Chasing Ecological Interactions

Pedro Jordano[1*,◕]

1 Integrative Ecology Group, Estación Biológica de Doñana, CSIC, Pabellón del Perú, Avda. María Luisa, s/n, E-41013 Sevilla, Spain

*** jordano@ebd.csic.es**

Abstract

Basic research on Biodiversity has concentrated on the study of species, naming new species, studying distribution patterns, and analyzing their evolutionary relationships. Yet Biodiversity is more than a collection of individual species; it is the combination of biological entities and processes that supports the Earth system. Understanding Biodiversity requires its cataloguing, but also assessing the ways species interact with other species and provide a functional support for the Tree of Life. Ecological interactions may be lost well before the species interacting go extinct, so that their ecological functions disappear. Here I address the challenges in studying the functional aspects of species interactions and how basic research is helping us to address the current fast-paced extinction of species due to human activities.

Author Summary

Biodiversity, all the different forms of life on Earth, is supported by ecological interactions among species. No single species on Earth lives without interacting with other species. Recent attempts to address the fast-paced loss of biodiversity are being supported by basic research stemming on its inventory (cataloguing species) but also in understanding how species are intertwined within complex webs of ecological interactions that support functional ecosystems.

> *I am tempted to give one more instance showing how plants and animals, most remote in the scale of nature, are bound together by a web of complex relations.* (Darwin Ch. 1860. On the origin of species by means of natural selection. Chapter 3, p. 75).
>
> *There is a much more insidious kind of extinction: the extinction of ecological interactions.*. (Janzen, D.H. 1974. The deflowering of Central America. Natural History, 83: 48-53).

Suppose you want to build the LEGO® *Triceratops Trapper* model (it is model no. 5885-1). It has 256 pieces, corresponding to 74 distinct parts. It's a relatively simple artifact; yet impossible to build by assembling these 256 pieces at random. To get the fully functional Triceratops Trapper we need to know not only the inventory of its parts: we also need to know how the different pieces are connected together. We'll have a functional Triceratops Trapper if and only if we assemble the model connecting its component pieces the right way. Species in ecosystems are not connected (linked) by random interactions; there are regularities independent on the type of ecosystem and even on the type of ecological interaction. This Web of Life [1] defines the wireframe that supports Biodiversity, and ecological interactions provide essential services and functionality for its persistence. Interactions might be lost (extinct) even well before the species. For instance, the "empty forest syndrome" [2] describes situations where animals and plants may persist in disturbed areas (e.g,, a tropical forest fragment) yet with so much reduced abundances that their functional ecological role is lost. Interaction extinction may result in collapse of important ecological functions such as pollination and seed dispersal, crucial for forest regeneration and ecosystem persistence. These losses of interactions cause unprecedented changes in cascade in natural communities, implying losses of ecological functions that are crucial for ecosystem persistence. For example, just imagine the myriad consequences of extinctions of pollinators and frugivore seed dispersers for ecosystems like tropical rainforests, where more than 90% of the woody plant species need their interactions to support their life cycles.

Ecological interactions are the wireframe of biodiversity. No single species on Earth lives without interacting with other species. Thus, Biodiversity is more than just species: interactions among them are the architecture that supports ecosystems. It's the Web of Life. Exploring and inventorying Biodiversity represents a fundamental challenge for basic research in ecology and conservation biology. This basic knowledge is urgently required to properly diagnose the status of Biodiversity conservation and develop early warning signals for situations of collapse.

Diversity: of species and their interactions

The Web of Life assembles species that interact with each other in a variety of ways, conforming complex interaction networks. A myriad of interaction modes exists in nature and illustrates with fascinating details the complexity of natural histories of partner species. Forms of interaction include predation, competition, commensalism, amensalism, mutualism, symbiosis, parasitism and in all cases involve reciprocal effects for the interacting species. Recent basic research on the topology and structure of these networks has revealed universal patterns that ultimately affect their stability and resilience, yet we are far from fully documenting all the types of interaction modes that exist even in simple ecosystems.

