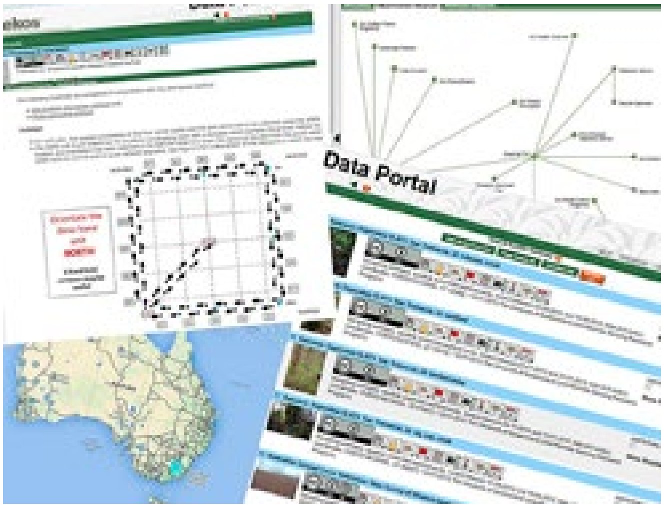

Screen grabs of the AEKOS portal highlighting site level data access and rich contextual information.

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Fine-scale vegetation and soil patterns in arid Western Australian ecosystems

Eddie van Etten

School of Natural Sciences, Edith Cowan University, Joondalup 6027, Perth, Australia

Correspondence: Eddie van Etten, e.van_etten@ecu.edu.au

Background & Aim: Redistribution of resources (water, soil, organic matter, nutrients, seeds) across the soil surface is a critical process contributing to and reinforcing much of the visually obvious vegetation patterns in arid ecosystems (at various scales), and is the key to maintaining many ecosystem functions in such ecosystems (Aguiar & Sala 1999). Although pioneering work on patch-interpatch differences and their interactions was done in mulga (*Acacia aneura sensu lato*) scrub at various locations in Australia (Ludwig & Tongway 1995), we know very little about this phenomenon for other arid ecosystems, such as hummock grasslands (spinifex, *Triodia* spp.) which dominate uplands of the arid zones of Western Australia.

Materials & Methods: For 10 sites in each of three major plant communities (spinifex, mulga woodland and eucalypt woodland in drainage lines) of the Chichester Ranges (Pilbara Bioregion, northern Western Australia), I measured attributes of vegetation and soil (at various depths) for patches (hummocks or clumps of trees) and adjacent inter-patches (bare zones between hummocks or trees). Soil attributes included microbial activity, nutrient levels, organic material, particle size, pH and soil seed bank. The effects of community, soil depth and microhabitat (patch vs inter-patch) were tested using GLMs (for single variables) and PERMANOVA (for species composition).

Main Results & Interpretations: Significantly greater seed density, species richness (above- and below-ground), fine alluvium, microbial activity and organic carbon/matter were found in and under patches compared to adjacent interpatches; these attributes were also higher in surface soil (0–5 cm) than in deeper layers. However, nutrients and moisture did not differ between patch and interpatch (although they were generally higher at the surface and differed between communities). Generally patch-interpatch differentiation was greater in mulga than that for spinifex and drainage line communities. The implications of the findings for ecosystem functioning and ecological restoration are discussed.

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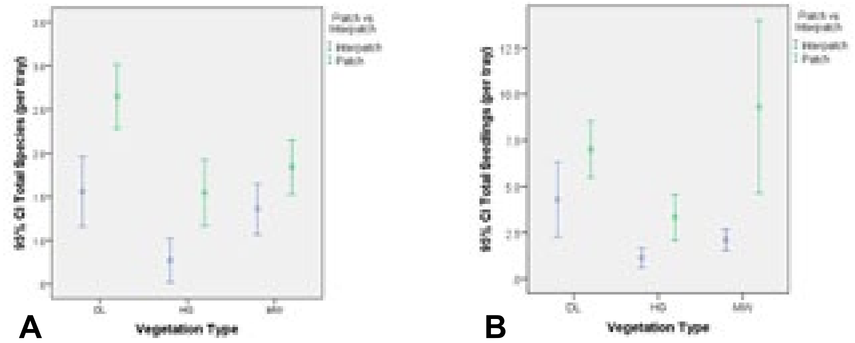
A typical *Triodia* hummock grassland of the study area in the Chichester Ranges, Pilbara bioregion, Western Australia.
Photo: Eddie van Etten.



Error bar graphs showing mean and 95% confidence intervals of the: **A:** number of species emerging per tray; and **B:** number of seedlings per tray, for each vegetation type and microhabitat type (i.e. patch or interpatch). DL=drainage line community; MW=mulga woodland; HG=hummock grassland.

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The influence of fog on flowering times – a mechanism for endemism?

Sula Vanderplank (1,2) & Exequiel Ezcurra (2)

1) Botanical Research Institute of Texas, 1700 University Drive, Fort Worth, TX 76107, USA

2) University of California, Riverside, Department of Botany and Plant Sciences, 900 University Ave, University of California, Riverside CA 92521, USA

Correspondence: Sula Vanderplank, sula.vanderplank@gmail.com

Background & Aims: The primary control of plant phenology in mediterranean-climate scrub habitats is moisture. Temperature and day length can be expected to play a much smaller role in phenological timing in mediterranean climates than moisture availability, which is very seasonal and seems to be the primary driver of flowering in coastal habitats. The southernmost extent of the California Floristic Province is a biological diversity hotspot of high endemism and conservation value, with two steep moisture gradients: rainfall (N-S), and coastal fogs (W-E). We aimed to evaluate the floral syndromes as related to moisture, and understand the significance of fog moisture, to see whether distance from the coast has a significant effect on the timing of flowering in mediterranean climates.

Materials & Methods: We installed five weather stations along the coast of Baja California, spanning a 140-km north-south winter rainfall gradient (high to low) from 31.57 to 30.52 degrees of latitude, and flowering phenology was monitored at each site from 2010–2013. Each weather station was the center of a 1 km square study area at each site to avoid micro-climate effects, and we assessed the flora phenology of all perennial species at each site (86 in total). The flowering intensity was initially recorded intensively but after the first year a simplified ordinal scale was developed: a value of 1 for low flowering intensity to 3 for peak bloom (>75% of the population in full flowering) and a 0 value for species that were not in flower. Sites were visited every 6-8 weeks continuously throughout the study. We generated a matrix of 17 dates X 86 species; and later analyzed just the 16 species present at all five sites against 85 dates-nested-within-sites. Weather data were averaged and a time-series analysis was conducted on the daily temperature and humidity averages, by fitting the first harmonic of a Fourier series. To obtain a quantitative measure of seasonality, we converted all observations to Julian days (sequential day counts). To analyze the time-trajectory of phenological samples across dates, we used principal component analysis (PCA) of the raw matrices.

Main Results & Interpretations: Combined data analysis demonstrates a general cyclical seasonal pattern in flowering times but distinct differences in local weather and phenology between the five study-sites. Three flowering syndromes are revealed in the flora: (a) water-responders or spring bloomers, (b) day-length responders or fall-blooming taxa, and (c) aseasonal bloomers with no seasonal affinity.

The two moisture gradients are the strongest drivers of flowering times. The fog gradient is of particular interest, with inland sites showing higher phenological variation than coastal sites, where seasonality is dampened by ocean-derived moisture, which extends and buffers perennial plant phenology and is a probable driver of local endemism. Fog is playing a critically-important role in the extension of the southern range limit of many species in this region by ameliorating the lack of rainfall. Similarly, the inland fog limit is likely to define the inland (eastern) range limit of many taxa. This insight shows the importance of fog in extending reproduction, and identifies a probable driver of endemism in coastal ecosystems that has significant conservation implications in a changing climate.

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Transplant experiments reveal interactive effects of temperature and precipitation change on alpine plant community composition and functioning

Vigdis Vandvik (1), Kari Klanderud (2), John Guittar (3), Richard J. Telford (1) & Deborah E. Goldberg (3)

1) Department of Biology, University of Bergen, PO Box 7803, N-5020 Bergen, Norway

2) Department of Ecology and Natural Resource Management, Norwegian University of Life Sciences, PO Box 5003, N-1432 Ås, Norway

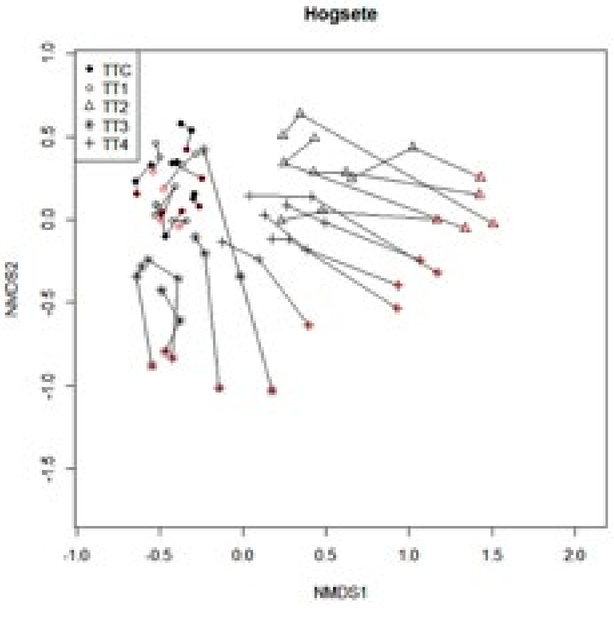
3) Department of Ecology and Evolutionary Biology, University of Michigan, Ann Arbor, MI 48109, USA

Correspondence: Vigdis Vandvik, vigdis.vandvik@bio.uib.no

Background & Aims: A growing body of evidence indicates that ongoing climate change is impacting on plant community composition and function. Arctic and alpine areas are especially vulnerable, and both experimental and observational studies document pervasive change, but also inconsistencies in the rates and even in the direction of change in these systems. Such inconsistencies challenge our understanding of the underlying processes as well as our abilities to predict future community and functional trajectories. Variation in precipitation regimes has been implicated as a potential explanation of these inconsistencies, but the data are inconclusive, and as precipitation itself is also predicted to change, we need approaches that allow investigation of the interactive effects of temperature and precipitation change.

Materials & Methods: In order to tackle these challenges, we set up a climate grid consisting of three levels of temperature (tetraterm of 7.5° C, 9.5° C, 11.5° C) and four levels of precipitation (annual precipitation of 700 mm, 1500 mm, 2300 mm and 3000 mm) and carried out a factorial transplant experiment where turfs with intact plant communities from each of these sites were transplanted into warmer and/or wetter climates, paralleling the climate change projections of our study region. The experiment was initiated in 2009 and it has been monitored for the past four years.

Main Results & Interpretations: Temperature and precipitation change instigate non-additive changes in the plant community; the communities generally respond faster to temperature change than to precipitation change. After four years, however, the response to precipitation change became comparable to, and in some cases exceeding, the temperature response. For each site and treatment we identify winner and loser species, and used plant functional traits (specific leaf area, plant height, seed mass) to infer the underlying processes driving the temperature and precipitation change responses at different positions along our climatic gradients. The results suggest that both environmental sorting and biotic interactions were important in determining species' fates within local plant communities under climate change, and that these processes vary along broad-scale climatic gradients and with the specific climatic change scenario the community is subjected to (i.e., precipitation and/or temperature change). Our study illustrates the power of combining experimental and gradient approaches to assess and understand the impacts of global environmental change on natural ecosystems.



Vegetation change in plots transplanted into one of the 12 SEEDCLIM sites as depicted by non-metric multidimensional scaling. In the first year (red symbols) the sites were dissimilar, but over time, all plots became gradually more similar to the local target site communities (upper left corner).

Acknowledgements: We thank the Norwegian Research Council for funding (NORKLIMA grant # 184912/S30), SEEDCLIM partners and students for collaborative data collection, and the landowners for granting access to their lands.

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The nature of connectivity of estuarine habitats with neighbouring terrestrial environments and the drivers of the formation of the estuarine-terrestrial interface

Dimitri A. Veldkornet & Janine B. Adams

Department of Botany, Nelson Mandela Metropolitan University, P.O. Box 77000, Port Elizabeth 6031, South Africa

Correspondence: Dimitri Veldkornet, Dimitri.veldkornet@nmmu.ac.za

Background & Aims: The effective identification of the lateral boundary of an estuary is a critical component in estuary management and currently the 5 m topographical contour is used to demarcate the boundary in South African estuaries. However, in some cases this has been found to leave salt marsh vegetation outside the boundary, resulting in inappropriate development pressures. The border between salt marsh and terrestrial vegetation is important, as it is often an area of great biodiversity, but is frequently the first choice for development, resulting in the loss of connectivity between these two vegetation types. The aims of the study were: (1) to identify boundaries and establish the connectivity between salt marsh and terrestrial vegetation by identifying the floristic composition of the different zones and relating this to the surrounding terrestrial biome, and (2) to determine which environmental factors are important in forming boundaries.

Materials & Methods: In each of eight targeted estuaries (Olifants, Verlorenvlei, Berg, Uilkraals, Goukou, Gouritz, Keurbooms and Kabeljous Rivers, South Africa), six transects (45–450 m long) were sampled. Along each transect, sediment and groundwater characteristics were measured in the salt marsh, fringe and terrestrial habitats. The Morisita index of similarity was used to determine how the three different habitats were connected in terms of species composition and abundance. Different land-use categories within the 5 m estuary boundary as well as the length of boundary impacted were mapped in ArcGIS 10.

Main Results: The salt marsh habitat had lower species richness compared to the fringe and terrestrial vegetation due to stressors such as high salinity and high sediment moisture content. Low growing shrubs and annual species characterised the fringe zone. In the warm-temperate regions these species showed affinities with subtropical thicket and afromontane forest. The cool-temperate species showed succulent karoo and fynbos (for characteristics see Mucina & Rutherford 2006) affinities with species such as *Salsola aphylla* and *Atriplex vestita* being abundant in the fringe zones. Sediment characteristics could be used to distinguish the different habitats. At all sites, the salt marsh habitat had the highest sediment electrical conductivity and sediment moisture content. No terrestrial vegetation occurred where sediment electrical conductivity was greater than 2.6 mS.cm-^{1}. Some estuaries, such as Goukou, Kabeljous and Olifants, had distinct boundaries with no ecotone vegetation as there was a sharp elevation change between the salt marsh and terrestrial habitat and therefore high connectivity. In contrast the Gouritz, Keurbooms, Verlorenvlei and Uilkraals estuaries had developed distinct ecotones driven by gradual changes in elevation, sediment and groundwater electrical conductivity. Our approach can be used successfully to delineate the landward margin or functional zone of an estuary.

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How much does 'transplant shock' affect the results of your transplant experiment?

Susanna E. Venn

Research School of Biology, The Australian National University, Canberra ACT 0200, Australia

Correspondence: Susanna Venn, susanna.venn@gmail.com

Background: Transplant experiments are powerful tools, often used to investigate the responses of species and communities to changed environmental conditions predicted with climate change. Transplant experiments can also separate the effects of genetic versus plastic responses to changed environmental conditions, thereby allowing the researcher to determine the species' potential for adaptation to future, novel environments across existing gradients such as temperature or precipitation. In the majority of seed and seedling transplant experiments, a biological response from the target individual(s) or species is used as the results of the experiment. Such responses include germination rate, growth rate, flowering time, number of new leaves produced, or biomass. These responses then form the basis for the statistical analyses and/or for modelling the effects of the experimental environment on the target species/individuals. Transplant shock, also referred to as transplant stress or planting check, is used to describe the negative effects on growth and survival when nursery-raised seedlings or saplings are planted into a new environment. Transplant shock is expressed through a range of symptoms that include a decreased growth rate of newly planted seedlings compared to naturally regenerating seedlings of the same age, leaf abscission and mortality under severe conditions. Transplant shock is also associated with acclimatisation of seedlings to new environmental conditions (Close et al. 2005). In preparation for transplant experiments, most researchers will try and minimise transplant shock by using locally sourced material for the experiment (depending on the research questions) as well as attempting to acclimate the transplants at the site of the experiment for a period of time prior to planting. Despite their best efforts, however, transplant shock remains an important, yet under-accounted for, part the experiment; it can impact unknowingly by the researcher on the biological response recorded as the results, and is rarely accounted for properly in the statistical analyses of the results.

Results of the Literature Screening: A literature search of seedling transplant experiments across altitudinal gradients revealed how little attention transplant shock received in the design and implementation of the various transplant experiments worldwide. And very rarely was seedling mortality or poor performance attributed to transplant shock, even where 'control' transplants were assessed. As a consequence, the published results of some of these experiments are likely to have been misinterpreted, whereby slow growth rates or mortality rates were simply attributed to the harsh experimental conditions that the researcher has imposed on them.

Challenges: As a group of researchers interested in transplant experiments, how can we factor transplant shock into our experiments? Rather than provide all the answers to this topic, several questions for discussion are posed: Would minimising transplant shock undermine the experimental design; in that the signal representing the biological response to environmental conditions may be too weak if transplants are nurtured prior to the experimental planting? Could the Transplant Stress Index (South & Zwolinski 1996) be used in ecological experiments? What can we learn from the horticulture, re-vegetation and forestry industries about using products such as Hydrogel to improve transplant performance? And given that many tree seedlings can experience transplant shock for up to three years, are our short-term experiments (generally less than five years) really telling us the full story about individuals or species responses to environmental changes?

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Potential of the soil seed bank to improve understory vegetation condition in riparian corridors undergoing restoration treatment

Tricia Wevill (1) & Singarayer K. Florentine (2)

1) School of Biological Sciences, Monash University, Clayton VIC 3800, Australia
2) School of Science, Information Technology and Engineering, Federation University, Mt. Helen VIC 3350, Australia

Correspondence: Tricia Wevill, tricia.wevill@monash.edu

Background & Aim: Extensive works have been undertaken in southwestern Victoria to reinstate native vegetation along riparian corridors. Past restoration efforts have focussed on fencing riparian zones to exclude grazing mammals, and planting native tree species to re-establish a canopy layer. The understorey is dominated by exotic perennial species and few native species persist in the ground layer (Wevill & Florentine 2014). Here we explore the dynamics of the soil seed bank. If native understorey species persist in the seed bank at these sites, there is potential to reinstate these species to the ground layer and improve vegetation structural complexity and diversity. A second aim of this study was to test different germination techniques to maximise germination of the soil seed bank.

Materials & Methods: The study was conducted along waterways in three sub-catchments in southwestern Victoria (Australia). Six 1200 m^2 sites were established in each sub-catchment on rural properties, re-vegetated in the riparian zone over the past 12 years. At each site, 10 soil samples (10 cm diameter; 5 cm depth) were randomly collected from the riverbank and from the centre of the re-vegetated zone and then aggregated for each zone. The same protocol was followed for 12 remnant sites of the same vegetation type in the region. Each soil sample was sub-divided for five treatments: submerged, waterlogged, regular watering, heat treatment (soil heated to 80° C for 1 hour) and heat/ smoke treatment, with commercial smokewater (Smokemaster™). Germination trays were maintained in a glasshouse for 12 months at a temperature of 17° C, after which germinant emergence was recorded. Species richness of the soil seed bank at remnant and revegetated sites, and differences in seedling emergence among germination treatments were tested using one-way Analysis of Variance, followed by post-hoc Tukey's tests (Systat 12©).

Main Results & Interpretations: A total of 3583 germinants were recorded, comprising 77 native species, 68 exotic species and 11 unidentified taxa. Across all sites (re-vegetated and remnant), 12% of germinants were native species, yet these represented 44% of the total number of species that germinated. Consequently, exotic species contributed significantly more seed to the seed bank than native species ($F = 45.237$, $P < 0.001$). Remnant sites had almost three times the number of native species germinating than at treatment sites, indicating a depleted soil seed bank at treatment sites. With fewer species in the seed bank and substantially higher input of seed by exotic species, it is unlikely that understory condition at treatment sites will improve, without substantial intervention (i.e., supplementary planting) and management (i.e., weed control). The smoke treatment produced a significantly higher number of native germinants than all other germination treatments ($F = 13.064$, $P < 0.001$), yet native species diversity was highest in the heat and smoke treatment. Therefore, smoke or heat and smoke treatments could be utilised to improve understorey condition at riparian sites.

Acknowledgements: This research was funded under the Australian Research Council *Linkage Projects* funding scheme and contributions from Parks Victoria, Corangamite CMA, Glenelg-Hopkins CMA and Greening Australia.

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Indicator values of functional traits

Otto Wildi

WSL Swiss Federal Institute for Forest,
Snow and Landscape Research,
CH-8903 Birmensdorf, Switzerland

Correspondence: Otto Wildi,
otto.wildi@wsl.ch

Background & Aim: Indicator values of species, first devised by Ellenberg (1974) and Landolt (1977), are of interest to both scientists and practitioners in vegetation ecology. While the scientific community ignored indicator values of species for decades, this has changed after the year 2000. Since then *Journal of Vegetation Science* and *Applied Vegetation Science* have published more than 100 papers featuring indicator values. Frequently asked questions are, if mean indicator values are equivalent to environmental factors, or if they are just a method for reducing dimension, if they should be weighted by abundance when calculated for plots, if they are ecologically reliable or highly biased by the phytosociological background of their authors. Only in case they were true surrogates of environmental factors then they were suited for statistical inference. The outcome of this debate constrains both, statistical considerations and ecological interpretation. Analyses and interpretations of alternative descriptors, individually or jointly, has gained importance with a database published by Landolt et al. (2010) for the Alpine region now including indicator values, species traits related to growth form, breeding system, dispersal, life strategy (Grime 1981), area, etc. A paper recently published by Zelený & Schaffers (2012) further complicates the issue. In this they suggest mean Ellenberg indicators are biased.

Materials & Methods: I present a framework for ecological data analysis to formally illustrate how information-flow among different sources – plot by species data, indicator values, species based functional traits, life strategies and plot-based environmental variables – can be assessed and ecologically as well as statistically interpreted. For this I use a published real-world data set where all the above- mentioned matrices are available. This is done by standard software implemented in the R computing environment.

Main Results & Interpretation: I demonstrate why Zelený & Schaffers address a frequently ignored problem, and why their conclusions are based on a misinterpretation of results: many of their analyses are hampered by circularity. However, their observations suggest restrictions in the use of indicator values, but unfortunately, the same holds for the analysis of plant functional traits. One of the conclusions illustrating the issue is that the frequently encountered high performance of indicator values is an outcome of computation and the same happens when using plant functional traits. Although indicators and traits are excellent means of vegetation description, their correlation seems to remain weak and useful 'indicators of traits' are rare.

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Towards a revised classification of the Pontic-Pannonian steppe grasslands

Wolfgang Willner (1), Anna Kuzemko (2), Norbert Bauer (3), Thomas Becker (4), Claudia Biţă-Nicolae (5), Zoltán Botta-Dukát (6), Milan Chytrý (7), Jürgen Dengler (8), Ruzica Igić (9), Monika Janišová (10), Zygmunt Kącki (11), Iryna Korotchenko (12), Mirjana Krstivojević (9), Tamás Rédei (6), Eszter Ruprecht (13), Luise Schratt-Ehrendorfer (14), Yuri Semenishchenkov (15), Zvjezdana Stančić (16), Yulia Vashenyak (17) & Denis Vynokurov (12)

Background & Aims: Steppe grasslands contribute a major part to the overall biodiversity of Central and Eastern Europe. However, the area of species-rich grasslands has strongly declined during the last century. A consistent supra-national classification of these habitats is urgently needed as a basis for their effective conservation and monitoring.

Material & Methods: We studied main phytosociological patterns within the Pontic-Pannonian steppe grasslands using a large dataset of vegetation plots covering the whole Carpathian Basin (E Austria, Moravia, Slovakia, Hungary, Romania, N Croatia and N Serbia) as well as Ukraine and adjacent regions in S Poland and SW Russia (Bryansk region). Altogether 43 706 relevés from 11 countries were gathered. Species taxonomy and nomenclature was unified according to the Euro+Med Checklist (www.emplantbase.org). Critical species were merged to aggregates. From this initial data set, we selected all relevés with the presence of at least one (of 143 pre-defined) diagnostic species of the target vegetation types (steppe meadows, meadow steppes and grass steppes), of rocky steppes or of Pannonian sand steppes. Thus, we included all units traditionally included or closely related to the *Festuco-Brometea* class. Relevés with a plot size $<9\ m^2$ or $>100\ m^2$, and relevés with a shrub or tree layer covering >10% were excluded. To avoid bias due to oversampling of some areas, we applied a geographically stratified random resampling. The resampled data set (17 993 relevés) was classified using TWINSPAN.

Main Results & Interpretations: The classes of the *Molinio-Arrhenatheretea, Nardetea, Festuco-Brometea* and *Koelerio-Corynephoretea* were well separated in the classification. The position of the *Festucetalia vaginatae* (Pontic-Pannonian sandy steppes) within the *Koelerio-Corynephoretea* was confirmed. The *Agrostion vinealis* (steppic meadows on intermittently wet floodplains) was grouped together with the *Deschampsion caespitosae,* while the meadow steppes classified as the *Trifolion montani* were closely related to the *Brometalia erecti*. The delimitation between the *Festucion valesiacae* and the *Stipion lessingianae* was reproduced only partly and needs further evaluation.

Outlook: As next step, a detailed classification of the *Brometalia erecti* (incl. the *Trifolion montani*) and the *Festucetalia valesiacae* at the association level will be elaborated.

1) Vienna Institute for Nature Conservation & Analyses, Giessergasse 6/7, A-1090 Wien, Austria

2) National Dendrological Park “Sofiyvka” of NAS of Ukraine, Kyivska 12a, 20300 Uman’, Ukraine

3) Dept. of Botany, Hungarian Natural History Museum, Baross u. 13, H-1088 Budapest, Hungary

4) Dept. of Geography and Geosciences, University of Trier, Behringstr. 21, D-54286 Trier, Germany

5) Institute of Biology, Romanian Academy, Splaiul Independentei 296,s.6, RO-060031 Bucharest, Romania

6) MTA Centre for Ecological Research, Alkotmány u. 2-4, H-2163 Vácrátót, Hungary

7) Dept. of Botany and Zoology, Masaryk University, Kotlářská 2, CZ-61137 Brno, Czech Republic

8) Disturbance Ecology, University of Bayreuth, Universitätsstr. 30, D-95447 Bayreuth, Germany

9) Dept. of Biology and Ecology, University of Novi Sad, Trg Dositeja Obradovića 2, 21000 Novi Sad, Serbia

10) Institute of Botany, Slovak Academy of Sciences, Ďumbierska 1, SK-97411 Banská Bystrica, Slovakia

11) Institute of Plant Biology, University of Wroclaw, Kanonia 6/8, P-50-328 Wroclaw, Poland

12) M.G. Kholodny Institute of Botany, NAS of Ukraine, Tereshchenkivska 2, 01601 Kyïv, Ukraine

13) Faculty of Biology and Geology, Babeş-Bolyai University, Republicii 42, RO-400015 Cluj-Napoca, Romania

14) Dept. of Botany and Biodiversity Research, University of Vienna, Rennweg 14, A-1030 Wien, Austria

15) Dept. of Botany, Bryansk State University, Bezhitskaya 14, 241036 Bryansk, Russia

16) Faculty of Geotechnical Engineering, University of Zagreb, Hallerova aleja 7, HR-42000 Varaždin, Croatia

17) State Inspection of Environmental Protection, I. Franka 2/2, 29010 Khmelnytsky, Ukraine

Correspondence: Wolfgang Willner, wolfgang.willner@vinca.at

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Aspect preferences of alpine plants on European mountain tops

Manuela Winkler (1), Andrea Lamprecht (1), Sophie Niessner (1), Sabine Rumpf (2), Klaus Steinbauer (2) & Harald Pauli (2)

1) University of Natural Resources and Life Sciences (BOKU), Center for Global Change and Sustainability, Silbergasse 30, A-1190 Wien, Austria

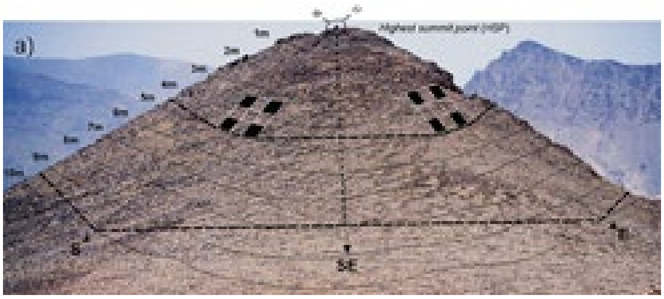
2) Austrian Academy of Sciences, Institute for Interdisciplinary Mountain Research, Silbergasse 30, A-1190 Wien, Austria

Correspondence: Manuela Winkler, manuela.winkler@boku.ac.at

Background & Aim: Topography has a strong influence on the duration and magnitude of solar radiation and, thus, on the distribution of vegetation types and plant species. This is especially relevant in alpine environments where no tall-growing plants compensate the effect of relief. In principle, biological diversity is positively related to energy input (Wright 1983). For example, plant diversity generally decreases with elevation or along a latitudinal gradient (Willig et al. 2003). Similarly, irradiation energy differs among slopes oriented to different directions (Barry 1992) which, therefore, are expected to differ in biodiversity.

Materials & Methods: Data collected along the GLORIA Multi-Summit sampling design (Pauli et al. 2004; www.gloria.ac.at) are especially suitable for comparing both thermal differences and species diversity among the four cardinal directions of mountain summits. On four summits in each of 32 European mountain regions, the cover of vascular plant species was estimated on four $1m^2$ plots in each cardinal direction, accompanied by hourly soil temperature measurements. In 17 of these regions, resurveys were conducted seven years after the baseline survey. Aspect differences were determined using linear mixed effect models.

Main Results & Interpretations: Preliminary results indicate that the southern and eastern aspects of mountain summits distributed across Europe received significantly higher temperature sums during the vegetation period, with the most pronounced aspect differences in the temperate biome, and declining differences towards the equator and the pole. Accordingly, plant species richness and Shannon index were higher in the east and south than in the west and east on temperate summits, but there were no significant aspect differences on mediterranean and boreal summits. In the mediterranean biome, summer drought may limit species richness especially on southern and eastern slopes. Thermal advantages of eastern slopes are the result of convective cloud formation which occurs most frequently after midday and thus reduces total potential direct solar radiation on the western slopes. Moreover, in most European mountains the western or north-western sides are exposed to the main weather system and therefore experience harsher and windier conditions than eastern to south-eastern slopes. In contrast, changes in species richness did not differ significantly among aspects as yet, and were not correlated with changes in temperature sums.



Oblique view of an example of a GLORIA summit with four 1 m^2 sampling plots (black quadrats) at the 5 m contour line in each cardinal direction. Modified from Pauli et al. (2004).

