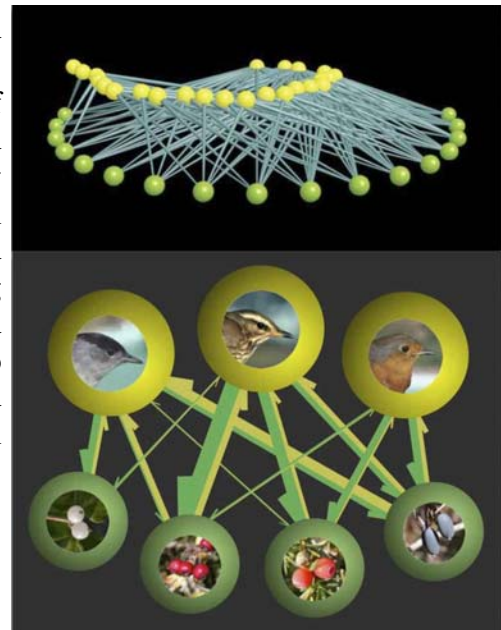




## Seed dispersal services from the network theory perspective

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Network theory has helped to unveil universal and specific properties of complex systems including plant-animal mutualisms. Those patterns permit assessment of crucial aspects such as structural differences and resilience of systems towards disturbance. By comparison, pollination and networks on myrmecophily have been much better studied than seed dispersal networks. Therefore, we want to bring together researchers who are investigating seed dispersal systems as complex networks, in order to evaluate advances that have been made in this field and discuss future perspectives with a strong emphasis on conservation issues.



(Photo : Two joint figures from the symposium's page <http://is.gd/5Xe4u>: top © [Foodwebs.org](http://Foodwebs.org), bottom © Pedro Jordano)

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### **The backbone of seed dispersal: within- and among-network variation in the importance of different dispersers**

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In seed dispersal services some species are more important than others. Furthermore, as species are mosaics of local populations with different interactions, the importance of each species probably varies among sites. We assessed the relative importance of seed dispersers as their “accessibility”. Widespread species were expected to exhibit different accessibilities among networks. Primary frugivores were expected to be more accessible than secondary frugivores. 15 Neotropical datasets on bat-fruit (8) and bird-fruit (7) interactions were transformed into one-mode diet-overlap networks and for each animal we calculated accessibility to their direct and indirect neighbors (species with similar diets). 32 bat, 125 bird and 443 plant species were analyzed. Animal species that were more accessible to direct neighbors were also more accessible to indirect neighbors. 14 bat and 27 bird species occurred in two or more networks, and their accessibility varied largely among sites. Primary and secondary frugivores were similarly accessible in the networks. Our findings suggest that the importance of seed dispersers should be assessed at a local scale. Furthermore, opportunistic frugivores may be also important as backups in the maintenance of seed dispersal services.

### **Disentangling seed dispersal of an endangered conifer**

Jessica Lavabre<sup>1</sup>, Jordi Bascompte<sup>1</sup>

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Ecological interactions form the backbone of ecological communities. In particular, mutualistic interactions, such as seed dispersal, have received much attention. Recently, the static, structural picture of mutualistic networks has been well described. However, their spatio-temporal variability is still poorly understood, despite numerous empirical and theoretical studies. Here we focus on an endangered conifer, *Taxus baccata* L., and its associated frugivorous community over two consecutive years in Western Spain. Our central objective is to disentangle the role of landscape features from frugivore's guild characteristics--such as frugivore identity or foraging behavior--in explaining components of the observed seed shadow. Specifically, we develop a GIS-based, spatially-explicit model. We find a variable frugivorous community; nevertheless, we find consistent, spatially-structured patterns of seed shadows across years. We argue that this spatial structure results from the interaction between frugivores and landscape features. Frugivorous birds display predictable interaction patterns with the surrounding vegetation and thus generate predictable seed shadows. Currently, we are complementing our analysis with molecular techniques to draw the complete picture of the underlying processes.



## **Specialization of seed-dispersal networks decreases at edges and disturbed sites of an African rain forest**

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Human disturbance is a prevailing threat to tropical rain forests and affects frugivores and their seed-dispersal services in manifold ways. We analyzed how tropical seed-dispersal networks respond to forest edge and local disturbance in Kakamega Forest, Kenya. In a two-factorial design, we carried out frugivore observations on eight species of canopy trees in the interior and at the edges of a disturbed and an undisturbed forest. Frugivore abundance and richness were not affected by local disturbance, but were higher at the edges than in the interior, although fruit availability did not differ. Forest visitors were more abundant at the edges and in the disturbed forest, whereas forest specialists followed the opposite pattern. These differences in community composition changed the specialization in the seed-dispersal networks. Specialization of plants and animals was much lower at the edges than in the interior and in the disturbed than in the undisturbed forest, resulting in the most specialized network in the undisturbed forest interior. In this tropical forest, edge effects increase the visitation frequency on fruiting trees, while forest edge and disturbance change the composition of the frugivore community. Our findings suggest that tropical seed-dispersal networks are more redundant in disturbed habitats, which may increase the stability of seed-dispersal services, but may also lead to a decoupling of co-evolved seed-dispersal systems in response to human disturbance.