Just in the same way we sample individuals of free living species to estimate the diversity in a particular area or ecosystem, we can sample interactions. In this way we can assess the full complexity of ecosystem structure.The task is enormous. Imagine how difficult is to assess and catalog the number of species (e.g., arthropods) present in a given tropical forest; then consider how much effort is requiered to catalog their full set oif interactions with partner species (e.g., their interactions with plants for pollination, with fungi, with parasitoids, with food plants, etc.). In the same way as we talk of diversity of species we can talk about the diversity of interactions. The distinct feature of interactions, however, is that their outcomes embed functional consequences not only for the partner species, but also for the ecosystem where they live.

Nulla mi mi, venenatis sed ipsum varius, volutpat euismod diam. Proin rutrum vel massa non gravida. Quisque tempor sem et dignissim rutrum. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Morbi at justo vitae nulla elementum commodo eu id massa. In vitae diam ac augue semper tincidunt eu ut eros. Fusce fringilla erat porttitor lectus cursus, vel sagittis arcu lobortis. Aliquam in enim semper, aliquam massa id, cursus neque. Praesent faucibus semper libero.

Basic conservation science in the Anthropocene: challenges

3rd Level Heading. Nulla mi mi, venenatis sed ipsum varius, volutpat euismod diam. Proin rutrum vel massa non gravida. Quisque tempor sem et dignissim rutrum.

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Morbi at justo vitae nulla elementum commodo eu id massa. In vitae diam ac augue semper tincidunt eu ut eros. Fusce fringilla erat porttitor lectus cursus, vel sagittis arcu lobortis. Aliquam in enim semper, aliquam massa id, cursus neque. Praesent faucibus semper libero.

Concluding remarks. Nulla mi mi, venenatis sed ipsum varius, volutpat euismod diam. Proin rutrum vel massa non gravida. Quisque tempor sem et dignissim rutrum. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Morbi at justo vitae nulla elementum commodo eu id massa. In vitae diam ac augue semper tincidunt eu ut eros. Fusce fringilla erat porttitor lectus cursus, vel sagittis arcu lobortis. Aliquam in enim semper, aliquam massa id, cursus neque. Praesent faucibus semper libero.

Acknowledgments

My work was funded by grant CGL2013-47429P and a Severo-Ochoa Excellence Grant (SEV2012-0262) from the Spanish Ministerio de Economía y Competitividad (MINECO), and RNM-5731 from the Junta de Andalucía.

References

1. Thompson JN. The coevolving web of life. Amer. Nat. 2009; 173: 125–140. doi:10.1086/595752
2. Redford KH. The empty forest. Bioscience. 1992; 42: 412–422.
3. Dirzo R, Young HS, Galetti M, Ceballos G, Isaac NJB, Collen B. Defaunation in the Anthropocene. Science. 2014; 345: 401–406. doi: 10.1126/science.1251817
4. Lima-Mendez G, Faust K, Henry N, Decelle J, Colin S, Carcillo F, et al. Ocean plankton. Determinants of community structure in the global plankton interactome. Science. 2015; 348: 1262073–1262073. doi:10.1126/science.1262073

Figure 1. The structure of ecological interactions. Top, examples of ecological interactions between plants and animals. a, *Ramphastos vitellinus* feeding on *Euterpe edulis* (Arecaceae) fruits; b; *Ectatomma tuberculatum* over extra-floral nectaries at the base of a leaf of *Qualea multiflora* (Vochysiaceae); c, *Xylocopa violacea* visiting a flower of *Allium* sp. (Amaryllidaceae). Bottom, different visualizations of the complexity of interaction networks among species (colored spheres) illustrated by their actual links (light grey lines): d, food webs typically describe all the interactions occurring in a given ecosystem with multiple trophic levels; e, most plant–animal interactions can be displayed as bipartite graphs describing the pairwise pattern of mutual interdependencies among two distinct sets of animals (orange nodes) and plants (yellow); f, interactions among species with a higher degree of intimacy, such as ant-plants show a distinct pattern of structure, often with multiple distinct groups (modules) of closely intimate associations. Photos: ©Guto Baileiro, with permission, ©Kleber del-Claro, with permission; and Pedro Jordano. Images d, e, and c produced with FoodWeb3D, written by R.J. Williams and provided by the Pacific Ecoinformatics and Computational Ecology Lab (www.foodwebs.org).