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How should data access policies reflect the changing data-sharing landscape: a case study with New Zealand's National Vegetation Survey Databank

Susan K. Wiser, Nick Spencer, Larry Burrows & Rob Allen

Landcare Research, PO Box 69040,
Lincoln 7640, New Zealand

Correspondence: Susan Wiser,
wisers@landcareresearch.co.nz

Background: According to the Global Index of Vegetation Databases, the NZ National Vegetation Survey (NVS) databank is among the top ten largest vegetation plot databanks in the world. For more than 30 years, NVS has been facilitating access to previously archived vegetation plot data to allow these data to be used for new purposes. In the late 1990s, the NVS data use policy was formalised to maximise benefit to both data providers and users, by requiring compulsory attribution and prohibiting data being provided to third parties or used for purposes not specified in the original data request. Currently the data use policy and attribution can only be applied at the level of whole datasets. With changing technologies and expectations around data use, ranging from the large scale to highly specific science questions, this policy has proved simplistic.

Challenges: In this talk we will outline three evolving challenges encountered in the on-supply of data archived in NVS and present potential solutions. The first is where we make data available to other data accumulators, such as the Global Biodiversity Information Facility and sPlot. This can lead to complex attribution, i.e. tracking and acknowledging the original data source, and lack of clarity regarding authorship. We will describe how we are applying Creative Commons licensing, publisher-based and query-based citations suggested by GBIF (Global Biodiversity Information Facility), and the sPlot authorship rules that include both data owners and custodians to NVS data attribution and licencing. The second is where we need to provide long term access to versions of data exactly as they were when downloaded to support data reuse and reanalysis. We will describe how use of a science data repository designed for 'published' data (DataStore) presents the most workable solution. The third is where scientific journals require that data supporting publications is made available to third parties to verify original results or to allow data to be used for other purposes. We will discuss our approach to engaging with journals to develop policies that balance needs of data owners with data users and how we can ensure that these groups understand the implications of these policies.

Outlook: Finally, we articulate the generic issue of how a relatively small country with limited resources can best benefit from international data sharing efforts. We will specifically focus on the need for benefits to accrue by increasing our knowledge base at both a country and individual researcher scales.

Te Urewera, central North Island, New Zealand. *Beilschmeidia tawa* podocarp forest with a dense ground cover of *Hymenophyllum demissum* and an epiphytic *Collospermum* The dominant species include *Beilschmeidia tawa*, shrub *Weinmannia racemosa*, and the crown fern, *Dicksonia squarrosa*. Photo: Landcare Research NZ.

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A multivariate classification of dry and mesic grasslands in the southern boreal region of Karelia

Sergey R. Znamenskiy

Biology Institute, Karelian Research
Center of Russian Academy
of Sciences, Pushkinskaya 11,
Petrozavodsk, 185910,
Russian Federation

Correspondence:
Sergey R. Znamenskiy,
seznam@krc.karelia.ru

Background & Aim: Although the grasslands cover only 0.39% of Karelia, these grasslands are among the best-studied ones in the Russian Federation. The first studies of the grasslands from the mid-1900s re captured in the monograph entitled *‘Meadow vegetation of Karelia‘* by Ramenskaya (1958). This publication distinguished some 260 grassland vegetation associations, of which 50 were regarded as dry or mesic grassland types. Over time, this number of associations increased to about 80. The main reason of such a highly detailed division was (and remains) the physiognomy-dominated approach to classification, ignoring year-to-year and seasonal variations. In this study I aim at revising the vegetation classification of the Karelian grassland using multivariate analyses.

Materials & Methods: From 2002–2013, some 102 grassland sites across the southern part of Karelia were visited. In each grassland site, 12–15 1-m^2 plots were sampled, arriving at total of 1463 grassland sample plots. These data were analyzed at the site and plot level. Beta-flexible clustering was employed to classify the data. In order to determine which flexible beta option yielded the most informative classification, multiple beta values were tested (β = -0.24, -0.4, -0.6, -0.8). The indicator species analyses used Dufrène & Legendre's method with phi coefficient at various division levels, starting from two clusters to as many as 16. Non-metric multidimensional scaling was used to assist the ecological interpretation of the classification results. All analyses were conducted in PC-ORD (McCune & Mefford 2011).

Main Results & Interpretation: Indicator species formed clearly separated groups when divided into four clusters, interpreted as four associations: (1) *Deschampsieta flexuosae* are dry meadows forming usually small patches on shallow (10–30 cm) soil over bedrocks of slightly acid or neutral reaction. Dominant (and characteristic) species include elements of rocky and boreal forest vegetation, such as *Campanula rotundifolia*, *Deschampsia flexuosa*, *Festuca ovina*, *Nardus stricta*, *Pilosella lactucella*, *Ranunculus polyanthemos*, *Vaccinium myrtillus*, and *Viola canina* subsp. *montana*, (2) Forb-rich *Varioherbetum* is supported by sandy soils on moraines or fluvioglacial deposits. Currently those sites are used as small pastures near old villages. Characteristic species of this association are *Campanula glomerata*, *Centaurea phrygia*, *Festuca rubra*, *Hieracium umbellatum*, etc. This association has the highest biodiversity value. (3) *Magnograminetum* occurs on well-developed fertile soils over lacustrine clayey sediments and flat eskers (long narrow ridge, often sinuous, composed of stratified sediment and marking the former location of a glacial tunnel; http://www.landforms.eu/). This landform is favorable for extensive agriculture hence the grasslands here have been used as large-scale pastures or hay meadows until recent time. Characteristic species are, for instance, *Alopecurus pratensis*, *Angelica sylvestris*, *Cerastium fontanum*, *Ranunculus repens*, *Campanula patula*, *Festuca pratensis*, etc. Finally, (4) *Antriscetum sylvestris* is nitrophilous meadow-like herb-rich vegetation that forms on abandoned fields and hay meadows of *Magnograminetum* and *Varioherbetum* as a result of dead organic matter accumulation and possible eutrophication. Species such as *Anthriscus sylvestris*, *Cirsium arvense*, *Elymus repens*, *Epilobium angustifolium*, *Galeopsis tetrahit*, *G. speciosa* and *Heracleum sibiricum* are typical of this grassland type. The main ecological factors separating these associations were differences in soil nitrogen content and soil moisture. For three of these associations (*Deschampsietum flexuosae*, *Carioherbetum*, *Magnograminetum*) soil grain size was an additional important ecological variable.

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Poster Presentations

Myrtaceous-proteaceous kwongan found near the Fitzgerald river. Photo: L. Mucina.

Eliminating species based on proportional within-site abundance gives useful results in dominance-based classification

Eda Addicott (1,2,3)

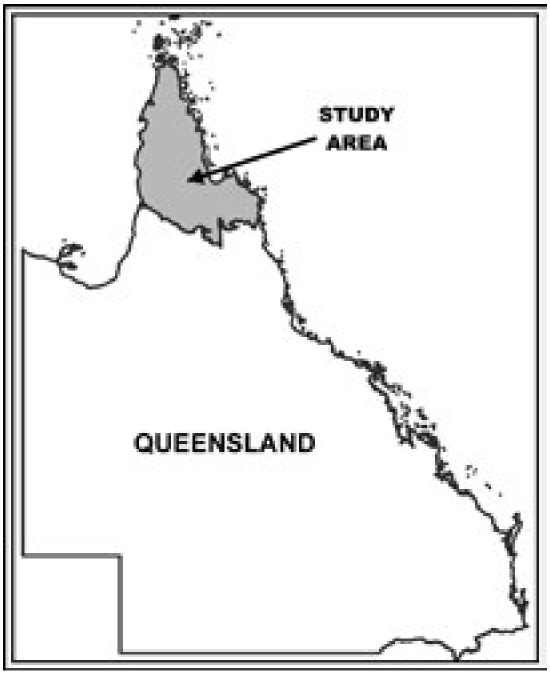
1) Queensland Herbarium, Department of Science, Information Technology, Innovation and the Arts, Brisbane Botanic Gardens, Mt Coot-tha Road, Toowong, Brisbane QLD 4066, Australia
2) Australian Tropical Herbarium, James Cook University, P.O. Box 6811, Cairns QLD 4870, Australia
3) Centre for Tropical Environmental and Sustainability Studies (TESS), School of Marine and Tropical Biology, James Cook University, P.O. Box 6811, Cairns QLD 4870, Australia

Correspondence: Eda Addicott, Eda.Addicott@science.dsitia.qld.gov.au

Background & Aim: In Queensland, Australia, we use plant communities defined by the dominant species as the primary dataset for land management tools. However, Queensland's methodology for collection of vegetation data prescribes recording all species at a site regardless of abundance (Neldner et al. 2012). In a numerical classification analysis this produces characterising species that are not useful for describing communities defined by dominance. Standard practice is to exclude all species whose occurrence is below a minimum number of sites (Kent 2012), but this excludes singleton sites. Singleton sites may be representative of valid communities (Clarke & Warwick 2001). An alternative may be to retain only species in the dataset that reach a minimum threshold of contribution to abundance at any site, thus keeping valid singleton sites but deleting species that are not useful as characterising species. The aim of this work is to compare communities derived when using all recorded species to those when using subsets of species, and, secondly, to compare the usefulness of characterising species from the subsets to those from the full list of species.

Material & Methods: We used 101 vegetation sites from Cape York Peninsula in north-east Queensland, covering grasslands, shrub lands and woodlands. We defined subset species lists using thresholds of percent contribution to abundance within any site. Cluster analysis (UPGMA, Bray-Curtis coefficient) produced plant communities and allocation of sites for each subset species list. Indicator Species Analysis (Dufrêne & Legendre 1997) and SIMPROF (Clarke & Warwick 2001) determined the optimal classification divisions and ISA and SIMPER (Clarke & Warwick 2001) produced characterising species.

Results & Interpretation: The subset species lists produced very similar communities and site allocations to the full species list, across and within vegetation formations. They also produced higher proportions of useful characterising species and reduced the number of species required for classification. It is possible to use a subset of a full floristic list based on proportional within-site abundance, rather than a minimum number of site occurrences, for dominance-based classification. The benefits are retention of singleton sites that are representative of communities, a more useful set of characterising species and a reduction in the number of species that need to be recorded.



Location of the Cape York Peninsula Bioregion, NE Queensland.

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FLOWBASE: a trait database for Mediterranean riparian flora

Francisca C. Aguiar (1), André Fabião (1), M. D. Bejarano (1), C. Nilsson (2), D. M. Merritt (3) & M. J. Martins (1)

1) Centro de Estudos Florestais, Instituto Superior de Agronomia, Universidade de Lisboa, 1349-017 Lisboa, Portugal
2) Department of Ecology and Environmental Science, Umeå University, SE-90187 Umeå, Sweden
3) USDA Forest Service, Natural Resource Research Center, Fort Collins, CO 80526, USA

Correspondence: Francisca C. Aguiar, fraguiar@isa.ulisboa.pt

Background: There is increasing evidence on the importance of traits to explain responses of biotic communities to disturbances, including the adaptive strategies of species and communities to varying stream flow conditions. Approaches based on functional traits hold great potential both in ecological research and in decision sciences. However, for some regions or flora types, such as Mediterranean riparian flora, the existing databases are limited to specific taxa. In addition, there are generally few attributes that can be related with responses to flow disturbances (Stromberg et al. 2010). This contribution presents FLOWBASE – a trait database for Mediterranean riparian flora

Description & Data Structure: The FLOWBASE was first developed to feed an OASIS project *'How to run regulated rivers in semi-arid regions'* (http://www.isa.ulisboa.pt/proj/oasis/) but later has been expanded to include species co-occurrence data in the Mediterranean. This database collects plant trait data of 225 riparian woody species from 65 families found in the Mediterranean and in the semi-arid worldwide riparian habitats. The FLOWBASE links information on traits, species, sites of occurrence. At the moment, it contains data on 55 functional plant traits summarised into four groups (Morphology, Phenology, Reproduction and Ecology) and characterising dispersal, establishment, and persistence in riparian habitats and expected linkages with hydrological changes, water availability, and flood resistance. It provides taxa information including scientific name, family, genus, vernacular names, common synonyms, region of origin, (obligate, facultative, preferential riparian, non-riparian species), and photos. Flora Europaea (http://rbg-web2.rbge.org.uk/FE/fe.html), as well as national and international checklists, used to harmonize taxonomic data. The sources of trait and geographic data compilation were classified as primary sources of information (floras, herbaria, scientific articles, project OASIS) and secondary sources. The secondary sources (e.g. books, field guides, other databases) were used only if the primary data were not available. Data repository on plant traits currently contains around 11 500 trait values, and co-occurrence entries. The species co-occurrence data include site coordinates, site name, basin, sub-basin, and a landscape photo (when available). The FLOWBASE is freely available at www.isa.ulisboa.pt/proj/flowbase/.

Vilarinho das Furnas Dam (Case study 3) in NW Portugal showing the reservoir and the riparian woodlands at the Homem River downstream the dam. Photo: D.F. Pinto. http://portugalfotografiaaerea.blogspot.pt/search/label/Barragem%20de%20Vilarinho%20das%20Furnas.

Future directions: The FLOWBASE is an open-ended, steadily growing database. In future we plan to enlarge the database to quantitative traits, and to add more non-European species.

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Herbaceous plant species interactions under *Acacia gerrardii* Benth. canopies in the arid environment of Saudi Arabia

Ali Al-Namazi (1,2), Magdy I. El-Bana (3) & Stephen P. Bonser (1)

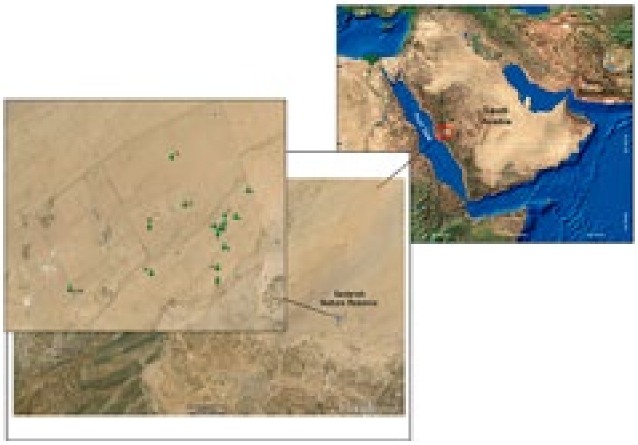
1) Evolution and Ecology Research Centre, School of Biological, Earth and Environmental Sciences, University of New South Wales, Sydney NSW 2052, Australia
2) King Abdulaziz City for Science and Technology (KACST), P.O Box 6086, Riyadh 11442, Saudi Arabia
3) Department of Botany, Faculty of Science, Port Said University, Port Said, Egypt

Correspondence: Ali Namazi,
a.namazi@student.unsw.edu.au

Background & Aim: Interactions between plant individuals play a key role in structuring plant communities. The Stress Gradient Hypothesis (SGH, Bertness & Callaway 1994) poses that competition is usually dominant in productive habitats with experiencing low abiotic stress, whereas facilitation is more common in unproductive and stressful habitats. In stressful environments nurse plants ameliorate stress by creating new environments that, on the other hand, may intensify competition between plants sharing the understory of a nurse plant. In this study, we tested the following predictions: (1) in an extremely stressful environment, interactions between species would shift from competition to facilitation along a gradient of increasing stress from the centre to the edge of canopy of nurse plant (*Acacia gerrardii*); and (2) under the nurse-plant canopies, species distributions will be limited by competitive interactions at the centre of the canopy, and by facilitation at the edge of the canopy.

Materials & Methods: We conducted a neighbour removal experiment in arid and high-stress desert habitats of Saudi Arabia. We identified nurse trees (*A. gerrardii*) in an enclosed reserve. These trees support multi-species herbaceous communities nursed in their understories. We selected individuals of four of the most common herbaceous species growing both in the understory (near the centre of the canopy) and at the edge (near the outside edge of the canopy). Individuals were assigned to 'neighbour removal' or 'neighbours left intact' treatments. We measured growth of the individuals over the duration of the Saudi vegetation growth season.

Solitary *Acacia gerrardii* Benth. with herbaceous undergrowth.



Position of the study are in the Sederah Nature Reserve, Saudi Arabia.

Main Results & Interpretations: We found an overall shift from competitive to facilitative interactions along a gradient from the centre to the edge of the canopy in herbaceous understory communities. Species that were most frequent under the centre of the canopy were also the dominant competitors, but grew poorly in absence of facilitator (nurse) species at the edge of the canopy. In contrast, the species that was more abundant at the edge of the canopy performed poorly under competition, but did not grow faster in the presence of facilitator plants at the edge of the canopy. Our results demonstrate that competitive interactions can structure the understory communities in extremely stressful environments. Intriguingly, the shifts between competition and facilitation in these stressful environments may help to explain the inconsistent results found in some tests of the stress gradient hypothesis.

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Impact of exotic invasive plants on the vegetation of southwestern Saudi Arabia

Abdulrahman A. Alatar, Mohamed A. El-Sheikh, Jacob M. Thomas & Ahmed K. Hegazy

King Saud University, College of Science, Botany & Microbiology Department, P.O. Box 2455, Riyadh 11451, Saudi Arabia

Correspondence: Abdulrahman A. Alatar, aalatar@ksu.edu.sa

Background & Aim: A primary evaluation on the spread of invasive species and their impact on the flora of southwestern regions of Saudi Arabia, including the Farasan Archipelago, have been carried out. Invasive species, particularly *Opuntia* spp. and *Nicotiana glauca* have invaded and established in the habitats of some of the high altitude mountain ranges rich in vegetation types. The study showed that the invasive exotic species have become the dominant components of the pristine habitats and thereby threatened the existence of the native flora including the endangered, endemic plants, to the brink of extinction. The objective of the research is to provide a method of collecting, and identifying non-native plants that cause destructive impacts to the biodiversity. A protocol was designed to distinguish between species that cause high, medium, low, or insignificant negative impacts onto native biodiversity within the region or the entire country.

Materials & Methods: Data were collected from 66 relevés in 13 locations in habitats representing mountains, escarpments, wadis, coastal regions and islands. The relevés were done using classical Braun-Blanquet field methodology (recording all species in a quadrat and estimation of cover-abundance of each species). TWINSPAN was used to classify the vegetation data.

Main Results: 18 vegetation units were identified from these relevés, each represented by a group of significant associations of plants. 355 species belonging to 211 genera have been recorded from these relevés. Among these, 45 species were trees, 111 were shrubs, 139 were subshrubs, 33 were perennial grasses and 27 were forbs. Raida Escarpment, one of the plant diversity hot-spots and a nature reserve, is the most affected area in the Kingdom, followed by the mountains of Taif and Jazan Provinces. The most important invasive species identified in the surveyed area so far include: *Prosopis juliflora, Nicotiana glauca, Opuntia dellenii, O. ficus-indica, Argemone mexicana* and *A. ochroleuca*. Among these *Prosopis juliflora* was recorded in the *Capparis sinaica-Abutilon pannosum* community and in the *Salvadora persica-Acacia ehrenbergiana* community. *Nicotiana glauca* was found to dominate the *Rumex nervosus-Lavandula dentata-Dodonaea angustifolia* community and the *Acacia ehrenbergiana-Anisotes trisulcus* community. *Argemone ochroleuca, A. mexicana* and *Opuntia ficus-indica* were found in the *Rumex nervosus-Lavandula dentata* community and the *Juniperus procera-Acacia origena* community. *O. dillenii* occurs in a wide range of plant communities and dominated communities of *Rumex nervosus, Juniperus procera* and *Acacia asak*.

Invasive *Nicotiana glauca* (Solanaceae) in the Rida Mountains in SW Saudi Arabia. Photo: J. Thomas.

Prosopis juliflora (*Fabaceae*) invading coastal areas along the Red Sea in the Western Region of Saudi Arabia. Photo: J. Thomas.

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Distinct plant extinction scenarios affect the robustness of a mutualistic ecological network

Vinicius A.G. Bastazini (1), Vanderlei Júlio Debastiani (1), Bethânia O. Azambuja (1) & Valério D. Pillar (2)

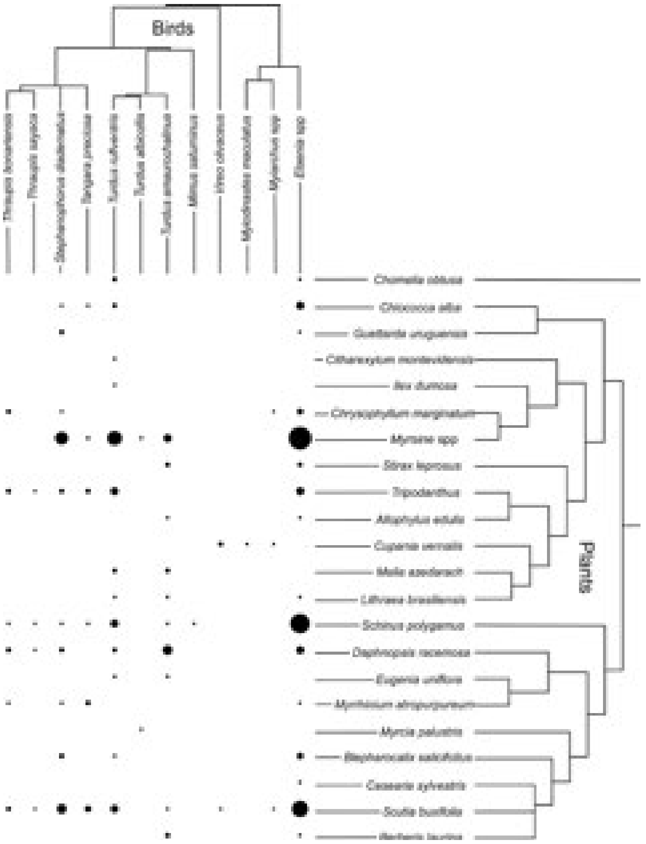
1) PPG-Ecologia, UFRGS. Av Bento Gonçalves 9500, CEP 91501-970, Porto Alegre, Brazil

2) Department of Ecology, UFRGS. Av Bento Gonçalves 9500, CEP 91501-970, Porto Alegre, Brazil

Correspondence: Vinicius Bastazini, bastazini.vinicius@gmail.com

Background & Aim: Understanding how ecological systems respond to disturbances is a central and long-standing issue in both theoretical and applied ecology. Ecologists have long acknowledged that the loss of some species may trigger cascading effects in ecological communities, which might bring other species, and even entire ecosystems, to extinction. The robustness of ecological networks, i.e., the system's tolerance to species loss, has been traditionally evaluated based on scenarios where secondary extinctions are driven by species specialization and/or on stochastic processes (e.g., Memmot et al. 2004). These simplistic scenarios usually ignore other important ecological and evolutionary factors. Here, we take a step forward and evaluate network robustness using functional and phylogenetic information.

Material & Methods: We applied our framework to a qualitative mutualistic network, composed of 22 plants and 12 frugivorous birds, from southern Brazil. We simulated secondary extinctions of plants, based on five distinct elimination schemes, and 1000 simulations: i) species are eliminated at random; extinctions are based on species specialization either with ii) the most generalist (most-linked) or iii) the most specialist (least-linked) species disappearing first; iv) species are eliminated based on their evolutionary distinctiveness (how isolated a species is on the phylogenetic tree); and v) based on species' functional distinctiveness (how distinct a species is in terms of its functional traits). For each scenario, we calculated network robustness (*R*; values closer to 1 indicate higher network robustness), defined as the area below the so-called Attack Tolerance Curve (ATC; Albert & Barabási 2002; Burgos et al. 2007). We also fitted a hyperbolic function to each ATC, as the exponent (*e*) of this function is an important parameter with biological meaning: large values of *e* imply a rapid die-off, which is indicative of high initial redundancy within the network.



Interaction matrix of plants and seed dispersers (birds) from southern Brazil, with the respective phylogenies plotted along the margins. The different sizes of circles indicate the frequency of interaction.

Main Results & Conclusions: Based on these five scenarios, the network is more robust when species are eliminated based on their evolutionary uniqueness ($R = 0.85$; $e = 7.58$), followed by scenarios i) ($R = 0.79$; $e = 4.24$), iii) ($R = 0.78$; $e = 4.13$), v) ($R = 0.74$; $e = 3.17$) and ii) ($R = 0.54$; $e = 1.12$). Despite its simplicity, our approach may help ecologists to understand the collapse of ecological systems. Moreover, our results provide important information for forest management in southern Brazil, as they indicate that the sequential extinction of the most 'evolutionary distinct' species has a small effect on network robustness, whereas the loss of generalist species and functional diversity makes the system more likely to collapse.

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Libyan jird (*Meriones libycus* Lichtenstein) activities promote soil and vegetation degradation in conserved hyper-arid rangelands of Central Saudi Arabia

Abdulaziz M. Assaeed (1), Magdy I. El-Bana (2) & Dawood S. Al-Harbi (1)

1) Department of Plant Production, College of Food and Agriculture Sciences, King Saud University, P.O. Box 2460, Riyadh 11541, Saudi Arabia

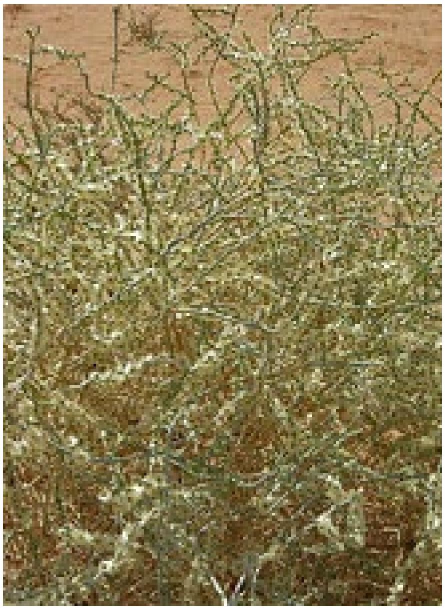
2) Department of Botany, Faculty of Science, Port Said University, Port Said, Egypt

Correspondence: Abdulaziz M. Assaeed, assaeed@ksu.edu.sa

Background & Aim: Soil burrowing and displacement by rodents can substantially influence the spatial pattering of soil and vegetation. We examined the contribution of burrowing and feeding by *Meriones libycus* (Libyan jird) in degradation of hyper-arid rangelands of central Saudi Arabia.

Materials & Methods: The study area was Thumamah National Park (northeast of Riyadh 25° 10′ 47.03 N, 46° 39′ 38.6 E), Saudi Arabia. The burrow entrances and mounds under 15 shrubs of each *Haloxylon salicornicum* (*Chenopodiaceae*) and *Rhanterium epapposum* (*Asteraceae*) grazed by *M. libycus* were compared with their counterparts of ungrazed shrubs. Plant canopy cover, size index, density of rodent burrows, and the number and size of excavated soil mounds were measured.

Main Results & Interpretations: The measured attributes showed significant differences between grazed and ungrazed plots. Grazed plots of both species (*H. salicornicum* and *R. epapposum*) were characterized by reduced shrub canopy cover and size indices, and with higher density of burrow entrances and excavated mounds. However, the size of displaced soil mounds was smaller in the grazed plots (49916.65 m^3) than in the ungrazed ones (50226.92 m^3) of *H. salicornicum*. Similarly, they attained lower value (29951.66 m^3) in grazed plots compared to the ungrazed ones (72743.33 m^3) of *R. epapposum*. The results indicate that with reducing vegetation cover and the dry climatic nature of the area, large amounts of soil are liable for wind erosion as a result of *M. libycus* activities. Such physical and biological impacts contribute to arid-land rangeland degradation and biodiversity loss even in the conserved parks.



Haloxylon salicornicum (*Chenopodiaceae*)

Merionetus lybicus (jerb)

Rhanterium epapposum (*Asteraceae*)

Assaeed, A.M., El-Bana, M.I. & Al-Harbi, D.S. 2014. Libyan jird (*Meriones libycus* Lichtenstein) activities promote soil and vegetation degradation in conserved hyper-arid rangelands of Central Saudi Arabia. In: Mucina, L., Price, J.N. & Kalwij, J.M. (eds.), *Biodiversity and vegetation: patterns, processes, conservatio*n, p. 217. Kwongan Foundation, Perth, AU.

Understanding the process of invasion by *Eragrostis plana*: what are community functional traits showing?

Rodrigo Baggio (1), Lidiante Boavista (1), Sandra C. Müller (1) & Renato B. de Medeiros (2)

1) Graduate Program in Ecology, Department of Ecology, Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, Brazil

2) Department of Forage Plants and Agrometeorology, Faculty of Agronomy, Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, Brazil

Correspondence: Rodrigo Baggio, meinkebaggio@gmail.com

Background & Aim: Species interactions, resource availability, and disturbance are important drivers structuring plant communities under invasion. South-Brazilian grasslands have been strongly invaded by *Eragrostis plana*, mainly due to land-use conversion and inadequate pasture management. *E. plana* (known as South African lovegrass, or 'capim-annoni' in Brazil) is a South African C4 grass, unpalatable to cattle. This study aims to understand how do community functional traits respond to invasion facing different initial disturbances and grazing regimes in grasslands.

Material & Methods: We did an invasion experiment with different management of cattle grazing and initial disturbances, in a grassland area originally not invaded by *E. plana*, in southern Brazil. The experiment was a split-plot design with three complete blocks of 30 m X 90 m. Three grazing management regimes were applied at the plot level (nine plots): (1) none, (2) rotational, and (3) continuous grazing. In each plot, we applied three levels of initial disturbance: (1) light grazing, (2) heavy grazing, and (3) heavy grazing plus soil disturbance. The combination of factors and their levels produced nine different treatments. All subplots were sown with *E. plana* at the beginning of the experiment and 12 months after (~1500 seeds/m^2 per year). Plant species surveys were done twice, 4 and 29 months after the beginning of the experiment. Then we used the most abundant species (53 species) to evaluate the community functional composition, by using the following traits: photosynthetic mechanism (C3, C4), life form, growth form, life cycle (perennial, annual) and specific leaf area (SLA). Community-weighted mean traits (CWM) of both surveys were submitted to ordination analysis. We also tested the variance of functional diversity and redundancy (ANOVAs) between treatments.