## **Network theory and the seed dispersal loop**

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<sup>1</sup> Pennsylvania State University

Existing network representations of plant-frugivore interactions allow for a greater understanding of community complexity, but generally do not use temporal and spatial factors that are known to be important for seed dispersal. Incorporating these factors will thus be a crucial component of developing dynamical network models of seed dispersal. Currently, we are exploring temporal patterns in plant-frugivore networks of forest communities in Puerto Rico. Thus far, we have found that system phenology, in both fruit availability and frugivore diet, contributes to structural properties that are common in mutualistic networks. Preliminary results suggest that generalist species can either be always generalists or serial specialists. Generalists have been hypothesized to be the backbone of mutualistic communities, but these two different modes of generalization may differ in how they protect the community from disturbances. In addition, in order to assess the relationship between network generalization and successful seed dispersal by frugivores, we present network models that include more stages of the seed dispersal loop. Initial results show that not all generalists are effective seed dispersers, and that the most highly generalist frugivores may not be as important as other frugivores for recovery from disturbances, especially during community assembly. Overall, network theory not only improves our understanding of seed dispersal from a community-wide perspective, but also highlights exciting new areas of research.



## Can we scale up seed dispersal? Incorporating dispersal into vegetation-climate models

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Dynamic Global Vegetation Models (DGVMs) simulate the distribution and structure of vegetation as a function of climate. These models are used to simulate biogeochemical cycles and vegetation shifts in response to paleo, current and future climate change. DGVMs have been criticized for not including biological interactions, which also play an important role in shaping ecological communities. Most significantly, none of the current DGVMs include a representation of seed dispersal. The models assume *perfect dispersal*, where plants can arrive at any location, regardless of distance or physical barriers. Model predictions likely overestimate vegetation migration rates, and underestimate the sensitivity of vegetation to rapid climate change. I will be presenting the first attempt to incorporate a phenomenological representation of seed dispersal into a regional dynamic vegetation-climate model (LPJ-GUESS). I will illustrate an approach that allows us to represent dispersal across large spatial scales, while still maintaining dispersal biology. Incorporating seed dispersal and migration limitations into vegetation-climate models will improve future predictions and help illustrate the factors which influenced historical vegetation migration rates.

## Linking frugivore behaviour to plant population dynamics: thrushes and fleshy-fruited trees in the Cantabrian range

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We present results from simulations of frugivore-dispersed plant dynamics and observational studies of *Turdus* spp foraging for fruits to show that frugivore behaviour can have an important role in determining plant spatial distribution and abundance. Simulated plant dynamics showed increased clustering and smaller population sizes as dispersing agents were less willing to move larger distances while foraging. This tendency was further modulated by how selective animals were. Field work was conducted in a 400 x 440m plot in Sierra de Peña Mayor (Asturias, N Spain) during three fall-winter seasons (2007 to 2010). The plot was divided into 20x20m cells where we estimated forest cover and fruit abundance. We followed individual birds, recording their position and time spent on different perches and the species and number of fruits eaten on fleshy-fruited trees. Birds were highly mobile, but net travel distances from source plants were short, as birds frequently returned to the same feeding patches. *Turdus merula* and *T. philomelos* moved shorter distances and were more selective for fruit abundance than *T. iliacus* and *T. viscivorus*. Furthermore, *T. iliacus* was more associated to forest cover than *T. viscivorus*. Overall these movement behaviours would result in highly aggregated seed dispersal but with seeds deposited in open areas occasionally. However, in order to fully link seed dispersal patterns to plant demography, studies of plant establishment and survival are required.



## **The role of animals for Dandelion seed dispersal**

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Adaptations of dispersules are often interpreted as morphological dispersal syndromes, assuming a close relationship with dispersal types. Dandelion seeds, for example, have a pappus and are thus classified as wind dispersed. However, this assumption may be misleading, as dispersal may also be caused by non standard means. To assess the role of non standard dispersal means, especially animal mediated seed dispersal. A variety of methods was used to assess the importance of different dispersal types for Dandelion. The methods comprise literature compilation, experimental measurement of indicator traits, and process based modelling of dispersal kernels with SEED (animal dispersal) and PAPPUS (wind dispersal). Dandelion is regularly dispersed by non standard means. Dandelion ranks among the 10% of the herbs with the highest wind dispersal potential, among the 20% with the highest potential for epizoochory and has a medium potential to survive digestion. Simulation of dispersal kernels showed that dispersal by animals may be several orders of magnitude more efficient than wind dispersal at distances from 10 to several 1.000m. Animals are effective seed dispersers via epi- and endozoochory. Even for species like Dandelion, which is unquestionable adapted to wind dispersal, animal mediated seed dispersal may be much more efficient for long distance dispersal than wind dispersal, given that animal move over large distances.