Main Results & Interpretations: The CWM pattern of the first survey (4 months) revealed a gradient related to initial disturbances, separating the communities submitted to heavy grazing plus soil disturbance. These communities were dominated by C3 species, forbs, and annuals, and positively correlated with *E. plana*, which started the invasion. This caused a lower functional redundancy in comparison to the other initial disturbances. Light grazing and heavy grazing have not shown any difference regarding the functional responses facing the initial process of invasion. Grazing management regimes also did not differ in terms of functional composition and diversity at this time. The second survey, however, showed different patterns. There was a separation of communities under grazing exclusion independently of initial disturbances, showing clear differences in functional composition and a lower correlation with the invader. This might indicate the need for vegetation gaps to increase establishment and dominance of *E. plana*. On the other hand some communities managed with rotational or continuous grazing submitted to heavy grazing plus soil disturbance were still different from all others. Our results showed that in a short time the soil disturbance strongly modified the functional structure of communities, further allowing the dominance of *E. plana*. Grazing management also influenced the communities, and those without grazing were able to reduce the invasion process in the second year after colonization (sowing of invader). Thus the invasibility of grasslands can be reduced through managing the grazing regime, avoiding the occurrence of gaps and allowing the maintenance of communities with a functional structure able to control the invasion process of *E. plana*.

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Reliability and coherence of diversity patterns in plant community succession

Sándor Bartha (1), Eszter Ruprecht (2), Anna Szabó (2), Zita Zimmermann (1), Cecília Komoly (1), Gábor Szabó (1), Andrej Paušić (3), Nina Juvan (3) & Andraž Čarni (3)

(1) Institute of Ecology and Botany, MTA Centre for Ecological Research, Alkotmány u 2-4, H-2163 Vácrátót, Hungary

(2) Hungarian Department of Biology and Ecology, Babeş-Bolyai University, Republicii St 42, RO-400015 Cluj Napoca, Romania

(3) Scientific Research Centre of the Slovenian Academy of Sciences and Arts, Jovan Hadži Institute of Biology, Novi trg 2, SI-1000 Ljubljana, Slovenia

Correspondence: Bartha Sándor, bartha.sandor@okologia.mta.hu

Background and Aims: It is generally accepted that ecosystem level adaptation, efficiency and stability depend strongly on the diversity and complexity of ecosystems. Theoretical and field evidence show that biodiversity increases functional reliability of ecosystem processes (Naeem & Li 1997). However less is know about the stability and reliability of the related diversity patterns. Spatial stationarity (i.e. the invariance of detected patterns against spatial shifts) of community state variables (alpha diversity and beta diversity) were used as a surrogate for structural reliability and explored in different stages of spontaneous vegetation succession. In order to increase the generality of results, three secondary successional series were compared.

Material & Methods: Abandoned fields of various ages and mature (target) natural grasslands were sampled. These communities were located in (a) karst region of Slovenia (3, 6, 9, 13, and 100 year old stands), (b) sand region of Kiskunság, Hungary (2, 7, 28, 36 years old stands and open sand steppe), and (c) dry grassland region in the central part of the Transylvanian Lowland, Romania (1, 4, 6, 14 year old stands and meadow steppe). In each stand, fine-scale spatial pattern of vegetation was sampled in long (52 m) transects of small (5 cm X 5 cm) contiguous micro-quadrats recording the presence of plant species. Data were analysed at multiple scales by information statistics (Bartha et al. 1998). Alpha diversity was defined as the number of species in a sample while the beta diversity was represented by the diversity of species combinations. Spatial dependence was expressed by the difference between the expected and found diversities of species combinations. Reliability (spatial stability) of community parameters was tested by subdividing the whole transects into 8 m long fragments, repeating estimates in each sub-transects and assessing spatial variability/stability between these local estimates. To quantify spatial stability, we calculated the relative variance (CV%) of these repeated estimates (N=8) of community parameters within each transect for each site.

Main Results & Interpretations: The highest spatial variability and highest spatial dependence appeared in the middle stage of succession, while the most reliable patterns appeared in late successional or mature communities. Compositional variability (beta diversity) increased at fine-scales and decreased at coarser scales in succession. The most pronounced trends appeared during secondary succession of meadow steppe. Beta diversity trends found in succession were the opposite of the trends previously described in a landscape scale degradation process (Bartha et al. 2011). We conclude that spatial reliability (spatial symmetry, i.e. coherence of diversity patterns) develops in succession in spite of the parallel increase of compositional variability (beta diversity). Our results suggest increasing fine-scale coexistence of species and convergence of meta-communities to similar local assemblages in succession. This pattern seems to be general and robust appearing spontaneously during the self-organization of vegetation.

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Functional traits as predictors of species commonness and rarity in forest-grassland ecotones, southern Brazil

Rodrigo S. Bergamin (1), Vinicius A.G. Bastazini (1), Mariana G. Silva (1) & Sandra C. Müller (2)

1) Graduate Program in Ecology, Universidade Federal do Rio Grande do Sul, Av Bento Gonçalves 9500, CEP 91501-970, Porto Alegre, Brazil

2) Department of Ecology, Universidade Federal do Rio Grande do Sul, Av Bento Gonçalves 9500, CEP 91501-970, Porto Alegre, Brazil

Correspondence: Rodrigo S. Bergamin, rodrigo.bergamin80@gmail.com

Background & Aim: Predicting how plant communities are assembled is a central goal in functional ecology. Nonetheless, few studies have focused on the relationship between functional traits and species commonness and rarity. Understanding this relationship is crucial for providing sound scientific basis for the development of long-term conservation strategies (Murray et al. 2002). In southern Brazil, forest-grassland ecotones originated during paleoclimatic fluctuations, yet now the current climate enables forest to expand into grasslands. However, local disturbance factors (e.g., fire and grazing) tend to impede the establishment of woody species in grasslands (Overbeck et al. 2007). In this study, our aim was to evaluate the influence of leaf traits in the patterns of abundance of woody species in forest-grassland communities. Leaf traits can infer about species ability in resource acquisition and storage, influencing the fitness of species in the communities, and also frequently reflect environmental filters that are acting on the species assembly. Contrasting vegetation types thus might show how different strategies of plants are driving processes that support patterns of species abundance.

Material & Methods: We sampled forest-grassland communities at six different sites in Rio Grande do Sul, southern Brazil. In each site, two paired transecta of 140 m X 70 m were marked in ecotones, with 70 m towards the forest and 70 m to the adjacent grassland. In each habitat (forest and grassland) we randomly distributed 15 subplots of 100 m^2. In each subplot, we sampled trees and shrubs with diameters ≥ 5 cm. The individuals were identified and the following leaf traits were collected: specific leaf area (SLA), leaf area (LA) and leaf dry-matter content (LDMC). To evaluate the relationship between leaf traits and species abundance, we fitted linear models using second order Akaike Information Criterion in order to measure model plausibility and the relative trait importance (TI; ranging from 0 to 1). We also estimated averaged slopes (b_{avg}), based on all tested models and Akaike weights (Anderson 2008).

Main Results & Conclusions: In forest communities, LDMC was the most important trait in predicting plant species abundance (TI=0.76, $b_{avg} = 0.057$) followed by LA (TI=0.69; $b_{avg} = -0.002$) and SLA (IT=0.30; $b_{avg} = -0.189$), whereas for grasslands, LA (TI=0.61; $b_{avg} = -0.005$) was the most important trait, followed by LDMC (TI=0.29; $b_{avg} = 0.016$) and SLA (TI=0.27; $b_{avg} = -0.167$). In general, we found a low predictive power of these leaf traits for the abundance of woody species in grassland-forest ecotones. Despite the weak relationship, abundant species in forests tend to invest in tough leaves (high LDMC), a conservative strategy that might give some competitive advantage over species with low LDMC. On the other hand, abundant species in grasslands have small LA, which might confer better conditions to face the abiotic variables of open ecosystems, such as extreme temperatures (heat and cold) and higher evapotranspiration, favouring small-leaved plants.

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An overview of the *Isoëto-Nanojuncetea* class in the western part of Ukraine

Liubov Borsukevych

Botanical Garden, Ivan Franco
National University, 44 Cheremshyna
St, Lviv 79014, Ukraine

Correspondence: Luba Borsykevych,
lborsukiewicz@gmail.com

Background and Aims: Up to now the vegetation of the *Isoëto-Nanojuncetea* was only poorly studied in Ukraine. Solomakha (2008) listed, for instance, only two associations from Ukraine. This paper is presenting the first report on the progress of my research into the inventory and mapping of the *Isoëto-Nanojuncetea* in the western part of Ukraine.

Material and Methods: My studies are based on vegetation data from the literature as well as my own field vegetation data. The work was done during the period of 2005–2013 in the following regions of Ukraine: Western Polissya, Roztochya, Opillya, Prycarpattya, Zacarpattya and Western Podillya. I have used the Braun-Blanquet (1964) approach to classify and describe the plant communities.

Main Results: The plant communities of the *Isoëto-Nanojuncetea* are the most diverse in the central and especially southern parts of Ukraine. I have established that the *Isoëto-Nanojuncetea* is rather rare in the study area where this vegetation is found mainly in lowlands and usually avoiding highlands (Western Podillya) – the region where the influence of periodical floods is diminished by an articulated landscape characterized by deep narrow riverbeds and a small amount of temporary-flooded water pools. A critical revision of literature sources revealed that the communities occurring in the western part of Ukraine should be classified into two alliances, such as the *Nanocyperion* and the *Eleocharition soloniensis* (syn. *Elatini-Elerocharition ovatae*). The communities of the former alliance occur in semi-natural and anthropogenic habitats on acidic sandy-loamy and sandy soils in periodically flooded depressions among arable fields throughout the whole region. They are usually not associated with riverbeds or fishponds. The *Nanocyperion* comprises four associations (*Cyperetum flavescentis*, *Cypero-Limoselletum*, *Cypero-Juncetum bufonii*, *Junco bufonii-Gypsophiletum muralis*). These communities are poor in rare species. The *Eleocharition soloniensis* consists also of four associations (*Polygono-Eleocharietum ovatae*, *Cyperetum micheliani*, Eleocharito *acicularis-Limoselletum aquaticae*, *Lythro-Pulicarietum vulgaris*); this vegetation occurs on exposed bottoms of fishponds and banks of rivers. Here the soils are heavy, clayey and nutrient-rich. The communities of this alliance occur in the warmest southernmost parts of the study area, mainly in Zacarpattya and only rarely north of the Carpathians. Despite the low species richness, these communities support a number of endangered and rare taxa, such as *Carex bohemica* Schreb., *Elatine alsinastrum* L., *E. triandra* Schkuhr, *Lindernia procumbens* (Krock.) Borb.

I found very variable species richness (spanning 4 and 21 species) in the studied communities (the total number of species was 96). Many diagnostic species of the *Isoëto-Nanojuncetea* are found on the eastern and/ or northern border of their distribution in Ukraine.

A stand of the *Cypero-Limoselletum* on the bank of the Zahidnyj Bug River (Sokal District, Lviv Region, Ukraine). Photo: L. Borsukevych.

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Is understorey plant species diversity in cerrado affected by the dry season?

Emilia P. Braga (1), Adriano J.B. Souza (2) & John D. Hay (1)

1) Laboratory of Plant Ecology, Department of Ecology, The University of Brasilia, Campus Darcy Ribeiro, Asa Norte, Brasilia, DF, 70910-900, Brazil

2) Center for Science Education (NECBIO), Institute of Biology, The University of Brasilia, Campus Darcy Ribeiro, Asa Norte, Brasilia, DF, 70910-900, Brazil

Correspondence: Emilia Braga, bragaep@gmail.com

Background & Aim: Savannas are tropical ecosystems characterised by a co-dominance of woody and understorey grassy-herbaceous layers of vegetation. The proportion of these components can vary over a large scale. In Brazil, the savanna (also called 'cerrado') covers approx. 20% of the country. With a large variation in latitude, the cerrado can vary physiognomy, from forest (closed arboreal canopy), woodland (open arboreal canopy), scrubland and open grassland forms (Eiten 1979), but the most common and representative form is a tree-scrub woodland, or cerrado stricto sensu. The knowledge of the distribution patterns of species in an area can contribute to understanding the main environmental factors that are determining community structure. Because cerrado is biome characterised by seasonal climate, the aim of this study was to verify the effect of rainfall on the structure and composition of the herbaceous-subshrub component in true cerrado (open savanna woodlands) in two distinct hydrological periods in 2009 – June (dry season) and November 2009 (wet season).

Materials & Methods: This study was done in the interfluvial region of the Ecological Station of the Botanic Garden of Brasilia. The climate is tropical, with an average temperature during the study period of 24° C. Twenty-five (5 m long) line transects were established in the cerrado strico sensu, and data were collected using the line intercept method in two distinct vegetation seasons. The area was protected from fire for, at least, 5 years before this study. We collected frequency and linear coverage of each species encountered at each period. During the dry season (May–July), cumulative rainfall was 69.5 mm and evaporation was 416.1 mm; for the wet season (Oct–Dec) rainfall was 551.4 mm and evaporation was 327.5 mm.

Main Results & Interpretations: A total of 82 species from 31 families were recorded during this study: 75 for dry season (6 exclusives) and 76 for wet season (7 exclusives). The most frequent growth form was forbs (41%) followed by subshrubs (38%), grasses (16%) and lianas (5%). During the dry season, the total area was 56% covered by grasses, 29% by subshrubs, 13% by forbs and 2% by lianas. For the wet season, the grass cover retracted to 52% while subshrubs expanded the cover to 32% and forbs to 15%, probably with new leafs and seedlings stimulated by rainfall. Lianas retracted to 1% of total cover. In spite of the retraction, expansion and substitution of species between periods, no significant difference in diversity (H = 3.05) or equitability (J = 0.70) was observed between seasons. The one-year seasonal variation of moisture was not enough to explain the dynamics of this ground community of cerrado.

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A stand of cerrado *stricto sensu* (tree-scrub woodland), with a termite mound, in the Botanical Garden of Brasilia. Photo: E. Braga.

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Preserving biodiversity: is the threatened flora effectively protected by the Natura 2000 Network?

Juan A. Campos, Diego Liendo, Vlatka Horvat, Julen Villasante, Idoia Biurrun, Itziar García-Mijangos, Javier Loidi & Mercedes Herrera

Department of Plant Biology and Ecology, University of the Basque Country, UPV/EHU. PO Box 644, ES-48080 Bilbao, Spain

Correspondence: Mercedes Herrera, meme.herrera@ehu.es

Background & Aims: In the last few years, great efforts have been made in Europe in the conservation of plant species and vegetation. The IUCN Red List, and the Natura 2000 Network (see http://ec.europa.eu/environment/nature/natura2000/), have become increasingly powerful tools for conservation planning, management, monitoring and decision making. However the effectiveness in the selection of plant species and natural protected areas has rarely been assessed. The aim of this work is to evaluate the effectiveness of Natura 2000 Network for the protection of the 205 threatened plants included in the Basque Catalogue of Endangered Species of Wild Fauna and Flora.

Materials & Methods: Data on threatened plant species were obtained from the database used to draw up the Red List of Vascular Flora of the Basque Country (Spain). We assessed the degree of species representation within existing protected areas. For each species, we obtained information on the number of 1 km X 1 km UTM squares in which the species was present as well as the inclusion or not of the squares within the Natura 2000 Network's Sites of Community Importance, SCI. Many different algorithms and software have been used for the selection of natural reserves. We used the simulated annealing algorithm in the Marxan reserve selection software package (Ball & Possingham 2000) to find the minimum area required to meet the conservation targets. Marxan can assist with the evaluation of existing reserve systems to identify gaps in biodiversity protection. We entered relative weights of 1000 for Critically Endangered species, 200 for Endangered species, 50 for Vulnerable species, 10 for Near Threatened species and 2 for Least Concerning species and Data Deficient species.

Euphorbia peplis (*Euphorbiaceae*) in strandline plant communities on Azkorri Beach in the Bay of Biscay). Photo: J.A. Campos.

Main Results: After comparing the sites selected by Marxan with the current distribution of the protected area network in the Basque Country, we can conclude that not all the threatened plants are inside these 25 protected areas and many sites with high botanical value remain unprotected. We determined that to ensure the effective conservation of all threatened plant species, at least 40 additional areas are needed. A network of plant micro-reserves (Laguna et al. 2004) could help to conserve the endangered flora.

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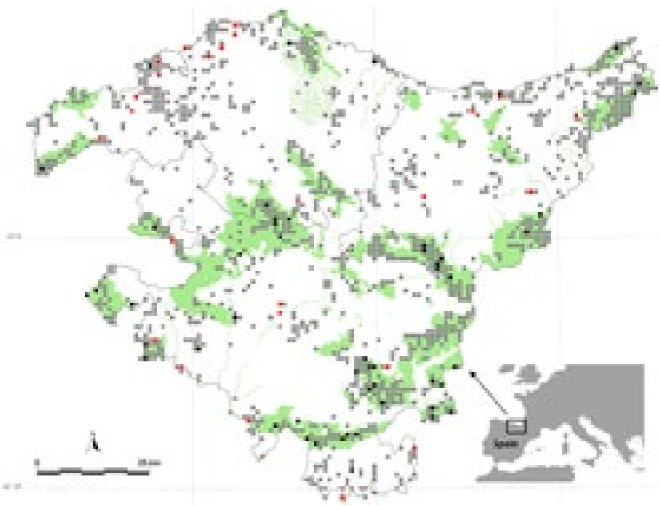

Occurrence of threatened plants (grey) in the Basque Country, northern Spain. Marxan programme has selected 76 sites, 51 of them inside (in black) and 25 outside (in red) the Natura 2000 network (in green).

Campos, J.A., Liendo, D., Horvat, V., Villasante, J., Biurrun, I., García-Mijangos, I., Loidi, J. & Herrera, M. 2014. Preserving biodiversity: is the threatened flora effectively protected by the Natura 2000 Network? In: Mucina, L., Price, J.N. & Kalwij, J.M. (eds.), ***Biodiversity and vegetation: patterns, processes, conservation*****, p. 223. Kwongan Foundation, Perth, AU.**

Classification of the steppe vegetation of the Don River Basin

Olga N. Demina

Department of Natural Sciences,
U.D. Aliev Karachay-Circassian State
University, 369200 Karachaevsk,
Russian Federation

Correspondence: Olga Demina,
ondemina@yandex.ru

Background & Aim: The steppes of the Don River region are very diverse. They have been studied in the past, but there is no study which would be summarizing the steppe vegetation patterns of the region in a synoptic way. This study is aimed at synthesis of the available vegetation data on steppe vegetation of the region which are believed to belong to the Festuco-Brometea Br.-Bl. et Tx. ex Soó 1947.

Materials & Methods: I sampled (during the period 2004–2013) 1450 relevés of steppe vegetation of the Don River Basin. This data set was classified using the Braun-Blanquet (1964) floristic-sociological approach. The classification was performed using packages PC-ORD (McCune & Mefford 1999) and JUICE 7.0.42 (applying TWINSPAN; Hill 1979). Ordination analyses involving detrended correspondence analysis (Hill & Gauch Jr. 1980) and non-metric multidimensional scaling; (Clarke 1993) were also used to assist the interpretation of the classification patterns.

Main Results & Interpretations: The steppes of the Don River Basin belong to the *Festuco-Brometea* class, which in the regions comprises two alliances, six suballiances. 21 associations and 43 subassociations. The *Festucion valesiacae* Klika 1931, the most important steppe alliance in the region, is composed (at this stage) of the *Bupleuro falcate-Gypsophilenion altissimae* Averinova 2005, *Phlomenion pungentis* Saitov et Mirkin 1991 and two new suballiances – the *Festuco rupicolae-Stipenion pennatae* Demina 2012 and *Cleistogeno bulgaricae-Jurinenion stoechadifoliae* Demina 2012. I am planning to up-rank the suballiances of the *Phlomenion pungentis* and the *Festuco rupicolae-Stipenion pennatae* to the rank of the alliances representing the Western Black Sea steppes (Azov Region) and the Eastern Black Sea steppes, respectively. Semi-desert steppes dominated by sub-shrubs and bunchgrasses on solonetz-like chestnut soils in the southeastern part of the Rostov Region belong to the *Tanaceto achilleifolii-Artemision santonicae* Demina 2012.

The sub-saline steppes of the Western Black Sea and Pontic-West Caspian regions are considered to be a new suballiance – the *Trifolio arvensis-Limonienion sareptani* Demina 2012 classified within the latter alliance. The desertified steppes of the Eastern Black Sea and adjacent West Caspian regions belong to a new suballiance – the *Artemisio lerchianae–Stipenion lessingianae* Demina 2012. The vegetation on steep chalk slopes belongs to the *Thymo cretacei-Hyssopetalia cretacei* Didukh 1989 (previously classified within a class in its own right – the *Helianthemo-Thymetea* Romashchenko et al. 1996, but today considered as part of the *Festuco-Brometea*. The steppes on deep sands represent zonal vegetation and most probably should be classified within and *Festucion beckeri* Vicherek 1972 (*Festucetalia vaginatae* Soó 1957, *Koelerio-Corynephoretea canescentis* Klika in Klika et Novák 1941). The halophytic (saline) vegetation of the region is was classified as the *Poo bulbosae–Artemisietum pauciflorae* Karpov, Lysenko et Golub 2003 and belongs to the *Artemisio pauciflorae-Camphorosmion monspeliacae* Karpov 2001 (*Artemisietalia pauciflorae* Golub et Karpov 2005, *Festuco-Puccinellietea* Soó ex Vicherek 1973).

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Vegetation database of Najd – the Central Region of Saudi Arabia: an overview

Mohamed A. El-Sheikh (1), Jacob M. Thomas (1), Ahmed H. Alfarhan (1), Myandi Sivadasan (1), Stephan M. Hennekens (2), Joop H.J. Schaminée (2) & Ladislav Mucina (1,3,4)

1) Botany and Microbiology Department, College of Science, King Saud University, P.O. Box 2455, Riyadh 11451, Saudi Arabia
2) Team Vegetation, Forest and Landscape Ecology, Alterra, Wageningen, P.O. Box. 47, NL-6700 AA Wageningen, The Netherlands
3) Iluka Chair in Vegetation Science and Biogeography, School of Plant Biology, The University of Western Australia, 35 Stirling Hwy, Crawley WA 6009, Perth, Australia
4) Centre for Geographic Analysis, Department of Geography and Environmental Studies, Stellenbosch University, Matieland 7600, Stellenbosch, South Africa

Correspondence:
Mohamed A. El-Sheikh,
el_sheikh_eg@yahoo.co.uk

Background & Aim: During the last decade many electronic databases of vegetation plots, were established in different countries around the world. These databases contain a lot of valuable phytosociological information data which help the nature conservation agencies to formulate various surveys and provide proper guidelines for the conservation of biodiversity. The aim of this paper is to provide an account on the nature of data of various vegetation relevés of the vegetation and environmental data collected and collated in the vegetation database of the Central region of Saudi Arabia.

Current Structure of the Database: The data come from the Najd – the Central Region of Saudi Arabia. They are traditional vegetation relevés of the Braun-Blanquet approach, accompanied by a series of general vegetation characteristics including vegetation cover, life-form of species and geographical (coordinates, altitude, soil typology, topography and the like). More than 1000 vegetation-plot records (relevés) were so far done in Najd of which more than 700 have already been stored electronically using TURBOVEG database software. The field records cover many different habitats such as depressions, wadis (dry river beds), agricultural lands, sand dunes, sabkhas, ruderal and rural areas. Most of the data comes from low-lying habitats such as depressions and wadis.

Future of the Database and Outlook: The ecological information collected in the database is currently the largest set of vegetation data collated into a database in the Middle East. These data are of great importance for the future of biodiversity studies in Saudi Arabia as the region is losing its biodiversity at an alarming rate due to environmental problems like global warming and ongoing land-use changes. We envisage that this database would serve as seed for large data collection on vegetation of the entire Arabian Peninsula and shall serve as one of the most important data-sets in mapping vegetation of the Kingdom of Saudi Arabia.

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Extremely xeromorphic scrub of the Gibela Hill, Central Saudi Arabia, on wadi cliffs and rocky outcrops with *Acacia gerrardii*, *A. ehrenbergiana*, *Fagonia* spp., *Haloxylon salicornicum*, *Helianthemum lippii*, *Gymnocarpos decandrum*, *Lasiurus scindicus*, *Lycium shawii* and *Panicum turgidum*, Photo: M. El-Sheikh.

Evergreen scrub with *Acacia gerrardii* and *A. ehrenbergiana* in a valley filled with fine sandy loam in the Gibela Oasis, Central Saudi Arabia. Photo: M. El-Sheikh.

Desert wadi pseudo-savannah of the Najd Desert plain (Wadi Alghat, Central Saudi Arabia) with trees *Acacia ehrenbergiana*, *A. gerrardii* and associated grasses, herbs and shrubs such as *Achillea fragrantissima*, *Dichanthium annulatum*, *Haloxylon salicornicum*, *Hyparrhenia hirta*, *Lasiurus scindicus*, *Lycium shawii*, *Ochradenus baccatus*, *Panicum turgidum*, *Rhanterium epapposum*, *Zygophyllum coccineum* and *Zilla spinosa*. Photo: M. El-Sheikh.

El-Sheikh, M.A., Thomas, J.M., Alfarhan, A.H., Sivadasan, M., Hennekens, S.M., Schaminée, J.H.J. & Mucina, L. 2014. Vegetation database of Najd – the Central Region of Saudi Arabia: an overview. In: Mucina, L., Price, J.N. & Kalwij, J.M. (eds.), *Biodiversity and vegetation: patterns, processes, conservation*, p. 225. Kwongan Foundation, Perth, AU.

Does clonality lead to ecological generalization or specialization?

Fatih Fazlioglu & Stephen P. Bonser

School of Biological, Earth and Environmental Sciences, University of New South Wales, Sydney NSW 2052, Australia

Correspondence: Fatih Fazlioglu, f.fazlioglu@student.unsw.edu.au

Background & Aim: Phenotypic plasticity can allow existence of a genotype in a changing environment increase environmental tolerance and therefore the range of habitats (Griffith & Sultan 2011). We tested whether plant reproductive strategies (obligate sexual versus clonal) were associated with different phenotypic plasticity capabilities. Obligate sexual reproduction can permit rapid adaptation and specialization to a given environment. Thus, sexual species may express low adaptive plasticity, but high plasticity in fitness traits (maladaptive plasticity). Alternately, limited dispersal and low genetic variability in clonal offspring can promote habitat specialization in clonal species. Under such conditions, clonal species may express low adaptive plasticity, but high plasticity in fitness traits.

Materials & Methods: We assembled studies reporting plasticity in growth and reproduction in clonal and non-clonal plants by searching ISI Web of Knowledge and Scopus. Data were collected from over 90 studies. We recorded sexual strategies, treatment types, fitness, growth and allocation related traits across resource/environmental treatments. We used an index of plasticity (PIv; Valladares et al. 2000) to quantify and compare phenotypic plasticity across species.

Main Results & Interpretations: We found that non-clonal (obligate sexual) plants expressed greater plasticity in the functional traits than clonal species across resource treatments. However, there was no significant difference in the fitness plasticity between clonal and non-clonal plants, and high plasticity in functional traits did not always result in high fitness across resource treatments. Therefore, it is not clear if the high plasticity exhibited by obligate sexual species is adaptive. Smaller plasticity in functional traits in clonal species suggests these species express a specialist strategy where a genotype (or population) can perform well only in a limited range of habitats and cannot express optimal trait values across resource environments. Clonal plants produce many offspring genetically identical to the mother plant. These offspring would already be adapted to the maternal environment and would reinforce the habitat specialization. In addition, clonal reproduction can limit gene flow between habitats further favouring the habitat specialization. Sexual reproduction can increase the ability of adapting to environmental changes by quick shuffling of the genes that would be advantageous in expanding of the habitat ranges. Moreover, the ability to express different trait values in functional traits in different environments might be an adaptive response to heterogeneous environments. Overall, our results suggest that, non-clonal plants exhibit a more generalist ecological strategy in order to persist and flourish in a range of environments while clonality tends to promote ecological specialization.

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Modern and fossil assemblages of high-altitude forest vegetation in the Mexican subtropics

Blanca Lorena Figueroa-Rangel (1), Miguel Olvera-Vargaş (1), J. Martín Vázquez-López (1) & Socorro Lozano-García (2)

1) Universidad de Guadalajara, Centro Universitario de la Costa Sur, Departamento de Ecología y Recursos Naturales-IMECBIO, Independencia Nacional # 151, Autlán de Navarro, Jalisco, CP 48900, México

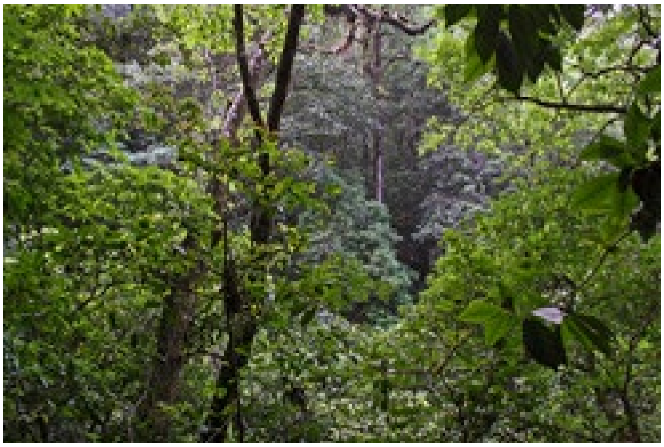
2) Departamento de Paleontología, Instituto de Geología, Universidad Nacional Autónoma de México, Cd. Universitaria, Del. Coyoacán, 04510 México D.F., México

Correspondence: Blanca Lorena Figueroa-Rangel, bfrangel@cucsur.udg.mx

Background & Aim: High-altitude regions of the Mexican subtropics support a number of important ecosystems in terms of biodiversity and structure. Most of these are communities such as Pine forests and Oak forests that are home to temperate taxa while others, in particular Cloud forests comprise both temperate and tropical taxa. All those forests are dominated by *Pinus* and *Quercus* are also well represented in the fossil pollen signature in paleoecological studies (Torres-Rodríguez et al. 2012). In order to set the baseline for biodiversity conservation in these ecosystems, the long-term perspective is essential, as most ecological processes require the consideration of temporal scales (Willis et al. 2007). This research therefore aimed to address the following objectives: (1) to distinguish patterns of variation between different high-altitude forests using modern pollen signatures; (2) to relate forest structure, forest diversity and the differences in altitude to modern pollen taxonomic composition, and (2) to establish if the modern and fossil pollen assemblages can reflect present-day forest vegetation composition.

Materials & Methods: We used data collected on forest structure and diversity as well as modern pollen sampling and forest vegetation reconstruction through fossil pollen in three high-altitude types of forests: pine-forest, cloud-forest, and a mixed *Pinus-Quercus-Carpinus* forest. Our analyses involved constrained and unconstrained ordinations to discern patterns of variation and the possible causes originating the patterns as well as the estimation of dissimilarity indexes between each of the three fossil pollen sequences and their modern assemblages.

Main results: Our studies demonstrate that modern pollen represents local vegetation at stand level with rare taxa as an important attribute in each of the three forest types. Mean tree diameter and altitude were the main variables related to differences among modern pollen signature. Modern and fossil pollen assemblages are both good indicators of the present-day vegetation. Each of the tree forests was more distinctive in some of three life forms (trees, herbs and epiphytes). Hence when reconstructing high-altitude vegetation in the subtropics it is important to consider all life forms as well as rare taxa – their presence and, most importantly, their abundances is an indication of the local vegetation signature.



High-altitude cloud forest in the Mexican subtropics.

Acknowledgements: This work was supported by CONACyT project CB-2008-106435 CoecytJal Project 5-2010-875 and Universidad de Guadalajara.

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Assessment of the dynamics of vegetation boundaries as depicted by vegetation mapping based on aerial photographs and satellite remote sensing

Michiro Fujihara (1,2), Kyuichi Ito (3), Ippei Harada (4), Mizuki Tomita (4) & Keitarou Hara (4)

1) Department of Landscape Design and Management, Graduate School of Landscape Design and Management, University of Hyogo, Awaji 656-1726, Japan

2) Awaji Landscape Planning and Horticulture Academy, Awaji 656-1726, Japan

3) Ryokusei Institute Ltd., Toyonaka 561-0882 Japan

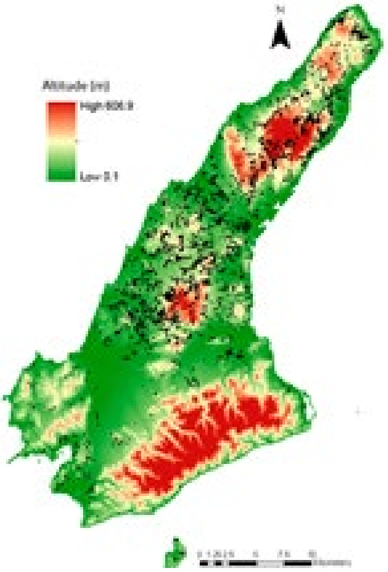
4) Tokyo University of Information Sciences, Chiba 265-8501, Japan

Correspondence: Michiro Fujihara, fujihara@awaji.ac.jp

Background & Aim: Actual vegetation maps are useful tools in the investigation of biodiversity and the current environmental situation in Japan. However, considerable time and effort would be required to construct such maps for the whole of Japan. Satellite remote sensing offers complementary techniques for the production of high-resolution vegetation maps. In the present study, the pattern of vegetation change and the boundaries between bamboo forests and adjacent communities on Awaji Island, western Japan, were investigated in order to provide fundamental information for the classification of vegetation types on vegetation maps based on satellite data.

Study Sites & Methods: The study sites were located on Awaji Island located in the eastern part of the Seto Inland Sea district, where precipitation is relatively low compared to other regions of Japan. Vegetation change was clarified from actual vegetation maps from 1982 (1:50 000 scale; Ministry of Environment) and 2001 (1:50 000 scale; Hyogo Vegetation Research Group). Each vegetation map was divided into an approximately 0.9 km X 1.1 km grid. In each grid, all vegetation types were inventoried and the dominant vegetation recognised. The distribution of bamboo forests on Awaji Island and their adjacent communities were determined using vegetation maps from 2010 (1:25 000 scale, Ministry of the Environment). The perimeters of the bamboo patches and the lengths of boundaries between the bamboo patches and adjacent patches were calculated using Geographic Information System software (ArcGIS version 9).

Main Results: From 1982 to 2001, the relative dominance and frequency of pine forest decreased from 23.9% to 6.3% and from 61.5% to 17.5%, respectively. Conversely, the relative dominance and frequency of the *Quercus serrata* community increased from 3.3% to 12.7% and from 29.1% to 61.7%, respectively. Similarly, the frequency of the *Q. phylliraeoides* community increased from 56.1% to 85.2%. The *Pinus thunbergii* and *P. densiflora* communities changed to *Q. serrata* and *Q. phylliraeoides* communities, owing to pine wilt disease. In 2010, there were 1313 bamboo patches covering a total area of 26.6 km^2 on Awaji Island. The total lengths of the boundaries between the bamboo community and paddy fields, *Q. variabilis*-*Q. serrata* communities, *Castanopsis*-*Quercus* secondary forests, and *Q. phylliaeoides* communities were 334.9 km (36.2%, the total length of boundaries to the total perimeters of bamboo patches), 204.9 km (22.1%), 119.9 km (13.0%), and 115.6 km (12.5%), respectively. The boundaries between bamboo patches and paddy fields can be determined based on topography. Conversely, the boundaries between bamboo patches and secondary forests were changeable and could be determined effectively using fine-scale aerial photographs. Cultivated land, secondary evergreen broad-leaved forest, and secondary deciduous broad-leaved forest were distributed adjacent to bamboo patches frequently. It is necessary to compare changes in vegetation based on satellite images to changes in vegetation and boundaries derived from actual vegetation maps.



Distribution of bamboo patches (black circles; larger that in reality) in relation to altitude on the Awaji Island, Japan. Source: Fujihara, M. & Ito, K. 2013. A preliminary study on the area, distribution, and inclination of bamboo forests on the basis of the actual vegetation map of Awaji Island, Hyogo Prefecture. *Hikobia* 16: 393–402. (In Japanese with English summary.)

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Ficus natalensis facilitates the establishment of a montane rain-forest tree in southeast African tropical woodlands

Tomohiro Fujita

Graduate School of Asian and African
Area Studies, Kyoto University, 46
Shimoadachi-cho, Yoshida, Sakyo-ku,
Kyoto 606-8501 Japan

Correspondence: Tomohiro Fujita,
tfujita0727@gmail.com

Background & Aim: Nucleation, leading to the formation of tropical forest patches in open areas, has occurred in various tropical ecosystems. In northern Malawi (southeastern Africa), circular patches of tropical forest can be found within tropical woodlands. Large, fleshy-fruited trees of *Ficus natalensis* are located in the center of these patches. These structures are a common feature of nucleated forest patches, rather than in fragmented forests (Duarte et al. 2007; Favier et al. 2004). I hypothesized that *F. natalensis* trees in woodlands initiate nucleation by promoting seed arrival and facilitating forest tree establishment. In order to examine the role of *F. natalensis* as a nucleus of forest establishment and development, the seed rain and seedling survival of *Syzygium guineense* subsp. *afromontanum* (a common forest species) were studied.

Materials & Methods: Using seed traps, seed rain of *S. guineense* subsp. *afromontanum* under eight *F. natalensis* crowns were compared to those in another three microsites in the woodland, these were: (1) under *Brachystegia floribunda*, (2) under *Uapaca kirkiana* and (3) in open habitats. In addition, seedling survival of *S. guineense* subsp. *afromontanum* was measured for 10 months. Seedling death was assigned to the most evident causes, such as desiccation, attacked by insects, trampling by ungulates, and fire.

Main Results & Interpretation: Most dispersed seeds (85%) were found under *F. natalensis*, and the number of dispersed seeds was significantly greater under *F. natalensis* than in the other three microhabitats. Seedling survival was greater under *F. natalensis* (76%) when compared to those in treeless open microsites (16%). Mortality of the seedlings was largely due to fire and it was strongly concentrated to open sites. Fire burned the surrounding of *F. natalensis*, but failed to enter below the *Ficus* canopy and hence only a few seedlings died due to fire in this microhabitat. These results suggest that *F. natalensis* trees act as an effective nucleus, promoting establishment of forest species through assisting seed arrival and suppression of mortality due to low fire occurrence.

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A patch of forest surrounded by a miombo woodland in northern Malawi. Photo: T. Fujita.

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Relationships between plant community mycorrhization and plant species richness

Maret Gerz, Martin Zobel & Mari Moora

Department of Botany, Institute
of Ecology and Earth Sciences,
University of Tartu, EE-51005 Tartu,
Estonia

Correspondence: Maret Gerz,
maret.gerz@ut.ee

Background & Aims: Mycorrhiza is an ancient symbiosis between plant roots and fungi by which plants are providing fungi with carbon and getting soil nutrients like nitrogen or phosphorus in return. Besides being important on a single plant level, mycorrhizae also plays an important role in the functioning of plant communities and determining their composition and diversity. When looked at the ecosystem level, three types of mycorrhizae are prevailing - arbuscular (AM), ecto- (ECM) and ericoid (ERM) mycorrhiza. However, to date research about mycorrhizae has been done with only one type of mycorrhiza or mainly focused on individual plants and interactions between them in micro- and mesocosms. Less attention has been paid to plant communities and ecosystems as a whole including all the main mycorrhizal types and if done so, mostly qualitative approaches have been used and quantitative information is scarce. We have targeted this issue and quantified the mycorrhization and arbuscular mycorrhization in Estonian forest and grassland ecosystems. In addition the influence of soil nitrogen and moisture content and soil reaction on community mycorrhization was tested. Also, we aimed to reveal how mycorrhization affects the diversity of plant communities.

Materials & Methods: We addressed two ecosystems – forests and grasslands – both including a set of community types along environmental gradients in Estonia. In two replicates of each community type vegetation was sampled in ten 1 m X 1 m plots, where cover values of each plant species were estimated. The quantification of mycorrhization was done using the community mycorrhization index (MI) proposed by Moora (2014), which takes plant relative abundance and their mycorrhizal status (obligatorily mycorrhizal, facultatively mycorrhizal or nonmycorrhizal) into account. Arbuscular mycorrhization index (AMI) was calculated using the same approach, but plants were classified as obligatorily AM, facultatively AM or plants never forming AM. Soil factors were included in the analyses as community weighed Ellenberg mean values. GLM mixed effects model was used to estimate the effects of soil factors on mycorrhization. Partial correlations calculated between mycorrhizations and plant species richness were done to exclude confounding factors.

Results & Conclusions: Mycorrhization significantly differed between ecosystems, being higher in forests and lower in grasslands. Arbuscular mycorrhization however showed the opposite results. This pattern is due to the prevalence of obligatory ECM and ERM plants in forests and the dominance of often facultative AM plants in grasslands. Regarding environmental factors, soil nitrogen and moisture content was found to negatively influence mycorrhization in grasslands. Soil reaction was shown to positively affect arbuscular mycorrhization in forests. When the relationship between mycorrhization and plant species richness was looked at over all ecosystems no relationship was found. However, if forests and grasslands were considered separately, increasing mycorrhization was found to be associated with decreasing plant species richness in forests, while increasing arbuscular mycorrhization was associated with increasing species richness in grasslands. In conclusion – the use of a new approach – calculation of the mycorrhizal index for plant communities – is a promising tool for evaluating the community mycorrhization and thus help us better to describe plant communities and unravel the mechanisms structuring them.

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Ecosystem services and plant diversity: a case study in a *Pinus hartwegii* forest near Mexico City

Eileen Gómez-Álvarez (1), Xarhini García-Cepeda (2), Raquel Ortíz-Fernández (2) & Víctor Ávila-Akerberg (3)

1) Facultad de Estudios Superiores Iztacala, Universidad Nacional Autónoma de México, Av. de los Barrios 1, Los Reyes Ixtacala, 54090 Tlalnepantla, México

2) Laboratorio de Ecosistemas de Montaña, UNAM, Av. Universidad 3000, Coyoacán, 04510, México D.F., México

3) Instituto de Ciencias Agropecuarias y Rurales, Universidad Autónoma del Estado de México, Carretera Toluca – Atlacomulco Km. 14.5, 50000, Toluca, México

Correspondence:
Eileen Gómez-Álvarez,
eileenfatima.92@comunidad.unam.mx

Background & Aim: Humans get benefits from different ecosystems, which represent some of the relationships that men have with natural systems. Plant diversity represents one of the main sources of goods and services that can be obtained from nature (for food, medicine, carbon sequestration, fodder, rituals, etc.). Guadalupe Dam catchment (38 km^2 spanning an altitudinal gradient of 2200–3750 m) lies in the outskirts of Mexico City. Around 35% of its total area is covered with forests, mainly oak and fir, which face enormous land use change pressure. In the highest parts, *Pinus hartwegii* forest occurs, the pine species that marks the timberline of the country, with a flora and vegetation that provide several ecosystem services.

Materials & Methods: Through personal interviews and field work, we evaluated the importance and perception that different stakeholders in the area (visitors, local inhabitants, authorities and landowners) have on plant diversity' goods and services. A floristic guide with the most common 40 plant species was developed in order to show their different uses and services.

Main Results & Interpretations: Carbon storage, water provision and food supplies are some of the main services that people get from this forest, as well as indirect or non- material ecosystem services such as cultural, spiritual or aesthetic spaces for outdoor recreation, an important economic income source for the local people, which provide some touristic infrastructure. The main recognized benefits from the flora are: medicinal, food and wood for construction, and fuel. Some of the main recognised useful species include *Arceuthobium vaginatum* (dwarf mistletoe), *Pinus hartwegii* (Hartweg's pine), *Salix paradoxa* (mountain willow), *Castilleja moranensis* (paintbrush) and *Eryngium carlinae* (toad herb). It is of importance to assess and promote the recognition of ecosystem services rendered by vegetation in order to assure conservation of this forest and other habitats within the Guadalupe Dam catchment.

Pinus hartwegii forest near Mexico City. Photo: E. Gómez-Álvarez.

Location *Pinus hartwegii* forest in the Guadalupe Dam catchment (near Mexico City).

Gómez-Álvarez, E., García-Cepeda, X., Ortíz-Fernández, R. & Ávila-Akerberg, V. 2014. Ecosystem services and plant diversity: a case study in a *Pinus hartwegii* forest near Mexico City. In: Mucina, L., Price, J.N. & Kalwij, J.M. (eds.), *Biodiversity and vegetation: patterns, processes, conservatio*n, p. 231. Kwongan Foundation, Perth, AU.

Invasibility patterns of grassland communities in southern Brazil

Anaclara Guido & Valério D. Pillar

Department of Ecology, Universidade Federal do Rio Grande do Sul, Porto Alegre 91540-000, Brazil

Correspondence: Anaclara Guido, anaclara.guido@ufrgs.br

Background & Aim: Southern Brazilian grasslands are very rich in species (supporting ca. 2500 vascular plant species), but currently are being threatened by invasive species. Identifying invasive species distribution patterns and the factors that influence their spread are fundamental to developing appropriate management programs. We present the results of a regional invasive species survey in southern Brazil, in which we evaluated invasibility of native grassland communities in relation to land use, climatic conditions and landscape metrics.

Methods: We selected 20 areas (2 m X 2 km) representing the heterogeneity of grassland vegetation types across an area of about 6 million ha occupied by grassland remnants in the state of Rio Grande do Sul. For each grassland type, one area was randomly located in a fragmented landscape context (with grassland remnant cover < 25%) and another in a non fragmented landscape (grassland remnant cover >75%) in a paired design. Each area was divided into a grid of 200 m x 200 m plots, among which five were randomly selected for the survey. In each plot we sampled four transects (spaced 40 m apart) to record invasive species. We recorded the presence and the abundance (measured as percentage cover) of *Cynodon dactylon*, *Eragrostis plana*, *Pinus* sp., *Senecio madagascariensis* and *Ulex europaeus*, which are the five most invasive exotic species in the grasslands of this region. For each area, we also collected data related to land use (percentage natural grassland cover in each area, using the classification proposed by Hasenack & Cordeiro 2006), climatic conditions (altitude, mean annual precipitation and mean annual temperature), and landscape context (road density, distance to the closest city, and population density in the municipality). To compare invasiveness in fragmented and non fragmented areas, we used analyses of variance with permutation tests, restricting permutations within each grassland type. We applied regression trees to identify which factors among the measured ones could be used to predict invasive species abundance and richness (seven predicted variables). All data analyses used the MULTIV package (http://ecoqua.ecologia.ufrgs.br).

Main Results & Conclusions: *E. plana* was the most frequent species, appearing in 41% of transects, suggesting the species is a substantial threat to native grasslands. The results indicated that fragmented areas have greater invasive species cover (mean=7.51 %; P=0.013), and marginally greater richness (mean=1.02; P=0.056) than non fragmented areas (mean cover=2.63; mean richness=0.64), suggesting that fragmented habitats are more susceptible to being invaded. Further, the regression tree model showed that invasive species cover was higher in areas with less natural grassland cover, closer to cities and with less mean annual precipitation and lower altitude. Furthermore, invasive species richness was higher in areas with less natural grassland cover, higher roads density, less mean annual precipitation and lower altitude. The results indicate that land use, climatic conditions and the landscape context are critical factors for invasive species introduction and spread.

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Effects of plot shape and arrangement on species richness counts in grasslands

Behlül Güler (1,2), Anke Jentsch (2,3), Iva Apostolova (4), Sándor Bartha (5), Juliette Bloor (6), Giandiego Campetella (7), Roberto Canullo (7), Judit Házi (5), Jürgen Kreyling (3,8), Gábor Szabó (5), Tsvetelina Terziiska (4), Emin Uğurlu (1), Camilla Wellstein (9), Zita Zimmermann (5) & Jürgen Dengler (2,8,10)

1) Biology, Faculty of Science & Letters, Celal Bayar University, Muradiye, Yagcilar Campus, 45140 Manisa, Turkey

2) Disturbance Ecology, University of Bayreuth, Universitätsstr. 30, D-95447 Bayreuth, Germany

3) Bayreuth Center of Ecology and Environmental Research (BayCEER), University of Bayreuth, Universitätsstr. 30, D-95447 Bayreuth, Germany

4) Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences, G. Bonchev Str. Block 23, 1113 Sofia, Bulgaria

5) Centre for Ecological Research, Hungarian Academy of Sciences, Alkotmány ú. 2-4, H-2163 Vácrátót, Hungary

6) INRA, UR0874 Grassland Ecosystem Research Unit, 5 Chemin de Beaulieu, F-63100 Clermont-Ferrand, France

7) Plant Diversity and Ecosystems Management Unit, School of School of Biosciences & Veterinary Medicine, University of Camerino, Via Pontoni 5, I-63032 Camerino (MC), Italy

8) Biogeography, University of Bayreuth, Universitätsstr. 30, D-95447 Bayreuth, Germany

9) Faculty of Science and Technology, Free University of Bozen, Universitätsplatz 5, I-39100 Bozen, Italy

10) Synthesis Centre (sDiv), German Centre for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig, Deutscher Platz 5e, D-04103 Leipzig, Germany

Correspondence: Jürgen Dengler,
juergen.dengler@uni-bayreuth.de

Background & Aims: Due to the universal distance decay in ecological similarity, the shape of the sampling unit should affect species richness counts, with more species being found in elongated vs. compact units. Similarly, where a sampling unit consists of several non-contiguous plots within a larger spatial extent (e.g. rarefaction curves), it should contain more species than a contiguous unit of the same area (Dengler & Oldeland 2010). Although the differences of elongated vs. compact (shape) and non-contiguous vs. contiguous (arrangement) are theoretically clear, ecologists rarely acknowledge them when comparing biodiversity data originating from different sampling schemes (Dengler 2008). Moreover, from the few existing studies the effect sizes are hard to assess. With this study we thus aimed to quantify the relative differences in species richness counts resulting from varying shapes and arrangements of sampling units at different, small spatial grain sizes.

Methods: We used monitoring plots of the BiodivERsA project SIGNAL in semi-natural grasslands of six Eurasian countries (France, Germany, Italy, Hungary, Bulgaria, and Turkey). In each study site we established six blocks of 2.80 m X 0.40 m, subdivided into 448 micro-quadrats of 25 cm^2. We recorded the vascular plant species composition in each of these micro-quadrats. Then we calculated species richness values for different sampling unit sizes (4, 16, and 64 micro-quadrats) for different shapes (1:1; 1:4, and 1:16) and arrangements (contiguous vs. three non-contiguous variants, drawn from different extents: sub-block, block, and site). We tested for differences by means of linear mixed-effect models.

Main Results & Interpretations: Both shape and arrangement had highly significant effects on richness values of sampling units. These responses were consistent across the six countries and the sampling unit sizes. Generally, the differences between squares and 1:4 rectangles were negligible while 1:16 plots showed a clear increase in species richness. This indicates that compact and slightly elongated plots of the same size can be combined without problems in the same study, while serious distortions are to be expected only for extremely long and thin plots. In contrast, the contiguous and the various non-contiguous arrangements showed significant differences in species richness, with richness increasing strongly with the spatial extent from which the subplots were drawn. This suggests that rarefaction curves are highly idiosyncratic and should not be compared between studies because their spatial extent is hardly ever the same (see also Chiarucci et al. 2009).

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Remote sensing analysis of tsunami damage and recovery of coastal vegetation in northeast Japan

Keitarou Hara (1), Yi Zhao (1, 2), Mizuki Tomita (1), Noritoshi Kamagata (3) & Yoshihiko Hirabuki (4)

1) Department of Informatics, Tokyo University of Information Sciences, Chiba 265-8501, Japan

2) R&D Center, Pasco Corporation, Higashiyama, Meguro-ku, Tokyo 153-0043, Japan

3) Remote Sensing Unit, Kokusai Kogyo Co. Ltd., Fuchu, Tokyo 183-0057, Japan

4) Department of Regional Design, Tohoku Gakuin University, Sendai 981-3139, Japan

Correspondence: Keitarou Hara, hara@rsch.tuis.ac.jp

Background & Aim: On the 11th of March 2011, the Great East Japan Earthquake and subsequent huge tsunami caused widespread damage along the Pacific Ocean coast of eastern Honshu, Japan. Both the maximum inundation height and maximum run-up height exceeded 30 m. In the alluvial plain areas the tsunami penetrated several kilometers inland. In addition, the earthquake caused widespread land subsidence, as much as 1 m in some areas. The coastal vegetation of this area was damaged by the tsunami, however the extent and nature of the damage varied according to geographical position and landforms. This study utilizes satellite imagery to measure the damage to the vegetation caused by this disaster, and subsequent recovery process.

Methods: The damage sustained by four types of habitats/vegetation (coastal cliffs, sandy beaches, coastal forests, marshes) was analyzed and compared using both field research and remote sensing. Terra/Aqua MODIS data (250 m spatial resolution) was employed to map the overall extent of inundation on a wide regional scale. SPOT/HRG-2 data (10 m resolution) was used to analyze the amount of coastal forests loss and the extent of inundation of wetlands in the plain and delta; and very fine scale data from the GeoEye-1 (0.5 m resolution), LiDAR and aerial photos was used to analyze the minute details of the damage and recovery process.

Results & Conclusions: The results show that plants along rocky coasts survived relatively intact, but coastal forests and other vegetation on sandy beaches and other low-lying coasts were severely damaged (Hirabuki et al. 2011). This earthquake and tsunami resulted in heavy ecological damage, caused by the enormous physical impact of the tsunami, as well as the physiological impact of inundation by seawater. The disaster, however, occurred in March, before plants in this region had entered the spring growth season, and as a result, the damage to vegetation varied widely between woody (evergreen or deciduous) and herbaceous plants. Continuous monitoring using field work and remote sensing is required to develop regional recovery strategies that provide for economic and social recovery and as well as restoration of plant communities, biodiversity and vital ecosystem services.

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GeoEye satellite imagery of the coast of Sendai Bay before the 2011 tsunami (4 April 2010) on the left and after the tsunami (24 March 2011) on the right. The near-infrared band applied to false color composite images with vegetated areas is shown in red. The strip of pine forest running parallel to the coast has almost completely disappeared. Dense pine forest along Teizan-bori Canal has been decimated by the tsunami, but some trees remain along the raised banks of the canal, as well as in narrow strips to the landward side. Source: © GeoEye & Japan Space Imaging Corporation.

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Regional variability in Salmon Gum (*Eucalyptus salmonophloia*) woodland communities in the Great Western Woodlands of south-western Australia

Judith M. Harvey

Department of Environment and Agriculture, Curtin University, GPO Box U1987, Bentley WA 6845, Perth, Australia

Correspondence: Judith Harvey, harveyjm@live.com.au

Background & Aim: Salmon Gum is an iconic Western Australian gum tree once widespread through the Wheatbelt and now is only common east of the clearing line in the area known as the Great Western Woodlands (GWW). Little is known about its structure and understorey composition there, how this is influenced by climatic and edaphic factors.

Materials & Methods: The GWW is a 15 million hectare area of largely intact vegetation 350–700 km east of Perth. Unusually woodlands dominate this area, which only receives between 300 mm and 200 mm of annual rainfall. One hundred 400 m^2 plots in patches of mature salmon gum woodland were surveyed in 2011 and 2012, stratified to capture the range of variability in climatic, geology/soils, tenure and land use in the GWW. Floristic composition and structure was surveyed, and soil chemical and physical characterised. Patterns in the floristic data were explored using clustering classification techniques chosen by OptimClass, and correspondence analysis (CA), principal component analysis (PCA) and non-metric multidimensional scaling ordinations. To interpret the influences of the environmental variables, unconstrained PCA and constrained canonical correspondence analysis were undertaken.

Main Results & Interpretations: Analysis revealed two main communities whose composition was influenced by climate and to a lesser extent soils. A community dominated by species from the *Scrophulariaceae* and *Fabaceae* families occurred on sandier soils in higher (mainly winter) rainfall area to the south-west of the study area. To the north east where the rainfall gets down to 200 mm (but occurs throughout the year) the community, dominated by *Chenopodiaceae* species occur on soils higher in clay. The more fire prone nature of the former community means that the long-term survival of old-growth woodlands requires protection from wildfires. Conversely, the chenopod dominated salmon gum community is less susceptible to fire and therefore needs a different set of fire management objectives. The impact of historical timber cutting and the low levels of grazing do not appear to have and influence on the floristic composition of the salmon gum communities and would require further study to confirm this.

Laco Mucina helping to survey Salmon Gum woodland north of Bullfinch, Western Australia. Photo: J. Harvey.

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Wetland vegetation formed in a town damaged by the 2011 Tohoku-Oki tsunami

Yoshinobu Hoshino (1), Junko Hoshino (2) & Atsuko Fukamachi (3)

1) Institute of Agriculture, Tokyo University of Agriculture and Technology, Fuchu, Tokyo 183-8509, Japan

2) Tokyo College of Environment, Sumida, Tokyo 130-0022, Japan

3) United Graduate School of Agricultural Science, Tokyo University of Agriculture and Technology, Fuchu, Tokyo 183-8509, Japan

Correspondence: Yoshinobu Hoshino, hoshino@cc.tuat.ac.jp

Background & Aim: On March 11, 2011, the Tohoku-Oki Earthquake occurred off the Pacific coast of northeastern Honshu, Japan. With a maximum run-up height of 40.4 m (The 2011 Tohoku Earthquake Tsunami Joint Survey Group 2011), the tsunami generated by the earthquake inflicted widespread damage to towns and cities along the east coast of Japan. The site of our study, Otsuchi Town in the Rikuchu coastal area, is a place where devastated houses and buildings were removed and is in the process of turning into a natural wetland. Water spring waters, previously used by domestic households for non-commercial purposes before the earthquake, now feed the wetland. Wetland restoration activities are set to begin now that the town has been relocated. However, since no information exists on the flora and vegetation that previously inhabited the area, a vegetation survey was conducted to fill in this knowledge gap in order to identify vegetation that can be used in planning of the vegetation restoration program in the affected area.

Materials & Methods: The study area is located on premises of the former Otsuchi Town (39.37° N, 141.89° E) in Iwate Prefecture, northern Japan. The tsunami that hit the town after the Tohoku-Oki earthquake was more than 17 m high and powerful enough to destroy buildings constructed of concrete. Extensive land subsidence occurred after the earthquake and the town has sunk approximately 0.5 m. Consequently, the area covered by water at high tide (0.7 m a.s.l.) has also increased. We collected 184 relevés from a variety of wetland vegetation in 2013; these data were then classified using phytosociological method. Sorting and tabular comparisons were performed to identify the plant communities that were present at the study site. Non-metric multidimensional scaling (NMDS) ordination using Bray-Curtis similarity index was employed to clarify the differences in environmental conditions among the plant communities.

Results & Discussion: The following 14 community types were identified in the study area:
Artemisia indica var. *maximowiczii-Setaria faberi* community (perennial herbland)
Beckmannio-Veronicetum undulatae (biennial herbland)
Chenopodium glaucum-Atriplex prostrata community (annual salt marsh)
Eleocharis kamtschatica community (perennial wetland)
Fimbristylis squarrosa-Cyperus difformis community (annual weedy)
Lespedeza bicolor-Aster microcephalus community (perennial herbland)
Panico-Polygonetum hydropiperis community (annual wetland)
Persicaria lapathifolia-Bidens frondosa community (annual wetland)
Phragmites australis community (reed)
Puccinellietum kurilensis (perennial salt marsh)
Salicetum subfragilis (wetland scrub)
Scirpo-Typhaetum orientalis (reed)
Sparganium erectum community (perennial wetland)
Typha latifolia community (reed)

The first NMDS axis revealed a dry-wet gradient spanning the recognised plant community; the plant communities were arranged along a salt marsh to fresh water wetlands along the second NMDS axis. The third axis indicated the depth of water as potentially important ecological differentiating factor. Our study suggests that the area is well suited for wetland restoration due to the variability of currently present plant communities and pools of species. In addition, these results provide useful information for the planned construction of a new park and can be used as a tool for identifying suitable habitats for target plant communities.

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Evaluating general allometric models in herbaceous angiosperms: interspecific and intraspecific data tell different stories

Yingxin Huang (1,2), Charles A. Price (2), Martin J. Lechowicz (3) & Daowei Zhou (1)

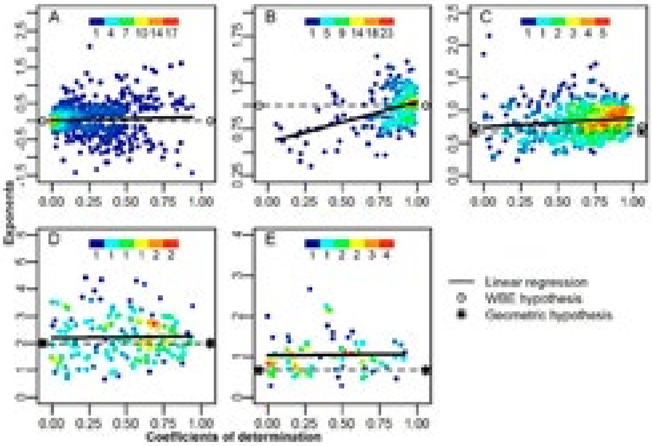
1) Northeast Institute of Geography and Agroecology, Chinese Academy of Sciences, Changchun 130012, China
2) School of Plant Biology, The University of Western Australia, 35 Stirling Hwy, Crawley WA 6009, Perth, Australia
3) Biology Department, McGill University, 1205 Docteur Penfield Avenue, Montreal, H3A 1B1, Canada

Correspondence: Yingxin Huang, huangyx@iga.ac.cn

Background & Aim: While support has been found within some growth forms and taxonomic groups of plants, the ability of scaling models to capture the central tendency or dispersion in biological data has been questioned. In fact, the appropriate domain of such models has never been clearly articulated and they have been supported and challenged using both interspecific and/or intraspecific data. Here we evaluate several simplifying assumptions and predictions of two prominent scaling models: West, Brown and Enquist's Fractal Model (WBE; West et al. 1997, 1999) and the Geometric Similarity Model (GEOM; Galilei 1638; Calder 1984).

Materials & Methods: We randomly sampled 11 individual plants with undamaged aboveground biomass from 53 non-graminoid, herbaceous angiosperm species (forbs) in 2010 and 2011 in the southern part of Songnen grassland region of China. We compared both the interspecific and intraspecific scaling relationships for plant geometry and biomass partitioning. Specifically, we considered biomass investment in shoots and leaves as well as related several traits not commonly collected in plant allometric analyses: shoot volume, leaf number, and mean leaf mass.

Main Results & Interpretations: Our results support the idea that the WBE model abstraction may be consistent with plant architecture at the species level, but that size dependent species differences in stem tissue density and leaf size, render interspecific comparisons less likely to conform to the models predictions. At the interspecific level, we find substantial variation in normalization constants, so the simplifying assumptions and predictions of the WBE model do not hold. In contrast, we find substantial support for the WBE model at the intraspecific level, and to a lesser extent for GEOM. These results highlight the domain within which simplifying model assumptions might be most appropriate, and indicate support for allometric models generally, and the WBE model in particular, as a potentially useful point of departure within some growth forms or taxonomic groups. Future studies linking measures of plant architecture to simultaneous measures of plant metabolism may ultimately help to resolve the drivers of intra and interspecific metabolic allometries.



Bivariate relationships between empirical scaling exponents and their corresponding coefficients of determination.

Acknowledgements: Y.H. is supported by the National Science Foundation of China (31000216) and the Knowledge Innovation Program of the Chinese Academy of Sciences (KZCX2-EW-QN315). C.A.P. is supported by an ARC Discovery Early Career Research Award.

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Forest fragmentation affects climate-driven migration of understorey herbs in Europe

Karl A. Hülber (1,2), Andreas Gattringer (1,2) & Stefan Dullinger (1,2)

1) Department of Botany and Biodiversity Research, University of Vienna, Rennweg 14, A-1030 Wien, Austria

2) Vienna Institute for Nature Conservation and Analyses, Giessergasse 6/7, A-1090 Wien, Austria

Correspondence: Karl Hülber, karl.huelber@univie.ac.at

Background & Aim: The warming climate forces species to shift their ranges. However, predicted velocity of climate change might exceed migration abilities of species, particularly in habitats that became highly fragmented due to anthropogenic activities. However, the reduction of migration rates of species due to land-use related habitat fragmentation has not yet been quantified at a continental scale.

Materials & Methods: We used the spatially and temporally explicit spread model CATS (Dullinger et al. 2012), which combines species distribution modeling with simulations of local demography (germination, growth, survival, reproduction) of age structured cohorts (seeds, juveniles, adults) and dispersal processes, to compute migration rates of virtual species representing European forest understorey plants at a spatial resolution of 250 m. Maximum migration rates under non-fragmented conditions were compared to those actually achievable under the current forest (Dendoncker et al. 2006) cover as well as under predicted scenarios for 2080 across Europe (Spangenberg 2007).

Main Results & Interpretations: Understorey plants will most likely not be able to keep pace with the moving template of suitable climate conditions, because even in non-fragmented forest landscapes endozoochorous, exozoochorous and wind dispersed species reach only about 200 m/y, 150 and 75 m/y, respectively. The current fragmentation of the forest cover further reduces migration rates to 120, 70 and 20 m/y on average. Only future scenarios under less sustainable storylines mitigate fragmentation effects leading to forest regrowth in parts of eastern and southern Europe due to agricultural abandonment. These results illustrate how the combined effect of habitat fragmentation and climate warming is a severe threat to a large number of species with a low migration ability.

Forest cover in 2080 based on the severe GRowth Applied Strategy (GRAS, A1FI) land use scenarios derived from the IPCC's 4th report's (Spangenberg 2007).

Acknowledgements: This work was supported by the EU 6th Framework Programme for Research, Technological Development and Demonstration (project ECOCHANGE, GOCE-CT-2007-036866)

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The role of ecological specialisation in divergence of closely related taxa within the complex of *Tephroseris longifolia* (*Asteraceae*)

Monika Janišová (1), Katarína Olšavská (1) & Tomáš Hlásny (2)

1) Institute of Botany, Slovak Academy of Sciences, Dúbravská cesta 9, SK-84523 Bratislava, Slovak Republic

2) National Forest Centre, Forest Research Institute, T.G. Masaryka 22, SK-96092 Zvolen, Slovak Republic

Correspondence: Monika Janišová, monika.janisova@gmail.com

Background & Aims: Natural selection caused by shifts in ecology or invasions of novel habitats are considered to play an important role in adaptive divergence and speciation. In this contribution we relate a large set of quantitative ecological data to morphological and genetic patterns in *Tephroseris longifolia* (*Asteraceae*). While *T. longifolia* subsp. *brachychaeta* and subsp. *moravica* are endemics with narrow distribution ranges, *T. longifolia* subsp. *gaudinii*, subsp. *pseudocrispa* and subsp. *longifolia* are more widely distributed. Along with the detailed characteristics of realized ecological niches of individual taxa, we addressed the following questions: i) Are narrow endemics more ecologically specialised than their widespread relatives? ii) Can quantification of niche differentiation aid explanation of the evolutionary relationships in the closely related taxa?

Materials & Methods: Ecological variables linked to climate, topography, soil and vegetation were gathered from 135 circular plots recorded at 35 population sites in Slovakia. They were either measured directly in the field, obtained from laboratory soil analyses, or were GIS-derived. Differences among the taxa for individual variables were tested by Kruskal-Wallis ANOVA and using multiple comparison tests. Related variables were grouped to express the partial ecological niches of the studied taxa: climatic, topographic, pedological, and coenotic (based either on vascular plants or on bryophytes) niches, respectively. Each partial ecological niche for a given taxon was characterized by its position (location of the centroid), width (volume of the convex polyhedron) and overlaps (with polyhedrons of the other taxa) in the 3-dimensional ordination space. Mantel test was used to relate the distance matrices representing the partial ecological niches. The partial ecological niches of the populations were also related to the morphometric (46 measured traits) and genetic data (genome size estimated by flow cytometry).

Main Results: The studied taxa of *Tephroseris longifolia* differed significantly in position (ecological optimum) and width (ecological amplitude) of their realized ecological niches. For most of the recorded environmental variables, the variance was lower for taxa with a narrow distribution than for the widely distributed taxa. The indicated ecological and coenotic patterns within the studied complex were consistent with patterns indicated by multivariate morphometrics and flow cytometry. Morphologically most similar taxa at the periphery of the Eastern Alps occupied ecologically the most similar habitats and had the closest coenotic relations. Our results demonstrate that quantification of ecological divergence is helpful in assessing the evolutionary history of closely related taxa.

Acknowledgements: Financial support was provided by the Scientific Grant Agency of the Slovak Republic (VEGA 2/0074/11) and the Millennium Seed Bank Project (Kew, UK).

Tephroseris longifolia subsp. *moravica* is an endemic of the Western Carpathians (Čavoj, Slovakia) occurring in semi-natural meadows (above) and in ecotones. Photo: M. Janišová.

Janišová, M., Olšavská, K. & Hlásny, T. 2014. The role of ecological specialisation in divergence of closely related taxa within the complex of *Tephroseris longifolia* (*Asteraceae*). In: Mucina, L., Price, J.N. & Kalwij, J.M. (eds.), *Biodiversity and vegetation: patterns, processes, conservation*, p. 239. Kwongan Foundation, Perth, AU.

Effect of a nitrogen-fixing tree on the abundance and feeding behavior of earthworms in the early stage of volcanic succession

Yuki Kadokura (1), Hiroshi Hashimoto (2), Nobuhiro Kaneko (3) & Takashi Kamijo (1)

1) Graduate School of Life and Environmental Science, University of Tsukuba, Tsukuba, Ibaraki, 305-8572, Japan

2) Faculty of Agriculture, Meijo University, Nagoya, Aichi, 468-8502, Japan

3) Soil Ecology Research Group, Graduate School of Information Science, Yokohama National University, Yokohama, Kanagawa, 240-8501, Japan

Correspondence: Yuki Kadokura, ykkdkr@gmail.com

Background & Aim: Earthworms contribute to vegetation development as they improve soil properties, and are also affected by vegetation through ingestion of plant litter. Miyake-jima, a volcanic island in Japan, erupted and released a large amount of volcanic ashes in 2000. 13 years after the eruption, two pioneer species, *Miscanthus condensatus*, a C4 grass species and *Alnus sieboldiana* (nitrogen-fixing shrub species) dominated the area with thick volcanic ash deposits. These species differ in litter quality, especially in nitrogen content. These differences can regulate the abundance of earthworms during succession. This study demonstrates differences in the abundance and feeding behavior of earthworms living in the volcanic deposits between *M. condensatus* and *A. sieboldiana* dominated patches.

Materials & Methods: We selected two sites – grassland dominated by *M. condensatus* (M site) and shrubland dominated by *A. sieboldiana* (A site). In both sites, earthworms were sampled under the canopies of *M. condensatus* and *A. sieboldiana*. To examine the effect of the sites (M site or A site) and the canopy plants (*M. condensatus* or *A. sieboldiana*) on earthworm abundance, we used generalized linear models (GLM) with negative binomial distribution. To estimate the diet of earthworms, we sampled plant litter as food resources of earthworms in both of the sites. We also measured carbon and nitrogen stable isotope of the litter and leaves of the two species, and that of earthworms. Since δ^{13}C values is higher in C4 plants (*M. condensatus*) than C3 plants (*A. sieboldiana*), δ^{13}C values can be used as the indicator to determine the earthworm diet.

Main Results & Interpretations: Earthworms density was highest under the canopy of *A.sieboldiana* in the A site. Results of GLM analysis showed that the A site and *A. sieboldiana* were positively selected by earthworms. Results of δ^{13}C values and amount of litter showed that earthworm ingested litter of *A. sieboldiana* preferentially. Thus, it is suggested that *A. sieboldiana*, a nitrogen-fixing shrub, effects abundance and feeding behavior of earthworms in the early stages of volcanic succession.

Seedling of *Alnus seiboldiana* with rhizobia. Photo: T. Kamijo.

Alnus seiboldiana (shrub) with understory grass *Miscanthus condensatus*. Photo: T. Kamijo.

Kadokura, Y., Hashimoto, H., Kaneko, N. & Kamijo, T. 2014. Effect of a nitrogen-fixing tree on the abundance and feeding behavior of earthworms in the early stage of volcanic succession. In: Mucina, L., Price, J.N. & Kalwij, J.M. (eds.), *Biodiversity and vegetation: patterns, processes, conservatio*n, p. 240. Kwongan Foundation, Perth, AU.

Species richness and composition of the soil seed bank in three mature forests dominated by *Fagaceae* in South Korea

Koo Bon-Youl, Kim Han-Gyeoul, Shin Jae-Kwon, Cho Yong-Chan & Oh Seung-Hwan

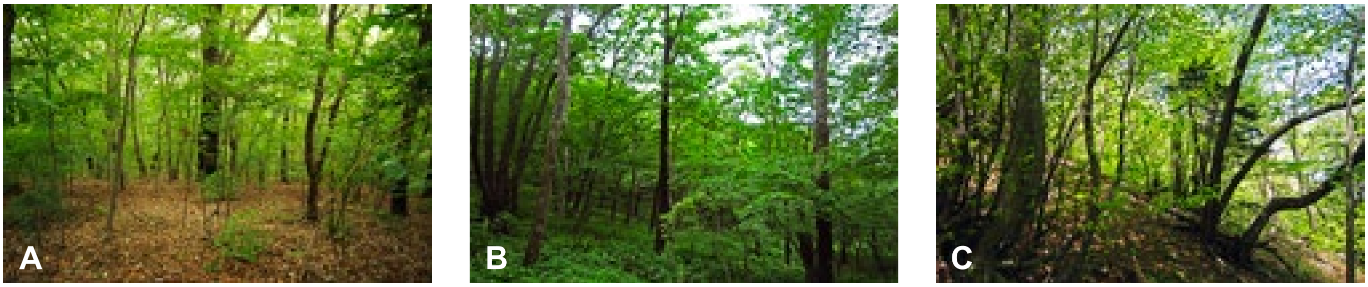
Plant Conservation Division, Korea
National Arboretum, Pocheon
487-821, South Korea

Correspondence: Oh Seung-Hwan,
oshwan@forest.go.kr

Background & Aim: Soil seed banks in mature forest fulfil important ecological roles in spontaneous re-vegetation processes after disturbance. Research and relevant data on the forest soil seed banks in Korea are rare, particularly in mature and old-growth forests. Two genera of *Quercus* and *Fagus* (both *Fagaceae*) very often dominate deciduous forests on the Korean Peninsula. The oak forests in Korea are dominated mainly by *Q. mongolica* at mid- to high altitudes, while *Q. serrata* are limited to low altitudes. Since much of lowland forests in Korea were transformed to plantations the *Q. serrata* forests are rarely encountered nowadays. *F. engleriana* (syn. *F. multinervis*) forest is endemic to the Ulleung-do Island in East Sea. In this study we compared species richness, composition and similarity between the belowground (seed bank) and aboveground (standing) vegetation in the Korean oak and beech forests.

Materials & Methods: We investigated old growth in Gwangneung Forest (9 plots; below 600 m of alt.) dominated by *Quercus serrata*, Mt Jumbong-san Forests (30 plots; above 800 m a.s.l.) dominated by *Q. monogolica* and *F. engleriana* forests of the Ulleungdo Island (8 plots; at alt. below 800 m). The soil samples were spread thinly on a mixture of vermiculate, peat moss, and pearlite in plastic trays. The trays were placed in a mesh-screened house of the Korea National Arboretum. Emerged seedlings were identified to species or genus level, and subsequently removed from the trays. We examined the floristic characteristics including habitat affinity and life form composition, changes in species composition by ordination analysis, and the abundance and richness of species. Further, we compared the similarity (using Sørensen's index) between the belowground and the aboveground vegetation.

Main Results & Interpretations: Some 27 species in *Q. serrata* forest, 46 species in *Q. monogolica* forest and 17 species in *F. engleriana* forest, respectively, were found germinated in the soil samples. The majority of germinated species were typical of the forest edge or early successional species such as *Lysimachia clethroides*, *Stephanandra incisa*, *Astilbe rubra*, and *Rubus takesimensis*. As for plant life forms, woody species attained 28% in *Q. serrata*, 26% in *Q. mongolica* and 41% in *F. engleriana* forests of all emerged species. The island species composition of the *Fagus engleriana* forest was clearly separated from that of the inland *Quercus* forests. Mean vegetation similarity between below and aboveground was the highest in the *Q. monogolica* forest (21%) and low in both *Q. serrata* (9%) and *F. engleriana* forests (3%). The seed banks of mature oak and beech forests in South Korea exhibited a high proportion of early-successional species. This finding points at a high re-vegetation potential of the studied forests if these are exposed to disturbance. The low similarity between the above- and belowground species composition suggests short-term persistence of the soil seed banks. The differences in seed bank composition between the sampling sites revealed geographical patterns.



The oak forests in Gwangneung **(A)** and Mt. Jumbong-san **(B)** and the beech forest of the Ulleung-do island **(C)** in South Korea.

Koo B.-Y., Kim H.-G., Shin J.-K., Cho Y.-C. & Oh S.-H. 2014. Species richness and composition of the soil seed bank in three mature forests dominated by *Fagaceae* in South Korea. In: Mucina, L., Price, J.N. & Kalwij, J.M. (eds.), *Biodiversity and vegetation: patterns, processes, conservation*, p. 241. Kwongan Foundation, Perth, AU.

Factors influencing plant species richness in sandy coasts: A case study in the Sanin Kaigan National Park, western Japan

Asumo Kuroda (1) & Yoshihiro Sawada (2)

1) Institute of Natural and Environmental Sciences, University of Hyogo, 6 Yayoigaoka, Sanda, Hyogo 669-1546, Japan

2) Graduate School of Landscape Design and Management, University of Hyogo, 954-2 Nojimatokiwa, Awaji, Hyogo 656-1726, Japan

Correspondence: Asumo Kuroda, kuroda@hitohaku.jp

Background & Aim: Sandy coastal vegetation has rapidly decreased and deteriorated due to various anthropogenic factors such as land reclamation and recreational activities. For planning effective conservation measures for coastal plants on a regional scale, knowledge on the major factors influencing species richness is essential. With this aim in mind we conducted this study in sandy coastal habitat in and around the Sanin Kaigan National Park.

Materials & Methods: The Sanin Kaigan National Park contains a number of sandy coastal habitats separated by long sea cliffs. We recorded all plant species established on each of the 46 sandy coastal sites (0.1–21.5 ha in size) during autumn of 2011 and summer of 2012. The recorded species were classified into three groups: native coastal plants, native inland plants, and exotic plants, according to the scheme presented by Sawada et al. (2007). Generalized linear model analysis was used to examine the effects of variables (the area, shoreline length, maximum width, and maximum height of the sandy coastal dunes or ridges, the extent of surrounding land reclamation, and the number of visitors during summer bathing season) on the species richness in the sandy coastal sites. The impact of these variables on the presence/absence of the native coastal plants was also assessed by logistic regression.

Main Results & Interpretations: We recorded a total of 229 species within the study area. Of these, 35 species belonged to the native coastal plant group. Generalized linear model analysis showed that the number of species was positively correlated with the area of the sandy sites for all three groups. For native coastal plants, the shoreline length and maximum height of the sandy coastal sites were selected as positive explanatory variables in the best-fitted model for the number of species. The number of visitors during summer bathing season was also selected as a negative explanatory variable, although its contribution was weak. Logistic regression analysis revealed that the occurrence of 13 species of native coastal plants showed no correlation with any of the variables. For example, *Calystegia soldanella* (*Convolvulaceae*) was detected in all sandy coastal sites. Meanwhile, the occurrence of 21 species of native coastal plants was positively correlated with the area, shoreline length, maximum width, and/or maximum height of the sandy coastal sites. The occurrence of several endangered species such as *Zoysia macrostachya* (*Poaceae*), *Scutellaria strigillosa* (*Lamiaceae*), and *Viola grayi* (*Violaceae*) was also negatively correlated with the extent of surrounding land reclamation. These results suggest that larger sandy coasts with more developed sand dunes have greater species richness of coastal plants, and that the preservation of such sandy coastal sites is primarily important for promoting the conservation of coastal plants on a regional scale. Thus, the reduction, fragmentation, and leveling-off of the sandy coasts significantly decreased the species richness of coastal plants.

Sand dune vegetation of the Kotohikihama coast, located near the Sanin Kaigan National Park, Japan. Dwarf shrub in the foreground is *Juniperus conferta*. Photo: A. Kuroda.

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The analysis of function and factors for the value assessment of ecosystem services in rice paddy wetlands

Lee Byung-Mo, Kong Min-Jae, Son Jin-Kwan & Kang Bang-Hun

National Academy of Agricultural Science, Rural Development Administration, Suwon, Gyeonggi-do, Republic of Korea

Correspondence: Kang Bang-Hun, ipmkbh@korea.kr

Background & Aims: The land area of South Korea is 99 720 km^2, of which the rice paddy wetlands cover 9 639 km^2 (9.6% of total area of the country). Paddy fields are artificial wetlands providing food, mainly rice, for humans. They play an important role in delivering various ecosystem services typically linked to the nature of wetlands in cultural landscapes. Paddy fields provide habitat for small animals and wintering habitats for seasonal birds. For this reason, all wetlands, including the paddy fields, are highlighted as habitats of international conservation and nature-management importance. Deeper insight into the nature of the ecosystem services rendered by the paddy fields is needed and this study is aimed at contributing to remedy this situation.

Materials & Methods: This study tried to evaluate the ecosystem services of paddy fields by applying Rapid Assessment Method (RAM; Tilton et al. 2001). RAM involves 52 items classified into 8 groups; 1) Floral Diversity and Wildlife Habitat, 2) Fishery and Reptile Habitat, 3) Flood/Storm Water Storage, 4) Runoff Attenuation, 5) Water Quality Protection, 6) Shoreline/Stream Bank Protection, 7) Aesthetics and Recreation, and 8) Groundwater Recharge. 16 study sites of paddy fields stratified by altitude and soil types as defined by the RDA (2014): Normal, Sandy, Immature, Ill-drained, Salty, Acid sulfate. Our observations were performed in the Normal, Sandy, Immature and Ill-drained types of the paddy fields.

Main Results: As the results of the assessment, the RAM average score are 110–118/156 and 2.17–2.50/3.00 in 16 research sites. It was similar to those of Lacustrine Wetlands, Palustrine Wetland and Riverine Wetland that served as survey sites in previous studies. The most significant factor affecting the RAM score (conservation value) was the area size of the paddy field. It found limitations in applying RAM to paddy wetlands. In order to assess more precisely the value of the paddy wetlands, factors such as rice-farming methods, topography, vegetation, and biodiversity should also be considered.

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A typical Korean rice paddy field.

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Compilation of the Red List of Plant Communities of Korea based on the Natural Environment Data of Korea

Lee Jung-Hyo (1), Cho Hyun-Je (2), Yun Chung-Weon (3) & Shin Hak-Sub (1)

1) Department of Climate & Ecology, National Institute of Ecology, 1210, Geumgang-ro, Maseo-myeon, Seocheon-gun, 325-813, Republic of Korea

2) Department of Medicinal Plant Resources, Andong National University, Andong 760-749, Republic of Korea

3) Department of Forest Resources, Kongju National University, Yesan 340-702, Republic of Korea

Correspondence: Lee Jung-Hyo, eco2014@nie.re.kr

Background & Aim: This study is to provide basic information on policy-making on the maintenance and protection of the diversity of plant communities in Korea.

Materials & Methods: We reviewed and analyzed all available vegetation databases of a nation-wide survey of natural environments (Ministry of Environment 1997–2012), natural heritage data (Cultural Heritage Administration 2013), related theses and dissertations, research reports, media reports, expert hearings and field observations. In total, nine selection criteria were applied (see below) of which the following were considered as key: 1) natural status, 2) rarity, and 3) value as a habitat for critically endangered species.

Main Results & Interpretation: We have identified 2 338 plant communities: 59% woody and 41% herbaceous plant communities of which 307 were recognized as red-listed. The red-listed plant communities, classified on physiognomic criteria included: 59.3 % tree-dominated, 23.5 % shrub-dominated, 16.0 % herbaceous, and 1.3 % vine-dominated. The Red List of the plant communities based on nine selection criteria types composed of 31.2 % scientific values, 28.7 % protective value, 15.2 % natural value, 14.7 % national endemic value, 4.6 % historical value, 2.6 % special value in habitat, 2.4 % representative value in a vegetation zone, and 0.7 % limited local distribution. The most vulnerable plant communities to climate change were those considered endemic and of limited distribution.

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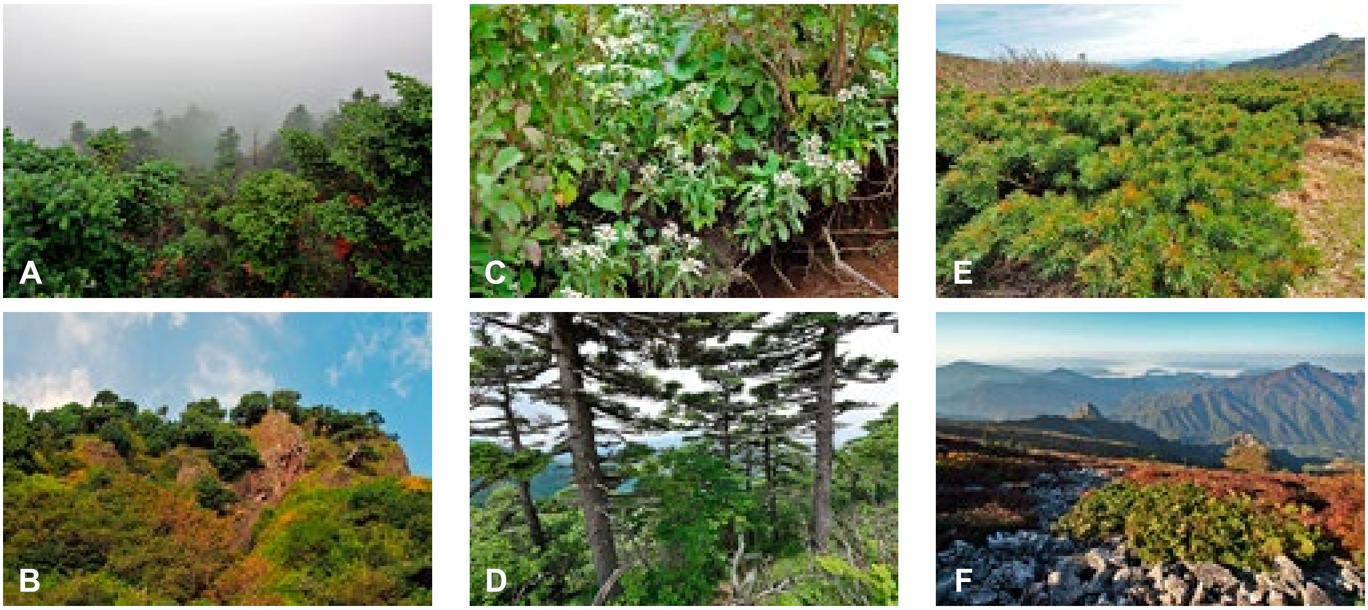


A. *Abies koreana* community (Mt Jirisan National Park); **B.** *Juniperus chinensis* community (Ulleungdo Island); **C.** *Leontopodium leiolepis* community (Mt Hyangnobong); **D.** *Picea jezoensis* community (Mt Jirisan National Park); **E.** *Pinus pumila* community (Mt Seoraksan National Park); **F.** *Thuja koraiensis* community (Mt Seoraksan National Park).

Lee J.-H., Cho H.-J., Yun C.-W. & Shin H.-S. 2014. Compilation of the Red List of Plant Communities of Korea based on the Natural Environment Data of Korea. In: Mucina, L., Price, J.N. & Kalwij, J.M. (eds.), *Biodiversity and vegetation: patterns, processes, conservation*, p. 244. Kwongan Foundation, Perth, AU.

The changing status of wetland vegetation following the creation of the Korea National Institute of Ecology

Lee Sung-Je (1), Kim Gyung-Soon (1), Cho Soo-Hyun (2) & Choi Bong-Su (3)

1) National Institute of Ecology, Geumgang-ro 1210 Seocheon Chung-Nam, Republic of Korea

2) National Institute of Biological Resources, Hwangyeong-ro 42 Seo-gu Incheon, Republic of Korea

3) Ministry of Environment, Doum6-ro, Sejong, Republic of Korea

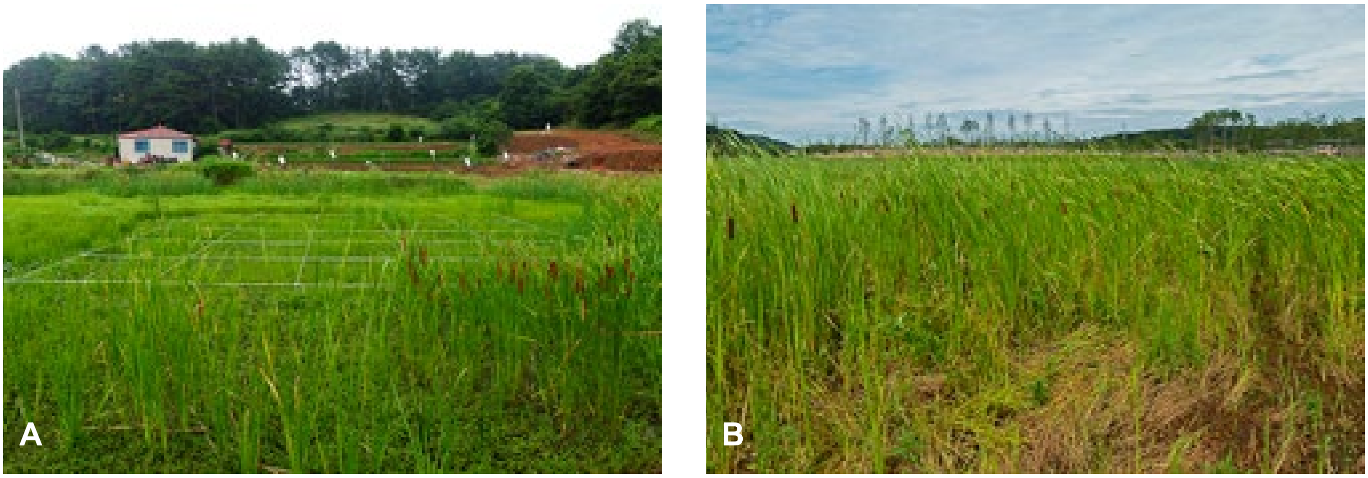
Correspondence: Lee Sung-Je, phytoeco@gmail.com

Background & Aims: The construction of the National Institute of Ecology in Korea took four years and was completed in December, 2012. The institute is supposed to focus on ecosystem research, predict changes in ecosystems, study ecological restoration, and to provide research on ecosystem services. Changes took place in wetland vegetation during the development of the Institute. In the past, the landscapes were dominated by both natural and man-made wetlands, such as rice paddies, marshes, and small streams. This study was carried out to identify the changing status of flora in the wetlands as response to land-use changes.

Materials & Methods: We monitored plant species in seven fixed quadrats (10 m X 10 m) throughout the spring, summer and autumn seasons. We selected the quadrats in the representative wetlands according to water level.

Main Results: In 2012, we identified 34 families, 93 genera, and 140 species. 20 species such as *Oenothera odorata* were present in all three seasons. There were 14 alien species, such as *Bidens frondosa* and little difference in the number of alien species between the quadrats and between seasons. The vegetation in 2012 consisted of a total of 63 communities, such as the *Alopecurus aequalis* community. The closer it came to autumn, the vegetation structure tended to become more complex, as exhibited by the numerical increase in the number of communities, but there was a tendency to have less species diversity because of the increased relative coverage by alien species. We concluded that the vegetation structure continued to be disturbed by the appearance of many alien, annual, and biennial species. The appearance ratio (percentage of alien species per total number of species) of alien species decreased by 2.5% from 12.5% in 2011, although 5 species such as *Melilotus alba* were more abundant. We concluded that the area is currently in a state of succession because the appearance of woody plants, the decrease in therophytes, and the increase of perennial hydrophytes.

Outlook: We plan conducting surveys of natural wetlands in the surrounding areas to identify the restoration period and the restoration process of this space by comparison therewith.



Paddy fields on the premises of the National Institute of Ecology supporting plant communities with **(A)**: An*elilema keisak*, *Najas graminea*, *Eleocharis kuroguwai*, *Miscanthus sacchariflorus* and **(B)**: *Typha orientalis*, *Scirpus triangulatus*, *Echinochloa crus-galli* and *Phragmites australis*.

Lee S.-J., Kim G.-S., Cho S.-H. & Choi B.-S. 2014. The changing status of wetland vegetation following the creation of the Korea National Institute of Ecology. In: Mucina, L., Price, J.N. & Kalwij, J.M. (eds.), *Biodiversity and vegetation: patterns, processes, conservation*, p. 245. Kwongan Foundation, Perth, AU.

Fruiting and pollination of black locust (*Robinia pseudoacacia*) by flower-visiting insects along the Tama River, Japan

Xirepujiang Maimaiti (1), Hoshino Yoshinobu (2) & Yoshikawa Masato (2)

1) United Graduate School of Agricultural Science, Tokyo University of Agriculture and Technology, Fuchu, Tokyo 183-8509, Japan

2) Institute of Agriculture, Tokyo University of Agriculture and Technology, Fuchu, Tokyo 183-8509, Japan

Correspondence: Xirepujiang Maimaiti, xirepjan17@yahoo.co.jp

Background & Aim: Black locust (*Robinia pseudoacacia* L., *Fabaceae*) is a deciduous broad-leaved leguminous tree of North American origin. It was introduced to Japan in 1873, and has been used as street tree, in afforestation of infertile land, and for honey production. However, black locust is now invading river flood-plains, creating many problems for the river management and the associated ecosystems. Although clonal growth of black locust by root suckers has been widely studied, few studies have examined sexual reproduction process from flowering to fruiting. Here, we aimed to bring insight into flower-visiting insect fauna and their visiting frequency, and to determine the effects of flower-visiting insects on the fruiting of the black locust.

Materials & Methods: Our study site was located at the higher floodplain of the Tama River, south of Tokyo, Japan, some 52 km upstream of an estuary. A beekeeper managed around twenty hives of western honeybee (*Apis mellifera* L.) near the study site. To examine the relationship between fruition rate of black locust and flower-visiting frequency of insects, 2-4 inflorescences of eight individual trees (a total of 22 inflorescences) were photographed by interval shooting using a digital camera. Photos were taken in 30-sec intervals from 10:00–16:00 for an 8-day period in mid-May at the peak of the flowering season. When inflorescences were not photographed, they were contained in mesh bags in order to prevent insect pollination. The number of matured pods per photographed inflorescence was counted in September fruiting rates were calculated. In order to estimate the duration of honeybee visits, three inflorescences per tree were selected (N = 69 flowers) and video-recorded for one hour from 10:30–11:30 over a 3-day period in mid-May. During the video-recording, the same inflorescences were photographed at 30-sec intervals to estimate the usefulness of interval shooting. In the pollination experiment, we applied four treatments, such as (i) self-pollination by using another inflorescence of the same tree, (ii) cross-pollination by using pollen from the nearest tree, (iii) exclude pollination by bagging inflorescences, and (iv) control. All artificially pollinated inflorescences were bagged after treatment.

Main Results & Interpretations: Some 44 713 photos were collected during the 8-day observation period, with 1 755 photos recording a visiting insect. The high correlation between the interval shooting method and the video-recording method ($r^2 = 0.94$, $P < 0.0001$) indicated that our method was accurate and precise. Most flower-visiting insects were the Western Honeybees (90.4% of all individuals). The dominance of the Western Honeybees suggests that the black locusts depended on the honeybees of the local beekeeper for their pollination. However, we found no significant correlation between visiting frequency of honeybees and fruition rate. The pollination experiment showed that self-pollination resulted in very low fruiting rates, indicating that black locust is largely self-incompatible. Cross-pollination resulted in higher fruiting rates but still significantly lower than control. These results indicate that the fruiting rate of black locust is not only be determined by the visiting frequency of honeybees, but also by other factors such as the presence of other black locust trees. Since black locust expands through root suckers, adjacent trees are likely to be of the same genet. Therefore, pollination between adjacent trees by honeybees it limited by self-pollination from nearby clones.

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Some like it cold: bryophyte responses to a warmer and wetter climate

Pascale Michel (1), Kristian Hassel (2), Heinjo J. During (3), Kari Klanderud (4) & Vigdis Vandvik (1)

1) Ecology & Environment Change Group, Department of Biology, University of Bergen, P.O. Box 7803, N-5020 Bergen, Norway

2) Department of Natural History, NTNU University Museum, Norwegian University of Science & Technology, N-7491 Trondheim, Norway

3) Ecology & Biodiversity, Institute of Environmental Biology, Utrecht University, P.O. Box 80.084, NL-3508 TB Utrecht, The Netherlands

4) Department of Ecology & Natural Resource Management, Norwegian University of Life Sciences, P.O. Box 5003, N-1432 Ås, Norway

Correspondence: Pascale Michel, pascale.michel@bio.uib.no

Background & Aim: Understanding the relative importance of biotic and abiotic factors on species assemblages in changing environments is critical to assess climate change effects on ecological processes and biodiversity (Lavergne et al. 2010). Bryophytes differ from flowering plants in their responses to climate and yet they remain largely overlooked in the climate-change focused research. In this study, we take a non-experimental approach to determine environmental factors structuring bryophyte communities along climatic gradients.

Materials & Methods: Twelve sites were selected along a climatic grid (four levels of annual precipitation 600 mm, 1200 mm, 2000 mm and 2700 mm – three levels of mean summer temperature: 7.5°, 9.5° C and 11.5° C) in subalpine and alpine grasslands of southwestern Norway. Bryophyte species frequency, richness, biomass, height and vascular plant cover were recorded within five 25 cm X 25 cm quadrats. We also measured abiotic (temperature, precipitation, solar radiation, soil moisture, aspect, pH) and biotic (vegetation height, biomass, cover of vascular plants and litter) factors. We extracted bryophyte traits (plant and spore size, life form, Ellenberg habitat indicators) from the BRYOATT database (Hill et al. 2007). We used DCA analyses to assess pattern in vegetation-environment relations and GLM to test bryophyte responses to environmental variables.

Main Results & Interpretations: In a set of 61 bryophyte species we found that high temperature and low solar radiation were positively correlated with dense and thick layers of bryophytes, covering more area yet harbouring a lower number of species (1–2 species). Bryophyte biomass, cover and richness were negatively correlated with vascular plant cover, suggesting competitive interactions. Precipitation and moisture influence bryophyte cover, height and composition at the warmest sites only. Bryophyte response to temperature and precipitation was strongly reflected in plant traits. Warmer and wetter environments favoured larger species that were light- and acidity-tolerant, and produced smaller spores. These results highlight the importance of multiple climatic drivers and biotic interactions in determining community composition and abundance. Future warmer climates in the region might lead to shifts in bryophyte assemblages and reduced species diversity directly via physiological limitations and indirectly via increased competition with the vascular flora. Because the growth of bryophytes is greatly variable in time and space, compositional predictions are difficult to formulate. Numerous studies have approached this issue through multifactorial experiments (Pedersen et al. 2001); multiple approaches (combined natural gradient and experimental studies) are needed to better understand these complex systems.

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Xerophytic vegetation of Arequipa, southern Peru

Daniel B. Montesinos Tubée (1), Karlè V. Sýkora (1), Víctor Quipuscoa S. (2) & Antoine M. Cleef (3)

1) Environmental Sciences, Nature Conservation and Plant Ecology Group, Wageningen University, Droevendaalsesteeg 3a, NL-6700 AA Wageningen, The Netherlands

2) Departamento Académico de Biología. Universidad Nacional de San Agustín, Arequipa, Perú

3) University of Amsterdam, Institute for Biodiversity and Ecosystem Dynamics (IBED), P.O. Box 94248, NL-1090 GE Amsterdam, The Netherlands

Correspondence: Daniel B. Montesinos Tubée, daniel.montesinos@wur.nl

Background & Aims: The vegetation of the Arequipa region (southern Peru) is still poorly known. In our paper we have studied phytosociology and ecology of the xerophytic vegetation of the region in order to provide baseline data for the establishment of nature reserves to protect this endemic-rich and diverse vegetation.

Materials & Methods: The study area (southern Arequipa Peru) has pluviseasonal bioclimate with scarce summer rainfall and the vegetation is typically montane arid and semi-arid. In 2012, a rainfall event that resulted in tripling the average mean annual precipitation in the region created extraordinary conditions, rarely seen flora displays and short-lived formation of annual vegetation occurring on the arid slopes. Here we made 219 phytosociological relevés at altitudes spanning 2020–3260 m. Besides the vegetation data, in each relevé data on environmental parameters were collected, including altitude, inclination, rock percentage, vegetation cover, and % bare soil. TWINSPAN (Hill 1979) was used for classification of the vegetation. PC-ORD (McCune & Mefford 1999) was used to construct a dendrogram based on the Bray–Curtis Distance Measure. Detrended correspondence analysis, principal components analysis and CANOCO 4.5 (ter Braak & Šmilauer 2002) were used to explore the relationship between the species composition and environmental variables.

Main Results & Interpretations: 192 vascular plant species were recorded in the studied plots. The most diverse families were *Asteraceae, Cactaceae, Fabaceae, Malvaceae,* and *Solanaceae,* followed by *Boraginaceae* and *Poaceae*. The xerophytic vegetation of Arequipa hosts some rare, endangered and/or in Peru protected plant species. Three main vegetation types were distinguished in the study area, such as (1) hyper-arid vegetation composed of the prostrate cactus *Haageocereus platinospinus* together with some columnar and prostrate cacti and annual herbs, (2) arid vegetation with a high frequency of columnar cactus *Weberbauerocereus weberbaueri* and a great variety of dwarf biennial shrubs and annual herbs, and (3) semi-arid vegetation in which columnar cactus *Corryocactus brevistylus* together with annual and perennial shrubs, grasses and herbs co-occur. Several new plant communities were described. The value of these vegetation types for the protection of endemic species was highlighted. Sahley (1996) and Aragón (1982), stated that *Weberbauerocereus weberbaueri* is the most abundant and representative columnar cactus in the vicinity of Arequipa City. *Corryocactus brevistylus,* however, is more common on clay soils and it is associated with scrubland vegetation (Galán de Mera et al. 2009) in semi-arid ecosystems on the slopes of the volcanoes in north and northwest of Arequipa city and in contact with the pre-puna and puna, with many species belonging to highland ecosystems.

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Effects of logging trees crashed by an avalanche on secondary succession on scoria in the sub-alpine region of Mt Fuji, Japan

Takashi Nakano & Taisuke Yasuda

Mount Fuji Research Institute,
Yamanashi Prefectural Government,
5597-1, Kami-Yoshida, Fuji-Yoshida,
Yamanashi, 403-0005, Japan

Correspondence: Takashi Nakano,
nakano@mfri.pref.yamanashi.jp

Background & Aim: Stressful environments such as deserts or alpine regions are famous for facilitation effects when plants help the growth and survival of other species. In an alpine belt of Mt. Fuji, *Salix reinii* (*Salicaceae*) helps establishment of seedlings of *Larix kaempferi* (*Pinaceae*) – a primary successional tall tree species (Endo et al. 2008). In the subalpine belt of Mt Fuji, avalanches destroy the subalpine forests exposing bare-ground covered with volcanic scoria, leaving logging (fallen) trees behind that might play a role in seedling establishment of late-successional species of evergreen coniferous forest. In this study, we evaluate the effects of the logging trees on establishment and growth of seedlings of primary successional species in a subalpine belt of Mt. Fuji.

Materials & Methods: The study was carried out in the subalpine belt on the northern face of Mt. Fuji (alt.: 2250 m). In the study site, about 30 years ago, all standing trees were crashed by an avalanche, and secondly succession started by establishments of two major pioneer species – *Larix kaempferi* and *Betula ermanii* (*Betulaceae*) on the scoria debris. In a 10 m X 10 m quadrat we recorded all tree saplings and recorded their taxonomic identity, position, diameters at breast high (DBH), height, and distance from the nearest logging tree. Within the quadrat, we have studied two sites: one near logging trees (less than 25 cm from logging trees) and the other without logging trees.

Main Results & Interpretation: One hundred and forty three saplings of *L. kaempferi* and 122 saplings of *B. ermanii* were recorded in the quadrat. 75% of saplings of *L. kaempferi* and 60% of saplings of *B. ermanii* were recorded in the site near logging trees. This results show that the logging trees crashed by an avalanche play an important role as contributing safe sites to the seedling establishments of *L. kaempferi* and *B. ermanii* in the course of secondly succession on scoria debris in the subalpine belt of Mt. Fuji. There were no differences in DBH and tree height of saplings between the saplings established in the sites near logging trees and those without logging trees for both species. This shows that nursing effects of the logging trees were limited only at the period of the establishment of seedlings. These results show that the logging trees crashed by avalanches play an important role in secondary succession in the scoria debris by contributing safe sites for seedling establishment. We have no insight at present which environmental factors were important for the establishment of seedlings. However, soil movements easily occur on scoria slope of the mountain, and this may hinder seedling establishment (Endo et al. 2008). Logging trees might arrest the soil movement and hence form microsites for successful seedling establishment. This slowing down (or arresting) of the soil movement by logging trees may be seen as important factor in progressive secondary succession on scoria bare field created by avalanches.

Logging trees crashed by a slush avalanche in the subalpine belt of Mt. Fuji, Japan. Photo: T. Nakano.

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More than vegetation maps: the contribution of vegetation survey and mapping to herbarium collections and botanical knowledge in Queensland

Victor John Neldner

Queensland Herbarium, Department of Science, Information Technology, Innovation and the Arts, Brisbane Botanic Gardens, Mt Coot-tha Road, Toowong 4066 QLD, Brisbane, Australia

Correspondence: John Neldner, john.neldner@science.dsitia.qld.gov.au

Background & Aim: The benefits of vegetation surveying and mapping projects are not easily assessed, particularly as they may be used over protracted periods by numerous individuals or agencies for various purposes. Information within a single survey area may be used for different purposes in different localities over many years. By providing inventories of natural resources, land surveys allow management options to be examined at regional and district level and informed decisions to be made. Many of these benefits, (e.g., preservation of endangered species or communities, discovery of new species, collection of plant specimens, or prevention of degradation), are not easily equated into economic terms, and are most likely to become more evident in the long term. However, Dent and Young (1981) reported that both in the USA and Australia, benefit-cost ratios are in the order of 40:1 or 50:1.

This study investigates the contribution of the Queensland Herbarium Regional Ecosystem Survey and Mapping (QHRESM) program to the knowledge of the Queensland flora through the provision of botanical specimens. The QHRESM program includes all projects since 1970 that result in the production of a vegetation or regional ecosystem paper map or digital map coverage at a variety of scales.

Materials & Methods: The study area was the state of Queensland which covers 1 730 600 km^2. Queensland has a diverse range of landscapes, vegetation and ecosystems. The vegetation ranges structurally from rainforests in the Wet Tropics bioregion to sparse-forblands and open-hummock grasslands in the Channel Country bioregion (Sattler & Williams 1999).

Main Results & Interpretations: The QHRESM program has contributed almost 90000 (89389) specimens to the Queensland Herbarium in Brisbane accounting for 28% of the specimens added to the Herbarium between 1970 and 2011. These specimens have been collected across all bioregions and vegetation communities in Queensland in a systematic sampling program driven by the requirement to comprehensively sample all vegetation communities. The QHRESM's Queensland Herbarium (BRI) specimens represent more than 79% of the native, and 73% of the naturalised, vascular flora of Queensland, and also make valuable contributions to the collections of bryophytes, lichens and liverworts. As well as adding to the number of specimens in BRI Herbarium, the QHRESM program has greatly improved the distribution of specimens because the ecological sampling for mapping is stratified to cover all of the different vegetation types present and also to sample across the whole map area. This helps to overcome some of the problems associated with herbarium specimens worldwide that have been found to be generally clumped around specific areas (Feeley & Silman 2011) and biased towards species that are demographically rare in the field. The data and specimens collected by the QHRESM program enhance the ability to assess local, state and continental scale plant diversity values, and will undoubtedly be used by botanists, ecologists, governments, business and the public for long into the future.

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The role of co-evolution between competitors on community structuring in calcareous grasslands

Siim Nettan, Anette Sepp, Maria Abakumova, Rein Kalamees, Anu Lepik, Kersti Püssa, Sirgi Saar, Merilin Saarma, Marge Thetloff, Qiaoying Zhang, Kristjan Zobel & Marina Semchenko

Institute of Ecology and Earth Sciences, University of Tartu,
EE-51005 Tartu, Estonia

Correspondence: Siim Nettan,
siimnettan@gmail.com

Background & Aim: Research on invasive plant species has shown that the success of invasive species often stems from the lack of co-evolution between the invader and biotic components of the community that is invaded (Thorpe et al. 2009). It is also known that common evolutionary history can affect interacting plants through root exudates and microbial communities (Chanway et al. 1989). The aim of this study was to examine the function of root exudates (experimentally treated with activated carbon) and microbes (treated with soil sterilization) as mediators of interactions between plants with different geographical location (originating either from the same community – 'natural' or from two different communities – 'novel'). By using artificial communities, we wanted to learn more about the role of plant-plant co-evolution in community functioning.

Materials & Methods: Seeds of eight common plant species were collected from three species-rich Estonian calcareous grasslands located at least 40–150 km apart. Collected seeds were germinated separately. Seedlings were planted in pots either together with seedlings originating from a single grassland site ('natural community') or together with seedlings from another grassland site ('novel community'), resulting in 16 seedlings per pot. To assess the potential effect of root exudates and soil microbes on plant species' coevolution, we treated the pots with activated carbon, sterilization, or left untreated in a full-factorial design. All pairwise combinations of the three study communities and treatments resulted in eight experimental combinations in 30 replicates. At the end of the growing season, the aboveground biomass of each individual was harvested separately. Species richness, community evenness (modified Hill's ratio; Alatalo 1981) and productivity were calculated. In addition, belowground biomass and various root traits were calculated (specific root length and root volume).

Main Results & Interpretations: In the 'natural community', the addition of activated carbon significantly reduced (19%) community productivity in the soil inoculated with microbiota but had no effect in sterilized soil (p=0.001). If the effect of activated carbon was due to neutralization of organic root exudates, this result suggests that root exudates promote productivity in co-evolved plant communities, and that this effect is mediated by soil microbes. In the 'novel community', no significant effect of activated carbon on productivity was observed, suggesting that root exudates were not an important factor in determining productivity in such assemblages. Although 'natural community' resulted in average one plant species less, the evenness index was about 5% higher than in 'novel communities' (p=0.001). Further, within 'natural community' treatment, addition of activated carbon reduced species richness by 0.5 species and root volume by 20%, but had no effect in pots without activated carbon and in 'novel community' treatment. Specific root length increased significantly in 'natural community' compared with 'novel community' treatment (p=0.034). Higher root proliferation might indicate that belowground competition is more important in co-evolved stable plant communities than in novel communities.

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Patterns and causes of tree regeneration in the high-altitude subtropical *Quercus* forests in Mexico

Miguel Olvera-Vargaş, Blanca Lorena Figueroa-Rangel & Ramón Cuevas Guzmán

Centro Universitario de la Costa
Sur, Departamento de Ecología
y Recursos Naturales-IMECBIO,
Universidad de Guadalajara,
Independencia Nacional # 151,
Autlán de Navarro, Jalisco CP 48900,
México

Correspondence:
Miguel Olvera-Vargaş,
molvera@cucsur.udg.mx

Background & Aims: Tree regeneration is a multiphase process involving several sequential life-history stages from seed germination to an established reproductive stage (seedlings, saplings, adult) connected by transitional processes (i.e. dispersal, emergence, survival) (Gómez-Aparicio 2008) thereby, influencing the spatio-temporal structure of species composition, coexistence and species diversity. In particular, tree regeneration is consistently determined by habitat filtering, which has been referred as the non-random germination, establishment and survival of individuals with respect to variation in habitat characteristics (Baldeck et al. 2013). The filtering effect may act upon individuals either independently of the species they belong to, or differentially across species. In this study, we investigated patterns and causes of tree regeneration in high altitude sub-tropical *Quercus*-dominated forests by: *i*) determining whether regeneration community show non-random spatial patterns of floristic composition; *ii*) identifying which environmental variables explain the observed patterns of floristic composition; *iii*) examining if similarity in floristic composition is related to similarity in environmental variables. We hypothesized that spatial patterns of floristic composition of regeneration communities show non-random distribution due to spatially structured environmental filters.

Materials & Methods: Our database was derived from an 86 circular permanent plots (500 m^2 each) network established at random in *Quercus*-dominated forests; the plots were distributed across 10 km and over an altitudinal range from 2000 to 2450 m a.s.l., We used data on woody tree species considering adult trees, saplings and seedlings. Our analyses involved unconstrained ordination analyses (non-metric multidimensional scaling) to characterize the spatial patterns of floristic composition; constrained ordination analyses (canonical correspondence analysis) to assess the contribution of environmental variables (litter, clay, silt, aspect, canopy height, canopy openness, crown length, magnesium, organic matter content, slope and grazing) in explaining patterns of floristic composition and, the simple and partial Mantel test to correlate the floristic composition similarity to environmental similarity.

Main Results: Our results postulate that regeneration communities display non-random spatial patterns of floristic composition related to environmental filters such as canopy-related variables, litter, grazing and aspect. Floristic compositional similarity is not dependent on geographical distance or on differences in the environment; consequently a number of plots were similar in floristic composition, but have no environmental similarity.

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How do vegetation, soil, and biomass chemical properties change after 10 years in a cut and an unmanaged mountain hay meadow?

Lenka Pavlů (1), Vilém Pavlů (1,2), Jan Gaisler (2) & Michal Hejcman (1)

1) Department of Ecology, Faculty of Environmental Sciences, Czech University of Life Sciences, Kamýcká 1176, CZ-165 21 Praha 6 – Suchdol, Czech Republic

2) Department of Plant Ecology and Weed Science, Grassland Research Station Liberec, Crop Research Institute, Rolnická 6, CZ-460 11 Liberec, Czech Republic

Correspondence: Lenka Pavlů, lpavlu@vurv.cz

Background & Aim: The mountain hay meadows of the *Polygono-Trisetion* are threatened due to inappropriate management. As a consequence, large areas of these meadows became degraded. Given the actual low demand for forage from mountain hay meadows and the high cost of management, it is essential to determine how long these grasslands can be left unmanaged without losing their species richness. Therefore, the aim of this experiment was to analyse the effects of long-term annual cutting with herbage removal in comparison with the effects of no management on vegetation, soil and herbage chemical properties and their relationship.

Materials & Methods: The annual cutting and unmanaged treatments were undertaken from 1999 to 2009 in the Jizerské hory Mts, Czech Republic. The cover (%) of all vascular plant species was recorded in five permanent paired plots (5 m X 5 m) annually over the course of the whole experiment; soil and herbage were annually sampled here for nutrient concentration from 2003 to 2009.

Main Results & Interpretation: The total number of plant species was significantly higher in the cut treatment after the first four years of the study. However, the number of species with cover ≥1% was the same in both treatments throughout the experiment. Only rare species were affected by the treatment. The main effect of the management treatments on plant species composition was the change in cover of some of the dominant species. The cover of *Festuca rubra*, *Agrostis capillaris*, *Anthoxanthum odoratum*, *Briza media* and *Trifolium repens* significantly increased by the cutting treatment, while the cover of *Cirsium heterophyllum*, *Geranium sylvaticum*, *Hypericum maculatum*,*Trisetum flavescens* and *Luzula luzuloides* was significantly higher on the unmanaged treatment compared with the cutting treatment. Yet, these changes in abundance of the dominant species had only a small effect on species richness and the plant community. Potassium was the only nutrient for which the soil concentration significantly decreased under the cutting treatment. Concentrations of P and K in the herbage were significantly lower in the cutting than in the unmanaged treatment, but concentrations of N were lower only in some years. Concentrations of Ca and Mg were not affected by the different treatments. A positive relationship between the nutrient concentration in the soil and the herbage was recorded only for K. Ten years of contrasting management resulted in changes in abundance of some of the dominant species but these changes had no effect on the *Polygono-Trisetion* grasslands. With the exception of K, this period was too short to affect nutrient concentrations in the soil; however, it was long enough to decrease concentration of P and K in the herbage. Small changes in soil and herbage nutrient concentrations show that direct effect of the management regime on plants is probably bigger than nutrient depletion in soil.

The main practical message of the study is that some types of mountain grasslands can be left unmanaged for several years without substantial changes in plant species composition. However, although these changes are small they are still in progress so a cutting management combined with several years of no management may be a suitable strategy to maintain appropriate rate between the dominant species.

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Evolutionary history of the flora from Western Mediterranean continental islands: phylogeography of the palaeoendemic species *Arenaria balearica* (*Caryophyllaceae*)

Julio Peñas (1), Javier Bobo-Pinilla (2), Sara Barrios (2), Jaume Seguí (2), Giuseppe Fenu (3), Gianluigi Bacchetta (3) & M. Montserrat Martínez-Ortega (2)

1) Plant Conservation Unit, Department of Botany, University of Granada, E-18071 Granada, Spain
2) Department of Botany, University of Salamanca, E-37007 Salamanca, Spain
3) Centro Conservazione Biodiversità (CCB), Dipartimento di Scienze della Vita e dell'Ambiente, Università degli Studi di Cagliari, I-09123 Cagliari, Italy

Correspondence: jgiles@ugr.es

Background & Aim: Within the Mediterranean global biodiversity hotspot, the Tyrrhenian Islands support a high percentage of endemic taxa (c. 10–20%; Cañadas et al. 2014). Some endemic plant species shared among Corsica, Sardinia, and the Balearic Islands have been designated 'Hercynian endemics' (Mansion et al. 2008), and have been frequently considered palaeoendemics. Although it has been traditionally accepted that *Arenaria balearica* L. (*Caryophyllaceae*) could be a Tertiary relict plant species, this has never been tested by phylogeographic data. Our aim is investigate the palaeohistorical reasons underlying the highly disjunct distribution of the species in the Western Mediterranean region.

Materials & Methods: We have analysed AFLP data and cpDNA sequences from a total of 231 plants from 29 populations sampled along the entire distribution range of the species in Majorca, Corsica, Sardinia, and Tuscan Archipelago. We obtained some populations genetic traits (i.e., genetic structure and diversity) and a halotype network using the statistical parsimony algorithm was constructed. Thus, we examined the comparative historical effects of the main biogeographical events.

Main Results & Interpretations: The AFLP data analyses indicate very low geographic structure and population differentiation. The star-like topology of the parsimony network based on cpDNA data suggests that all haplotypes were derived probably in situ from a single ancient ancestor. The data compiled for *A. balearica* seem to support the conventional view that the species has a relict character, as it probably had an Early Oligocene origin from an ancestor distributed along the ancient Hercynian massif. The present-day distribution of this palaeoendemic species is consistent with the fragmentation of the anciet Hercynian massif in the Tyrrhenian area. The plant's genetic structure and diversity patterns, and with life-history traits support further post-Oligocene – either Miocene or Plio-Pleistocene – inter-island contacts in *A. balearica*, but seem to have been restricted to populations from Corsica and Sardinia. The overall low levels of genetic diversity and cpDNA variation found seem to be in correspondence with the morphological constancy of the species among populations distributed in different continental fragments in locally long-term stable habitats. Although the Mediterranean region displays a long history of geological and climatic changes, the local availability of ecologically stable habitats (e.g. rocky habitats) may have favoured the survival and long-term preservation of ancestral molecular lineages and the long persistence of populations in different territories along the Mediterranean region.

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Do N_2-fixing plants show higher root phosphatase activity on P-poor soils?

Guochen K. Png (1), Etienne Laliberté (1), Patrick E. Hayes (1), Benjamin L. Turner (1,2) & Hans Lambers (1)

(1) School of Plant Biology, The University of Western Australia, 35 Stirling Hwy, Crawley WA 6009, Perth, Australia

(2) Smithsonian Tropical Research Institute, Apartado 0843-03092, Balboa, Ancon, Republic of Panama

Correspondence:
Guochen Kenny Png,
kenny.png@research.uwa.edu.au

Background & Aim: Symbiotic dinitrogen (N_2) fixation in N_2-fixing plants enhances plant performance on N-poor soils, but may not be favoured on phosphorus-poor soils, due to its high phosphorus (P) costs. Yet surprisingly, N_2-fixing species are abundant in ecosystems with N-rich soils such as lowland tropical rainforests, where P is likely to limit plant growth (Vitousek & Sanford 1986). A prominent hypothesis seeking to explain this paradox is that N_2-fixing plants have a greater ability to acquire organic P than non-N_2-fixing plants through higher extracellular root phosphatase activity, due to their N-rich lifestyle that may favour greater investment of N in phosphatase enzyme production (Houlton et al. 2008). However, evidence to support this hypothesis remains limited and this study aims to establish if N_2-fixing plants produce higher root phosphatase activity than co-occurring non-N_2-fixing species along a natural soil age gradient.

Materials & Methods: The study sites are located along a soil age gradient in Jurien Bay, Western Australia, 225 km north of Perth, which shows a ~40-fold decline in total soil P from the youngest to the oldest soils – leading to some of the most P-impoverished soils found in any terrestrial ecosystem. We collected fresh roots of 18 species of N_2-fixing (including legumes and non-legume *Allocasuarina* spp.) and non-N_2-fixing species from three sites along the soil age gradient, which are of contrasting stages of ecosystem development. We measured extracellular root phosphomonoesterase (PME) activity of the N_2-fixing and non-N_2-fixing species using *para*-nitrophenyl phosphate (*p*NPP) substrate (Turner et al. 2001). A series of mixed-effects models were used to compare PME activity between N_2-fixing and co-occurring non-N_2-fixing species of each site.

Main Results & Interpretations: In support of the hypothesis by Houlton et al. (2008), we found that N_2-fixing legumes produced higher PME activity than co-occurring non-legumes on all sites, and that the difference in PME activity between legumes and non-legumes increased with declining soil P. However, PME activities of N_2-fixing *Allocasuarina* spp. (which form associations with *Frankia*) were consistently low across all soils, which does not support the hypothesis. We conclude that the high root phosphatase activity of legumes on P-poor soils is likely a phylogenetically conserved trait that is not necessarily linked to their N_2-fixing ability.

Kwongan in bloom on a Bassendean dune, Lesueur National Park, Western Australia. Photo: K. Png.

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Growth changes in a Neotropical gallery forest in the Brazilian savanna

Iris Roitman & John D. Hay

Universidade de Brasília, Ecology Department, Biology Institute, Universidade de Brasília, 70919-900, Brasilia, Brazil

Correspondence: Iris Roitman, irisroitman@ig.com.br

Background & Aim: Describing and understanding growth patterns in tropical forests is crucial to recognize their function either as carbon sinks or sources. Tropical forests behave differently worldwide because of regional and historical differences (Phillips et al. 2004; Feeley et al. 2007). We describe the growth rate (basal area increase rate) patterns in a seasonal tropical gallery forest in the Brazilian savannah, in six successive periods, spanning a 24-year period (1985–2009).

Materials & Methods: The study was done in the Gama gallery forest (64 ha), located in the East-Central region of Brazil, near the city of Brasília (approx. at 16º S, 48º W), at an altitude of about 1100 m a.s.l. The climate is Aw (Köppen's classification) with marked rainy summer and dry winter seasons. Mean annual rainfall between 1985 and 2009 was 1403 mm, and mean annual temperature of 22.2º C. Measurements were made in 151 permanent plots (10 m X 20 m), in 10 transects perpendicular to a watercourse, sampling a total area of 3.02 ha. The transects were 100 m apart and data were collected in 1985, 1988, 1991, 1994, 1999, 2004 and 2009. All stems > 10 cm diameter at breast height (dbh) in each plot were mapped, marked with permanent tags, and measured. We tested statistical significance of the changes using Wilcoxon signed-rank test ($p<0.05$).

Main Results & Interpretation: Basal area increase rate alternated in pulses (increases and reductions), and slowly decreased during the study period. This resulted in a significant reduction ($p<0.05$) in growth rate between the first and last time intervals: from 2.5 % per yr (1985–1988) to 1.55 % per yr (2004–2009). Even though growth rate decreased, the period was too short to cause significant impact over forest basal area, which decreased by 6.52% between 1985 and 2009 (not significant, $p>0.05$): from 30.39 m^2ha^{-1} to 28.60 m^2ha^{-1} in 2009. Decreases in growth may be associated with observed increases in temperature and low rainfall during the study period. The alternating pattern in growth rates shows a fast response of the forest to environmental changes.

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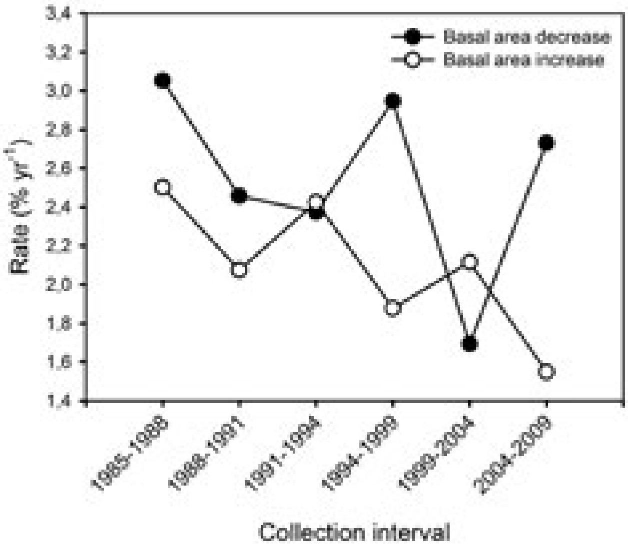

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Land developments affect the distribution patterns of alien plants in Fuchu, Tokyo

Moe Sakio & Yoshinobu Hoshino

Department of Agriculture, Tokyo University of Agriculture and Technology, Tokyo, Japan

Correspondence: Moe Sakio, moe.at-will@hotmail.co.jp

Background & Aim: The purpose of this study is to identify the effects of urbanisation on the distribution of alien plants, as urbanisation may lead to a reduction in native species diversity and replacement by alien species (McKinney 2006; Grimm et al. 2008). This study was set up to identify 1) changes by comparing recent data with a historical data set, 2) the land features where the proportion of alien plants is high, and 3) the patterns of distribution of invasive alien species.

Materials & Methods: All the plant species found in each of the governmental districts in Fuchu were recorded twice a year (spring and autumn) between 2004 and 2013. Alien species were classified into three categories: 1) only recorded in the past data (Lost); 2) recorded in the both data sets (Common), and 3) only recorded in the new data (New). Relationships between the proportion of alien species and the degree of land development were tested using population density, green coverage ratio, city area ratio, number of vegetation types, and road and building area ratio. The effects of environmental factors were tested on the total number of species, alien species, new alien species, common alien species and also the proportions of those to the total species number. The ratio of the new alien species to the common alien species was also used. These data were analysed using Spearman's rank correlation and Generalized Linear Mixed Model (GLMM). The study separated the city into two regions, such as lowland and tableland that were used to test for differences in the environmental factors, and the number of species and proportion of alien species.

Main Results & Conclusions: In total, 1170 plant species were recorded of which 408 were alien species. Over the studied period, 226 species have disappeared and 504 species were introduced. The proportion of alien species has increased from 20% to 35%. The average proportion of alien species in districts was about 38%. It has a positive correlation with population, population density, road and building area ratio and city area ratio, and a negative correlation with the green coverage ratio and number of vegetation types. Among these environmental factors, green area coverage ratio and road and building area ratio were the best estimate factors (GLMM). The proportion of alien plants differs between the lowland and the tableland regions (35.1% and 38.8%, respectively, with an average difference of (t (131) = 4.68, $p < 0.05$). Population density, road and building area ratio and city area ratio were significantly higher in the tableland, whereas the number of vegetation type was greater in the lowland. The size of district and green coverage ratios did not differ between the two landscape regions. We conclude that the proportion of alien plants has increased as the city development progressed; these species are more frequent in highly urbanised areas.

Acknowledgement: The vegetation survey was supported by Tokyo University of Agriculture and Technology and Fuchu plants group.

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Habitat and ecology of *Lysimachia leucantha*: why has it become a very rare wetland plant in Japan?

Michiko Shimoda, Ukyo Serizawa, Mizuki Maezawa, Mai Nagata & Makoto Kasuya

Faculty of Social Environment, Tokoha University, 325 Obuch, Fuji 417-0801, Japan

Correspondence: Michiko Shimoda, michiko_shimoda@nifty.com

Background & Aim: *Lysimachia leucantha* (*Primulaceae*) is a perennial wetland plant distributed in the southern half of Japan and the Korean Peninsula. This endemic species is very rare and endangered in both these countries. Still, information on its habitat and ecology is very limited. To identify the appropriate management to conserve *L. leucantha* and its habitat, we studied its growth and vegetation on Ukishima (floating-island) Wetland in central Japan.

Materials & Methods: Ukishima is a wetland of about 15 km x 2 km in size and situated near Suruga Bay, Shizuoka Prefecture. Development of rice paddies began in the 17th century. Flood prevention and drainage works were constructed during the second half of the 19th and the first half of the 20th century. During the 1960s, most of the wetland was converted to rice fields for mechanical farming. Even now Ukishima is still changing because of residential, commercial and industrial development. Our study site is Ukishimagahara Nature Park (4.2 ha) managed by Fuji City. The park has the only habitat of *L. leucantha* open to the public in Japan. Wetland vegetation is partly cut and removed in winter for management and conservation. We surveyed the distribution and seasonal growth changes of *L. leucantha*, and conducted a vegetation survey of its communities in 2013 and 2014.

Main Results & Interpretations: Distribution of *L. leucantha* was restricted to the areas where vegetation was cut and removed in southern and eastern parts of the park. We confirmed that *L. leucantha* lived over winter with rosettes and photosynthesized on the areas receiving full sunlight. It developed aerial stems in April, flowering from the end of April to May, and bearing ripened fruits in June. Its above-ground part withered in July. Its tallest plant height was, 50–70 cm, in May. It grew with diverse wetland species, and *Phragmites australis* (*Poaceae*), *Carex thunbergii*, *C. dispalata* and *C. vesicaria* (*Cyperaceae*) dominated the vegetation. Young shoots of *P. australis* did not shade *L. leucantha* during its flower season. By the end of the growing season of *L. leucantha* in June, *P. australis* grew taller than 1.5 m and flourished on the wetland. Our survey results showed that the suitable habitat of *L. leucantha* is a wetland which is sunny without vegetation cover in winter and without tall plants in spring. According to historical documents, local farmers in Ukishima harvested the wetland plants, especially *P. australis*, for fertilizer, livestock feed and other uses in spring, early summer and winter. Such wetland uses seem to have maintained the suitable habitats of *L. leucantha*. Wet herbaceous vegetation maintained by traditional agricultural practices disappeared because of modernization of agriculture including the use of chemical fertilizer. It is obvious that wetland loss is the main cause of the reduction of *L. leucantha* habitats. There is a high possibility that vegetation changes of remaining wetlands because of agricultural changes also reduced the suitable habitats of *L. leucantha*, not only in Ukishima but also in other Japanese wetlands.

Figure 1. *Lysimachia leucantha*. Photo: Michiko Shimoda.

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Monitoring of the vegetation change in artificial forests established by the National Institute of Ecology

Shin Hak-Sub (1), Lee Jung-Hyo (1), Kim Hye-Jin (2), Han Sang-Hak (2) & Yun Chung-Weon (2)

1) National Institute of Ecology, Geumgang-ro 1210, Seocheon-gun, 325-813, Republic of Korea

2) Department of Forest Resources, Kongju National University, Yesan 340-702, Republic of Korea

Correspondence: Yun, Chung-Weon, cwyun@kongju.ac.kr

Background & Aim: The flora of Korea is biogeographically similar to that of southern Siberia and the north-central provinces of China and Japan (Oh et al. 2010). The forest vegetation of Korea has been classified by climate zone, topography, geological features, and other environmental factors (Yun et al. 2011). In this study we report on a habitats survey project that was established by the National Institute of Ecology in Korea. As part of this project, we investigated the artificial plant communities created for the purpose of research for climate change, habitat conservation, and restoration of biodiversity. We focused on typical plant communities in Korea such as those dominated by *Abies holophylla, A. koreana, Camellia japonica, Carpinus laxiflora, C. tschonoskii, Quercus acuta, Q. mongolica, Q. serrata, Q. variabilis, Pinus densiflora and P. koraiensis.*

Materials & Methods: Vegetation research was carried out in total of twelve typical forest vegetation stands. We sampled the plant communities using the phytosociological method (Braun-Blanquet 1964). Field surveys of plant species composition in habitats within typical forest communities in Korea were conducted using 400 m^2 plots. And the distribution of plant individuals was also recorded using a laser rangefinder.

Main Results & Interpretation: We identified and described the following plant communities:

Camellia japonica community and the *Quercus acuta* community in warm-temperate evergreen broadleaved forest zone;

Quercus serrata community and *Carpinus tschonoskii* community in warm-temperate deciduous broadleaved forest zone;

Pinus densiflora community in temperate deciduous broadleaved forest zone;

Pinus koraiensis community in temperate coniferous forest zone;

Abies koreana community and *Abies holophylla* community in the sub-taiga forest zone.

Considering the change of species composition and the coverage, tree layer indicated low change but shrub and herbaceous layer showed more changes from invasion of exotic species into the study area. We plan to continue monitoring these alternative habitat types created on the basis of vegetation zone through the comparison of original status of the forest communities in order to provide baseline data for vegetation restoration and habitat replacement.

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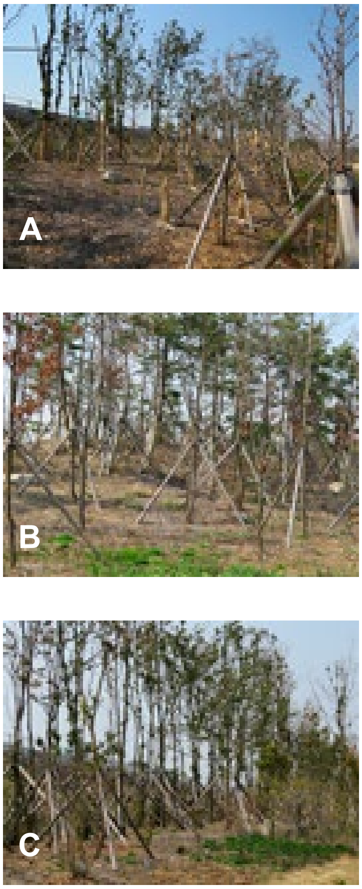

Artificial forests established by the National Institute of Ecology in Korea.
A: *Camellia japonica* forest;
B: *Quercus variabilis* forest;
C: *Quercus acuta* forest.

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The analysis of the plant diversity in agricultural pond wetlands in Korea

Son Jin-Kwan, Kang Bang-Hun, Kong Min-Jae, Lee Siyo-Ung & Kang Dong-Hyun

National Academy of Agricultural Science, Rural Development Administration, Suwon, Gyeonggi-do, Republic of Korea

Correspondence: Kang Dong-Hyun, kang6906@korea.kr

Background: The rains in Korea occur especially in summer when many pond wetlands used to be created to serve irrigation in spring and autumn. However, because of the construction of large-sized dams and reservoirs, the pond wetlands are no longer used for water irrigation; many have been reclaimed that lead to a decrease in biodiversity. Pond wetlands play an important role for the conservation of biodiversity at the national level. Yet the value of biodiversity conservation is not fully appreciated and there is also a lack of methods for the assessment of the biodiversity.

Materials & Methods: This study was conducted to analyze the environmental factors affecting vegetation diversity in order to assess the value of the pond wetlands. Study sites were classified into mountain, upland, paddy, and village types, and a total of 40 sites were selected. The vegetation diversity and environment factors such as wetland present condition (size, land-use value, altitude, depth, distance, age, use, and hydrological condition), water (pH, conductivity, turbidity, dissolved oxygen, biochemical oxygen demand, chemical oxygen demand, suspended solid, Total nitrogen, and Total phosphorus), and soil heavy metals (lead, cadmium, cuivre, arsenic, nickel, zinc, hydrargyre and hexavalent chrome), soil physical (texture and phase), soil chemical (pH, electrical conductivity, organic meter, available phosphate, total nitrogen, cation exchange capacity, Ca, K, Mg and Na) were surveyed and analyzed using standard statistics.

Results & Interpretations: The flora survey of the 40 pond wetlands yielded a total of 457 taxa, classified into 108 families, 309 genera, 392 species, 1 subspecies, 59 varieties and 5 formae. The average number of the plant taxa per site was approx. 31 families and 61 taxa. On average 10 *Asteraceae* and 8 to 9 *Poaceae* were found in the study sites. We recorded a total of 46 taxa of naturalized alien plants. The alien plants are known to reduce vegetation diversity, yet the findings of this study showed that plant diversity increased with the increasing number of naturalized plants. The survey result of environmental factors affecting plant diversity showed that there was correlation among the area, silt content, discharge structure, electrical conductivity of soil, and suspended solid of water. The total number of species increased by 2 to 3 taxa when the wetland size increased by 1 000 m^2; the species richness increased by 3 taxa when the soil silt increased by about 10%; by 8 taxa as the total nitrogen of soil increased by 0.1%; by 7 taxa as the electrical conductivity of soil increased by 1.0 ds/m, and by 5 taxa as the suspended solid of water increased by 10mg/L. We suggest that soil and hydrological condition should be considered when restoring and creating pond wetlands for the sake of preservation of biodiversity. The environmental factors identified in this study as possible drivers of the increase of the biodiversity of pond wetlands can be used as the baseline information to determine the conservation value and to establish management plans in the future.

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Changes in species composition and richness in an alluvial hardwood forest over 52 years

Ilka Strubelt (1), Martin R. Diekmann (2) & Dietmar Zacharias (1)

1) Applied and Ecological Botany, Faculty 5, University of Applied Sciences Bremen, Neustadtswall 30, D-28199 Bremen, Germany

2) Vegetation Ecology and Conservation Biology, Institute of Ecology, FB 2, University of Bremen, Leobener Str., D-28359 Bremen, Germany

Correspondence: Ilka Strubelt, ilka.strubelt@hs-bremen.de

Background and Aims: Alluvial forests are among the species-richest and most productive forest ecosystems in the temperate zone. Human influence in the form of river deepening and regulation, lowering of the ground water table and agricultural intensification has resulted in a strong decrease in natural floodplain forests over the last centuries. As a consequence, floodplain forests at present are rare and worthy of protection. The Haseder Holz (dominant tree species: *Quercus robur* and *Fraxinus excelsior*) represents one of the most well-preserved alluvial hardwood forests in NW Germany. We have been pursuing a long-term monitoring of plant diversity over 52 years in this forest. Our main research questions were:
(1) What are the main drivers of the species richness in this alluvial forest?
(2) How has species richness changed over the past 52 years?
(3) Has the species composition changed over this period?

Materials & Methods: In 2012 we re-surveyed 19 permanent plots (20 m x 20 m) first sampled in 1960 and later in 2002. Apart from sampling the vegetation applying the methods already used in the previous years (according to the classical Braun-Blanquet approach; Dierschke 1994), we measured photosynthetic active radiation, soil water content, groundwater level, pH and soil nutrients (P, Ca, Mg, K, C, N). General linear models were used to examine the relationship between explanatory variables and species richness as well as to ascertain the amount of variation explained by the used models.

Main Results: The number of species generally decreased with increasing nutrient (except for Mg) content and increased with a higher variation in light availability and in K content. The significant increase in species richness from 1960 to 2012 was mainly attributed to the increase in the number of typical forest species, such as *Paris quadrifolia* and *Mercurialis perennis*. The increase was least pronounced in plots with higher soil phosphate content. Species showing a pronounced decrease in constancy from 1960 to 2012 were mostly those characteristic of open habitats. In contrast, more than half of the increasing taxa were woody species (young trees and shrubs). We also detected a homogenization of the forest plots over the studied time period.

Conclusions: Despite being an ecosystem characterized by a continuous input of nutrients by flooding, the species richness in the studied forest was highest in the least fertile sites. Local heterogeneity in terms of light availability and potassium content also enhanced the number of species.

Flooded alluvial hardwood forest Haseder Holz (Germany) in May 2013. Photo: I. Strubelt.

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Identification of the relatively sensitive and important physical parameters with the Lund-Potsdam-Jena model

Guodong Sun (1) & Mu Mu (2,1)

1) The State Key Laboratory of Numerical Modelling for Atmospheric Sciences and Geophysical Fluid Dynamics (LASG), Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing 100029, China

2) The Key Laboratory of Ocean Circulation and Wave, Institute of Oceanology, Chinese Academy of Sciences, Qingdao 266071, China

Correspondence: Guodong Sun, sungd@mail.iap.ac.cn

Background and Aims: The parameter errors in a dynamic global vegetation model (DGVM) are an important source of the uncertainty in the simulation of terrestrial ecosystem and vegetation pattern. However, it is costly to reduce all parameters errors in the DGVM through observational data. A new theoretical framework is advanced to determine the most sensitive and important parameters. In this study, we explored how to identify the most sensitive and important physical parameters to implement the theoretical framework using a DGVM.

Materials & Methods: A Lund-Potsdam-Jena (LPJ) DGVM, is an example, that could show the regional and seasonal character of terrestrial ecosystem and vegetation, and could discuss the vegetation patterns, is employed to validate the key part of the theoretical framework. To find the most sensitive and important parameters, 24 physical parameters are chosen within the LPJ model. The approach of conditional nonlinear optimal perturbation (CNOP) is applied because the approach could consider the nonlinear interaction among parameters.

Main Results: It was found that the most important subset of parameters in the arid and semi-arid regions of China was different to those in northern, northeastern and southern China. The results imply that the nonlinear interaction among parameters plays a key role in the uncertainty of numerical simulation in arid and semi-arid regions of China. The uncertainties in the numerical simulation were reduced considerably through reducing the errors of the subset of relatively more sensitive and important parameters compared to other types of parameter errors in these regions. The results based on the LPJ model demonstrate that our approach not only offers a new route to identify relatively more sensitive and important physical parameters, but also that it is viable to then apply 'target observations', to reduce the uncertainties in model parameters.

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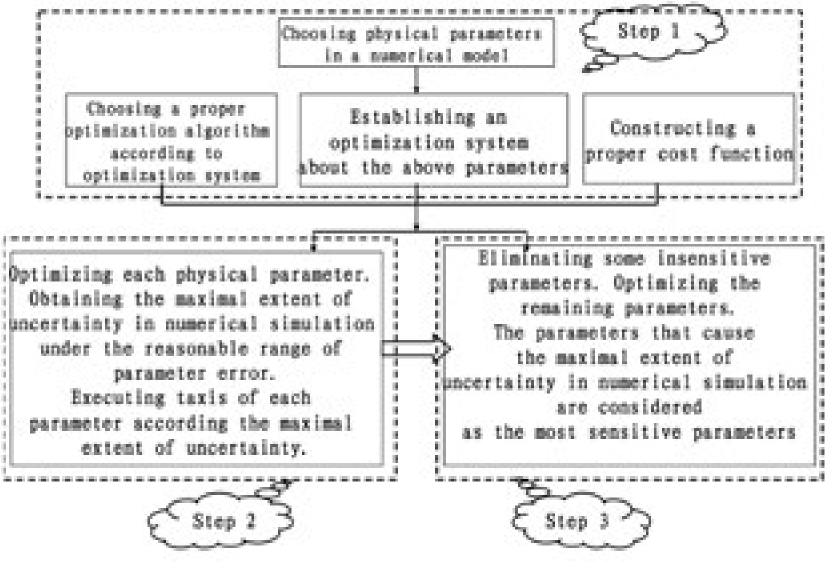

Flowchart depicting the steps involved in the new theoretical framework.

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Changes in soil seed bank species composition following the 2010 eruption of Mt Merapi, Yogyakarta, Indonesia

Sutomo (1,2), Eddie van Etten (1) & Dini Fardila (3)

1) Centre for Ecosystem Management, School of Natural Sciences, Edith Cowan University, 270 Joondalup Drive, Joondalup 6027, Perth, Australia

2) Bali Botanical Garden, Indonesian Institute of Sciences, Candikuning, Baturiti, Tabanan 82191, Bali, Indonesia.

3) Department of Biology, Syarif Hidayatullah State Islamic University, Tangerang Selatan, Banten 15412, Jakarta, Indonesia

Correspondence: Eddie van Etten, e.van_etten@ecu.edu.au

Background & Aim: The soil seed bank (SSB) is defined as the cumulative number of seeds in the soil that are viable and have the potential to replace adult plants. Studies which quantify the species richness and abundance of SSBs are valuable as they improve our understanding of tropical forest regeneration and their recovery following disturbance. Mt Merapi is one of the most active volcanos in Indonesia. Eruptions from Mt Merapi are unique as they are characterized by distinct pyroclastic flows (fast-moving currents of very hot gas and particles) that usually kills all of the plants and other biota in the affected area. Recent eruption events were in 2006 and 2010. We were particularly interested in whether the species composition of SSBs obtained from surface soil sampling in eruption and non-eruption sites differed and, if confirmed, which species were most responsible for the differences as indicated by their dominance.

Materials & Methods: Thirty sampling plots were randomly selected across two areas: 1) areas affected by eruption via pyroclastic flows (Kalikuning) in which virtually all plants were killed; and 2) nearby areas not affected by eruption (Kaliurang). Several samples of surface soil (0-10 cm) were collected from each plot, thoroughly mixed together (for each plot) and then brought to glasshouse for germination. All emerging seedlings were identified to family level at minimum and to species level where possible. We calculated the importance value index (IVI) and conducted an ordination analysis (using non-metric multidimensional scaling or NMDS) based on the Bray-Curtis index of similarity. Significance testing was conducted using ANOSIM.

Main Results & Interpretations: The NMDS ordination showed that there were significant differences in species composition between the two areas ($R_{ANOSIM} = 0.622$, $P < 0.01$). *Asteraceae* species were abundant in the unaffected plots, followed by the *Poaceae*. In the eruption-affected area, *Asteraceae* species also had the highest abundance, while *Fabaceae*, *Cyperaceae* and *Poaceae* followed in roughly equal abundance. In non-eruption plots, an invasive exotic, *Ageratina riparia,* dominated the SSB with an IVI of 74%. This species was also found in eruption-affected plots, but not the same extent. *Borreria occimoides* (also an invasive exotic) had the highest IVI (of 62%) in eruption-affected plots, followed by other herbaceous species such as *Cyperus rotundus*, *C. flavidus* and *Ageratum conyzoides (*also exotic*)* with IVIs of 27%, 26% and 25%, respectively. Although SSB species richness was greater in non-eruption areas, there were greater numbers of exotic species in eruption-affected soils. This suggests that early succession in areas impacted by severe pyroclastic flows will be dominated by invasive, shade-intolerant and herbaceous species until at least several decades when a dense canopy of trees will most likely developed (as has been reported elsewhere in Java). The invasive exotic *A. riparia* is however likely to continue spreading on Mt Merapi because it tends to remain in the system even after a canopy has developed. Hence, ecological intervention in the form of weed management to alter the Mt Merapi succession should be considered.

Mt Merapi in central Java, Indonesia. The open areas are areas affected by eruption via pyroclastic flows ('kalikuning') in which virtually all plants are killed. Photo: Sutomo.

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Effects of tsunami disturbance on the vegetation of coastal forest habitats in northeastern Japan

Mizuki Tomita (1), Hiroshi Kanno (2), Yoshihiko Hirabuki (3) & Keitarou Hara (1)

1) Tokyo University of Information Sciences, 4-1 Onaridai Wakaba-ku, Chiba, Japan
2) Tohoku Afforestation & Environmental Protection Company Ltd., 2-5-1 Honcho Aoba-ku, Sendai, Japan
3) Tohoku Gakuin University, 2-1-1 Tenjinzawa Izumi-ku Sendai, Japan

Correspondence: Mizuki Tomita, tomita@rsch.tuis.ac.jp

Background & Aim: Understanding how disturbance shapes floristic composition is of fundamental interest to vegetation ecology. This study reports on the effects on floristic characteristics in three types of coastal forest habitat, resulting from disturbance by the infamous tsunami that followed the Great East Japan Earthquake of March 2011. Huge tsunamis, however, are infrequent, and our knowledge of their effect on vegetation is limited.

Materials & Methods: In May 2011, a coastal forest area of 280 m X 240 m was selected in the Miyagi Prefecture hit hard by the 2011 tsunami. Google *earth* images were used to map pre-tsunami canopy gaps, and the post-tsunami destroyed and remnant forests. In addition, pre- and post-tsunami ground elevation was obtained from digital elevation models (DEM) with a 1-m horizontal and 0.2-m vertical resolution to map tsunami-related changes in ground elevation. These GIS data were combined with field survey data to classify post-disturbance habitats into three types, these were (i) remnant forest, (ii) destroyed forest, and (iii) destroyed forest with a humus layer scoured or swept away by the tsunami. In July 2013, 12 quadrates (1 m X 1 m) were selected in each habitat type and sampled for floristic composition. In each quadrat, sampling included the species list, estimated abundance values for all vascular plants with a height of < 1 m, and the depth of the recently deposited sand layer.

Main Results & Interpretations: A total of 83 species were recorded: 56 herbs, 19 trees and 8 lianas. The destroyed forest with the lost humus layer was dominated by twice as many herbs (42 species) as in the remnant (17) or destroyed forest habitats (20). These herbs included both exotic and native coastal species. In the remnant and destroyed forests, however, trees and lianas were more common. In the remnant forests the sand layer was deeper (7.4 ± 3.2 cm) than in the other habitats (5.3 ± 4.3 cm). The loss of the humus layer created better opportunities for the colonisation by exotic and native coastal herbs from nearby inland areas and sandy beaches than on the deposits of coastal sand. Continued monitoring will be required to determine which successional pathway these forest habitats will take in response to this large-scale tsunami-related disturbance event.

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Figure 1. Coastal forest disturbed by tsunami in Sendai, Japan. The length of surveying pole is 2 meters. Photo: M. Tomita.

Figure 2. A destroyed forest in the study area. Many pits originated from uprooted trees. Photo: M. Tomita.

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Plant richness declines due to changes in disturbance regime and stoichiometry of soil (pH and P) in semi-natural grasslands around agricultural lands

Kei Uchida (1), Shuntaro Hiradate (2), Sayaka Morita (3), Yoshinobu Kusumoto (2), Tomoyo Koyanagi (4) & Atushi Ushimaru (1)

1) Graduate School of Human Development and Environment, Kobe University, 3-11 Tsurukabuto, Kobe, Japan

2) National Institute for Agro-Environmental Sciences (NIAES), 3-1-3 Kannondai, Tsukuba, Japan

3) National Institute of Advanced Industrial Science and Technology, 1-1-1 Higashi, Tsukuba, Japan

4) Field studies institute for Environmental Education, Tokyo Gakugei University, 4-1-1 Nukui-kitamachi, Koganei, Japan

Correspondence: Kei Uchida, k.uchida023@gmail.com

Background & Aim: Recently, biodiversity declines due to land-use changes in agricultural landscapes have been central issues worldwide (Sala et al. 2000; Kleijn et al. 2011). Land-use changes, including both land intensification and abandonment, have caused biodiversity loss in semi-natural grasslands in Japan (Uchida & Ushimaru in press). Although many studies have described patterns of species richness declines in semi-natural grasslands, only a few studies demonstrated process of richness declines.

Materials & Methods: This study was conducted in 77 plots across 25 paddy terraces (in an area of c. 19 X 30 km) in western Japan. In the study area, semi-natural grasslands are maintained by periodic mowing on the field margins of the paddy terraces, levees of irrigation ponds and at edges between the paddy terraces and secondary forests (dominated by *Quercus serrata*). Here, mowing is considered to act as a disturbance agent for plants. The paddy terraces were categorised into three land-use types, these were 1) abandoned terraces, where farmers ceased rice cropping and mowing of semi-natural grasslands 3–15 years ago, 2) traditional terraces, managed by traditional methods for at least 100 years; and 3) intensive terraces, which underwent land-consolidation 12–31 years ago. We established 1 m X 1 m plots in semi-natural grasslands. We studied 23 plots in seven abandoned terraces, 28 plots in nine traditional terraces, and 26 plots in nine intensive terraces. From August to October in 2012, we recorded all vascular plants at each plot. Soil condition was estimated from five subplots (0.02 m^2) within each plot, and analyzed (pH & phospohorus content) in the laboratory. In analyses, we compared richness for plant life history groups (annual, perennial, woody) and native/invasive plants among the three land-use types. We then analyzed relationships between plant richness and disturbance frequency (the number of mowing events in each plot during April to October in 2012) and soil condition (pH & P content), using the Generalized Linear Mixed Model. To evaluate the significance of the effects of the explanatory variables, we used a model-selection procedure based on Akaike's Information Criterion.

Main Results & Interpretations: We found that species richness of native and perennial species was the highest in the traditional terraces. Contrary, invasive species had the most pronounced presence in the intensive terraces. The relationships between native plant species richness and disturbance (mowing) frequency followed a unimodal pattern. The richness of native species decreased with increasing P content. Our results demonstrated that the α-diversity of plant species has a stronger relationship with mowing frequency than soil condition. This study contributes to a better understanding of processes of biodiversity decline due to land-use changes in semi-natural grasslands surrounded by agricultural land.

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Trait-based assembly rules across climatic gradients of European grasslands

Camilla Wellstein (1), Anke Jentsch (2,3), Stefano Chelli (4), Giandiego Campetella (4), Roberto Canullo (4), Iva Apostolova (5), Juliette Bloor (6), Kevin Cianfaglione (4), Jürgen Dengler (2,7,8), Philipp von Gillhaußen (2), Behlül Güler (9), Judit Házi (10), Cecília Komoly (10), Jürgen Kreyling (3,7), Julien Pottier (6), Gábor Szabó (10), Tsvetelina Terziiska (5), Emin Uğurlu (9), Zita Zimmermann (10) & Sándor Bartha (10)

1) Faculty of Science and Technology, Free University of Bozen, Universitätsplatz 5, I-39100 Bozen, Italy

2) Disturbance Ecology, University of Bayreuth, Universitätsstr. 30, D-95447 Bayreuth, Germany

3) Bayreuth Center of Ecology and Environmental Research (BayCEER), University of Bayreuth, Universitätsstr. 30, D-95447 Bayreuth, Germany

4) Plant Diversity and Ecosystems Management Unit, School of Biosciences & Veterinary Medicine, University of Camerino, Via Pontoni 5, I-63032 Camerino (MC), Italy

5) Insitute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences, G. Bonchev Str. Block 23, 1113 Sofia, Bulgaria

6) INRA, UR0874 Grassland Ecosystem Research Unit, 5 Chemin de Beaulieu, F-63100 Clermont-Ferrand, France

7) Biogeography, University of Bayreuth, Universitätsstr. 30, D-95447 Bayreuth, Germany

8) Synthesis Centre (sDiv), German Centre for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig, Deutscher Platz 5e, D-04103 Leipzig, Germany

9) Biology, Faculty of Science & Letters, Celal Bayar University, Muradiye, Yagcilar Campus, 45140 Manisa, Turkey

10) Centre for Ecological Research, Hungarian Academy of Sciences, Alkotmány út 2-4, H-2163 Vácrátót, Hungary

Background & Aims: Trait-based studies of species assembly can reveal mechanisms of species coexistence. European grasslands support a rich flora with high small-scale species density, mirroring intricate coexistence mechanisms. These mechanisms might show differences related to climate, soil conditions and disturbance history of a site. We compare assembly rules across European grasslands differing in climate, soil and land use history.

Study sites: We investigated fine-scale patterns of trait-based community assembly in European grasslands across continental gradients within the framework of the BiodivERsA project SIGNAL. The gradient extends from the mesic grasslands in France and Germany (mean annual precipitation/MAP: 750–1200 mm; mean annual temperature/MAT: 8° C to 7° C, resp.), to intermediate ones in Italy and Bulgaria (MAP: 880–560 mm; MAT: 12.1° C to 10.2° C, resp.), to xeric ones in Turkey and Hungary (MAP: 715–550 mm; MAT: 16.7° C to 10.5° C, resp.). The sites also differ in management, disturbance history, geology and edaphic factors. They represent common types of grasslands of the respective study country.

Methods: Fine-scale patterns of species combinations (rooting individuals) were sampled in 2.80 m X 0.40 m blocks, subdivided into 448 micro-quadrats of $25\ \text{cm}^2$ (5 cm X 5 cm). To account for within site heterogeneity, six blocks were sampled at each site. Specific leaf area (SLA), plant height and seed mass were assessed, using literature sources and direct measurements, for all recorded vascular herbaceous species. Based on these traits, Rao's functional diversity was calculated for each micro-quadrat and compared to a null model. We used Schamp's method for randomization: keeping the abundances of species and the local species richness as in the field and assigning traits at random to each species combination. Deviation of functional diversity from random expectation was interpreted as trait divergence or trait convergence.

Main Results & Interpretations: Several occurrences of trait-based assembly rules could be detected across countries. The strongest deviations from randomness in terms of seed mass were found in the Turkish grassland (driest one). In Bulgaria, Hungary, France and Germany, by contrast, we detected convergence of seed mass. Strong convergence of plant height appeared in tall mesic grasslands of Germany and France, while this trait showed random pattern in dry grasslands. The Turkish grassland showed convergence for SLA. Similar tendency occurred at the German and the Italian sites while those of France and Bulgaria mostly showed random patterns. Italian grasslands (spatially very close) showed both convergence and divergence of seed mass indicating heterogeneous environmental conditions and/or complex site history. We conclude that assembly rules can be contrasting and context dependent at different grassland sites and climatic differences are often masked by local factors such as disturbance regime or soil heterogeneity.

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Correspondence: Sándor Bartha, bartha.sandor@okologia.mta.hu

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A floristic survey of the riparian zone of the Warren and Tone Rivers in the Southwest Australian Floristic Region, Western Australia

Helen A. White (1,2), John K. Scott (1,2) & Raphael K. Didham (1,2)

1) School of Animal Biology,
University of Western Australia,
35 Stirling Hwy, Crawley 6009 WA,
Perth, Australia

2) CSIRO Ecosystem Sciences,
Underwood Avenue, Floreat 6014
WA, Perth, Australia

Correspondence: Helen White,
helen.white@csiro.au

Background & Aim: The southwest of Western Australia has one of the highest levels of floristic diversity and endemism in the world, with more than 7200 species of native vascular plants, 79% of which are endemic to the region. While the unique nature of these systems is widely acknowledged, very little is known about species and community ecology. Where research has been undertaken it has focused on profitable terrestrial systems, such as forestry. The riparian communities running through these forests however remain largely undescribed, with exception of some anecdotal accounts. This study targeted the riparian vegetation of the Warren River system of south-west Western Australia. Systematic vegetation surveys of the Warren River riparian zones were undertaken with the aim of quantifying the distributional limits of the riparian species along a rainfall gradient (historically, 600 mm to 1400 mm per annum) of the Warren and one of its main tributaries, the Tone River.

Materials & Methods: The Warren River catchment was divided in to 200 mm rainfall zones from interpolated historical rainfall records. Within each rainfall zone, 10 randomly allocated survey sites were identified. At each site, paired 5m by 5m quadrats were run the width of the riparian zone. Within each quadrat, trees, shrubs and perennial grasses were identified, quantified and assigned age classes. River topology was measured to 1 m resolution from Aerial LiDAR surveys and flow data obtained from the WA Department of Water gauge stations. Ecologically important variables of flow, such as inundation frequency and duration were generated from ground topology and flow data and modelled with distribution of species and age classes.

Main Results & Interpretations: The vegetation of the Warren River riparian zone differed across the length of the catchment. Preliminary results suggest that the distribution of species varied at both a local scale, with changes in bank morphology as well as at catchment scale suggesting that local disturbance regimes as well as climatic limitations are acting on species distribution in these systems. The results presented provide (1) the first comprehensive description of the riparian vegetation of the Warren and Tone Rivers and, (2) relate the distributions of major riparian species to habitat, environmental flow requirements and climate of the major riparian species.

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Figure 1. Typical riparian vegetation (with swamp paperbark, *Melaleuca rhaphiophylla* the flooded gum, *Eucalyptus rudis*) of the Tone River within the 600 to 800 mm annual rainfall band. Photo: Helen White.

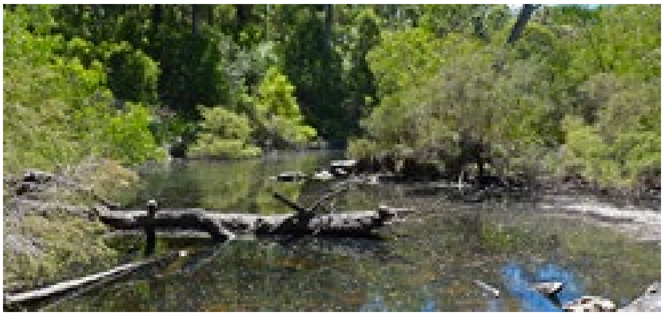

Figure 2. Riparian vegetation of the Lower Warren River. The small tree, *Astartea leptophylla*, is typically found at the waters edge. Photo: Helen White.

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Difference assessments of five dynamic vegetation circles according to groups of diagnostic species: a case study from the Bogdanka River valley

Monika Wiśniewska

Department of Plant Ecology and
Environmental Protection, Faculty of
Biology, Adam Mickiewicz University
Poznań, Umultowska 89, 60-995
Poznań, Poland

Correspondence: Monika Wiśniewska,
mzgr@amu.edu.pl

Background & Aim: Anthropogenic pressure significantly contributes to heavy disturbance and destruction of natural plant communities that are replaced by other vegetation, often called 'replacement plant communities'. The group of natural plant communities and all other communities that potentially develop as their replacement after disturbance or destruction of the original vegetation cover is called 'dynamic vegetation circle' (DVC; Schwickerath 1954). Among series of those replacement plant communities, those ones that show the strongest connection with the 'final' potential community are considered as 'indicator communities'. They can be recognised by some parameters describing the habitat and by sharing of groups of diagnostic species. In order to compare the contribution of the given group of species in various replacement communities, G- and D-values are used. G-value characterises the composition of the groups of diagnostic species. D-value, is a G-value weighted by the average constancy of the species (Tüxen & Ellenberg 1937). The aim of this study was to assess differences between various DVC using groups of diagnostic species, and to recognise those differences that could be applied in the process of ascribing replacement plant communities to five potential natural vegetation (PNV) units.

Materials & Methods: We compared DVC for the presence of diagnostic species. G- and D-values were used as indicators of 13 syntaxonomic classes, 4 orders and 12 alliances. We used 700 relevés, collected in 2008–2012 from 84 plant communities in the Bogdanka River valley (Poland). Some 45 of these communities were ascribed as locally diagnostic to five PNV units distinguished in the area, such as the *Carici elongatae-Alnetum* (Car-Aln), the *Fraxino-Alnetum* (Fra-Aln), the *Querco-Ulmetum* (Que-Ulm), the *Galio sylvatici-Carpinetum* (Gal-Car) and the *Quercetum* s.l. (Sil-Fes). Predefined locally diagnostic replacement plant communities calculated according to D-value were used for comparison. The differences between the DVC were tested using non-parametric Kruskal-Wallis test.

Main Results & Conclusions: The results revealed groups of locally diagnostic species that can be useful in ascribing replacement plant communities to PNV units on the territory of the Bogdanka River valley. The G-value calculated for DVC of Car-Aln presented a large share of the *Phragmito-Magnocaricetea* (35.5%) and the *Alnetea glutinosae* (14%). Comparisons according to D value confirmed the important role of the *Alnetea glutinosae*, *Phragmito-Magnocaricetea* and *Bidentetea* in the communities of the circle (Car-Aln) and *Molinietalia* in the circle of Fra-Aln. The analysis showed a statistically significant difference for the group of diagnostic species of the *Alnetea glutinosae* (p=0.002), the *Phragmito-Magnocaricetea* (p=0.002), the *Bidentetea* (p=0.002) and the *Molinietalia* (p=0.0077). The D value obtained for the *Filipendulion ulmariae* showed also a significant difference between circles of Fra-Aln and Que-Ulm (p=0.03). DVC of Gal-Car might be identified by share of the *Galio-Alliarion* (p=0.0020) and the *Arrhenatherion* (p=0.0004).

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Development of characteristic vegetation on termite mounds in north-eastern Namibia

Chisato Yamashina

The Center for African Area Studies,
Kyoto University, 46, Shimoadachi-cho, Yoshida, Sakyo-ku, Kyoto, Japan

Correspondence: Chisato Yamashina,
yamashinachisato@gmail.com

Background & Aim: Mound-building termites function as ecological engineers in landscapes dominated by tropical savannas. Large termite mounds support a greater diversity of plants and mammals than the surrounding off-mound habitats. Termite-induced resource heterogeneity affecting soil texture (Sileshi et al. 2010) and soil moisture (Dangerfield et al. 1998) that putatively affects vegetation patterns. Spatial heterogeneity is also a factor, in that termite mounds act as fire refugia (Joseph et al. 2013) and flooding (McCarthy et al. 1998). However, little is known about the processes underpinning the development of the diverse mound vegetation. This study examined the dispersal modes of woody plants on termite mounds in relation to development of plant assemblages on the termite mounds.

Materials & Methods: This study classified the termite mounds into active *vs.* inactive (depending on the termite activity) and mound microtopography (mound cones *vs.* off-mound areas). In order to compare the vegetation between the active and inactive mounds, species richness and the abundance of mature woody plants (height ≥ 1.3 m and diameter at breast height ≥ 1 cm) were recorded on the 70 mounds, 13 on-mound and 13 of-mound quadrats (20 m X 20 m).

Main Results & Interpretation: The frequency of occurrence of woody plants was less on the active mounds (67%), especially on cones (46%), when compared to the inactive mounds (95%). Species richness and the abundance of woody plants increased along a sequence involving (1) cones, (2) pediments of active mounds and (3) inactive mounds. The proportion of bird-dispersed plant species was much higher on mounds (>40%) than in off-mound areas (3%). *Salvadora persica* was the main bird-dispersed plant and occurred preferentially on active mounds. In conclusion, I suggest the following scenario to explain the development of mound vegetation: First, *S. persica* fruits/seeds are preferentially dispersed to mounds by their vectors (birds) that use them as perching or mating sites. Some of the dispersed seeds establish and these sampling and young trees may attract more animals to the mounds, possibly bring in seeds of other woody species, hence contributing (through a positive feedback) to increase of the environmental heterogeneity on the mounds and hence increasing the species and vegetation diversity in these habitats. I suggest that testing of this hypothesis should contribute to a better understanding of savanna vegetation ecology.

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Flora and plant communities of small wetlands along the rocky coast of Sanriku area, northern Japan

Masato Yoshikawa (1), Shintaro Tetsu (2) & Eri Ayukawa (3)

1) Institute of Agriculture, Tokyo University of Agriculture and Technology, Fuchu, Tokyo 183-8509, Japan

2) Graduate school of Agriculture, Tokyo University of Agriculture and Technology, Fuchu, Tokyo 183-8509, Japan

3) Hachinohe Institute of Technology, Hachinohe, Aomori 031-0814, Japan

Correspondence: Masato Yoshikawa, masato@cc.tuat.ac.jp

Background & Aims: Vegetation of rocky coasts mainly consists of plants which grow on shallow soil on the rocks and epipetric plants which are tolerant to drought and sea breezes. However, several types of small wetlands were distributed along the rocky coast of Tohoku district, northern Japan. We observed many characteristic hygrophytes around such wetlands. We aimed to clarify the topographic and hydrologic types of the small wetlands and their role for habitats of hygrophytes in the rocky coast vegetation.

Study Site & Methods: The study area was the northern part of the Sanriku coast, Tohoku district, Japan, facing the Pacific Ocean. In four sites of this area, we selected 25 small wetlands (approximately 5–400 m^2). Flora was surveyed for each wetland, and 75 vegetation relevés were taken for plant communities around the wetlands in 2013. Surface water was sampled from each wetland to measure some physico-chemical characteristics such as pH, EC, ROP, NO_3, PO_4, and Ca. Canonical correlation analysis was used to investigate the nature of the relationship between the sampled vegetation and water quality.

Main Results & Discussions: Surveyed wetlands were classified into five types based on topography and hydrological features: mud-flat type, pool type, fen type, streamside type, and spring type. Each type contained different flora and plant communities. The mud-flat type developed on sandy coastal deposits adjacent to the strandline. This type had many halophilous plants such as *Triglochin maritimum*, *Puccinellia nipponica*, *Potentilla egedei* var. *grandis*, and *Glaux maritima* var. *obtusifolia*. The surface water of this type showed the highest EC and Ca concentrations reflecting the strong influence of sea water. The pool type that had stagnant water body independent from the sea, had emergent plants such as *Carex rugulosa* and *C. lyngbyei*, and submerged plants such as *Ruppia maritima* and *Myriophyllum spictum*. The fen type that developed on alluvial fans or gentle slopes facing the sea, was characterised by tall grasses and tall herbs such as *Hemerocallis dumortieri* var. *esculenta*, *Ilis ensata* var. *spontanae*, *Lysimachia vulgaris* var. *davurica*, and *Eupatorium lindleyanum*. The water of this type had relatively high EC and N indicating that it was fed by nutrient-rich ground water. The streamside type that is formed along flowing water (streams) among the rocks supported small hygrophytes such as *Fimbristylis subbispicata* and *Epilobium pyrricholophum*. The spring type occurred around spring water soaking out of rocky soils. This type characteristically had *Drosera spathulata*, *Haloragis micrantha*, and *Saxifraga fortunei*. The water of this type showed the lowest pH that suggests feeding by nutrient poor ground water or by rain. CCA ordination of the wetlands using flora data suggested that the floristic difference between the wetland types could be explained mainly by altitude, pH, Ca, and NO_3, hence by the difference in water quality feeding the wetlands. Remarkably, four of five wetland types were strongly affected by fresh water despite their location. Small freshwater wetlands provide habitats for hygrophytes that are uncommon along the rocky coast. Although all surveyed wetlands were presumed to have suffered from tsunami and were inundated temporarily in March 2011, clear evidence of physical disturbance was not observed. Therefore, these small wetlands are considered to be quite stable habitat and have an important role for floristic diversity in the rocky coast of this area.

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Higher plant species richness and diversity accompany declining soil nutrient availability across a long-term dune chronosequence

Graham Zemunik (1), Benjamin L. Turner (2), Hans Lambers (1) & Etienne Laliberté (1)

1) School of Plant Biology, The University of Western Australia, 35 Stirling Hwy, Crawley WA 6009, Perth, Australia

2) Smithsonian Tropical Research Institute, Apartado 0843-03092, Balboa, Ancon, Republic of Panama

Correspondence: Graham Zemunik, graham@graduate.uwa.edu.au

Background & Aims: Soil chronosequences are soil series derived from the same parent material, with gradients in soil age and nutrient availability. Because soil nutrient availability is one of the fundamental components shaping ecological communities, soil chronosequences allow ecologists to investigate fundamental processes of ecosystem development driven by changes in soil nutrient availability. We used a long-term dune chronosequence to investigate plant community responses to changing soil age and nutrients. We hypothesised an increase in species richness and diversity, as well as an increase in the range and diversity of nutrient-acquisition strategies (Lambers et al. 2008), across this chronosequence.

Materials & Methods: The study area was the Jurien Bay dune chronosequence (Laliberté et al. 2012), located in the southwest Australian Global Biodiversity Hotspot (Lambers & Hopper 2014), which spans up to two million years of soil development. We delineated the chronosequence into six stages, encompassing Holocene dunes (stages 1-3), Middle Pleistocene dunes (stages 4 and 5), and Early Pleistocene dunes (stage 6). Flora surveys of 60 plots (10 per stage) were combined with root analyses, for mycorrhizal colonisation, and soil analyses to quantify species richness, abundance and nutrient-acquisition strategies employed by each species.

Results & Interpretations: The plant communities changed across the chronosequence along with the exceptionally strong soil phosphorus (P) and pH gradients. Both plant species diversity and diversity of nutrient-acquisition strategies increased from the youngest to the oldest soils. Absolute species richness in the oldest stage (6) was 2.9 times the richness in the youngest stage (1). Likewise, rarefied species richness in stage 6 was 2.6 times that of stage 1. Shannon's diversity increased over 60% and Simpson's (1/D) diversity tripled. Species β diversity increased across the chronosequence: additive β diversity (γ - α) quadrupled and multiplicative β diversity (γ/α) increased by 25%. Richness of nutrient-acquisition strategies doubled across the chronosequence and the diversity of nutrient acquisition strategies also increased using several metrics. Whilst both mycorrhizal and non-mycorrhizal plants increased in richness across the chronosequence, canopy cover of mycorrhizal plants decreased, with non-mycorrhizal plants correspondingly becoming increasingly abundant. Our interpretation is that the size of the plant species pool adapted to low-P soils is considerably greater than that for higher P conditions; an increasing range of specialisations for nutrient-impoverishment allows survival in these challenging conditions. Furthermore, our results suggest that the effectiveness of mycorrhizal symbioses is near its limit in the poorer stages of the chronosequence; this, in turn, allows increased abundance of non-mycorrhizal plants, especially those with root specialisations that effectively mine the soil for P.

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The Loiseleurio-Vaccinietea class in the Altai-Sayan mountain system, Russian Federation

Evgeny G. Zibzeev

Laboratory of Ecology and Geobotany, Central Siberian Botanical Garden of Siberian Branch of the Russian Academy of Sciences, 101 Zolotodolinskaya St., 630090, Novosibirsk, Russian Federation

Corespondence: Evgeny G. Zibzeev, egzibzeev@gmail.com

Background & Aims: Shrubs and dwarf shrub communities represent important elements of the alpine vegetation in the Altai-Sayan mountain system, Siberia. Most of the available papers on classification of shrub vegetation in this mountain system followed the traditional Russian vegetation-classification approach where vegetation types were distinguished on basis of dominants and subdominants. The aim of this study was to elaborate classification of plant communities of alpine shrub vegetation of the *Loiseleurio-Vaccinietea* of Sayan and Altai Mts. and analyze the diagnostic features of associations, alliances and orders.

Material & Methods: The Altai Mts and Sayan Mts are forming a large mountainous region situated in the central part of Eurasia. They are characterized by a system of high mountain ridges (up to 4500 m of altitude) with a well-developed alpine belt occupying about 16% of the area. The basis for classification was 320 relevés of the alpine shrub collected from different parts of Altai-Sayan mountain system. The classification of plant communities was carried out using the Braun-Blanquet approach (Westhoff & van der Maarel 1973). The relevés records were stored in the TURBOVEG database (Hennekens 1996) and classified by TWINSPAN (Hill 1979).

Main Results: The *Loiseleurio-Vaccinietea* class represents the prevalent vegetation type of the alpine vegetation in humid and moderately humid regions of the Altai-Sayan mountain system. The plant communities of this class occupy about 1/3 of the alpine belt of the mountain system at altitudes spanning 1800–3000 m. The Altai-Sayan alpine tundra is characterized by predominance of ericoid dwarf-shrubs (*Empetrum nigrum, Vaccinium myrtillus, V. vitis-idaea, V. uliginosum*), well-developed shrub layer of *Betula nana* subsp. *rotundifolia, Salix glauca* and some *Rhododendron* species (*R. adamsii, R. aureum, R. parviflorum*), developed layer of lichens and bryophytes. The floristic composition alongside the widespread ericoid dwarf shrubs includes a group of arctic-alpine species of Eurasian and Holarctic provenience (*Anthoxanthum alpinum, Bistorta vivipara, Gentiana algida, Hierochloë alpina, Minuartia arctica, Pedicularis oederi*). Presence of an Asian group of species related to the mountains of Southern Siberia, Mongolia and Central Asia (*Campanula dasyantha, Gentiana grandiflora, Patrinia sibirica, Schulzia crinita, Viola altaica*) is a regional peculiarity of the Altai-Sayan alpine tundra. These species play an important role in the geographical differentiation of communities of the *Loiseleurio-Vaccinietea*; they may be used for discrimination of the new order (*Schulzio crinitae-Betuletalia rotundifoliae* Ermakov et Zibzeev 2012) characteristic of the alpine tundra of mountain systems of Southern Siberia and Northern Mongolia. The *Schulzio crinitae-Betuletalia rotundifoliae* include two distinct ecological types of the alpine tundra that might be classified as two new alliances – the *Pleurozio-Betulion rotundifoliae* Ermakov et Zibzeev 2012 and the *Thamnolio-Betulion rotundifoliae* Ermakov et Zibzeev 2012 (Ermakov & Zibzeev 2012). These alliances include five associations and ten rank-less communities.

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Do different disturbance types affect resprouting patterns of shrub species in cerrado?

Talita Zupo, Elizabeth Gorgone-Barbosa, Mariana N. Rissi & Alessandra Fidelis

Departamento de Botânica,
Universidade Estadual Paulista,
Av 24A, 1515 Rio Claro, Brazil

Corresponence: Talita Zupo,
talita.zupo@gmail.com

Background & Aim: Resprouting is a key regenerative trait allowing species to persist after a wide range of disturbances. Fire is an important disturbance in many ecosystems, including in the Brazilian tropical savanna (cerrado). Fire can increase light and nutrient availability in the soil, alter soil temperatures and is known to stimulate flowering and germination in many species. Additionally, different fire regimes (with different fire intensities) can influence resprouting success by altering production of new shoots. The aim of this study was to test which type of disturbance event affected more the resprouting success of dominant cerrado shrub species, using clipping and fire as experimental treatments.

Materials & Methods: This study was carried out in a cerrado *campo sujo*; a physiognomy characterized by a continuous herbaceous layer and scattered shrubs. We sampled four shrub species, all belonging to the *Fabaceae* family: *Chamaecrista orbiculata*, *Mimosa leucocephala*, *Harpalyce brasiliana* and *Bauhinia* sp. For each treatment, at least ten individuals per species were selected and marked. Treatments consisted of clipping at the base or subjecting to prescribed burning. Both treatments were applied in July, mid-dry season. All individuals were surveyed four times: shortly before treatment, and three, six and twelve months after treatment, respectively. We sampled maximum height and number of shoots.

Main Results & Interpretation: Three months after the clipping treatment *Bauhinia* sp and *H. brasiliana* had significantly less shoots than burnt individuals ($p<0.001$ and $p=0.02$, respectively). After six months, this difference still existed for *Bauhinia* sp ($p=0.01$), but disappeared for *H. brasiliana* ($p=0.09$). Clipped individuals of *C. orbiculata* remained significantly shorter than burnt individuals for as long as six months after the treatment ($p<0.001$), but treatment did not affect the number of new shoots. Height and number of new shoots of *Mimosa leucocephala* did not differ between treatments. Although all species displayed the ability to resprout following disturbance, it seems fire, and not only aboveground biomass removal, influenced resprouting success in some species.

Figure 1. Campo sujo at Serra do Tombador Nature Reserve, Goiás, Brazil.

Figure 2. Shrub species used in this study: (a) *Chamaecrista orbiculata*, (b) *Mimosa leucocephala*, (c) *Harpalyce brasiliana*, (d) *Bauhinia* sp.

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Index of Authors

Ladislav Mucina

Ladislav (Laco) Mucina, born on 28 May 1956 in Piešťany (then Czechoslovakia, today Slovakia), received his education in Slovakia and obtained various scientific degrees and pedagogical qualifications at the Comenius University and Slovak Academy of Sciences, both in Bratislava, and later at the Technical University Berlin. He spent a postdoctoral period at the University of Nijmegen in the Netherlands and was later lecturing at universities in Austria, Germany, Italy, Sweden, Kuwait, South Africa (Pretoria, Qwaqwa, Stellenbosch) and Australia. Currently he serves as Winthrop Professor and the Iluka Chair in Vegetation Science and Biogeography at The University of Western Australia, Perth. Recently he has been appointed as Professor Extraordinnaire at the Department of Geography and Environmental Studies of Stellenbosch University. Prof Mucina is a long-serving member of executive and advisory bodies and working groups of the International Association for Vegetation Science (IAVS). He is co-founder of the journal *Applied Vegetation Science* and former Chief Editor of the *Journal of Vegetation Science*. In South Africa he founded the National Vegetation Database and participated in management of the National Vegetation Mapping project. Prof Mucina is working on a wide range of botanical research topics, including vegetation science (vegetation surveys, mapping, data-banking), population and evolutionary biology, plant systematics and biogeography. He has participated in the vegetation survey of Slovakia and Austria, and Europe, studied vegetation patterning and population ecology of Central European dry grasslands, contributed to syntaxonomic calibration of the EUNIS habitat system of the European Union, and participated in several crucial studies into ecology and conservation of indigenous forests. At present he pursues research in vegetation mapping in Western Australia and is active in community functional and evolutionary community ecology focusing on rehabilitation processes in species-rich shrublands and general vegetation dynamics.

Iluka Chair, School of Plant Biology, The University of Western Australia, 35 Stirling Hwy, Crawley WA 6009, Perth, Australia

Department of Geography and Environmental Studies, Stellenbosch University, Private Bag X1, Matieland 7602, Stellenbosch, South Africa

Jodi N. Price

Jodi Price is a Research Associate, currently working at The University of Western Australia, in the Ecosystem Restoration and Intervention Ecology Group (ERIE). Jodi recently spent years abroad doing a post-doctoral fellowship at the University of Tartu, Estonia in the Macroecology working group. Prior to this Jodi worked at the University of New England in NSW, Australia. She completed her PhD at La Trobe University in Melbourne, Australia in 2007. She is a member of the Editorial Review Board for Journal of Vegetation Science, and an Associate Editor for Plant Ecology. Jodi's main research interests are functional community ecology, and recent projects include: a global study of plant community assembly in grasslands, examining the relationship between environmental heterogeneity and plant traits, and community assembly in restoration plantings.

School of Plant Biology, The University of Western Australia, 35 Stirling Hwy, Crawley WA 6009, Perth, Australia

Jesse M. Kalwij

Jesse Kalwij (1976) is a Researcher at the Institute of Botany, Academy of Sciences of the Czech Republic in Brno, and a Research Associate at the University of Johannesburg, South Africa. After receiving his MSc degree from Wageningen University, the Netherlands, he spent a year as an environmental consultant in a bush camp in the Okavango Delta, Botswana, monitoring vegetation dynamics, herbivore populations and large carnivore distributions. He then moved to Switzerland, where he received his PhD degree from the University of Bern on indicator species and forest dynamics in the Swiss Jura Mountains. He subsequently spent five years as a postdoctoral research fellow in at Stellenbosch University, South Africa, studying the spatio-temporal dynamics of invasive plants and savanna trees, and four years as Senior Researcher in Tartu, Estonia. Jesse is now working on the forest ecosystems of Moravia. He describes himself as a landscape ecologist with particular research interest in invasive plant species, savanna ecosystems, alpine ecosystems and population dynamics. He is a regular reviewer for a broad range of ecological journals, and has served as an editor on the IAVS 2008 Symposium abstract book.

Department of Vegetation Ecology, Institute of Botany, Academy of Sciences of the Czech Republic, CZ-602 00 Brno, Czech Republic

Department of Zoology, University of Johannesburg, Auckland Park 2006, South Africa